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IAEE ENERGY FORUM

CONTENTS

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PRESIDENT'S MESSAGE

It was great to connect with so many of you just before the summer at our 27th Internation Conference in Istanbul. Additionally, it was great to introduce our Executive Director Julie Sutter to the association and to connect her with many of you. The USAEE successfully held its North American Meeting in Baton Rouge earlier in December and suddenly the year is almost over!

The preparation for next year's international conference in Paris are well under way and you should mark your calendars for 15–18 June 2025. Thank you for your feedback on the Istanbul meeting via the form or comments via social media. Be assured that we do appreciate to hear from you and take your concerns very seriously. All male panels should be a thing of the past and I thus invite you to come forward with speaker suggestions and urge you to consider volunteering, looking at you bright women out there! Other lessons learned include that vicinity of locations during the daily conference program is a prerequisite to maximize the value of participating and that six presentations could be too many in any one session. Also, bringing new faces (and perspectives) to panel sessions as well as the interaction of session participants would be highly valued by many of you. Let me tell you that I have heard you!

Congratulations to Aaron Praktiknjo, Andrew Slaughter, Swetha Ravi Kumar, Nils-Henrik M. von der Fehr, Roula Inglesi-Lotz, Seung-Jin Kang and Ange Blanchard to their nomination, (re-)election and willingness to accept positions in council as President-Elect, VP Finance, VP Communications, VP Academic Affairs, VP Membership and Affiliate Relations, VP Business and Government Affairs, and Student Representative from 2025 onwards. Our association is run by volunteers and it is us members who shape the future of the association. Thank you, Peter Hartley, for serving the Association over the past years when it was in turmoil, that was not an easy task. With your perspectives and experience you sailed that boat out of the storm.

This edition of the Energy Forum is a double feature with a thematic focus on Energy Poverty in all its breadth and depth mainly due to the large number of contributions from you.

Citizens living in energy poverty lack sufficient access to affordable and reliable energy to meet their basic needs. This can take various forms, such as a lack of lighting, cooking, space heating or cooling options. Energy poverty often affects low-income households and can have negative impacts on quality of life, health and economic development. Today, 50 million people lack access to electricity and more than 2 billion people do not have access to clean cooking technologies and fuels (IEA, Strategies for Affordable and Fair Clean Energy Transitions, 2024). In the least developed countries over half of the people lack access to the basic energy needs.

We are overwhelmed by the response from you which highlights the relevance of the topic. It is a difficult issue to address since it includes a variety of definitions (fuel poverty, access to electricity) and the interplay with other goals of energy policy. Therefore, it cannot be a standalone policy objective but needs to be aligned or considered within context such as a "Just Energy Transition."

As for other activities I am happy to inform that s of next year, the Saudi Arabian and Turkish Association will join forces and create the Middle Eastern and Asian Conference which will take place alternately in the Middle East and Central Asia to represent the region and create dialogue. In Denmark, the Danish Association has been revived and is on track becoming an Affiliate to the Association again—welcome back!

For the remaining time of the year let me close by thanking you members wherever you are located geographically: it has been a pleasure to serve you as the Association's president during the year 2024. At times it was very challenging (Kudos to Stephanie, Rebecca, Ethan, Julie, Gregg and the whole team at Talley who provided excellent service and guidance to me!) but also rewarding.

I do really hope the Association continues on its current track of re-inventing itself and I want to close off by inviting you, every single one of you, to contribute. The times they are a changing but we do have to be in dialogue in order to find the best solutions.

Editor's Notes

We have had a great deal of interest in the topic of Energy Poverty and are pleased to bring you this double issue of the Energy Forum. Ultimately, we have 19 articles that address various aspects of the topic.

Citizens living in energy poverty lack sufficient access to affordable and reliable energy to meet their basic needs. This can take various forms, such as a lack of lighting, cooking, space heating or cooling options. Energy poverty often affects low-income households and can have negative impacts on quality of life, health and economic development. Today, 50 million people lack access to electricity and more than 2 billion people do not have access to clean cooking technologies and fuels (IEA, Strategies for Affordable and Fair Clean Energy Transitions, 2024). In the least developed countries over half of the people lack access to basic energy needs. In this forum we focus on how this (to western economies new) social risk affects society and possible solutions. We also welcome contributions that consider the impact of increasing the share of renewable and low-carbon energy sources or even fully replacing fossil fuel sources on people affected by energy poverty.

Marine Cornelis reports that energy poverty in the EU is a growing crisis, with around 10% of the population unable to adequately heat their homes. This article explores the systemic roots of this injustice, exacerbated by rising costs, inefficient housing, and inadequate policies. It argues for a holistic, intersectional approach that integrates social justice, robust multi-level governance, and climate resilience to effectively combat energy poverty across Europe.

Inês Carrilho-Nunes explores how innovation in energy access, through technological advancements, policy solutions, and community-based projects, can reduce inequalities, including those related to income and gender, while promoting economic growth, improving health outcomes, enhancing education, and increasing productivity, ultimately contributing to a more sustainable and equitable future.

Philipp Riegebauer informs us that community-owned solar power offers rural areas a decentralized, renewable energy solution that fosters local engagement, economic opportunities, and energy security. By promoting peer-to-peer energy sharing and sustainable practices, these systems empower communities, reduce dependence on centralized grids, and address broader challenges like waste management, driving social and economic resilience.

Mamdouh G Salameh argues that the West puts so much importance on the climate change agenda in Africa but what Africa needs immediately isn't green energy transition but the immediate development of its vast oil and gas reserves in order to overcome a debilitating and chronic energy poverty.

Timothy C. Coburn considers the state of energy poverty today, its relationship to energy justice, and difficulties energy economists and policy makers face while seeking to alleviate it. The struggle to eliminate energy poverty is compounded by growth in demand for energy worldwide, and the need to transition away from fossil fuels.

Minglai Li, Qiang Li, Cong Li, and **Lin Zhang** explore the characteristics of global energy poverty, analyze its impact on human well-being, and propose strategies to combat it. Affordable clean energy is identified as the seventh Sustainable Development Goal by the United Nations. However, with only six years left to achieve the 2030 vision of the SDGs, energy poverty remains a pressing issue, especially in the global south. Therefore, it is crucial to examine the challenges posed by energy poverty to human well-being and propose effective strategies to address the associated social risks and promote sustainable development.

James Correia, Sheena Kanon Leong, and **Dina Azhgaliyeva** examine the drivers and dynamics of the nexus between energy poverty and gender inequality in developing Asia and the Pacific. First, this begins with an overview of the social, economic, health and environmental aspects of gender and energy poverty in the region. Second, the policy approaches adopted to address these challenges through the provision of green employment opportunities, infrastructural initiatives, access to financing, and targeted interventions to tackle household air pollution (HAP) are examined. Third, this paves the way toward a set of practical recommendations for improving energy access and affordability, promoting women's economic empowerment, and accelerating the green energy transition.

IAEE MISSION STATEMENT

IAEE's mission is to enhance and disseminate knowledge that furthers understanding of energy economics and informs best policies and practices in the utilization of energy sources.

We facilitate

- **Worldwide information flow and exchange of ideas on energy issues**
- **High quality research**
- **Development and education of students and energy professionals**

We accomplish this through

- **Leading edge publications and electronic media**
- **International and regional conferences**
- **Networking among energy-concerned professionals**

Orla Dingley posits that addressing energy poverty is seen as the way to ensure a just energy transition. However, energy poverty research and policy to-date has generally only considered energy use within the home. This article advocates expanding the concept of energy poverty to include the energy a household uses for transportation.

Amanda J. Harker Steele, Christopher Nichols, and **Gavin Pickenpaugh** state that replacing fossil assets with low-carbon alternatives will influence the costs associated with maintaining a competent, reliable grid (i.e., total systems costs). Noting over time any resulting system cost increases will likely be borne by consumers, this paper aims to provide insight into the potential energy poverty impacts that may result.

Rahil Dejkam and **Reinhard Madlener** predict fuel poverty risk by grouping households based on data from a survey in England. The analysis reveals important differences between household groups, helping policymakers to better understand which factors contribute most to fuel poverty and suggesting targeted interventions to address the issue.

J. Bohlmann, R. Inglesi-Lotz, and **W. Kritzinger** emphasize the role of institutional quality in addressing energy poverty, particularly in developing regions like Sub-Saharan Africa, where weak governance hinders energy access. It argues that sustainable solutions require strong institutions alongside technological and financial interventions, linking energy access (SDG 7) to good governance (SDG 16).

Emna Kanzari, Stefano Fricano, Gioacchino Fazio, and **Jing Yu** report that most of the people lacking access to energy are mainly concentrated in Africa, representing serious challenges to its socio-economic development. FDI can help alleviate energy poverty in Africa through infrastructure development, technological advancement and economic growth channels. However, the complex economic system within which it operates requires increased attention.

Kabirat Nasiru notes that data science and artificial intelligence are crucial in tackling energy poverty by enabling precise identification of energy-vulnerable households, optimizing energy use, and fostering sustainable practices. This article explores how AI-driven insights can guide energy poverty alleviation, offering potential socio-economic benefits for both developed and developing nations.

Moisés Obaco, Daniel Davi-Arderius, and **Xavier Rodríguez-Cruz** identify potential energy poverty patterns using poverty indicators in Ecuador. We discuss the extent to which the current subsidized electricity tariffs are efficient and might require improvements. We also address the potential impact of energy poverty on participation in clean cooking programs.

Sara Zaidan and Mutasem El Fadel examine advancing the United Nations Sustainable Development Goal 7 (SDG7) pertaining to "Affordable and Clean Energy", to address energy poverty (EP) and achieve the broader objectives of upcoming global agendas for the SDGs by 2030 and the Net Zero Emissions (NZEs) target under the Paris Agreement by 2050. We begin by exploring the relationship between EP and SDG7 through a comparative analysis of the six indicators monitoring SDG7 progress in the Middle East and North Africa (MENA) region. The drivers of EP and their subsequent impacts at national and regional levels are then discussed, followed by policy recommendations advocating the "right to energy".

Lungile Mikateko Muhlavasi Mashele reports on the gendered nature of energy poverty in Africa and disproportionately affects women and girl children. She explores approaches to addressing energy poverty, and the potential of microgrids. they must be affordable, reliable and considerate of social and traditional contexts.

Mafalda Silva writes that tackling energy poverty and promoting affordable quality housing are two key policy priorities. While the links between energy poverty and housing quality have been largely identified, those with housing affordability are less so. This paper calls for further exploratory work and improved data and metrics to inform future renovation policies.

Elisenda Jové-Llopis and Elisa Trujillo-Baute explore the effectiveness of Spain's bono social and energy efficiency measures on reducing energy poverty. By combining income support with long-term energy-saving solutions, the study reveals a significant reduction in energy poverty, highlighting the need for a holistic approach to address both immediate and structural challenges in the energy transition.

Emmanuel Asane-Otoo and Abigail Opokua Asare examine the impact of energy poverty on life satisfaction, drawing on data from the German Socio-Economic Panel (2010–2021). The findings show that energy poverty significantly diminishes life satisfaction, particularly through subjective perceptions of household energy inadequacy. The paper highlights the importance of multidimensional strategies to tackle energy poverty and its profound impact on well-being

CONFERENCE OVERVIEW

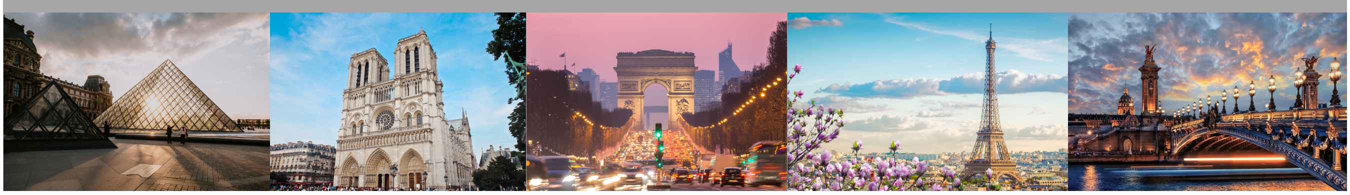
The 46th IAEE International Conference takes place in Paris, France, 15 – 18 June 2025, with the main theme "ENERGY SOLUTIONS FOR A SUSTAINABLE AND INCLUSIVE FUTURE"

The 46th IAEE International Conference will focus on the economies of the different energy solutions envisioned for a sustainable future. It will also examine contemporary and emerging policy and regulatory questions to energy and climate. The event will bring together an international audience of academics, industry executives, experts, analysts, regulators and policy makers.
For further information please visit:
iaee2025paris.org

CONFERENCE VENUE

Palais des Congrès Paris

The conference will be held at the Palais des Congres, the leading venue for international congresses in Paris.
On the first conference day, delegates will enjoy a welcome reception at the Conference hotel: Le Meridien. The Hotel interior is inspired by mid-century modern design, with clean lines accentuated by sculptural forms and rich fabrics, that are unmistakably reflective of Paris.
Conference's Gala dinner will be hosted by the City of Paris at the Hôtel de Ville. This unique venue will open its doors only for our delegates to guarantee an exclusive experience of the French hospitality, cuisine and fine wine.



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Energy Poverty in the EU: Why Do We Care, and How Must We Act?

BY MARINE CORNELIS

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The EU's promise of a just and inclusive transition risks becoming an empty pledge unless we decisively tackle energy poverty. The stakes are enormous: exacerbated by climate change, failure to act will perpetuate inequalities, condemn millions to further hardship, and undermine the social fabric of our communities.

In a Europe that aspires to lead the world in sustainability and equity agendas, how do we ensure our most vulnerable citizens are not left behind—whether in the cold or sweltering heat?

Energy poverty is more than an inability to afford heating or cooling. It cuts to the core of human dignity, affecting physical health, well-being, and social inclusion. It begins at home but stems from systemic inefficiencies and injustices that make daily life a struggle for many. The consequences extend beyond the often-cited "heating or eating" dilemma. Pushed by researchers and NGOs, as policymakers are starting to see[1], the question is no longer "How do we alleviate the symptoms?" but "How do we address the structural factors perpetuating energy poverty?"

Indeed, climate warming urges us to rethink: instead of focusing on immediate fixes, acting as simple blankets in winter, we need systemic improvements that make homes livable year-round. With climate change accelerating, energy poverty has become a multi-seasonal crisis, requiring urgent, coherent, and comprehensive action from policymakers, businesses, and citizens alike.

The Scope of the Problem

The pandemic, the war in Ukraine, and the subsequent energy price spikes have moved energy poverty high on the EU's political agenda. The rates jumped 35% from 2021 to 2022 as the cost-of-living crisis pushed even more households to the brink. The figures are staggering: 42 million Europeans—about 10% of the EU population — couldn't properly heat their homes in 2022.

A definition was long overdue. In Article 2 of the 2023 Energy Efficiency Directive, the EU formally recognised the unique nature of energy poverty, defining it as "a household's lack of access to essential energy services necessary for a basic standard of living and health, including adequate heating, hot water, cooling, lighting, and energy to power appliances, in the relevant national context, existing social policy and other relevant policies, caused by a combination of factors, including but not limited to non-affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes."

But behind figures and definitions lie real lives constrained by impossible choices: people cutting back on food to keep warm or cool or suffering from deteriorating health because of unfit living conditions.

What does energy poverty look like?

Energy poverty has long been defined by indicators focused on high expenditures, low income, and poor home energy efficiency. In short, it is about a low-income person living in a leaky 'thermal sieve' that is impossible to fix.

But these signs—these 'indicators'—are only part of the problem. Energy poverty becomes highly perceptible when bills become impossible to pay, debts pile up, mould—and coughs—set in, showers get shorter, and dining in your coat becomes 'normal'. How many families deprive themselves of modern comforts just to keep paying their bills and keep access to television or a telephone in the house? Energy poverty can be very hidden, showing only because children can't keep up at school after sleeping on an empty stomach in a poorly heated bedroom and waking up too early to walk to school because even the bus is not an option.

Less visible consequences are the toll on mental health and social isolation. Families unable to afford air conditioning in the summer or heat in the winter are unlikely to invite guests or engage in social activities. This isolation, combined with physical hardship, often remains overlooked in policy discussions that tend to focus primarily on affordability issues.

Besides, while winter energy poverty is widely recognised, climate change is adding a new dimension: summer energy poverty. Extreme heatwaves are now a regular occurrence, pushing homes beyond their limits. For vulnerable populations, such as the elderly, children, or those with pre-existing conditions, poorly insulated homes become death traps. Eurostat data revealed that up to 19% of EU households have not been comfortably cool in summer over the past years. In Europe only, heat is claiming more than 175,000 lives annually.[2]

Italy provides a stark illustration. In 2021, 2.2 million Italian households faced both winter and summer energy poverty. Poor insulation, outdated heating and cooling systems, and skyrocketing energy costs are leaving families making impossible choices: remain uncomfortable or incur crippling energy bills.[3]

Why do we care?

It gets clearer by the day that energy poverty and climate vulnerability are tightly linked. Those least able to afford rising energy costs are also the most exposed to climate impacts. These individuals have limited access to renewable energy technologies and are disproportionately exposed to environmental hazards. Addressing energy poverty is not just about affordability; it's about ensuring health, dignity, and resilience in the face of a warming planet.

Ironically, the poorest households often live the most sustainable lifestyles due to financial necessity. Their carbon footprints are much smaller than those of wealthier populations, yet they suffer most from the environmental degradation and higher costs associated with green policies. Low-income households already consume less energy due to financial constraints, demonstrating inherent sufficiency. They often cannot afford energy-efficient solutions, trapping them in a cycle of high energy costs and poor living conditions.[4] They may face an "ecological paradox", as green policies that focus on individual responsibility can unintentionally burden the very people least able to adapt.

Addressing energy poverty is fundamental to achieving the European Green Deal's goals. This cornerstone policy aims to make the EU climate-neutral by 2050, but its success hinges on fairness and inclusivity. If those most affected by the energy transition—low-income households—see their burdens increase without adequate support, there will be social resistance, which could slow or derail progress.

How must we act?

Tackling energy poverty requires bold, long-term solutions that go beyond short-term support. While EU policymakers have made strides with legislative measures like the Fit for 55 packages, these must be implemented swiftly and coherently. Here's a closer look at what must be done:

1. Treat energy poverty as the emergency it is

Member states have been rolling out subsidies and bonuses in response to energy poverty. Still, these efforts are like offering hot tea to someone with a cold: they provide temporary comfort yet fail to address the underlying problem.

Subsidies during crises are necessary, but they are not enough. Emergency measures, like those implemented following the energy price spikes of 2022, provided critical but temporary relief.[5] The next phase must be long-term resilience. This requires redesigning subsidy programs to offset bills and provide access to energy efficiency improvements and renewable energy. Doing so can transform short-term support into structural changes that reduce households' vulnerability to future price shocks.

The Energy Performance of Buildings Directive (EPBD)[6] and the Social Climate Fund[7] both emphasise this shift. These measures must now be translated into action focusing on sustainable solutions—from home renovations to clean energy access. The goal is not just to patch over the crisis but to ensure that households are no longer at the mercy of volatile energy markets.

2. Think Long-Term

While immediate financial support is essential during crises, it must be coupled with investments in long-term structural solutions. This includes upgrading home insulation, replacing outdated heating systems, and expanding access to renewable energy. By improving home energy efficiency and reducing dependence on fossil fuels, we can help households break free from the cycle of energy poverty.

The recent Energy Efficiency Directive (EED)[8] and Energy Performance of Buildings Directive (EPBD) provide a crucial framework for shifting from temporary fixes to enduring solutions, prioritising the most at-risk.

Public funds must be redirected to the households most vulnerable to energy poverty. These households often lack the means to invest in energy efficiency measures despite bearing the brunt of high energy costs and living in poorly insulated homes. The EED explicitly requires Member States to prioritise vulnerable and energy-poor households using public funds and financial incentives to address this. The Directive also calls for national energy efficiency funds to be set up or strengthened, ensuring that subsidies and grants reach the most needy households.

The EU's Renovation Wave[9], launched under the EPBD, pushes Member States to increase renovation rates, particularly focusing on older and less efficient buildings, many of which house low-income families. By tying renovation programs to energy poverty alleviation, Member States are now required to ensure that financial incentives are designed to cover upfront costs for these households, making renovations more accessible. This is crucial as many lower-income households are unable to pay for such improvements without external financial support.[10]

A significant portion of the EU's efforts is directed at social housing projects. Under the EPBD, Member States are required to prioritise energy renovations in social housing, where vulnerable households often live. The goal is to make social housing more energy-efficient and more affordable and resilient to future energy price shocks. This policy is central to achieving housing cost neutrality, where the energy savings from renovations offset any potential rent increases.

In tandem with these efforts, the EU's Emissions Trading System (ETS2)[11] for buildings introduces carbon pricing, incentivising the shift to cleaner energy. To prevent this from disproportionately burdening the most vulnerable, the Social Climate Fund and other ETS2 safeguards provide compensation mechanisms to offset rising costs for low-income households. The aim is to reduce carbon emissions and ensure the energy transition is socially just.

The energy transition must be led by the communities it aims to serve. Policies that promote energy democracy—giving households more control over their energy use—are critical. The EU has introduced reforms to encourage local energy generation and renewable energy sharing. For instance, individuals and communities can now produce and share solar energy locally, reducing energy costs and empowering communities to participate in the transition.

Energy communities and prosumerism (when consumers also produce energy) represent a fundamental shift towards a more democratic and resilient energy system. The EED supports these initiatives by calling for one-stop shops that offer advice and assistance, ensuring that low-income households and those at risk of energy poverty can easily access these opportunities. These services also provide holistic support by addressing related issues such as energy debt and access to affordable energy tariffs.

Additionally, national strategies to combat energy poverty, as mandated by the Governance Regulation,[12] must include clear action plans that engage stakeholders and protect vulnerable households from disconnection or energy market volatility. Policymakers must ensure that consumer protections are solid and financial incentives truly reach those most in need.

3. Act Coherently: Go Fast, Go Bold, Go Smart

Energy poverty cannot be addressed piecemeal. Recent EU legislation provides a robust framework, but its success depends on treating energy poverty measures as a well-funded coordinated package implemented strategically at national and local levels. The challenge is not simply to enact individual directives but to integrate them into a cohesive approach that links environmental goals with social equity.

One critical principle is the integration of social and ecological goals. Environmental policies designed to reduce carbon emissions must simultaneously address the inequalities they risk exacerbating. For example, energy efficiency measures aimed at decarbonising heating and cooling systems should prioritise low-income households, who are often least able to afford the transition but are most affected by poor housing conditions.

Coherent implementation is key. Measures to alleviate energy poverty, whether through energy efficiency programs, subsidies, or renewable energy access, must be connected across sectors—housing, health, and social welfare—and implemented holistically. National and local governments must work together to ensure these protections reach those who need them most while ensuring representation from affected communities in decision-making processes.

If a household is in energy debt, it should be referred to subsidy programs for energy efficiency upgrades. This ensures the family can prevent unmanageable bills in the future, breaking the cycle of energy poverty. The EU's Energy Efficiency Directive already calls for comprehensive action, including energy efficiency improvements and financial support. Still, success lies in ensuring these efforts are linked to social safeguards and practical assistance, such as one-stop shops or trusted partners that provide tailored advice. Barcelona's Punt d'Assessorament Energetic does exactly this: people come asking about their bills, they leave with dedicated accompaniment and practical, empowering tips.[13]

Cross-sectoral collaboration is essential. Energy poverty intersects with housing, health, and welfare, requiring a coordinated response that brings together policymakers, local governments, and civil society. Initiatives such as national energy poverty observatories, like France's ONPE[14], play a crucial role in establishing indicators, monitoring progress, conducting research, and ensuring policies are tailored to regional and local realities.

Vulnerable groups often use their rights less due to a lack of time or information, so understanding "hidden" energy poverty patterns requires expert networks[15]. For example, these networks can help local authorities navigate the complexities of the EPBD, which requires energy-efficient renovations and safeguards against evictions or rent hikes for vulnerable tenants.[16] Financial incentives for landlords must also benefit tenants, ensuring that housing remains affordable after energy renovations.

A good example is the Réseau Eco-Habitat in France,[17] which provides tailor-made renovation works to energy-poor homeowners. Throughout the process, they receive dedicated support from a Caritas volunteer while specialists work on financial and technical details. This helps overcome the main challenge: convincing families.

Decarbonising heating systems is another key focus of the EU's climate agenda. Moving away from reliance on fossil fuels for heating is essential to reducing energy bills and meeting climate goals. However, this transition must be inclusive and accessible, with support tailored to the needs of the most vulnerable populations. For instance, the digitalisation of energy systems must be aligned with accessibility measures to ensure no one is left behind.[18]

Lastly, we must ensure energy tariffs are designed in ways that are ecologically and socially sound. Households should not be penalised for the structural and financial barriers they face in accessing cleaner energy. This requires reforms that link subsidies, energy efficiency improvements, and demand-side flexibility with practical support to address related challenges such as debt, consumer and tenancy rights, and access to fair billing systems.

By acting coherently, with urgency and precision, the EU can turn its legislative frameworks into practical tools that tackle energy poverty in all its dimensions—economic, social, and environmental. The vision is to reduce bills, improve efficiency, and create a fair, inclusive energy system that leaves no one behind.

4. Go Beyond the Low-Hanging Fruit

However, to tackle energy poverty effectively, we must rethink the systems that sustain it. Too often, the discussion centres around cost reflectivity—the idea that individuals should pay proportionately to the strain they place on the system. But this logic is flawed. People don't cost the system; the system is built for people. It's a construct that can—and should—be redesigned to serve everyone, not just those who can afford it.

Energy poverty isn't a personal failure, nor is it about individual choices. It's the result of a system designed with winners and losers in mind. We've normalised a structure where the most vulnerable pay the highest price, even though they often have the least ability to control their energy consumption or adapt to rising costs. We must move away from the idea that those who use energy "inefficiently" are somehow at fault. Instead, we should focus on redesigning the system to support equitable access to energy for all.

This shift requires us to move beyond treating energy poverty as simply a matter of affordability and instead see it for what it is—energy insecurity. Energy insecurity doesn't just blame individuals; it reflects how systems fail to provide adequate and affordable access to energy services. Framing the issue this way opens up new possibilities for systemic change, making it less about individual shortcomings and more about redesigning an infrastructure that works for everyone.

We must also recognise the intersectional nature of energy poverty. Marginalised communities—particularly racial and ethnic minorities—face disproportionate challenges in accessing affordable energy. In the US, these issues are at the forefront of discussions on energy justice,[19] but Europe still lags in addressing the racial and social dimensions of this crisis. Tackling energy poverty means recognising these deeper inequalities and ensuring that the transition to clean energy doesn't exacerbate them. This is not just about reducing bills; it's about fundamentally realigning energy, climate, and digitalisation goals with principles of fairness and justice.

The energy transition must benefit everyone, especially those who have historically been left behind. Policies focused on individual responsibility—like asking people to pay for what they supposedly "cost the system"—are inherently regressive. The path forward requires a collective approach, where the system adapts to human needs rather than forcing humans to bear the system's burdens.

Conclusion

Tackling energy poverty isn't just about reducing bills; it's about ensuring access to the energy services necessary for a decent quality of life. The EU's legislative toolkit is comprehensive, but its success will depend on how well it's implemented.

We must ask ourselves what kind of Europe we want to build. Is it one where the green transition benefits everyone or one where the most vulnerable bear the brunt of change? The choices we make today will define the legacy of our generation.

The tools, knowledge, and responsibility to eradicate energy poverty exist. We need the political will to ensure no one is left behind. By embedding energy justice into our climate and energy policies, we can create a greener, fairer, and more resilient Europe for all.

Footnotes

1 See for instance the Draghi report on EU Competitiveness, 2024: https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en

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8 https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en

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15 "The Social and Local Dimensions of Governance of Energy Poverty: Adaptive Responses to State Remoteness", Creutzfeldt, N., Gill, C., McPherson, R. and Cornelis, M., Journal of Consumer Policy, 2020, SSRN: https://ssrn.com/abstract=3518384 or http://dx.doi.org/10.2139/ssrn.3518384

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Can Energy Accessibility Reduce Inequality and Foster Innovation?

BY INÊS CARRILHO-NUNES

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Abstract

This article explores how innovation in energy access, through technological advancements, policy solutions, and community-based projects, can reduce inequalities, including those related to income and gender, while promoting economic growth, improving health outcomes, enhancing education, and increasing productivity, ultimately contributing to a more sustainable and equitable future.

Introduction

Energy is a fundamental pillar of economic development, directly affecting the quality of life, economic opportunities, and social inclusion. However, millions still lack access to essential energy services, exacerbating poverty and inequality. Energy poverty disproportionately affects low-income households and communities, particularly women, who face greater energy challenges within their households and in the workforce (Acheampong et al., 2021). Indeed, energy poverty is a global problem with multiple concerns and definitions that vary and are highly dependent on the context or country. Energy poverty can be defined as the "inability of households to ensure their energy needs" (European Commission, 2023). However, there are different approaches to energy needs, and, consequently, energy poverty and its indicators, can be described with different approaches. First, energy poverty can refer to households without access to sufficient elemental energy services and commodities. These can include the lack of access to electricity and non-solid clean fuels (e.g., natural gas, biogas) and modern utilities for clean cooking. Typically, these households use kerosene, coal, and solid biomass as energy sources for cooking, which is highly damaging to the environment and public health. This definition focuses on the lack of access to modern energy sources essential to satisfying energy needs in an adequate lifestyle. It has a perspective based on primary energy access and is more commonly used to describe energy-poor households in lower-income economies, where access to electricity and clean cooking facilities is not guaranteed. The concepts of energy access and energy poverty are thus tidily connected. Yet the energy poverty bracket can also encompass individuals who struggle to afford energy services and are forced to lower their energy consumption bills to a degree that negatively affects the quality of their energy-related activities. Accordingly, energy poverty also includes cases where citizens spend most of their income (~10%) on energy debts. As a result, their inability to keep their homes warm or cold increases, or their arrears on utility bills surge (European Commission, 2023; Zhao et al., 2022). This second definition is more commonly used when studying energy poverty in higher-income countries.

The United Nations internationally recognizes the urgency of addressing energy poverty, underpinning several SDGs to the theme. Even though the seventeen objectives are tightly connected, it is possible to highlight three immediate goals for energy poverty and its implications: SDG 1 ("End poverty in all its forms everywhere"); SDG 7 ("Ensure access to affordable, reliable, sustainable and modern energy for all"); and SDG 13 ("Take urgent action to combat climate change and its impacts"). Combining these SDGs, there is potential for countries to improve their energy systems to bridge the poverty gap while fostering a cleaner energy transition.

At the intersection of these challenges lies the potential of technological change and innovation. Technological advancements in energy generation, distribution, and consumption can create new opportunities to address energy poverty while promoting inclusive economic growth (Capasso et al., 2019). The importance of bridging this energy gap is not only a technical issue but also a social one, with wide-ranging implications for economic inequality, education, and health.

Energy Accessibility and Inequality

Energy poverty has both direct and indirect effects on inequality. Households without access to clean, affordable energy are more likely to face health issues, miss educational opportunities, and remain economically marginalized. Research shows that energy accessibility is strongly linked to income inequality: regions with greater energy access tend to exhibit lower income disparities (Acheampong et al., 2021). This relationship emphasizes the critical need to ensure that vulnerable populations are prioritized in energy access initiatives. In addition, energy access plays a crucial role in reducing gender inequality. Women, especially in low-income and rural areas, disproportionately bear the brunt of energy poverty due to their traditional roles in household activities such as cooking and gathering fuel (IEA, 2017). Access to clean and modern energy reduces the time women spend on these labour-intensive tasks, allowing them to pursue education, economic opportunities, and improved living standards (Bouzarovski & Petrova, 2015; UNDP, 2018). Studies further show that reducing energy poverty promotes gender equality in the workforce and improves women's health outcomes (Nguyen & Su, 2021; Sovacool, 2012).

Energy poverty also directly impacts health, with millions exposed to harmful indoor air pollution from burning solid fuels for cooking (Sovacool, 2012). Women, children, and the elderly are particularly vulnerable, as they spend more time indoors, exposed to dangerous levels of pollutants. This exposure is linked to respiratory diseases, heart conditions, and millions of premature deaths annually (IEA, 2017; WHO, 2006). The lack of affordable, clean energy also leads to inadequate heating in colder climates, contributing to poor mental and physical health, particularly in underprivileged households (Adom et al., 2021; Hills, 2011). Moreover, energy accessibility is integral to improving education and productivity. In many developing regions, children, particularly girls, miss school to perform household chores like gathering firewood (Acheampong et al., 2021, 2024). Access to reliable energy not only enables children to attend school but also enhances learning environments through better lighting and technology. Energy access also increases productivity, especially in agriculture and manufacturing, by providing power for essential services like irrigation and machinery, contributing to job creation and economic growth (Shi et al., 2022).

Improving energy accessibility is thus a vital step toward addressing inequality in its many forms. From enhancing gender equality to improving health, education, and productivity, access to clean and affordable energy has the potential to transform lives and reduce disparities. However, achieving these outcomes requires more than just expanding energy infrastructure. It demands innovative approaches—both technological and policy-driven—that can effectively bridge the gap between energy access and economic empowerment. By fostering new technologies and creative solutions, innovation plays a pivotal role in addressing energy poverty and driving inclusive development.

The Role of Innovation in Addressing Energy Poverty

Innovation serves as a critical enabler of energy accessibility. Technological advances, such as off-grid solar systems, clean cooking technologies, and decentralized energy solutions, have already demonstrated their ability to reduce energy poverty in regions where traditional energy infrastructure is unavailable (Alola, 2024; Gui & MacGill, 2018). Moreover, the digitalization of energy systems offers new pathways to bring affordable energy to underserved populations by optimizing energy distribution and reducing inefficiencies (Bianchini et al., 2023; Vasconcelos-Garcia & Carrilho-Nunes, 2024). However, the transformative potential of innovation in energy systems is not limited to technology alone. Policy innovation, financial instruments, and new business models can also play significant roles in ensuring that the benefits of the energy transition reach marginalized communities.

A prime example of such policy and business model innovation is the development of community-based energy projects. These initiatives, often spearheaded by local innovators, enable regions that are traditionally underserved by national grids to achieve reliable and affordable energy access (Chapman et al., 2021). These localized solutions, ranging from renewable microgrids to cooperative energy systems, empower communities to manage their energy needs autonomously while also contributing to broader societal goals of sustainability and equity.

Innovation also fosters significant economic and social improvements by creating employment opportunities and promoting gender equality. By integrating renewable energy projects with community empowerment strategies, these innovations can drive economic growth in rural and disadvantaged areas. For instance, solar energy projects have been shown to create new opportunities for micro-entrepreneurs, particularly women, by providing them with reliable power for small businesses (Nguyen & Su, 2021). Moreover, the combination of digital tools and decentralized energy systems allows for enhanced energy efficiency and affordability, further driving down the cost of energy for low-income households (Bouzarovski & Petrova, 2015).

Beyond immediate energy provision, these innovative approaches have a ripple effect on reducing inequality. As energy becomes more accessible, women and other vulnerable groups spend less time on energy-related domestic tasks, such as gathering fuel, enabling them to pursue educational and economic opportunities (Acheampong et al., 2021, 2022, 2024; Rustagi et al., 2024). Innovation, therefore, not only addresses the issue of energy poverty but also becomes a mechanism for fostering broader societal changes, ultimately reducing inequality and promoting inclusive economic development.

Fostering a Just Energy Transition

A just energy transition requires that we address the unequal distribution of opportunities and resources both within and between countries. As the world shifts toward a low-carbon energy system, policymakers and energy stakeholders must ensure that this transition is inclusive and sustainable, leaving no one behind. A truly just transition goes beyond technological advancements; it incorporates social equity as a foundational principle. This means prioritizing the needs of the most vulnerable populations, who are often the hardest hit by both energy poverty and the adverse effects of climate change (International Labour Organization, 2022).

Innovation, when combined with sound policy frameworks and strategic investment, creates the enabling conditions for a just energy transition. By aligning energy access initiatives with broader efforts to reduce inequalities, we can foster a sustainable and equitable energy future. This alignment is crucial, as energy access alone does not guarantee social progress unless it is paired with policies that address structural inequalities. For instance, gender-sensitive policies that ensure women have equal access to the benefits of clean energy can have transformative impacts on communities, enhancing health, education, and economic outcomes for all.

Conclusion

Addressing energy poverty and promoting energy accessibility are fundamental steps toward reducing global inequality. Energy is deeply interconnected with critical societal dimensions, from economic development to health and education, and the lack of access to modern, reliable energy services perpetuates cycles of poverty and inequality. Innovation, whether through technological advancements, like off-grid solar systems or policy reforms aimed at supporting decentralized energy solutions, plays a pivotal role in transforming energy systems to be more inclusive and sustainable. By expanding access to clean and affordable energy, we not only improve living conditions but also drive progress in broader development goals. The ripple effects of energy access extend beyond simple electricity provision — accessible energy enhances health by reducing reliance on harmful fuels, boosts education by allowing students to study in well-lit environments, and strengthens local economies by empowering entrepreneurs and enhancing productivity. In this sense, energy accessibility serves as both a catalyst for growth and a pathway to equity.

However, achieving this vision of universal energy access is not without its challenges. Energy poverty disproportionately affects women, rural communities, and other vulnerable groups, highlighting the need for tailored approaches that prioritize social equity. Policymakers must recognize that energy is not just an economic issue but a social one, with far-reaching implications for poverty, gender, and overall inequality. Achieving universal energy access and reducing energy poverty is key to meeting the broader goals of sustainable development. This demands a multi-dimensional approach that prioritizes both technological solutions and equitable policy frameworks.

Achieving a just energy transition requires a coordinated effort that integrates technological progress with social justice. Only by bridging the gap between innovation and inclusivity can we ensure that the energy transition leads to shared prosperity, alleviating both energy poverty and inequality. In this way, the shift to clean energy becomes not only an environmental necessity but also a powerful tool for reducing inequality and fostering long-term, inclusive economic growth.

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Shared Power, Shared Prosperity—How Collective Ownership of Local Renewable Energy Sources Can Help to Build Resilient Rural Communities

BY PHILIPP RIEGEBAUER

Community-owned solar power offers rural areas a decentralized, renewable energy solution that fosters local engagement, economic opportunities, and energy security. By promoting peer-to-peer energy sharing and sustainable practices, these systems empower communities, reduce dependence on centralized grids, and address broader challenges like waste management, driving social and economic resilience.

Access to reliable and affordable energy is essential for improving quality of life, enhancing productivity, and driving economic development. However, in many parts of the world, particularly in rural and underserved areas of Africa, millions of people still lack access to electricity, with globally over 745 million people lacking access in 2023. Sub-Saharan Africa continues to account for about 80% of this deficit, despite efforts to improve access through decentralized energy solutions like solar home systems, which have seen growth in some regions. **[IEA, 1]**, **[SEforALL]**

Energy poverty disproportionately affects low-income communities, where centralized energy infrastructure often fails to reach, deepening inequality and limiting opportunities for social and economic development. The transition to renewable energy, particularly solar power, presents a unique opportunity to address these challenges. Solar energy, as a decentralized and sustainable source of electricity, can empower communities to take ownership of their energy systems, fostering energy democracy and decentralization. Renewable Energy Communities (RECs) have the potential to improve energy access, promote community engagement, and ensure long-term sustainability.

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This article explores the potential of solar power to overcome energy poverty in rural areas, focusing on community ownership, modular microgrids, and peer-to-peer energy sharing. By leveraging local energy sources and fostering pro-social behavior, rural communities can not only achieve energy security but also address other pressing challenges such as waste management and sanitation.

The challenge of community ownership

Energy poverty, defined as insufficient access to affordable and reliable energy for basic needs, is a significant issue, particularly in rural areas. Centralized energy systems, although beneficial for urban centers, often fail to reach remote and underserved

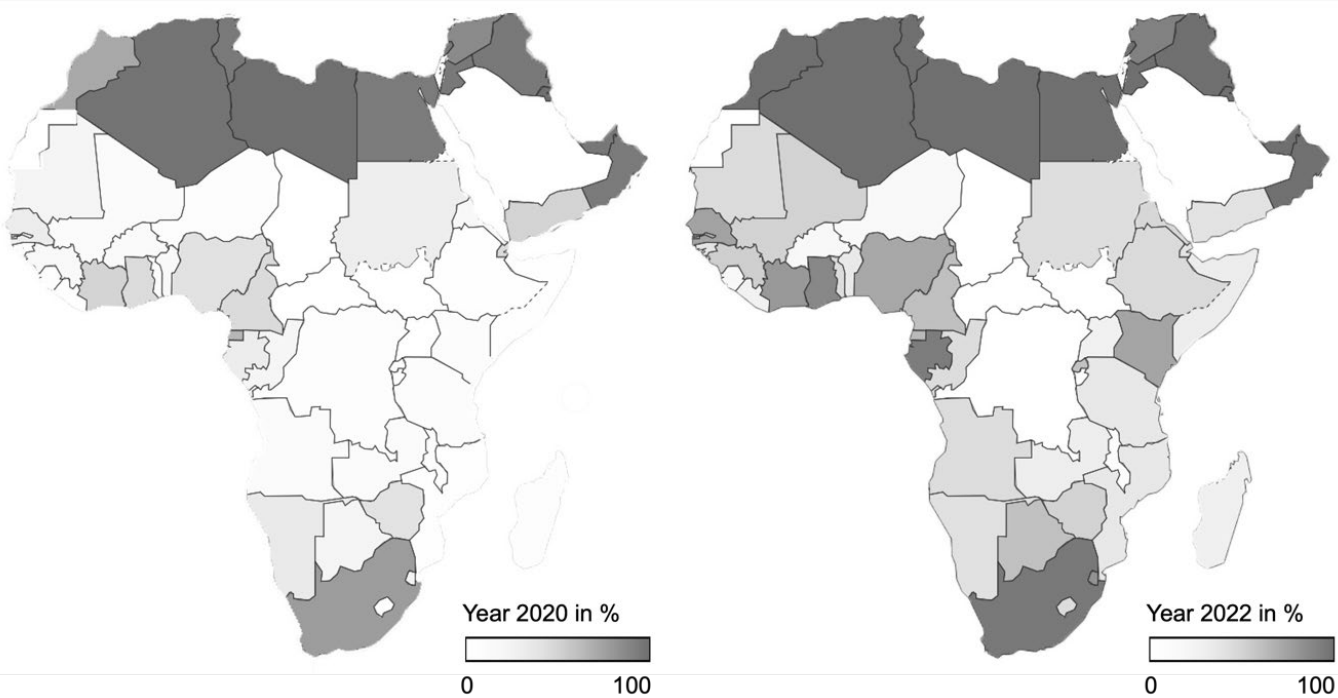

Figure 1: Share of population with access to electricity in Afrika; Source ***[IEA 2]***

areas. These systems tend to overlook community involvement, leaving residents dependent on external sources for their energy needs. Community ownership of energy resources is an emerging solution to these challenges. It fosters local engagement and provides a sense of control and empowerment. When communities are responsible for managing their energy systems, such as solar power installations, they are more likely to ensure the longevity of these systems. In rural areas, where centralized grids are either unreliable or entirely absent, solar energy represents a local solution that can be owned, managed, and maintained by the community.

Solar power and modular microgrids for reliable energy access

Solar power has emerged as one of the most promising solutions to energy poverty, particularly in rural and remote regions. The declining cost of solar photovoltaic technology, coupled with the abundant sunlight in many regions, makes solar power a cost-effective, local and scalable energy solution. In rural areas, solar energy systems can be deployed at various scales, from individual home systems to larger community-based projects. This flexibility is key to addressing the diverse needs of different communities.

However, one of the key challenges with solar energy is its intermittency. Solar panels generate electricity only when the sun is shining, and without affordable energy storage solutions, continuous electricity supply can be difficult to achieve. To address the intermittency of solar power and limiting the need for costly battery storage, modular microgrids and peer-to-peer energy sharing have gained traction as a solution. Microgrids are small, decentralized energy systems that can operate independently or in conjunction with the main grid. Solar-powered microgrids offer several advantages for rural communities. They can be designed to meet the specific needs of the community, with the ability to expand as demand grows. Moreover, because solar power can be locally generated and consumed, it eliminates the need for costly and complex transmission infrastructure that often makes centralized grid extensions unfeasible.

Peer-to-peer electricity sharing and tokenization

One of the most exciting developments in the field of decentralized energy is the concept of peer-to-peer (P2P) energy sharing. P2P energy sharing allows households and businesses to trade electricity directly with one another, without the need for a centralized utility. This approach is particularly well-suited to solar energy systems, where energy generation is distributed and often intermittent. Through blockchain technology and smart contracts, households who generate excess energy can sell their surplus to neighbors, creating a micro-economy around renewable energy generation. This not only improves energy access, ensuring that the entire community benefits from the collective solar energy generation, but also helps to build a more resilient local economy that is less dependent on external resources.

One of the key enablers for peer-to-peer networks and tokenization in Africa is the high penetration of mobile phones. Mobile technology has seen explosive growth across the continent, with smartphone adaption in Sub-Saharan Africa of 51% in 2022, and projections suggest that smartphone adoption will reach 88% by 2023. **[GSMA]** Many people in Africa, particularly in countries like Kenya and Nigeria, are already accustomed to using mobile-based financial systems like M-Pesa. This familiarity with mobile money and digital transactions makes it easier for communities to adopt token-based systems for energy trading. Second, while data privacy and protection are important issues, the lower regulatory barriers in most African countries allow for quicker adoption and innovation in decentralized technologies. Countries like Kenya and Nigeria have implemented Data Protection Acts, but these frameworks are generally less restrictive, offering more flexibility for peer-to-peer energy trading platforms.

Tokenization, the process of creating digital tokens to represent energy credits, can further enhance P2P energy sharing by encouraging energy-saving behaviors. Tokens can be earned by generating excess energy and spent by consuming energy from the grid. This system can incentivize households to participate in the energy market and manage their energy consumption more effectively. Therefore, in addition to providing reliable

Table 1: Tokenization in the context of energy systems and peer-to-peer energy sharing

Steps	Description
1st Energy Generation	In a community with solar panels or other renewable sources, electricity is generated and fed into a local energy microgrid or stored in batteries.
2nd Creation of Tokens	The energy generated can be quantified, and tokens are issued to represent this amount of energy. For example, one token might represent one kilowatt-hour (kWh) of electricity.
3rd Trading	Using blockchain technology, participants in the energy network can trade tokens among themselves. If one household generates excess energy, they can sell their tokens to a neighbor who needs more electricity.
4th Smart Contracts	Transactions are governed by smart contracts, which are self-executing contracts with the terms of the agreement directly written into code. These contracts automate the process of buying and selling energy, ensuring transparency and efficiency.
5th Incentives	Tokenization also allows for incentivizing pro-social behaviors, such as reducing consumption during peak times. Users can earn tokens for contributing to the energy grid or for participating in sustainable practices, which can be spent on energy or other services.

electricity, P2P networks encourage community engagement and foster pro-social behavior. When community members share energy, they develop a stronger sense of interconnectedness and responsibility for one another, laying the groundwork for addressing other community challenges. Despite challenges, decentralized renewable energy systems, such as solar-powered microgrids, offer a promising pathway to overcoming energy poverty and building resilient communities.

Leveraging pro-social behavior to build sustainable communities

A sustainable community can be seen as a community in which development is maintained over time. The sense of shared responsibility of RECs can lead to broader social and environmental benefits. Communities that develop strong networks around shared energy resources are more likely to collaborate on other infrastructure projects, such as sewage and waste management. For example, the use of tokenization can be expanded beyond energy to incentivize pro-social behaviors in other areas. Residents could earn tokens for participating in waste collection programs or maintaining communal sanitation facilities. These tokens could then be redeemed for electricity credits, creating a virtuous cycle of community engagement and infrastructure development. Moreover, the development of local carbon markets, as seen in the wake of the COP28 summit, presents an opportunity for communities to benefit financially from sustainable practices. In conclusion, solar power, when combined with decentralized energy systems, P2P sharing, and community-driven solutions, has the potential to address not only energy poverty but also broader social and economic challenges in rural areas.

Table 2: Challenges and Opportunities for Renewable Energy Communities

Core Aspect	Challenges	Opportunities
Energy Poverty in Africa	Limited access to electricity, high cost of extending the grid to remote areas, and reliance on fossil fuels.	Improving energy access can drive economic growth, enhance education and healthcare, and reduce inequality.
Solar Power Installation	Intermittency of solar generation, high initial investment for solar panels and and lack of affordable battery storage. Absence of finance mechanisms and opportunities for loans.	Decreasing costs of solar technology, renewable and abundant resource, scalable for local needs. Development of sustainable finance mechanisms.
Decentralized Energy Systems	Cost of establishing microgrids, lack of expertise and maintenance in rural areas.	Increased reliability and energy security, flexibility to scale, reduces reliance on central grids.
Community Ownership	Low levels of community involvement and initial community reluctance to maintain energy systems.	Fosters social engagement, long-term sustainability, promotes local ownership and responsibility.
Peer-to-Peer (P2P) Energy Sharing	Challenges in implementing blockchain, potential inequality in energy sharing.	Encourages community cooperation, can optimize energy use and distribution, enhances resilience.
Barriers to REC development	Insufficient regulatory frameworks, lack of funding, poor governance and community support.	Opportunity for growth with better policies and funding, development of local jobs and expertise.
Distribution of REC benefits	Ensuring equitable access to benefits, securing community engagement, and aligning with local economic needs.	Improves energy access, fosters local economic development, helps addressing broader social challenges.

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Energy Poverty Takes Precedence Over Western Green Policies: The Case of Africa

BY DR MAMDOUH G SALAMEH

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An Outlook

In 2010, the World Economic Forum defined energy poverty as the lack of access to sustainable modern energy services and products. To be more precise, it is not only a matter of sustainability. Energy poverty can be found in all conditions where there is a lack of adequate, affordable, reliable quality, safe and environmentally-sound energy services to support development.[1]

Energy poverty is a global problem. While the number of people without access to electricity worldwide has decreased very significantly since 2010 primarily driven by economic growth in Asia, 760 million people still lack access today.

However, nowhere energy poverty is more debilitating and chronic than in Africa where according to current statistics from the IEA, about 620 million Africans or two-thirds of the population do not have access to electricity while 730 million use traditional biomass for cooking,

The demand for energy in Africa is outstripping supply with the energy crisis deepening. Without significant intervention, Africa's energy supply will not keep pace with the rising demand stemming from increasing urbanization, economic growth and a rapidly growing population.

Despite having abundant oil and gas reserves accounting for 12.0% and 9.0% of global proven reserves respectively, the continent of Africa is suffering from energy poverty.[2] Insufficient investments compound this problem with the continent receiving less than 2% of global investments in renewable energy over the last two decades,

The greatest cause of energy poverty in Africa is poor governance characterized by corruption, weak institutions and lack of accountability all of which create an environment where resources are often wasted or mismanaged.

However, I single out a lack of investments as a most critical factor behind Africa's energy poverty and blame it on Western green energy policies hampering the development of Africa's vast oil and gas reserves.[3]

Western Green Energy Policies

Since Europe's energy crisis in January 2021 which was sparked by hasty European Union (EU) green policies aimed at accelerating energy transition to renewables and later transformed into an international crisis by the Ukraine conflict, African countries have been viewing the unfolding crisis as an opportunity to monetize their untapped reserves and eliminate the continent's energy poverty.[4]

However, a plethora of western-backed environmentalist groups, the EU parliament and US Presidential Climate Envoy John Kerry were all up in arms against any development of African oil and gas reserves (see Chart 1).

The EU has advised member states not to assist in the implementation of Uganda's oil and gas projects with 20 western banks and thirteen insurers already voicing opposition.

For his part, US Presidential Envoy John Kerry, speaking to Reuters on the sidelines of the 18th session of

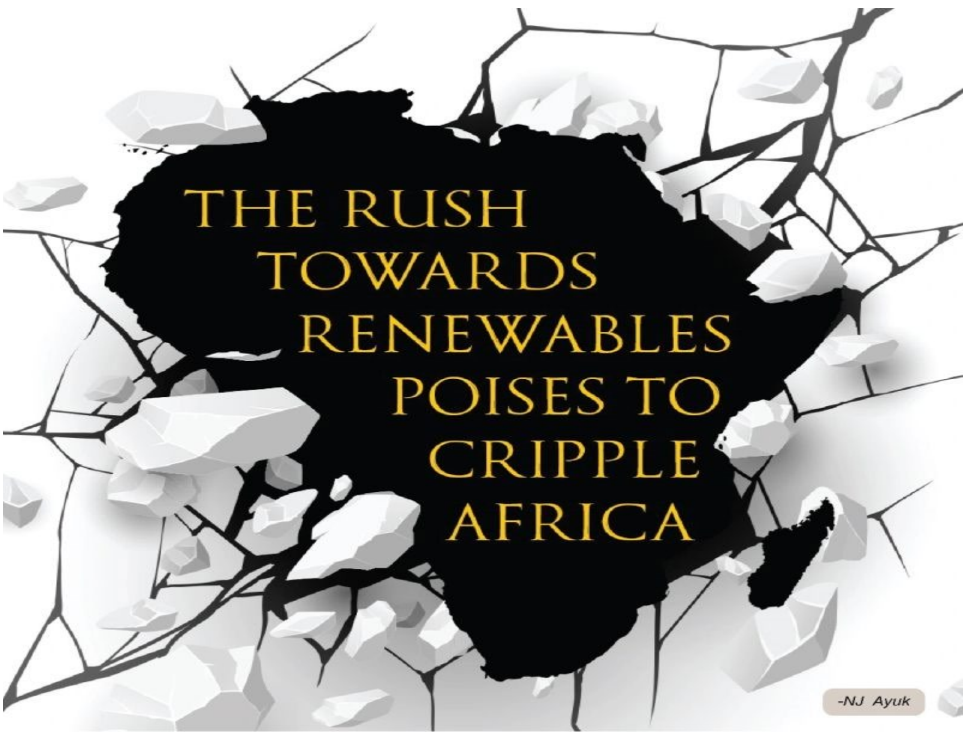

Chart 1
Source: Courtesy of Linkedin.

the African Ministerial Conference on the Environment (AMCEN) in Dakar, Senegal warned against investing in long-term gas and oil projects in Africa claiming that these projects will end up as stranded assets by 2030. Instead, he urged African countries to focus on reducing emissions in a continent that has contributed only 3.8% to global emissions in 2022, the least in the world.[5]

Civil society groups connected with the EU and US environmentalist Funds or Western climate networks argue that Africa's hydrocarbon projects will not benefit African people and that the investment would be better spent on a new green economy.[6]

The West puts so much importance on the climate change agenda in Africa. I would hazard two explanations for the West's attitude. The first is that the West is under the misguided and erroneous view that any future energy assets like investing in oil and gas production and building pipelines will end up after 2030 as stranded assets. The second explanation is a more sinister one with the West wishing to keep African energy resources underground in order to satisfy its own appetite for energy in the future.

West's Climate Change Hypocrisy

In the last two decades, Africa's contribution to global emissions fluctuated between 3.4% and 3.8%, the smallest share among all world regions.

Meanwhile, EU countries who promote green policies have abandoned their green credentials to resurrect coal-fired electricity plants because of rising prices of gas and oil. Similarly, Western multinational oil corporations have never stopped investing in oil and gas and they will be more than happy to discard their green credentials and exploit loose climate regulations in African countries.

While denying Africa's right to push ahead with its own energy endeavours, the West would be eager to offer investments and technological know-how to the continent in exchange for receiving the lion's share of the regional hydrocarbon wealth. The West doesn't care whether African countries are experiencing severe energy poverty or not as long as it gets its hands on these reserves.

A consortium of European investment firms have raised $200 million to fight deforestation in Africa, warning that the increasing consumption of charcoal by the continent's nations is putting pressure on forests. According to Bloomberg, the use of wood-based fuel jumped 90% in Africa to 34.9 million tons in 2020.[7]

With African people suffering immensely from energy poverty, lack of clean drinking water and starvation, the last thing on their minds would be deforestation. African people are being driven by energy poverty to cut trees from the forests to provide themselves with warmth in winter and fuel for cooking.

What Africa needs immediately isn't green energy transition as the World Economic Forum suggested but the immediate development of its vast oil and gas reserves. In fact, Africa will need $190 bn a year to meet energy demand.[8]

African countries are hardly alone in their refusal to succumb to global pressure to rush their transition from fossil fuels to renewable energy sources.

In May 2021, the International Energy Agency (IEA) issued a report, "Net Zero by 2050: A Roadmap for the Global Energy Sector ," calling for a halt to oil and gas exploration around the globe at the end of the year. That dramatic measure, the IEA argued, was the global energy sector's only hope of achieving net-zero emissions (ensuring that the amount of greenhouse gases being emitted into the atmosphere equals the amount being removed) by 2050, a goal outlined in the Paris Climate Agreement.

While some have put their support behind the IEA's recommendation, a number of oil- and gas-producing nations firmly and unapologetically rejected it.

Saudi Arabia's Energy Minister Prince Abdulaziz bin Salman dismissed it in a mocking way dubbing it La La Land 2050 roadmap.

The Deputy Director of International Affairs at Japan's Ministry of Economy, Trade and Industry (METI), Akihisa Matsuda, told Reuters that his government had no plans to immediately stop oil, gas, and coal investments.[9]

"The report provides one suggestion as to how the world can reduce greenhouse gas emissions to net-zero by 2050, but it is not necessarily in line with the Japanese government's policy," Matsuda said. "Japan needs to protect its energy security including a stable supply of electricity, so we will balance this with our goal of becoming carbon neutral by 2050."[10]

Norway Oil Minister Tina Bru pushed back against the IEA's recommendations, too. "It would not if Norway discontinues production," Bru said. "It would just move to other countries, and then we are no further. This is a complex global problem that requires many solutions."[11]

However, Africa hasn't been afforded the same consideration when African leaders expressed similar viewpoints.

African Gas for the EU

For years, the EU neglected if not completely ignored the needs of African countries for investment for the development of their infrastructure and their energy reserves.

The EU's hypocrisy is exposed by its sudden rush for African LNG while stressing that it doesn't want to fund projects that would allow the world's poorest continent to burn more of the fuel at home.

Western nations even criticized China when it invested in Africa's infrastructure and energy and mineral resources at a time when they were refusing to invest in Africa either because of sanctions they themselves imposed on African countries or because of their old imperialistic streak. Yet the world Bank credited China's investments with enabling Africa to achieve annual growth rates of 4%-5% for the past few years.

The Myths and Realities about Renewables

While great strides are being made in global energy transition and solar and wind electricity, the notions of imminent global energy transition and net-zero emissions by 2050 are myths. They will never be achieved by 2050 or 2100 or ever. The reason is the intermittent nature of solar and wind energy.

Renewables are incapable on their own of satisfying global demand for electricity without huge contributions from natural gas, coal and nuclear energy. Toay's technology doesn't allow yet for storing solar and wind energy in summer for use in winter.

With a global oil consumption exceeding 104 million barrels a day (mbd) in 2024, the notions of imminent energy transition and net-zero emissions look like illusions.[12]

Fossil fuels contribution to the global energy mix is still lingering well above 80%, a figure that has changed little in 30 years. In fact hydrocarbons accounted for 83% of global primary energy consumption in 2020.[13] That remains so despite being challenged by serious environmental policies and a global expenditure of $ 3.0 trillion on renewable energy during the last decade (see Chart 2). This is a hefty price to pay just to gain only a percentage point of market share from coal.

And whilst wind and solar are being deployed quickly at an exponential rate, renewable energy installations are far too slow to catch the still-voracious appetite for fossil fuels. It is a fact needing acknowledgement in a world of 7.9 billion people, each of whom is wanting for more light, heat, mobility and gadgetry.

For now, we're in an era of "energy diversification," where alternative sources to fossil fuels, notably renewables, are growing alongside not at the expense of the incumbents.

Most oil companies are also investing heavily in chemicals and petrochemicals. Environmental groups would correctly note that this is hardly a strategy for a clean energy transition, but oil companies see global demand for plastics, fertilizers and other petrochemical products contributing significantly to the growth in global oil demand along with the transportation sector. Petrochemicals for instance currently account for 13% of global oil demand and this is projected to rise to 16% by 2030 compared with 73% for transport.

The Guiding Principles of the Global Oil Market

Investments in both oil and gas and also in renewables will be guided by three pivotal principles.

The first is that there will be no post-oil era throughout the 21st century and probably far beyond. Oil will continue to reign supreme well into the Future.[14]

The second principle is that there will be no peak oil demand either. The IEA projects that peak oil demand will be reached before 2030. But the IEA's projection is wrong because it is based on a flawed assumption of rising number of EVs causing a steep decline in oil demand and leading to a peak. But this projection is disputed by the fact that there are only 26 million EVs currently on the roads compared with 1.4 billion ICEs. It is also undermined by OPEC+'s projection of global oil demand rising to 110 million barrels a day (mbd) by 2028 and hitting 116 mbd by 2045.[15]

Oil demand will continue to grow well into the future albeit at a slightly decelerating rate because of governmental legislations and a slightly deeper penetration by EVs into the global transport system. Stii, EVs could never prevail over ICEs throughout the 21st century and far beyond.

The third principle is business opportunities. While Big Oil is investing huge amounts in renewables, such investment pales in size when compared with that in oil and gas exploration and production, refining and petrochemicals. The slower pace of oil majors toward alternative energies is due to two key reasons. First, they believe that oil and gas will continue to be needed well into the foreseeable future. And second, and probably much more important, is that financial returns from renewables are nothing compared to the huge bonanzas oil firms are accustomed to rake in when oil prices rise.[16] While renewables accounted in 2020 for 5.7% of global primary energy demand, oil, natural gas and coal accounted for 83%.

Still, Big Oil does invest in clean energy solutions and has accelerated such investments in recent years partly to be genuinely involved in the clean energy solutions and partly to burnish its environmental credentials but the general mood, at least for now, is as Shell put it succinctly last year—we'll move away from oil when this makes commercial sense.

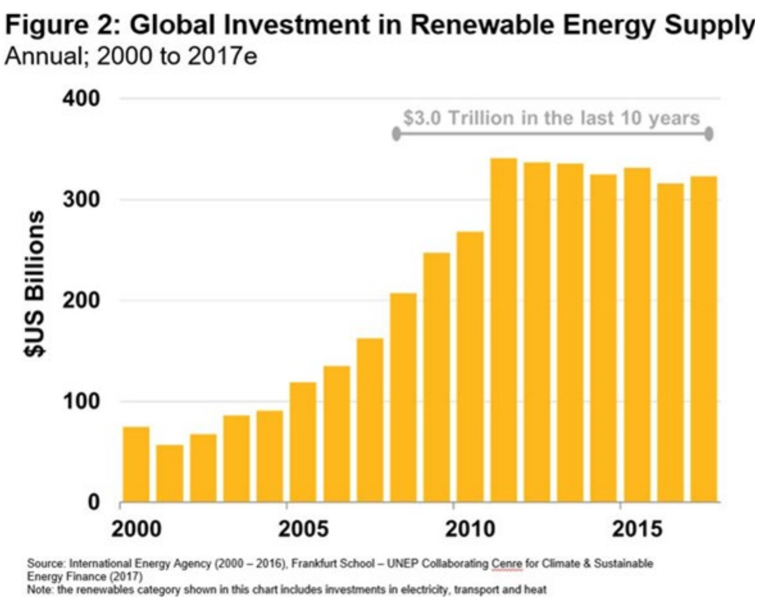

Chart 2
Source: Courtesy of IEA.

A Rational & Pragmatic Global Energy Strategy

With a world population projected to rise from 7.9 billion currently to 9.7 billion by 2050 and a global economy expected to grow from $100 trillion now to an estimated $245 trillion also by 2050, there is a huge need for every available energy source.

Therefore, a rational and pragmatic global energy strategy dictates that fossil fuels and renewables coexist and work diligently together to satisfy global energy needs. The bigger the contribution of renewables in global electricity generation, the less coal, natural gas and nuclear energy needed.

Oil and gas and the global economy are inseparable. Undermine one you undermine the other and vice versa.

Therefore, humanity has two quintessential options. One is to succumb to unsubstantiated apocalyptic existential threats to our planet and stop using oil and gas altogether and in so doing face an ultimate collapse of the global economy, starvation, famine, a spread of diseases, wars and the end of civilization. The second option is to continue using oil and gas and face death that may or may not materialize in the next 400-500 years. I am absolutely sure that if both options are put today to a vote, the overwhelming majority of humanity will give the thumps-up to oil and gas.

A case in point of unsubstantiated existential threats is the UN Secretary-General Antonio Guterres calling on world leaders to phase out oil and gas from their economies and stop new exploration.[17]

Speaking in Tonga during a meeting of Pacific Island leaders, the Secretary General said: "This is a crazy situation: rising seas are a crisis entirely of humanity's making. A crisis that will soon swell to an almost unimaginable scale, with no lifeboat to take us back to safety". He also said "The reason is clear: greenhouse gases overwhelmingly generated by burning fossil fuels are cooking our planet and the sea is taking the heat literally." To avoid the apocalyptic catastrophe, Guterres urged world leaders to stop using fossil fuels warning that "Without drastic cuts to emissions, the Pacific Islands can expect at least 15 centimetres of additional sea level rise by mid-century and more than 30 days per year of coastal flooding in some places."

Yet, thirty years ago there have been predictions that places such as the Maldives would be completely underwater by now but so far these have failed to materialize.

Conclusions

For Africa energy poverty takes precedence over both Western green policies and climate change agenda.

What Africa needs immediately isn't green energy transition but the immediate development of its vast oil and gas reserves to overcome its chronic energy poverty

The West puts so much importance on the climate change agenda in Africa at a time when the EU countries who promote green policies have abandoned their green principles to resurrect coal-fired electricity plants because of rising prices of gas and oil.

Renewables are incapable on their own of satisfying global demand for electricity without huge contributions from natural gas, coal and nuclear energy. Today's technology doesn't allow yet for storing solar and wind energy in summer for use in winter.

It is very probable that oil and natural gas will continue to be the driver of the global economy well into the future.

Footnotes

1. Habitat Humanity accessed on 23 August 2024.

2. BP Statistical Review of World Energy, 2021,p.16 & 34.

3. Mamdouh G Salameh, **Western Green Policies Could Hamper LNG Developments Out of Africa,** IAEE Energy Forum, Second Quarter 2023.

4. Mamdouh G Salameh, "**Has the Ukraine Conflict Changed Global Energy Trends for Good?"** an invited talk by the Energy Management Centre (EMC) of the ESCP Europe Business School in London on 11 October 2022.

5. Ekaterina Blinova, **"How West Uses Climate Agenda to Keep Africa's Oil & Gas Underground to Satisfy Own Appetite"** Sputnik International News, 18 September 2022.

6. Mamdouh G Salameh, "**Has the Ukraine Conflict Changed Global Energy Trends for Good?".**

7. **"A consortium of European Investment Firms have Raised $200 million to Fight Deforestation in Africa"**, Sputnik International News, 21 October 2022.

8. **"Africa Will Need $190 bn a year to Meet Energy Demand"** posted by oilprice.com on 29 November 2022 and accessed on 23 August 2024.

9. Linkedin post posted on 23 August 2024 and accessed on 23 August 2024.

10. Ibid.'

11. Ibid.,

12. OPEC's latest projection is that global oil demand will grow by 2.12 mbd in 2024.

13. BP Statistical Review of World Energy, June 2021, p. 11

14. Mamdouh G Salameh, "**A Post-oil Era Is a Myth**" (A USAEE Working Paper Series No. 16-290 published on 8 December 2016).

15. OPEC's projections made in 2022 and repeated in 2023 and 2024.

16. "**Two Reasons Why Big Oil Isn't Rushing into Renewables"** posted by Oilprice.com on February 14, 2019 and accessed on 25 August 2024.

17. **"UN Secretary-General Call's on World Leaders to Phase out Oil and Gas",** posted by Oilprice.com **on 27** August 2024 and accessed on 27 August 2027.

Reflections on Energy Poverty, Justice, and Equity

BY TIMOTHY C. COBURN

Abstract

This essay considers the state of energy poverty today, its relationship to energy justice, and difficulties energy economists and policy makers face while seeking to alleviate it. The struggle to eliminate energy poverty is compounded by growth in demand for energy world-wide, and the need to transition away from fossil fuels.

Timothy C. Coburn is Professor of Systems Engineering at Colorado State University where he teaches graduate courses on the energy transition, studies energy policy, and conducts research at the CSU Energy Institute on applications of data science across the energy landscape. He holds a joint appointment at the National Renewable Energy Laboratory and the Idaho National Laboratory, and serves as a non-resident Fellow of the Payne Institute for Public Policy at the Colorado School of Mines. He holds a Ph.D. in statistics and industrial engineering from Oklahoma State University.

Energy poverty is a curious and challenging phenomenon and a concept that is somewhat difficult to unpack. The contexts and state of affairs associated with energy poverty are certainly not new [1, 2], with numerous proposals, policies, and calls to action to mitigate its impacts, both locally and globally, having been promulgated for years by public and private entities, governments, and international agencies, as well as academicians and researchers alike [3]. Nonetheless, for a myriad of reasons that are more often place-specific, energy poverty still flourishes in the early 21st century without many prospects for abatement. In fact, in 2015 the World Economic Forum cited energy poverty as "the real energy crisis" [4].

Energy poverty is clearly confounded with social and economic development on the local, regional, national, and international scales, and also with technological innovation and deployment, human behavior and decision making, geopolitical scenarios and consequences, and more. Considering the magnitude and diversity of these issues, it is easy to understand how people, communities, and societies can become glib about energy poverty if they, themselves, are not currently experiencing it, or have never fallen into its clutches, either wittingly or unwittingly.

The notion of energy poverty has evolved from earlier ideas about fuel poverty introduced in the 1980s and 1990s [5, 6]. While the terms and descriptions have converged as the world's understanding of energy has broadened and matured, fuel poverty was originally associated with the lack of sufficient resources to heat and cool a home, whereas energy poverty came to be associated with a lack of access to energy services. Today, the terms are used nearly interchangeably [7]. The overarching idea has more recently come to be known as energy insecurity [8, 9] or energy vulnerability [10]. For purposes of the present discussion, energy poverty is defined to be the absence or lack of energy, and/or the absence or lack of access to energy or energy services, which has multiple impacts on the economic, social, behavioral, and physical livelihoods of individuals and households. In this context, energy typically refers to the electricity needed for heating, cooling, and cooking, but it can also refer to different aspects, such as the fuel other than electricity needed for personal transportation.

To be clear, people who live in poverty or who have experienced it in the past may not put access to energy at the top of their list of needs, since access to food and water are generally considered to be more basic living requirements, along with some semblance of medical care and personal hygiene. Still, people who live in poverty will likely never exit that state without access to energy, since energy drives so much of what is perceived to be a better way of life [11].

Energy poverty is also often seen through the eyes of individuals who live in developed economies; but, energy poverty exists to one degree or another in all countries across the globe. From the perspective of the developed West, for example, it is easy to consider people who have no more than dried dung with which to burn for cooking, or who cannot flip a switch to turn on lights in the evening, and declare them to be energy poor. However, those considered to be energy poor simply might not see themselves in this way, since this may be the condition in which they have lived for a long time. It is only when comparing to what others "have" that those who "have not" become dismayed.

Government agencies and social organizations often talk about food deserts, but energy deserts are not as commonly discussed. As in the case of food deserts, energy deserts can be large or small areas, and they may actually appear checkerboarded in nature. It is clearly possible to observe a community that is essentially an energy desert that is surrounded by other communities or neighborhoods that have full access to energy. This scenario plays out in urban centers around the world where wealth and destitution are immediately juxtaposed, even in countries like the United States [12].

Poverty, and by extension, energy poverty, may be original, in the sense that an individual may have lived in poverty all her/his life; or, it may be induced, and possibly even temporary, resulting from unfortunate circumstances or bad behaviors and choices. An individual who must choose between paying the gas bill in favor of buying groceries to feed children or paying the rent to keep them dry and safe is likely experiencing energy poverty even though they might not exist at the government's official poverty level. For example, it is doubtful that those who experience disconnection by the electric utility immediately become designated as energy poor. On the other hand, indigenous or rural people who live on lands far from connections to the grid, who have never had such access, and who lack the financial or political wherewithal to gain such access, could be described as originally (and continuously) energy poor even though they may not see themselves as such (since they live out their lives by other means). Further, having access to energy does not necessarily mean the ability to take advantage of it. In these senses, energy poverty is a term primarily used by the energy wealthy to describe the energy poor. Those living in a developed economy can readily see the effects of energy poverty from their own perspective, but those who are purported to live in energy poverty may not see it quite the same way.

For these and many other reasons, measuring/predicting/quantifying energy poverty [13-18] and counting those living in such conditions can be problematic; if for no other reason than being "energy poor" is not quite the same as being in "energy poverty." There are no official energy poverty designations in the same sense that some governments have established official poverty levels. It is purely a definitional problem and one of degrees. One who is energy poor still might have access to some energy, but just not consistently enough to get by (in the same sense that people who are food poor might have access to some food but not consistently enough). On the other hand, one who lives in energy poverty may be regarded as having little or none, or may be considered to have access to a kind of energy (e.g., wood or dried dung to burn for cooking and heating) that is inconsistent with an established standard of living. From this viewpoint, it is somewhat easy to identify individuals and communities who consistently and continuously live in energy poverty; but, it is not so easy for individuals in those same developed economies to identify all of those, for example, who may experience intermittent or cyclical energy insecurity or vulnerability (as in the case of those whose homes are involuntarily disconnected, either temporarily or permanently, by the utility).

A variety of techniques have been used to estimate the extent of energy poverty, but most of them are indirect [19] since it is so difficult to actually count the energy poor. Various estimates put the number of people living in energy poverty at one billion [20, 21] or more, but this again depends on definitions. There are at least two different categories: those who do not have enough and those who regularly use harmful sources [21] that lead to other unintended consequences.

Among the myriad solutions that could be embraced, the deployment of renewable technologies at the local or community levels is a potentially viable option. Community microgrids incorporating energy storage capabilities, for example, can provide a way for towns, villages, hamlets, and neighborhoods to establish the energy requirements of their citizenry, govern the delivery of energy services, and better serve the needs of the energy poor within their boundaries [22-24]. Other technologies such as agrivoltaics can provide both energy and food to local communities, and also present economic opportunities that can help raise the overall living standard of their energy poor [25]. Renewables have the potential to lead the way, particularly at the community level, since they lessen the physical infrastructure costs and requirements that constrain the expansion of fossil fuels, not to mention their more positive impacts on Earth's climate.

These kinds of socio-technical solutions serve to promote a deeper and richer approach to energy justice. Energy justice is a more all-encompassing concept that has gained traction in recent years [26, 27]. As defined in [28], energy justice is "the goal of achieving equity in both the social and economic participation in the energy system, while also remediating social, economic, and health burdens on those historically harmed by the energy system." Energy justice encompasses energy poverty, as well as energy insecurity, energy burden, and energy democracy [28]. While it is primarily centered on "the concerns of marginalized communities," it seeks to make energy more accessible, affordable, clean, and democratically managed within all communities [28]. Energy justice permits energy poverty to be addressed from a broader, over-arching, and more robust perspective.

Despite these considerations, addressing energy poverty head-on from an economics standpoint remains elusive. While the literature on energy poverty is both wide and deep, the economics of energy poverty tend to be addressed in more peripheral and oblique ways. Without sound economic research that gets directly at the roots of the energy poverty conundrum, and which establishes actionable solutions and policies, the situation is likely to remain unchanged. In his 2007 address, Birol [29] challenged the energy economics community to play its part in resolving energy poverty. While there has obviously been progress on this front, the issues and circumstances that sustain and promote energy poverty remain largely unresolved. Clearly, energy poverty and economic poverty go hand in hand. For either to be resolved, the two must be addressed in tandem, with a common goal in mind.

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The Impact and Coping Strategies of Energy Poverty on Human Well-being

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Abstract

This paper explores the characteristics of global energy poverty, analyzes its impact on human well-being, and proposes strategies to combat it. Affordable clean energy is identified as the seventh Sustainable Development Goal by the United Nations. However, with only six years left to achieve the 2030 vision of the SDGs, energy poverty remains a pressing issue, especially in the global south. Therefore, it is crucial to examine the challenges posed by energy poverty to human well-being and propose effective strategies to address the associated social risks and promote sustainable development.

1. Current Status of Global Energy Poverty

Energy poverty is generally defined as a state where households struggle to afford the energy required for daily living or lack access to modern fuels (Li et al., 2023). There have been efforts by policymakers worldwide to promote clean energy and eliminate energy poverty. By 2020, the number of people globally lacking access to clean cooking fuel decreased from 3 billion in 2010 to 2.4 billion, while the number of people without access to electricity reduced from 1.2 billion in 2010 to 733 million (IEA et al., 2022). Despite progress over the past decade, the ambitious goal of eradicating energy poverty by 2030 remains challenging.

Energy poverty not only affects a significant portion of the global population but is also unequally distributed. The majority of those affected reside in developing countries, particularly in Africa. For instance, in 2020, the countries with the highest population lacking access to electricity were Nigeria (92 million people), the Congo (72 million people), and Ethiopia (56 million people) (IEA et al., 2022). Energy poverty primarily affects the low-income segment of the population within these countries. The Russo-Ukrainian conflict, for example, has led to an increase in energy prices, pushing more low-income households into energy poverty (Guan et al., 2023).

2. Challenges of Energy Poverty to Human Well-being

Energy poverty imposes threats to human well-being. Firstly, the absence of clean energy leads to indoor air pollution, negatively impacting health (Basu et al., 2024). Traditional biomass cooking methods emit harmful gases, increasing respiratory issues, infant mortality rates, and health risks for the elderly. Energy poverty also affects cognitive and non-cognitive abilities, as the inability to meet basic cooking, lighting, and heating needs can lead to higher levels of depression and mental health issues.

Secondly, energy poverty hinders progress towards gender equality (Verma & Imelda, 2023). Women in most developing countries are primarily responsible for household chores, and energy poverty has specific gender implications within families, limiting women's development. The collection of biomass fuel, low combustion efficiency, indoor air pollution, and resulting health issues significantly restrict women's labor supply and their participation in the workforce.

Thirdly, energy poverty reduces the quality of life (Burlig & Preonas, 2024)as well as enable the effect of interventions to be evaluated over time. Methods.   A total of 2032 people aged 70 years and over recruited by stratified random sampling, and information obtained regarding physical and functional health, and psychological factors. The frailty index (FI. Energy is essential for household heating, cooking, and lighting. In energy-deprived settings, families struggle to provide adequate lighting and learning conditions, forcing children to assist with biomass collection, compromising their education time and efficiency.

Lastly, energy poverty is closely connected to environmental and climate concerns (Zhou et al., 2022), posing substantial risks to human well-being. Communities affected by energy poverty heavily rely on conventional biomass fuels, contributing to air pollution and greenhouse gas emissions. Resolving energy poverty requires the provision of clean and sustainable energy sources, which can effectively reduce carbon emissions and mitigate the impact of climate change.

3. Strategies to Address Energy Poverty in China

As one of the largest developing economies, China has made significant progress in addressing energy poverty issue. In particular, four strategies have been implemented to alleviate energy poverty across the country.

Firstly, strengthening energy infrastructure, such as electricity grids and gas pipelines, is crucial to ensure reliable energy access for all. Infrastructure plays a vital role in increasing the availability of clean energy. For example, China's "West-to-East Gas Transmission" project, which delivers natural gas from Western China to the major target consumer markets in Southeast China as well as users along the lines, has addressed the scarcity of natural gas resources in eastern China, making it one of the most widely used clean energy sources in the country.

Secondly, subsidies are provided for the adoption of clean energy and related appliances. Biomass fuels are often cost-free compared to modern energy sources like electricity and natural gas, causing low-income households to resort to non-clean fuels due to financial constraints. Subsidizing clean energy is essential in alleviating the energy burden on households. Additionally, proactive measures should be implemented to incentivize households to transition out of energy poverty, allowing them to benefit economically. For example, China has implemented the "photovoltaic poverty alleviation" policy, which effectively tackles both energy poverty and poverty reduction. This policy entails the placement of solar panels on the roofs or agricultural greenhouses of low-income households. The government covers the majority of the installation expenses, with a small portion being funded through credit resources. This allows these households to produce enough electricity to fulfill their daily requirements, and any excess electricity can be sold to the national grid. This policy combines the promotion of energy transition and the increase of household income.

Thirdly, enhancing energy literacy is crucial. Providing technical training and financial support in energy-deprived areas can promote the adoption of clean energy. Increasing energy literacy among the energy-deprived population is necessary for promoting energy transition. China has implemented a number of initiatives aimed at enhancing the public's literacy and awareness of clean energy and energy-saving products. For instance, new energy vehicles in China are identified by green license plates, while traditional vehicles bear blue or yellow plates. Likewise, energy efficiency labels are prominently displayed on Chinese appliances. These educational efforts have successfully increased residents' understanding of energy issues and their willingness to embrace clean energy solutions.

Lastly, stimulating market development and creating job opportunities are essential for addressing energy poverty through income effects. Strong job prospects increase household income. While clean energy promotion projects and foreign aid can provide short-term relief for energy poverty, establishing a thriving energy market and avenues for income growth are fundamental long-term solutions for households to afford clean energy. For example, China has implemented market-oriented reforms in its energy sector, which has resulted in the creation of a substantial number of employment opportunities and an enhanced reliability of energy supply through the introduction of market competition.

4. Conclusion

Energy poverty poses significant challenges to human well-being, particularly in developing nations and among low-income populations. It affects various aspects, including health, gender equality, child development, and climate issues. Addressing energy poverty requires a multifaceted approach involving improved access to modern energy, increased energy literacy, and the development of energy markets.

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Advancing Gender-Inclusive Clean Energy Solutions in Developing Asia and the Pacific

BY JAMES CORREIA, SHEENA KANON LEONG, AND DINA AZHGALIYEVA

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Abstract

This brief article explores the drivers and dynamics of the nexus between energy poverty and gender inequality in developing Asia and the Pacific. First, this begins with an overview of the social, economic, health and environmental aspects of gender and energy poverty in the region. Second, the policy approaches adopted to address these challenges through the provision of green employment opportunities, infrastructural initiatives, access to financing, and targeted interventions to tackle household air pollution (HAP) are examined. Third, this paves the way toward a set of practical recommendations for improving energy access and affordability, promoting women's economic empowerment, and accelerating the green energy transition.

Introduction and Context: Gender and Energy Poverty in Asia and the Pacific, and the Role of Women's Economic Empowerment in the Green Transition

Women are disproportionately exposed to the economic, health, social, and environmental aspects of energy poverty, particularly in developing Asia and the Pacific. Women often bear the primary responsibility for household tasks and spend more time on the collection and use of polluting solid fuels, which continue to form the key energy source for 1.2-1.6 billion people from across developing Asia and the Pacific.[1,2,3] This amounts to more than 20 hours per week on average, which entrenches existing gender inequalities, limits educational and job prospects, and carries health and physical security risks.[4] Due to persistent gender inequalities in labor markets and educational systems, women also often have lower incomes and more informal, poorly remunerated, and intermittent forms of employment.[5,6] This exacerbates affordability constraints and results in many female-headed households' spending more than 10% of their income on energy—a widely-used indicator of energy poverty. to 28% in Kazakhstan and 32% in Mongolia, for instance.[7,8] These factors often translate into gender-unequal intra-household dynamics, with women possessing lower bargaining power and decision-making authority for energy use decisions.[9] Women and children in developing Asia and the Pacific also tend to suffer most from household air pollution (HAP). Of the global total of 2.8-4.0 million deaths per year from HAP, more than 60% are women and children and almost three quarters are in developing Asia and the Pacific.[10,11]

Women's economic empowerment is crucial in accelerating the green energy transition. Despite widespread awareness of the harmful effects of traditional solid fuels on environmental sustainability and public health, significant barriers in infrastructure and access to finance continue to impede progress. A comprehensive governance framework and tailored financial support dedicated to women's empowerment is essential to addressing these constraints and expanding the uptake of climate-friendly energy sources, advancing gender equality, and reducing energy poverty.[12,13] This must be accompanied by infrastructural investments and expansions in grid connectivity to improve energy access, provide consistency of supply, and ensure the availability of access to greener alternatives.[14,15] Women's economic empowerment through employment significantly increases the likelihood that they will opt for cleaner energy, and accelerate the green transition. As women's employment prospects improve and incomes increase, the opportunity costs associated with fuel collection rise and the financial constraints on switching to cleaner energy options diminish.[16,17] This grants women the requisite economic capacity and bargaining power to choose cleaner energy, ultimately broadening the adoption of more climate-friendly alternatives.[18,19,20]

Addressing the Nexus: Policy Approaches to Advancing Women's Economic Empowerment, Energy Access, and the Green Transition in Asia and the Pacific

There are several avenues and initiatives through which to advance women's economic empowerment, expand energy coverage and access, and accelerate the green transition in Asia and the Pacific.

Employment in fossil fuel extraction and combustion is traditionally highly masculinized. For instance, almost 90% of those working with coal in Indonesia are male.[21,22] The energy transition presents opportunities for women's employment. For example, female participation in Indonesian renewable energy initiatives through the MENTARI and Solar Mamas programs have achieved 41% female workforce participation, and this is 28% in the country as a whole.[23,24] In the Maldives, an ADB-sponsored project has accelerated the transition away from diesel generators by driving the implementation of rooftop solar panels, contributed to green job creation for women, and enabled more than 160 islands to transition to climate-friendly energy sources.[25] Both initiatives are supported by an enabling ecosystem of public outreach, education and training, access to financing, and capacity building programs. These are marked by a near-equal participation of women, equipping them with essential skills and paving the way for a more socially equitable labor market in the energy sector going forward.

Comprehensive national infrastructure planning, development, and expansion is crucial. The electrification of rural households empowers women by granting them time to pursue employment opportunities, improving access to education and healthcare, and reducing the physical risks that come with fuel collection in unsafe lighting conditions.[26] The Fiji Rural Electrification Fund (FREF) provides an example of this approach, which is currently advancing the deployment of mini-grids, smart meters, and other modern technologies.

Government interventions to reduce household air pollution (HAP) are also pivotal in tackling gender inequalities, reducing environmental and health risks, and improving energy access. HAP represents the third most prominent cause of premature mortality among women across the globe and significantly reduces cognitive performance and economic productivity, locking women into cycles of energy poverty.[27,28] In Bangladesh, the Improved Cookstove Program and Rural Electrification and Renewable Energy Development II Project (RERED II) has enabled more than 3.4 million people to access greener and healthier energy sources, driven down direct emissions by 9.5 million tons per year, and created 3,000 green jobs.[29] In Mongolia, URECA's Coal to Solar project supports those living in Ger—traditional dwellings of nomads in which more than a quarter of the national population reside—to install solar panels. This has reduced the time spent collecting solid fuels by two hours per day, driven down energy costs by 70%, and contributed to indoor air quality improvements that reduce the incidence of respiratory illnesses, cardiovascular disease, and premature mortality.[30]

The delivery of financial support by governments, international organizations and multilateral development banks (MDBs) is also essential in accelerating a gender-inclusive green transition. Women often face high barriers to accessing finance, with longer times for processing loan requests, lower likelihood for them being granted, and a lack of collateral due to more limited property and capital ownership than men.[31,32] As a result, they generally tend to receive higher interest rates and less favorable terms. The gender finance gap can be reconciled and an enabling environment for women's participation the green transition can be crafted. As women are disproportionately affected by the negative environmental and health impacts of solid fuel use, they stand to gain outsize benefits from investments in clean energy.

Policy Recommendations

To address the identified challenges, the following measures are suggested to strengthen gender equity, enhance energy access and affordability and empower women economically, with a view to accelerate the transition toward a more environmentally sustainable and socioeconomically inclusive future.

1. Building the strategic and governance framework: the adoption of national gender action plans and their integration with climate mitigation and adaptation frameworks represent the central precondition of effectively addressing the gender-energy-climate nexus. As of July 2023, only 12 countries across Asia and the Pacific[33] had adopted National Gender Action Plans (UN Women, 2023).[34] The creation of government agencies and coordination between existing bodies is also a vital element of success. These steps should be supported by the establishment of national databases to monitor progress and performance, track women's access to energy and participation in the sector, and evaluate the outcomes of gender-focused interventions to enable more informed and evidence-based policymaking.[35] For example, the Solomon Islands has a dedicated Ministry for Women, five-yearly National Gender Equality and Development Policies, a National Climate Strategy that mainstreams gender-related considerations, and a monitoring, reporting, and verification (MRV) infrastructure.[36]

2. Developing gender-inclusive employment and educational systems: key transmission channels that can advance sustainable development include creating gender-inclusive educational and employment systems, particularly in the renewable energy sector. In Asia and the Pacific, for instance, women in India's renewable energy sector make up only 11% of the workforce, a disparity driven largely by significant barriers to STEM education and technical training. This is particularly pronounced in rural areas. Investment into capacity building and education projects that equip women from marginalized communities with technical expertise is critical to close this gap. Governments can draw valuable lessons from India's Skill Council for Green Jobs, which offers stipends and certification to participants upon completing courses in solar panel operation and wind turbine maintenance, equipping women with essential skills and opening up employment opportunities.

3. Boosting access to green and sustainable financing: ensuring access to capital is vital in enabling women and marginalized groups to participate in and benefit from the green transition. In Mongolia, the ADB, European Bank for Reconstruction and Development (EBRD), and Khan Bank have developed and rolled out a green gender bonds program designed to expand the number of loans held by women, provide targeted financial products and services for women borrowers, and upskill them in their appropriate use through a series of training academies.[31,32] For female entrepreneurs and employees, the UNEP-sponsored Pioneer Facility (PF) provides flexible debt financing to women-led, climate-friendly enterprises across Southeast Asia—including Cambodia, Bangladesh, Indonesia, and the Philippines—boosting low-carbon projects and empowering women simultaneously. For households, the PF unlocked capital and facilitated access to clean energy for 14,713 households, producing 21.5 million kWh of clean energy and avoiding 69,206 tons of CO2 emissions.[37]

4. Improving clean energy access for households: to reduce the exposure of women to the environmental and health risks of household air pollution, grant them the time to pursue educational and employment opportunities, and provide material support for green behaviors and prioritization, dedicated initiatives to encourage fuel-switching are required. A largescale example of this is India's Pradhan Mantri Ujjwala Yojana (PMUY), which provided over 95 million free LPG connections for cleaner cooking solutions to low-income households as of 2023, and contributed to an almost 40% rise in female employment in rural areas since 2019.[38] Going forward and taken together, these recommendations carry the potential to improve socio-economic productivity and wellbeing, advance gender equality, broaden energy access and affordability, and accelerate the green transition.

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Thank you to the TRAEE for hosting the 45th IAEE International Conference

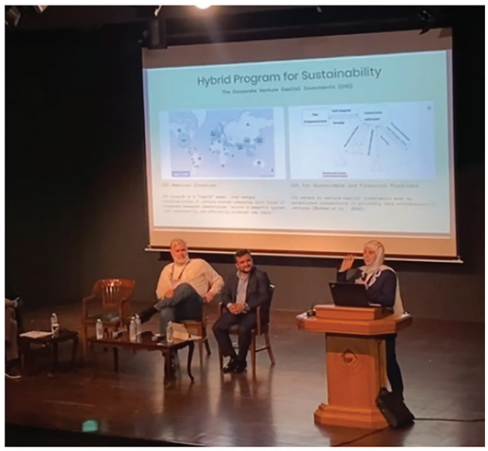
We appreciate and applaud the Turkish Association for Energy Economics (TRAEE) for hosting the event, titled “Energy Sustainability, Security, Efficiency and Accessibility in a Time of Transition,” and for organizing an outstanding program. The campus of Boğaziçi Üniversitesi, also known as Bosphorus University, was a glorious backdrop for learning and socializing. The program featured presentations, workshops, and poster exhibits, enriched by a celebration of Turkish culture. We enjoyed a classical music concert and a Mevlevi Sema ceremony, renowned for whirling dances. And the view was breathtaking in a dinner cruise along the Bosphorus.

Scenes from the 45th International Conference
Istanbul, Turkiye, 25 - 28 June, 2024






Energy Sector Reform in Georgia
45th IAEE
INTERNATIONAL
CONFERENCE


Hybrid Program for Sustainability

Expanding the Concept of Energy Poverty to Include Transportation

BY ORLA DINGLEY

Abstract

Addressing energy poverty is seen as the way to ensure a just energy transition. However, energy poverty research and policy to-date has generally only considered energy use within the home. This article advocates expanding the concept of energy poverty to include the energy a household uses for transportation.

Introduction

We all rely on energy in our everyday lives. Within the home we use energy for purposes such as heating, cooling, lighting, cooking and food preservation, etc. However, many people also use 'transport energy' to commute to work, and to access essential services such as education, health care, or to purchase clothing and food. For this reason, an individual's income and their quality of life can be highly influenced by their access to affordable and reliable transport.

With the introduction of climate change policies and with depleting levels of fossil fuels, fuel prices for both household energy and transport energy are expected to rise. As a result, an increasing number of households could face difficulties in their ability to warm their home, pay their energy bills, or fulfil their travel needs.

Addressing energy poverty is being heralded as the way to ensure a 'just' energy transition. However, to-date energy poverty research has overwhelmingly focused on energy use within the home and not the energy used for transportation. To ensure a just energy transition, energy poverty research needs to encompass all aspects of a household's energy consumption, both within the home and for transport.

Transport Poverty

The impact of a lack of access to reliable and affordable transport on the quality of life of an individual has been investigated in the field of transport poverty. Historically, energy use for transportation and energy use within the home have been treated as different areas of research. This segregation has led to the evolution of two fields of research - transport poverty (access and affordability of private and public transport) and energy poverty (access and affordability of energy use within the home). However, recently some academics and policy makers have begun to recognise the significance of transport energy use in relation to energy poverty. A new argument being made is that researchers should study all levels of a household's energy consumption together (e.g. Furszyfer Del Rio et al., 2023; Lowans et al., 2023; Martiskainen et al., 2021; Mattioli et al., 2017; Robinson & Mattioli, 2020; Sareen et al., 2022; Simcock et al., 2021). By uniting these two fields of research we might be able to understand any overlapping causes and links between both issues, and any cost trade-offs households make between aspects of their energy consumption.

A cross-national study into transport poverty and energy poverty across Ireland, Mexico and the United Arab Emirates (Furszyfer Del Rio et al., 2023) found that transport poverty and energy poverty were common issues across each of the different national, and sub-national contexts. In addition, the authors identified the occurrence of a 'double energy vulnerability', where people were simultaneously at risk of transport poverty and energy poverty. They argue that double energy vulnerability was identifiable in each country regardless of the political regime, level of economic development and sociodemographic profile.

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Mahumane & Mulder's (2022) case study of energy poverty in Mozambique revealed that expenditure for transport can make up about 50 percent of all modern energy used by households. They conclude that for households in urban areas with a high modern energy source usage, transport fuels can have a significant impact on energy poverty levels. Similarly, in France, research has suggested that high transport costs for commuting can result in energy poverty (Rosales-Montano et al., 2009; Jouffe & Massot, 2013). Rosales-Montano et al. (2009) argue that people living in areas with a lack of public transport are dependent on personal cars for transportation and this makes them vulnerable to energy poverty when transport fuel prices increase. Studies such as these highlight the impact transportation can have on energy poverty and the possible insight that can be obtained by studying both areas of energy use together.

Developing Effective Policies

To make public policies effective the policies need to target the right people. Since energy poverty is typically only associated with heating and energy services within the home, if we introduce transport energy to the analysis it might reveal sections of the population not currently identified as being in energy poverty. For this reason, the success of energy poverty policies will depend on the dimensions of energy consumption measured when targeting remedial policies.

A study from the UK (Salutin, 2023) investigated the financial burden of transport on UK households. The study revealed that transport is the largest single household expense, excluding mortgage repayments, for rural families, but the second largest for urban families. Households in urban and rural areas were impacted by energy costs in different ways. Similarly, another study from the UK (Chatterton et al., 2016) which combined the car usage data from over 27 million individual vehicles and the readings from over 24 million domestic energy meters, found that energy usage patterns differed across urban and rural areas. The researchers concluded that location had an influence on energy consumption. The results from studies like these would suggest that including transportation in the concept of energy poverty would require energy poverty policies to apply a spatial dimension to its targeting. Energy poverty policy would need to expand and adapt to include a wider set of energy-related vulnerabilities.

Channelling energy use into just one energy source

Under current plans for the energy transition, direct energy use for heating, cooking, and transport is likely to become increasingly electrified. As a result, many aspects of a household's energy consumption may become channelled into just one household expense - the electricity bill. This development could push households into making cost trade-offs between aspects of their electricity consumption including transportation and heating. By including transportation in current energy poverty research, it would be possible to prepare for a time when all aspects of direct energy use will become further intertwined.

Conclusion

To support a just energy transition, we need to implement energy policies that tackle climate change while improving, rather than worsening, socioeconomic and spatial inequalities. Addressing energy poverty is a necessary step to ensure a just energy transition. However, energy poverty measurement needs to encompass all aspects of a household's energy consumption not just energy use within the home. If energy poverty measurement is flawed, then the policy recommendations and remuneration will also be flawed.

To enable the formulation of effective energy poverty policies we need to collect more data on the trade-offs households make between all energy sources, and the impact of energy expenses felt across all groups of society. A changing energy system will impact individuals in different ways. If we include the transport dimension to energy poverty research, we may notice the influence of location on patterns of energy poverty. For example, in rural areas where transportation is the largest single household expense, households may react to changes in transport costs in a different way from households in urban areas where transport expenses are less important.

Since the quality of life of many people is affected by their access to affordable and reliable transport energy, it must be an aspect of energy poverty research. For this reason, there is a need to re-examine the specification and targeting of energy poverty policy and research to include energy used for transportation.

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Does How we Decarbonize Matter? An Examination of the Potential Energy Poverty Impacts of Fossil Asset Replacements

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ABSTRACT

Replacing fossil assets with low-carbon alternatives will influence the costs associated with maintaining a competent, reliable grid (i.e., total systems costs). Noting over time any resulting system cost increases will likely be borne by consumers, this paper aims to provide insight into the potential energy poverty impacts that may result.

1. INTRODUCTION

Energy systems are evolving in response to changing energy market and policy conditions. Perhaps the most notable of which are the goals set forth to achieve carbon pollution free electricity by 2035 and economy-wide net-zero emissions by 2050 (Fam & Fam, 2024; The White House, 2021; 2021). Different pathways have been prescribed to meet these stated targets, most of which have suggested replacing legacy fossil-based power generation assets (LFAs) with low-carbon alternatives (LCAs) (e.g., wind or solar photovoltaics [PV] paired with battery storage or advanced fossil-based assets equipped with carbon capture and storage [CCS]) (The White House, 2021; Williams, et al., 2020; Bistline, et al., 2023; IAE, 2023). As the grid mix changes, however, so too will the costs associated with maintaining its reliability, otherwise known as the total systems cost (TSC) (Bartlett, 2019; Byrom, et al., 2021).[1]

Replacements that lead to higher TSC can adversely impact households who are already energy burdened (i.e., spending more than 6% of their gross income on energy costs) (DOE Office of State and Community Energy Programs, 2024). As the costs associated with replacing generation assets will over time, either directly or indirectly, be financed by consumers including residential customers, who could end up paying a higher price per-unit of consumption, as a result (Byrom, et al., 2021; Davis & Hausman, 2021; Wood, et al., 2016).[2] Noting whether a household is energy poor (i.e., living in a state of energy poverty) is directly influenced by whether they are energy burdened, which depends on the price they pay to consume electricity, this paper aims to provide insight into the influence different LCAs could have on household energy burdens.

The potential effect of each competing LCA is inferred from further analysis of results produced by the National Energy Technology Laboratory's (NETL) System Cost of Replacement Energy (SCoRE) tool having been applied to the Electric Reliability Council of Texas (ERCOT) operating region (Harker Steele, Sharma, Pena Cabra, Clahane, & Iyengar, 2022). NETL's SCoRE tool provides estimates of the potential change to an operating region's TSC if its LFAs were to be replaced with competing LCAs. The replacement is assumed to occur in response to a need to achieve a percentage wise reduction in carbon dioxide (CO_2) emissions across the region (i.e., meet a decarbonization target) and each LCA is individually considered by the tool (i.e., assumed to be the only technology option available to replace the LFAs).

The SCoRE tool presents results for each competing LCA considered on a per-megawatt hour (MWh) basis, under the assurance that sufficient generation is available to meet hourly demand (i.e., zero loss of load events occur) (Harker Steele, Sharma, Pena Cabra, Clahane, & Iyengar, 2022). In this sense, results represent the average cost to the consumer from deploying the LCA considered (and any necessary additional grid services) in place of the region's LFAs (Byrom, et al., 2021; Greenstone & Nath, 2019).[3] All else equal, assuming a simplistic, vertically integrated environment where utilities are responsible for both power capacity and retail provision in the region, results represent first-best[4] estimates of the potential change in the retail price of electricity (i.e., retail rate) that may result from the replacement.

Understanding how retail rates could change in response to each LCA being deployed allows us to identify LCAs that could have progressive (i.e., decrease retail rates), regressive (i.e., increase retail rates), or proportionate (i.e., do not change retail rates) impacts on household energy burdens. Providing some insight into the distributional equity impacts of decarbonizing electric grids via the replacement of LFAs (Zachmann, Fredricksson, & Claeys, 2018). Although our results are based on a simplified model of the decision-making processes that occur within and across an operating region's grid to meet load, they do illustrate how replacing LFAs with different LCAs might affect people who are experiencing or nearing the experience of energy poverty, as requested of papers for this special issue of Energy Forum.

2. SYSTEM COST OF REPLACEMENT ENERGY (SCoRE) TOOL

The SCoRE tool can be implemented in any operating region so long as the data necessary to operate the

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tool are available for the region. Data include hourly generation and load (L) served by each legacy asset (fossil and non-fossil based) during analysis year, ; the cost to install, operate, and maintain each generation asset (i.e., the capital and O&M costs); the fuel costs to operate each asset; the costs associated with integrating a new asset into the grid; and if applicable, the CO_2 emissions produced by each LFA in year *t* (Harker Steele, Sharma, Pena Cabra, Clahane, & Iyengar, 2022). Once data is obtained, the SCoRE tool executes a scenario run by first identifying the LFAs within the operating region of interest, the capacity each supplied to the grid in year *t* and the CO_2 emissions they produce per annum.

The SCoRE tool then systematically steps through the replacement of capacity supplied by the region's LFAs with the candidate LCA under consideration. The tool replaces the LFA with the highest carbon footprint first, followed by LFAs that emit relatively fewer CO_2 emissions. Capacity is replaced on a one-to-one basis unless built-in checks within the SCoRE tool reveal there is insufficient generation available to meet L as a result. If this is the case, then generation from remaining firm low carbon intensive assets (FLCIAs) (e.g., natural gas combined cycle [NGCC] units) is used to make up any deficit. If any deficit is unable to be met using the remaining FLCIAs then the tool estimates the maximum legacy, fossil asset capacity (MAXFC) replaceable without the occurrence of a loss of load event (LOLE). [5]

After balancing, at each discrete addition of capacity from the candidate LCA considered (or similarly, removal of incremental capacity supplied by the LFAs) the SCoRE tool computes the resulting decrease in CO_2 emissions—decarbonization target achieved—and the SCoRE metric for the LCA corresponding to that target. The SCoRE metric is calculated following equation (1),

$$SCoRE_{ji} = \frac{TSC_j - TSC_i}{EG_j} \tag{1}$$

where TSC_j represents the TSC when a candidate LCA, *j* has been brought online to replace the LFAs, *i*; TSC_i represents the TSC under the baseline, business-as-usual (BAU), non-replacement, and *EG* is the electricity generation, measured in megawatt-hours (MWh). The TSC under both the replacement and BAU scenario are defined as the sum of the capital, fixed and variable operations and maintenance (O&M) costs, fuel costs, and interconnection costs.[6]

3. SETTING THE STAGE—DATA

Results from an application of the SCoRE tool to the ERCOT's 2019 grid mix are presented in Figure 1—see also Harker Steele et al. (2022).[7] Each point along a curve represents the resulting change in the TSC following the replacement of capacity supplied by the ERCOT's LFAs, which include coal and natural gas-fired generation assets, with the corresponding LCA. The LCAs we consider include coal with CCS, natural gas (NG) with CCS, wind plus lithium-ion (Li ion) battery storage, solar plus Li ion storage, and solar plus flow battery storage.

To compute electricity prices for residential customers in the ERCOT in 2019 we relied on data reported on EIA Form-861, a mandatory census of retail electricity sales by utility industry participants (EIA, 2024; Greenstone & Nath, 2019). The average revenue per MWh of electricity sold to Texas residential customers in 2019, weighted by the number of residential customers each utility provided electricity to together serve as a proxy for the retail rate paid by residential customers per-unit of electricity consumed ($/MWh).[8] Data reported by municipal, cooperative, and investor owned ERCOT utilities suggest the weighted average residential retail price of electricity in 2019 in the ERCOT was approximately $107/MWh.

4. CONSIDERATIONS FOR HOUSEHOLD ENERGY POVERTY VIA POTENTIAL IMPACTS TO HOUSEHOLD ENERGY BURDENS

Households who live in a state of energy poverty are unable to maintain adequate access to essential energy services, like electricity and heating, due to financial constraints (Faiella & Lavecchia, 2019; Cong, Nock, Qiu, & Xing, 2022; Reiner, Figueroa, Bates, & Reames, 2024). The consequences of energy poverty can in some cases be quite severe. For example, some households may forgo purchasing medication or seeking medical care in order to pay their home energy bills. A household's energy burden (i.e., percentage of gross income spent on energy/fuel costs) is the primary economic metric used to identify energy poor households in the United States (Bednar & Reames, 2020).

The U.S. Department of Energy's Low-Income Energy Affordability (LEAD) tool suggests Texas households, on average, spend 5% of their gross income on energy costs, indicating, the average Texas household is not yet but close to being energy burdened (DOE, 2024).[9] [10]To provide some insight into how each LCA considered might impact household energy burdens and thus energy poverty, we estimate the rate at which the calculated average retail price of electricity for residential customers serviced in the ERCOT in 2019 could change as result of each LCA (and any necessary FLCIAs) being

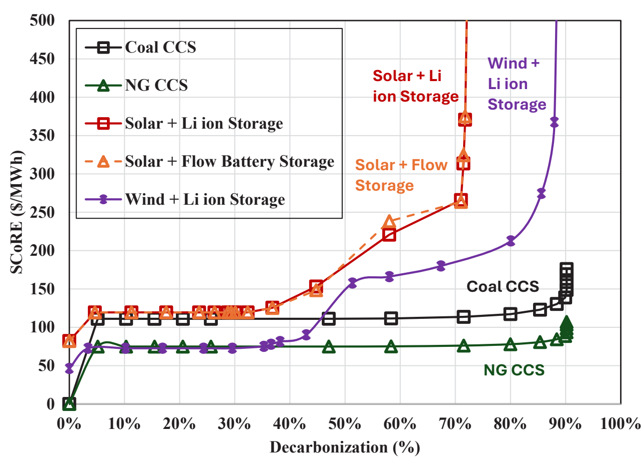

Figure 1. Results for the SCoRE values for replacements of legacy fossil assets with different new, low carbon assets

deployed in place of the region's LFAs within ranges of decarbonization targets achievable.

Assuming ERCOT based households do not adjust their electricity consumption and their gross income remains constant, the rate at which the average residential retail price of electricity is projected to change in response to a specific LCA being deployed in place of the region's LFAs is proportional to the change in the average household's energy burden we could expect. We calculate the projected rate of change in the residential retail electricity price in year *t*, $\%\Delta\, RRP_{p,t}$ following equation 2,

$$\%\Delta\, RRP_{p,t} = \left(\frac{[SCoRE_{i,j} + RRP_{A,t}] - RRP_{A,t}}{RRP_{A,t}}\right) \times 100 \qquad (2)$$

where $RRP_{A,t}$ is the calculated weighted average residential retail price of electricity in year *t*, which, recall for the ERCOT in 2019 was $107/MWh. All other terms in equation 2 are as defined previously. Applying equation 2 to the values presented in Figure 1 generates the results presented in Figure 2.

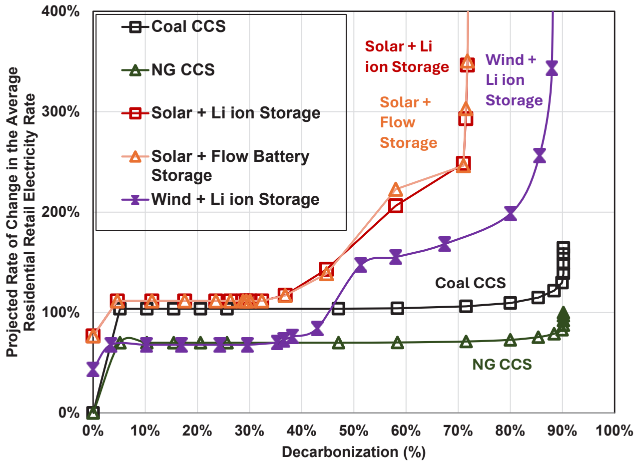

Figure 2. Projected rate of change in the residential retail electricity rate based on the SCoRE model results for each LCA

Given the operating characteristics of the LCAs vary, the decarbonization target they are able to achieve for having replaced a given amount of capacity from the region's LFAs varies. As such, how each LCA compares in terms of its potential influence on residential retail electricity rates at *a specific decarbonization target* (e.g., a 30% reduction in CO_2 emissions) is not able to be determined. Instead, LCAs can be compared in terms of their potential influence on residential retail electricity rates and corresponding household energy burdens, within set ranges of CO_2 emissions mitigation potential (a 25% to 50% reduction in CO_2 emissions). For the purpose of providing insight into how each LCA considered might influence household energy burdens we zoom in on four ranges of decarbonization potential—0% to 25% CO_2 emissions abated, 25% to 50% CO_2 emissions abated, 50% to 75% CO_2 emissions abated, and 75% to 100% CO_2 emissions abated—see Figure 3 through Figure 6 below.

Overall, our results suggest for decarbonization targets between 0 to 25%, using solar plus either Li ion or flow battery storage or coal with CCS in place of the region's LFAs could lead to more than a 100% increase in the presumed average retail price of electricity for ERCOT's residential customers in 2019. Replacing the region's LFAs with wind plus Li ion storage or NG with CCS leads to approximately a 70% increase in the presumed average retail price of electricity within the same range. Compared to NG with CCS, wind plus Li ion battery storage begins to lead to more significant increases in the presumed average retail price of electricity between 40% to 60% of CO_2 emissions being abated. Solar with either type of storage is not able to

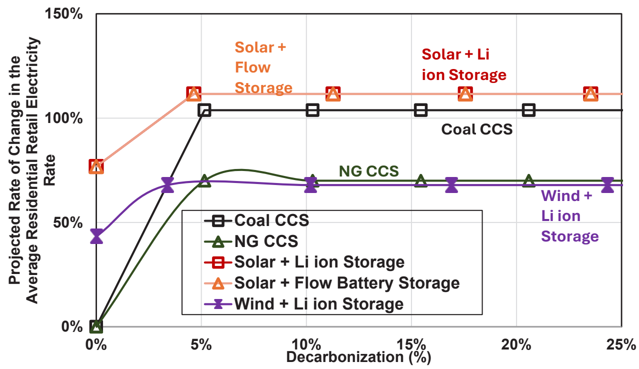

Figure 3. Projected rate of change in the residential retail electricity rate based on the SCoRE model results for each LCA between 0% to 25% CO_2 emissions abated

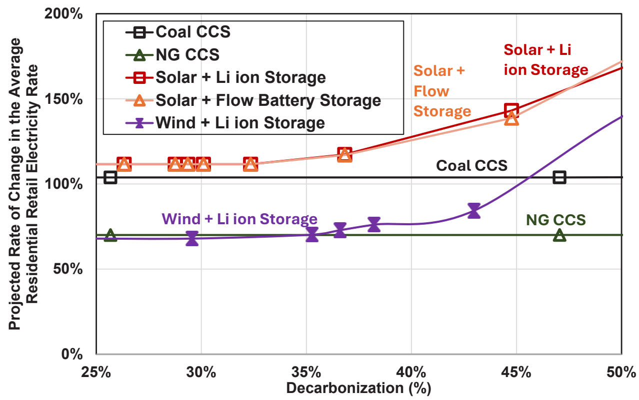

Figure 4. Projected rate of change in the residential retail electricity rate based on the SCoRE model results for each LCA between 25% to 50% CO_2 emissions abated

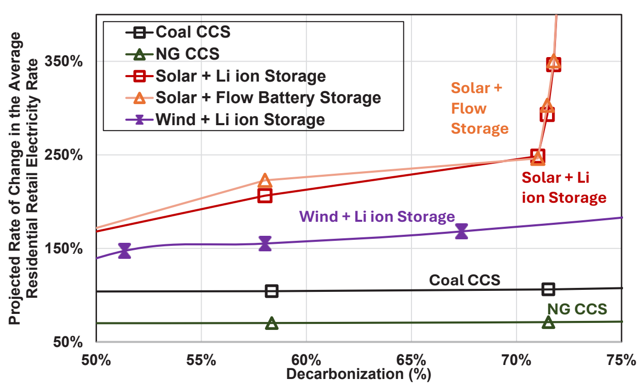

Figure 5. Projected rate of change in the residential retail electricity rate based on the SCoRE model results for each LCA between 50% to 75% CO_2 emissions abated

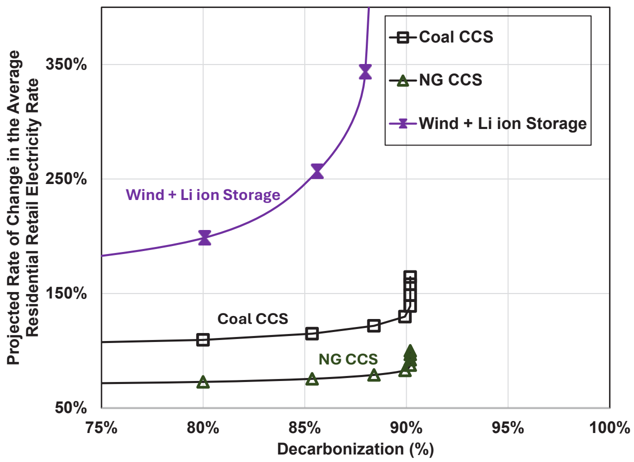

Figure 6. Projected rate of change in the residential retail electricity rate based on the SCoRE model results for each LCA between 75% to 100% CO_2 emissions abated

result in more than a 75% reduction in CO_2 emissions for the region without the rate at which it impacts the presumed average retail price of electricity increasing exponentially.

The rate at which coal with CCS and NG with CCS impact the presumed average retail price of electricity for residential customers in region remains relatively constant (somewhere between a 70 to 75% increase in the presumed average retail price of electricity for residential customers if NG with CCS is the LCA deployed; between a 100% to 110% increase in the presumed average retail price of electricity for residential customers if coal with CCS is the LCA deployed) until more than 80% of the region's CO_2 emissions are abated. None of the LCAs considered were found to be technically capable of sequestering 100% of ERCOTs CO_2 emissions in 2019.[11] As such, we are unable to provide a range of the potential impact each LCA considered could have on the presumed average retail price of electricity for residential customers in ERCOT under a zero-emissions future.

As suggested earlier, under the assumption that ERCOT-based households do not adjust their electricity consumption and their gross income remains constant, the results above suggest all else equal, achieving between a 0 to 25% reduction in the region's CO_2 emissions using solar plus storage or coal with CCS could lead to more than a 100% increase in their energy burden. For example, if households had an energy burden equal to 6%, then they could face an energy burden of 12% if solar plus storage or coal with CCS were used to replace the ERCOT's LFAs to achieve a 25% reduction in emissions. Doing so using wind plus Li ion storage or NG with CCS could lead to approximately a 70% increase in the household's energy burden (e.g., if households had an energy burden equal to 6% they would face an energy burden of 10.2% as a result).

The rate at which the presumed average retail price of electricity is estimated to change in response to a 25% to 50% reduction in CO_2 emissions being achieved is smallest if NG with CCS or wind plus Li ion battery storage are used to replace the region's LFAs. Both are projected to increase the presumed retail rate of electricity by about 70% until around 40% of CO_2 emissions are mitigated. At which point, wind plus Li ion battery storage is projected to lead to about an 85% increase in the presumed price. In terms of the possible impact on household energy burdens—up until about 40% of CO_2 emissions are mitigated, NG with CCS or wind plus Li ion storage cold lead to a 70% increase in the energy burden of ERCOT based households (e.g., households who had an energy burden equal to 6% would face an energy burden of 10.2% as a result). Once 40% of emissions have been mitigated, we project household energy burdens in ERCOT could increase by about 85% if wind plus Li Ion storage is used (e.g., households who had an energy burden equal to 6% would face an energy burden of 11.1% as a result).

Lastly, coal and NG with CCS are identified as having the smallest potential impact on the presumed average retail price of electricity and thus household energy burdens when between 50% and 75% of CO_2 emissions are mitigated in the region. NG with CCS outperforms coal with CCS in terms of its projected impact. Relationships hold until about 80% of CO_2 emissions are mitigated for region. At which point, coal with CCS is projected to lead to a 110% increase in the presumed average retail price of electricity and thus household energy burdens (i.e., households who had an energy burden equal to 6% would face an energy burden of 12.6 % as a result); NG with CCS is projected to lead to about a 75% increase in the presumed average retail price of electricity and thus household energy burdens (i.e., households who had an energy burden equal to 6% would face an energy burden of 10.5 % as a result), all else equal.

It is suggested that households who spend more than 6% of their gross income on energy expenses are energy burdened (Drehobl, Ross, & Ayala, 2020). Given whether a household is or is not energy burdened is the primary qualifier used to assess whether it is living in a state of energy poverty, it is important to consider how changes in the way we produce energy, in particular electricity, to achieve stated decarbonization targets could impact residential consumers. While the results above are based on some very broad assumptions and back of the envelope calculations, they begin to uncover how replacing a region's LFAs with a specific LCA might lead to higher home energy burdens and how the impact of each LCA on household energy burdens could change depending on the percent of CO_2 emissions needed to be mitigated. This highlights the importance of considering not only the technical efficiency of using LCAs in place of LFAs but also the distributional equity impacts associated with doing so.

5. LIMITATIONS & NEXT STEPS

It is important to note the results above are based on the first-iteration of NETL's SCoRE tool having been applied to 2019 data for the ERCOT operating region—for more information see Harker Steele et al. (2022). As such, they do not represent values produced by the most recent version of the tool, which considers the time it takes to construct each LCA separate from the time it operates and needs maintained, allowing for the change in the TSC to be distributed over several years. Second, results are based on a simplified version of how changes in the TSC occur and are passed along to consumers. While an increase in TSC may not directly transcribe to an increase in the rate customers pay per unit of consumption, there is a strong relationship between the two since both regulated and non-regulated utilities will eventually pass along the costs of construction and operation of their generating units, and any backup required for reliability onto consumers in some form. Next steps for this work include evaluating all of the cost components that are used to build out the SCoRE metrics produced by the most recent version of the tool, as the estimated change in the system costs must fully capture the associated costs to assess results at select decarbonization targets. We also plan to investigate household energy burdens more fully within the operating regions where the tool is applied so we can more robustly identify the potential influence of each LCA on household energy burdens.

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Footnotes

[1] See Section   for a complete definition of and a summary of the costs that make up the TSC.

[2] In the United States, privately held, municipally-run, and government owned utilities operate as natural monopolies, recovering their fixed cost of production by charging their customers higher fees overtime (Davis & Hausman, 2021).

[3] Examples of additional grid services include battery storage, increased monitoring, and transmission upgrades.

[4] A first-best estimate refers to an initial calculation or approximation of a value.

5 See Figure 7 in the Appendix for a depiction of the mechanics of each replacement scenario run executed by the SCoRE tool.

6 Interconnection costs refer to all of the costs incurred by an electric utility associated with connecting, switching, metering, and monitoring a physical asset along the grid system (Harker Steele, Sharma, Pena Cabra, Clahane, & Iyengar, 2022).

7 ERCOT is tasked with supplying electricity to more than 26 million customers across the state of Texas, serving nearly 90% of the state's population (Electric Reliability Council of Texas, 2022). ERCOT also operates one of the nine North American independent system operators (ISOs) and more uniquely as its own physical interconnection and balancing authority (Electric Reliability Council of Texas, 2022; EIA, 2016).

8 This assumes retail customers pay the same cost per-unit of electricity consumed regardless of their income level, other incentive structures or programs they engage in with their electricity provided (e.g., demand response).

9 The LEAD tool suggests Texas households who heat their homes using electricity spend about 2% of their gross income on energy costs.

10 Households who spend more than 6% of their income on energy costs are considered energy burdened (Drehobl, Ross, & Ayala, 2020).

11 The carbon capture systems modeled within the SCoRE tool had an assumed capture rate of 90%.

APPENDIX

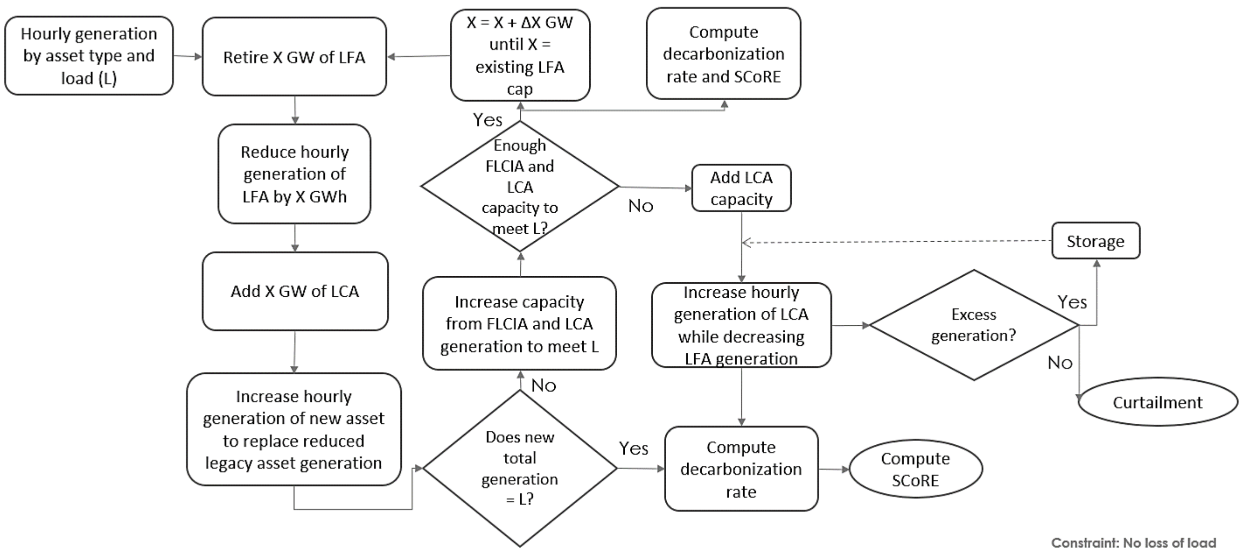

Figure 7. Mechanics of a Typical Replacement Scenario Modeled within the SCoRE tool

Fuel Poverty Prediction Using Socio-Economic Factors and Clustering Analysis

BY RAHIL DEJKAM[a] AND REINHARD MADLENER[a,b*]

Abstract

Our study predicts fuel poverty risk by grouping households based on data from a survey in England. The analysis reveals important differences between household groups, helping policymakers to better understand which factors contribute most to fuel poverty and suggesting targeted interventions to address the issue.

1. Introduction

Fuel poverty has garnered significant attention from both academics and policymakers in the EU (Castaño-Rosa et al. 2019). Despite numerous government-proposed solutions, such as the Winter Payment and Warm Home Discount, the fuel poverty rate continues to rise, with current solutions only reaching 10% of affected households (Charlier and Legendre 2021). Enhancing energy efficiency in housing requires substantial funding (Rzetelska and Combrinck 2022). Access to basic household energy services—heating, cooling, lighting, and such from appliances—is critical to welfare in the EU and UK. The EU Energy Poverty Observatory (EPOV) focuses on ensuring equitable energy access without imposing financial strain. Despite the UK being one of the world's leading economies, fuel poverty remains widespread due to socioeconomic factors, substandard housing, rising energy costs, and inefficient energy use (Boardman 2013). Vulnerability studies highlight that low-income households and disabled individuals are disproportionately affected by fuel poverty in the UK (Snell, Bevan, and Thomson 2015).

Current research attempts to address energy vulnerability by integrating social, political, and techno-economic perspectives [6]. However, these approaches often fail to account for unobserved heterogeneity within household characteristics and energy consumption patterns. Traditional regression-based models and spatial interpolation techniques lack the ability to capture the complex dynamics of fuel poverty (Abbas et al. 2020; Liu et al. 2021; Qurat-ul-Ann and Mirza 2021). Recent studies have utilized machine learning algorithms for more accurate predictions, but many still overlook important household features (Wong et al. 2018we can use spatial interpolation (SI; Robinson 2019; Puttanapong et al. 2022).

Unlike previous methodologies, our study introduces a novel cluster-based method that groups households based on socioeconomic and energy-related characteristics, allowing for a more nuanced analysis and targeted policy interventions (Dejkam and Madlener 2023). Using England as a case study provides an opportunity to apply this cluster-based method, given its large and diverse population that reflects many of the fuel poverty challenges seen across the UK. By focusing on England, where more comprehensive data is available, our approach captures more detailed patterns of fuel poverty, enabling policymakers to develop strategies to mitigate fuel poverty more effectively (Xu et al. 2021; Wang, Maruejols, and Yu 2021).

Our study addresses key gaps in the literature by offering a novel machine learning-based approach to fuel poverty prediction, helping to identify the most vulnerable households and the factors that contribute most to their energy struggles.

2. Methodology

This study employs a multi-step methodology to analyze fuel poverty in England using data from the English Housing Survey (EHS). Data was collected from April 2018 to March 2020, with April 2019 serving as the midpoint. The dataset includes 11,974 households and covers variables such as energy costs, household income, dwelling type, and heating characteristics. The methodology begins with data preprocessing, where missing values are removed, and categorical data that is converted to numerical form using one-hot encoding. The features for analysis were chosen based on a combination of literature review and a Pearson Correlation Coefficient analysis to remove irrelevant features. Households were grouped using a k-prototypes clustering algorithm, which combines both categorical and numerical data, making it ideal for mixed datasets. The optimal number of clusters was identified using the "elbow method", ensuring that households with similar characteristics were grouped together (see below). Microsoft Power BI was employed to visualize the clusters, helping to identify patterns within the data. In a next step, the fuel poverty risk within each cluster was predicted using a modeling algorithm. Finally, the contribution of each feature to the model's predictions was determined, providing insights into the factors that most influence fuel poverty.

3. Results

The study identified three distinct household groups in England that are most at risk of fuel poverty, using

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a method that helps to categorize homes based on shared characteristics. By applying the elbow method, which helps determine the optimal number of groups, it was found that splitting the households into three clusters offered the best balance between complexity and insight (cf. Figure 1). Figure 2 illustrates the three clusters, each representing different types of households and facing unique challenges when it comes to energy costs and affordability.

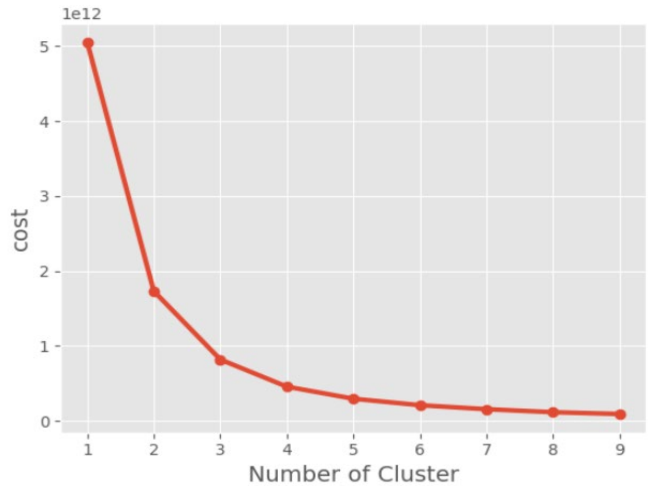

Figure 1: Optimal number of clusters determined by the elbow method

The first group (Cluster 0) consists of households with moderate energy costs, mostly living in detached homes with relatively good health and manageable expenses. The second group (Cluster 1) includes younger households that tend to have higher lighting and appliance costs, often due to more active household members and larger homes. The final group (Cluster 2) represents the most vulnerable households—older, low-income individuals struggling to meet their energy needs, especially for essential services like heating and lighting.

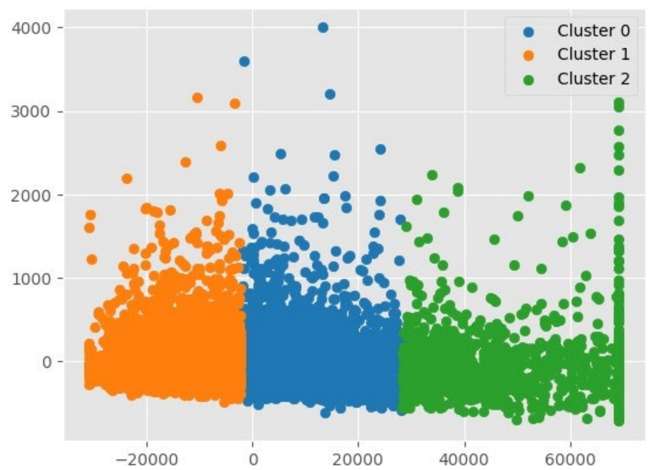

Figure 2: K-prototypes clustering of English households into three clusters

4. Discussion

This study shows the importance of tailored interventions for different household groups. Cluster 2, in particular, would benefit from direct financial aid and energy-saving measures, such as better insulation or energy-efficient appliances. In contrast, Cluster 1 would benefit from programs that help to reduce energy consumption for lighting and appliances, such as energy efficiency grants or appliance replacement programs.

Additionally, this study highlights the critical features contributing to fuel poverty, offering a clearer pathway for policymakers to design targeted interventions. Table 1 shows the key predictive features in each cluster; for instance, water heating costs and household income were significant predictors in Cluster 0, while age and lighting costs were more important in Cluster 2.

In conclusion, this study underscores the importance of tailored, data-driven interventions to effectively address fuel poverty. The combination of clustering analysis and machine learning provides a powerful tool for identifying at-risk households and guiding policymakers in designing targeted solutions. The insights gained from this research offer a clear path forward for combating fuel poverty, ensuring that the most vulnerable populations receive the support they need to improve their quality of life.

Table 1: Key predictive features in fuel poverty models

Cluster	Predictive Features
Cluster 0	Water Heating Cost, Floor Area, Income
Cluster 1	Lighting Costs, Household Composition
Cluster 2	Age, Income, Energy Costs

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Strengthening Institutional Quality–A Step towards Improving Energy Poverty

BY J. BOHLMANN, R. INGLESI-LOTZ, AND W. KRITZINGER

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Abstract

This article emphasises the role of institutional quality in addressing energy poverty, particularly in developing regions like Sub-Saharan Africa, where weak governance hinders energy access. It argues that sustainable solutions require strong institutions alongside technological and financial interventions, linking energy access (SDG 7) to good governance (SDG 16).

Despite global efforts to improve access to energy, energy poverty is still persistent globally. Institutional quality has been identified as important in shaping energy outcomes. Institutions, defined by their ability to enforce rules, manage resources, and create an enabling environment for investment and policy implementation, are central to addressing the underlying causes of energy poverty. Weak governance, regulatory failures, corruption, and inadequate policy frameworks often undermine efforts to expand access to clean and affordable energy, particularly in developing regions. This study explores the intricate relationship between energy poverty and institutional quality, arguing that sustainable solutions must go beyond technological and financial interventions to include strengthening the 'rules of the game.' By examining the impact of governance on energy access, we emphasise the need for robust institutions as a fundamental pillar in the fight against energy poverty and the achievement of Sustainable Development Goal 7 (SDG7) which aims to ensure access to affordable, reliable, sustainable, and modern energy for all.

Energy poverty is no longer a singular issue; it includes a complex variety of challenges that extend beyond the mere absence of access to electricity. It includes inadequate access to clean cooking facilities, unreliable energy supply, and the inability to afford modern energy services, all of which severely impact the quality of life, economic opportunities, and health outcomes of millions of people worldwide. There are many definitions of *energy poverty*, but a definition that encompasses the multifaceted nature of the issue is the one by Reddy et al. (2000): *"the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development".*

As pictured in Figure 1, and again highlighting the intricacies of energy poverty, SDG7 and having access to energy affects many other aspects of people's lives. Therefore, the success of SDG7 is deeply inter-aligned with SDG16, which emphasises peace, justice, and strong institutions. Robust institutions are essential for designing and implementing effective energy policies that sustainably reduce energy poverty. Transparent governance, the rule of law, and the eradication of corruption are crucial for ensuring that energy resources are managed efficiently and that investments in energy infrastructure reach the most vulnerable populations.

Institutions play a critical role in defining energy poverty, shaping the criteria used to measure it, and influencing the design of interventions. In Europe, energy poverty is often defined by the ability to adequately heat one's home, reflecting concerns about affordability and indoor thermal comfort. This definition drives

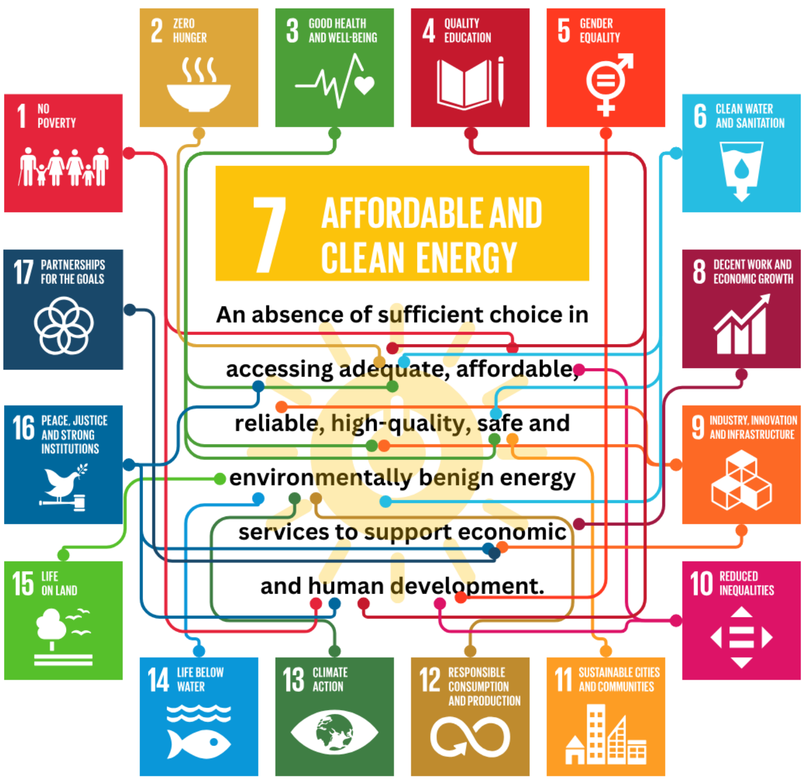

Figure 1: SDG7 in the centre of SDGs
Source: Authors' design

interventions focused on improving energy efficiency, reducing energy costs, and ensuring affordable access to heating. In contrast, in Sub-Saharan Africa, energy poverty is frequently defined by access to reliable electricity services, reflecting the region's development challenges. This definition leads to interventions centred on expanding electricity infrastructure and promoting access to renewable energy. These regional variations in defining energy poverty demonstrate how the objectives of the governing bodies shape the solutions implemented, ultimately determining which populations benefit and how effectively energy poverty is mitigated.

Figure 2 illustrates global disparities in access to electricity, clean cooking fuels, and institutional quality, as measured by the corruption perception index and rule of law. These factors are critical as they highlight systemic inequalities that impact development, economic growth, public health, and environmental sustainability. The maps reveal that sub-Saharan Africa is crucial in the energy poverty-institutional quality conversation, considering the region's low access to clean fuels and electricity, coupled with weak institutional quality, characterised by poor rule of law and high corruption.

The literature related to energy access and its link to institutional quality emphasises the critical role of governance in enhancing energy access, specifically electrification and access to clean cooking technologies (Ahlborg et al., 2015; Acheampong, 2023). Effective governance systems, characterised by transparency, accountability, and coordination among stakeholders, are crucial for designing and implementing successful energy policies that improve energy access, particularly in rural areas (Acheampong et al., 2022a,b; Acemoglu et al., 2003). Good governance can drive investment in energy infrastructure by creating a stable environment that enforces contracts and protects property rights, thereby encouraging private sector participation in clean energy solutions (Acheampong, 2023).

Empirical studies show mixed results on the impact of governance on electrification and access to clean cooking technologies, with some findings indicating positive effects of institutional quality, such as the rule of law and control of corruption, on household electricity consumption and rural electrification in Sub-Saharan Africa (Ahlborg et al., 2015; Trotter, 2016; Best and Burke, 2017). However, evidence on the impact of governance on clean cooking technologies is less consistent, with some studies showing significant positive effects while others report negligible impacts (Acheampong et al., 2023; Sarkodie and Adams, 2020). The effect of corruption on a country's economy, particularly on investment, is characterised by uncertainty. While it is widely assumed that increasing corruption deters investors, it also presents chances for corporations to profit from corrupt practices, perhaps leading to additional investment. On the other hand, Asiedu and Freeman (2009) discovered a negative impact on invest-

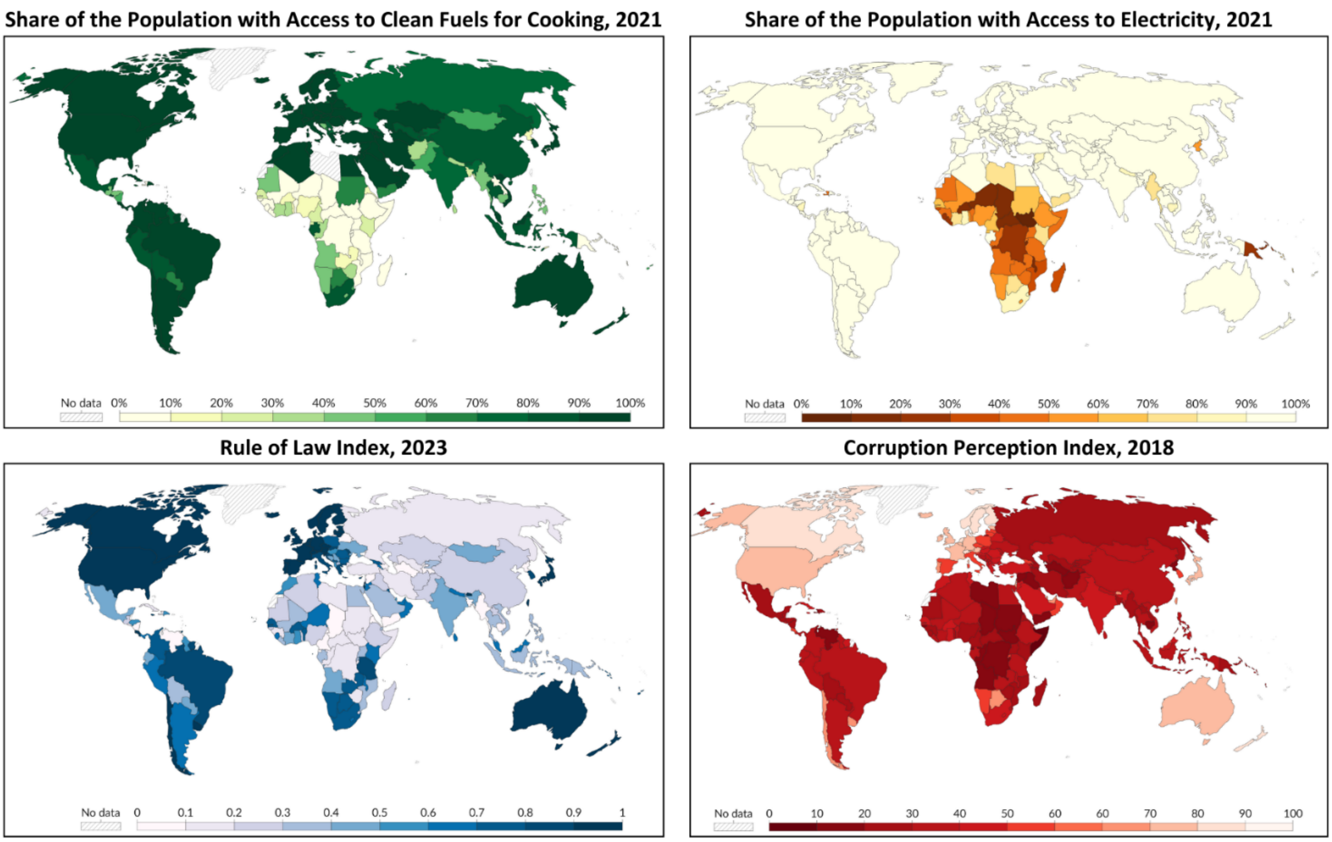

Figure 2: Geographical representation of global indicators: access to clean fuels for cooking, access to electricity, Rule of Law Index (0 = weakest, 1 = strongest), and Corruption Perception Index (0 = most corrupt, 100 = least corrupt)
Source: Our World in Data

ment growth, particularly in Latin America, the Caribbean, and Sub-Saharan Africa. However, they attribute this to the fact that their study was based on firm-level data, which did not account for potential barriers to entry for new firms. These entrance obstacles may result in investment losses, implying that corruption may harm investment growth. (Venter & Inglesi-Lotz, 2022). The literature highlights gaps, particularly regarding the effects of governance on rural access to clean cooking fuels and electrification in regions like Sub-Saharan Africa and Latin America, suggesting a need for further research in these areas.

Particularly for the African continent, energy poverty remains a significant challenge, closely tied to the quality of institutions. While South Africa has made progress in expanding energy access, millions still live in energy poverty, facing unreliable supply and high energy costs. Institutional weaknesses—such as corruption, lack of transparency, and inadequate regulatory frameworks—exacerbate these challenges, making it difficult to implement effective energy policies. Across the continent, similar issues persist, where fragile institutions hinder the development and maintenance of energy infrastructure. Without strong institutions, even the best-intended energy policies may fail to achieve their goals. Therefore, strengthening institutional quality is crucial for addressing energy poverty in Africa, ensuring that energy policies are not only well-designed but also effectively implemented and monitored to benefit all citizens, particularly the most marginalised. The intersection of SDG7 and SDG16 underscores the importance of good governance in achieving universal energy access and advancing sustainable development across the continent.

Figure 3 shows the relationship between the share of the population with access to clean cooking technologies and fuels (EP1) and various institutional quality indicators: Control of Corruption, Government Effectiveness, Political Stability and Absence of Violence/Terrorism, Regulatory Quality, Rule of Law, and Voice & Accountability. Across all six plots, there is a positive correlation, with access to clean cooking technologies increasing as institutional quality improves. The strength of this relationship varies: it is stronger for indicators such as Government Effectiveness and Rule of Law, where points are more clustered, compared to Political Stability and Voice & Accountability, where the correlation is weaker.

Figure 4 presents a similar analysis for the share of the population with access to electricity (EP2). Again,

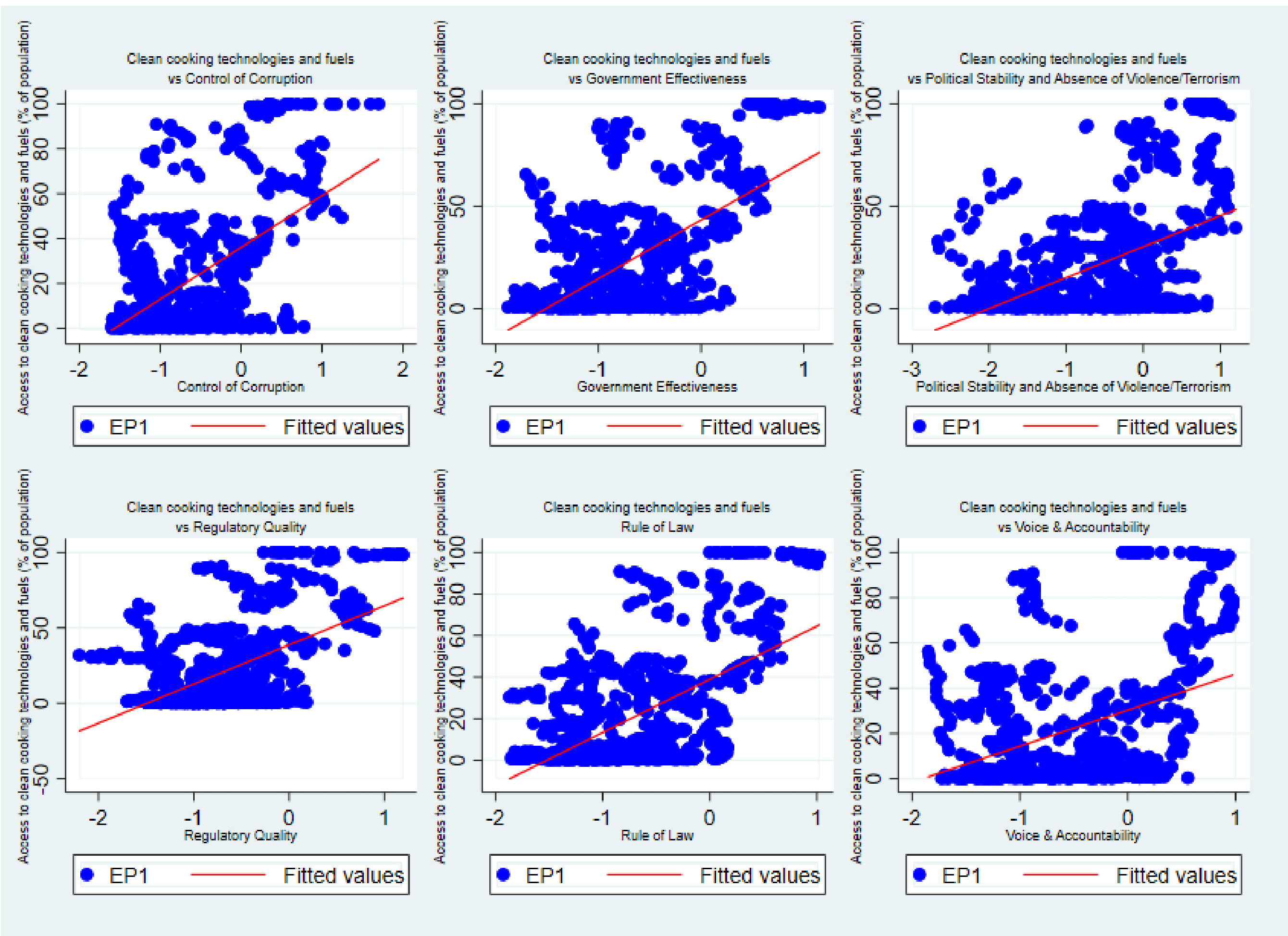

Figure 3: Relationship between access to clean cooking technologies and fuels and various institutional quality indicators
Data Source: World Development Indicators and World Governance Indicators

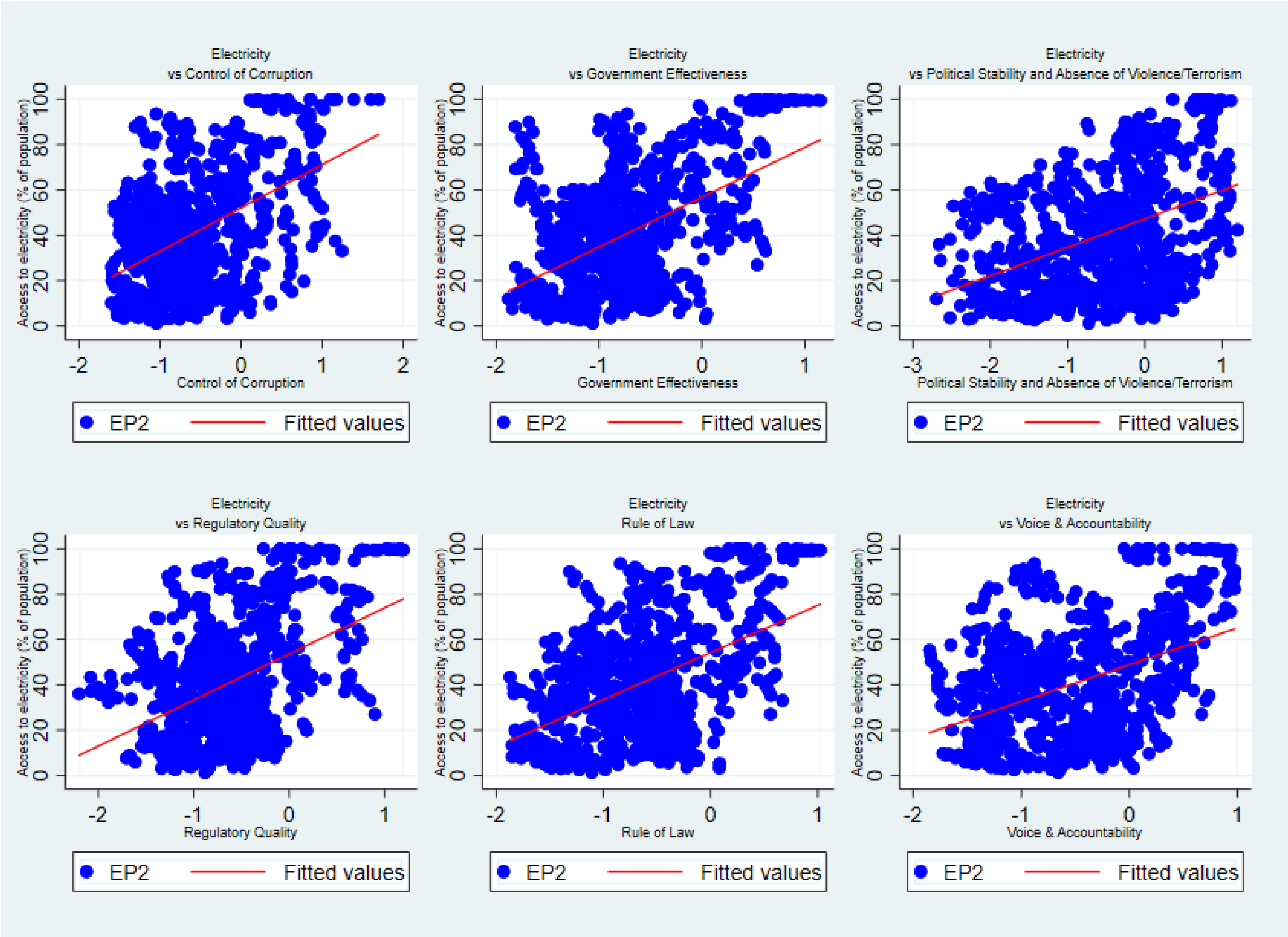

Figure 4: Relationship between access to electricity and various institutional quality indicators
Data Source: World Development Indicators and World Governance Indicators

each scatter plot shows a positive correlation, with access rising as institutional quality improves. The relationship appears stronger for Government Effectiveness, Regulatory Quality, and Rule of Law, and weaker correlations are observed for Political Stability and Voice & Accountability. Overall, these findings suggest that enhanced governance, regulation, and law enforcement are crucial for improving access to both electricity and clean technologies and fuels for cooking.

Energy poverty and institutional quality are related, and this relationship can be seen directly through the application of successful policies or indirectly through channels like economic growth. In order to ensure that investments in energy infrastructure benefit those who need them the most, regulate the energy market, and promote equal access to energy, institutions are essential. Robust institutions contribute to the establishment of a steady atmosphere for the execution of policies, catering to the particular requirements of energy-deprived communities and guaranteeing the equitable allocation of resources. Energy poverty is impacted by economic growth, which is indirectly driven by institutional quality. More people can now afford modern energy services because of good governance, which also creates a climate that is favourable for investment, stimulates economic activity, and raises household earnings. But without open, responsible, and effective institutions, economic progress could not result in better access to energy, underscoring the crucial role that institutions play in reducing energy poverty both directly and indirectly.

In theory, improved access to energy should be facilitated by high institutional quality, as defined by transparency, effective governance, and efficient regulation. However, in certain specific instances, strong institutional quality may inadvertently lead to temporary issues in energy access. Here are a few examples of how this could happen:

Regulatory rigour: In some circumstances, tight compliance requirements and high standards for energy providers may result from strong laws and institutional quality. While this is typically good for long-term sustainability and safety, it may cause difficulties for smaller or less established energy providers to satisfy these strict criteria, affecting access.

Price adjustments: Increased institutional quality may result in more transparent pricing systems and the phase-out of subsidies or price controls. While this is necessary for a fair and sustainable energy market, it may result in short-term price hikes, limiting access for low-income communities.

Renewable energy transition: As institutions prioritise sustainable and cleaner energy sources, there may be brief disruptions throughout the transition from fossil fuels to renewable energy. Such shifts can have an immediate impact on energy availability and access.

It is crucial to highlight that good institutional quality is expected to improve energy poverty in the long run by assuring efficiency, sustainability, and affordability. Any short-term disruptions or obstacles should be considered when building a more reliable and equitable energy system. Institutions should address these concerns proactively through targeted policies and support mechanisms to ensure that access to energy is not harmed while institutional quality is improved.

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Foreign Direct Investment (FDI) Impacts on Energy Poverty in African Countries

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Abstract

Most of the people lacking access to energy are mainly concentrated in Africa, representing serious challenges to its socio-economic development. FDI can help alleviate energy poverty in Africa through infrastructure development, technological advancement and economic growth channels. However, the complex economic system within which it operates requires increased attention.

1. Introduction

In today's technologically advanced world, energy represents the lifeblood that powers every single aspect of the life of human beings, starting from basic human needs such as heating and cooking to very advanced innovation and research. Despite the remarkable technological development, that the last century has witnessed, an important number of people around the world still live without access to energy and still suffer from energy poverty. Energy poverty is one of the serious challenges that the international energy system faces. It leads to poverty, hunger, poor health and low quality of education, and hinders innovation, industry and infrastructure development, spreading consequently inequality gaps. Hence, access to modern, reliable and affordable energy services offers more socio-economic opportunities by enhancing the use of basic and advanced electronic devices for example, which are necessary for extending daily activities during the night and improving the quality of education, health and work (Sambodo & Novandra, 2019).

However, enhancing economic growth, infrastructure and advanced technological levels is a key factor in mitigating energy poverty. Foreign direct investment (FDI) is known for being a main driver of these factors, thus FDI can represent an important opportunity to alleviate energy poverty through these three channels.

2. Energy poverty in developing countries: the case of Africa

Despite its relevance, access to basic energy is still lagging amid the international efforts to provide energy services for all. According to the Energy Progress Report 2023, despite that access to electricity raised globally between 2010 and 2021, there are still 675 million people around the world living without access to electricity in 2021. Most of these people are concentrated in the African continent with around 80% of this number is registered only in Sub-Saharan Africa. Due to its accelerating population growth, the sub-Saharan region is home to 567 million people lacking access to electricity, accounting for almost half of the regional population, with the highest numbers recorded in Nigeria, the Democratic Republic of the Congo and Ethiopia. On the other hand, North Africa has shown a significant decrease in its access deficit with a regional access rate of 94% (WorldBank, 2023).

Paradoxically, Africa is known for holding almost all types of natural and mineral resources, both renewables and non-renewables that are more than sufficient to meet its domestic needs. According to the United Nations Environment Programme, around 30% of the world's mineral reserves, 12% of the world's oil and 8% of the global natural gas are registered in the continent (UNEP, 2024). In addition, Africa is home to a high and diversified potential of renewable resources including solar, wind, hydropower and bio-energies which are fundamental to providing clean and modern energy for its population.

2.1 FDI in Africa

The natural resources sector not only can enable the continent to cover its needs for energy but also is one of the main drivers that can play a vital role in attracting foreign investors. In fact, like many developing regions, Africa has become recently one of the most attractive destinations for foreign investments due to its vast natural resources and also for being a growing consumer market (Gong, et al., 2023).

It is commonly understood that FDI is beneficial for host economies by boosting their economic growth, employment level (by creating new job opportunities), domestic investment, infrastructure, human capital development and productivity through technology and knowledge transfer (Zhang, 2021). In addition, FDI can contribute to ending poverty and its forms including energy poverty which can be reduced by increasing electricity generation access by investing directly in power generation and infrastructure (Aluko, et al., 2023). FDI can bring new technologies to local firms and transfer to them new knowledge. By imitating technologies and know-how from foreign firms and taking advantage of their expertise, local enterprises learn new ways to generate electricity and thus increase electricity access (Hu, et al., 2021; Aluko, et al., 2023). Accordingly, foreign capital has a strong influence on

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electricity access levels in hosting countries (Aluko, et al., 2023).

According to the United Nations Conference on Trade and Development UNCTAD statistics, the foreign direct investment inflows to Africa have seen a tremendous increase from nearly 5$ billion between 1991 and 1995 to around 53.5$ billion between 2018 and 2023. To date, an important part of these investments is mainly received from five countries namely France, the United Kingdom, the Netherlands, the United States and China. Despite that Western countries such as France and the United Kingdom have been for a long time the first investors in Africa, China has become its leading trading and investment partner, increasing its stock by more than 50% from 2013 to 2017 and surpassing some Western partners (Hu, et al., 2021).

2.2 Chinese FDI in Africa

In 2016, China topped the list of all foreign investors in the continent, which highlights the Chinese interest in investing in Africa. According to the China Statistical Yearbook, the Chinese FDI stock in Africa reached $40.9 billion in 2022 and almost 90% of total Chinese outwards were destined to Sub-Saharan Africa between 2003 and 2022. Like its Western partners, China's focus has been for a long time on the natural resource extractions sector, which has been the top recipient sector for years and in 2015, it accounted for 27.5% of the total Chinese FDI in the continent. After 2015, the construction sector has gained more importance and has topped all recipient sectors. In 2022, the construction for infrastructure sector received the highest share of Chinese FDI, representing 33.3% of total China's investment stock (CARI, 2024). In recent years, Chinese firms have heavily invested in electricity and transport sectors mainly in ports and roads construction and maintenance, hydropower stations, power grids, hospitals and other activities such as the nuclear power project in Kenya, the first modern tramway in Sub-Saharan Africa, in addition to Tazara railways linking Zambia with the Dar es Salam port in Tanzania (Akinshipe & Aigbavboa, 2022).

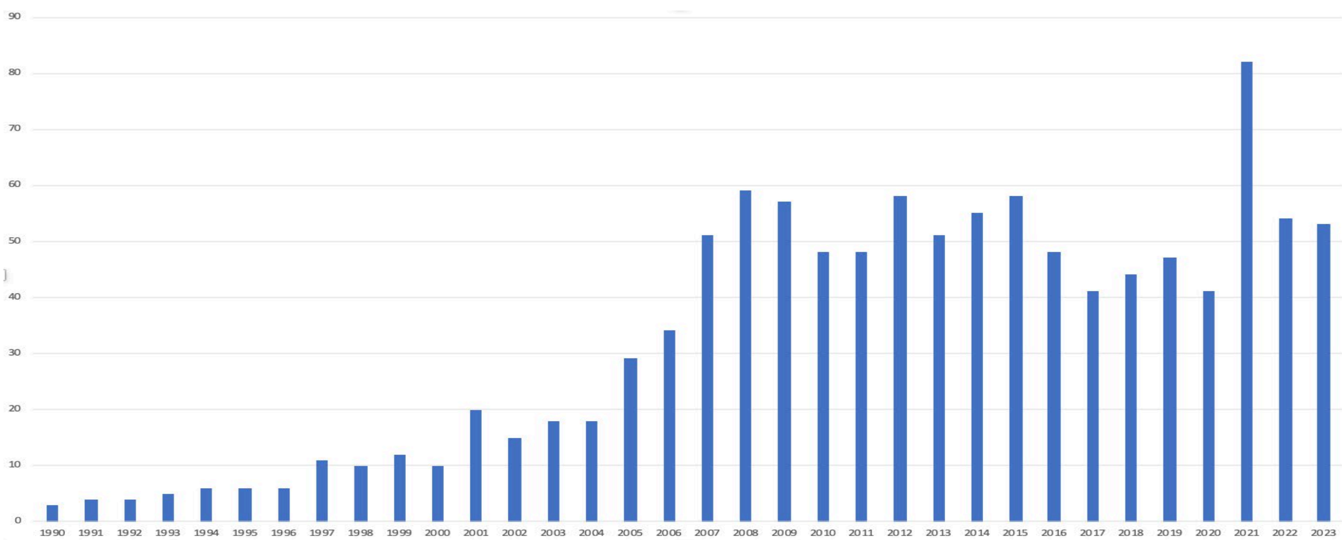
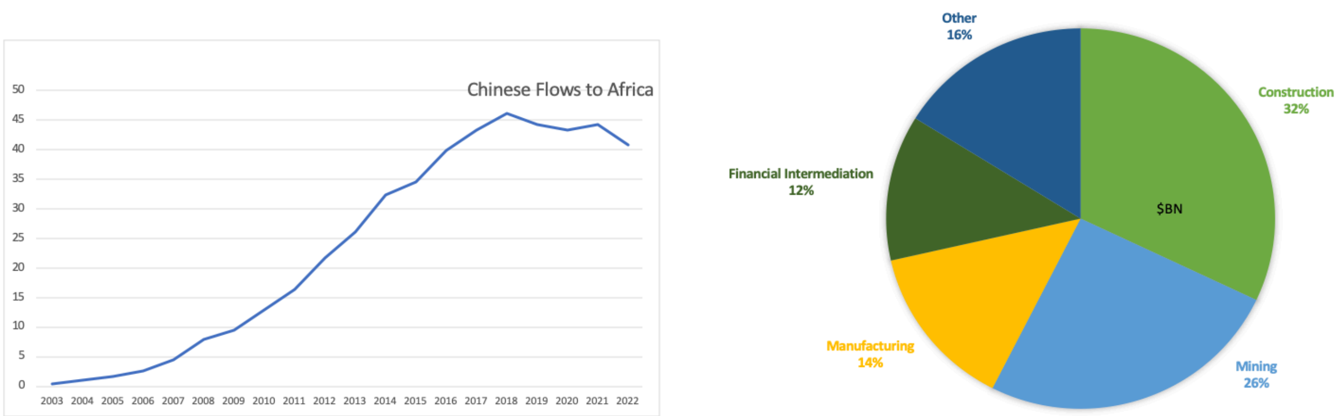


Figure 1: FDI flows to Africa (1990-2023, in billions of USD)
Source: The authors, based on data from UNCTAD statistics.



A: Chinese FDI to Africa (2003-2022, in billions of USD)

B: Chinese FDI to Africa by sector (2013-2022, in billions of USD)

Figure 2: Chinese FDI flows to Africa
Source: The authors, based on data from UNCTAD statistics.

3. FDI: a key factor to reduce energy poverty

Multinational firms can increase electricity connectivity through different channels. Firstly, they can raise energy access by developing and modernising electricity infrastructure since it is necessary for the investors' activities and thus expand energy generation. Foreign investors can directly develop infrastructure and new grids to provide the energy needed to facilitate their business activities (D'Amelio, et al., 2016). In addition, FDI can bring new technologies to local firms and transfer to them new knowledge. By imitating technologies and know-how from foreign firms and taking advantage of their expertise, local enterprises learn new ways to generate electricity and thus increase electricity access (Hu, et al., 2021; Aluko, et al., 2023). Accordingly, foreign capital has a strong influence on electricity access levels in hosting countries (Aluko, et al., 2023).

(D'Amelio, et al., 2016) has investigated how FDI and multinational firms from 83 countries could promote electricity access in 15 host countries in Sub-Saharan Africa between 2005 and 2011. Relying on different econometric techniques mainly the system Generalised Method of Moments GMM and Least Square Dummy Variable, they concluded that the presence of FDI increases electricity access, in particular, in countries characterised by weak institutional quality. According to their analyses, FDI is associated with the development of electricity infrastructure that is necessary for their operations which also helps them gain legitimacy with the stockholders in the local economies. Similar conclusions were found by (Garrone, et al., 2019) in their study on the effects of multinational enterprises on energy poverty in developing countries, specifically in Sub-Saharan Africa. The authors applied the system GMM to a sample of 73 investing countries and 15 host Sub-Saharan countries over the period 2005-2011. Their empirical results pointed out that the host countries affected by poor institutional framework have seen their electrification levels positively impacted by FDI coming from countries that are institutionally closer to them. (Nguea, et al., 2022) have extended the analyses on the relationship between foreign capital and electricity access of the local population to more African countries and a longer period (2000-2017), using the same technique, the system GMM which is suitable for panel data analyses. The findings reveal that while foreign aid decreases electricity access in Africa, FDI increases the share of the population that has access to electrification. However, these inflows do not seem to have a positive impact on reducing the urban-rural disparities in electricity access. More recent work on the same relationship conducted by (Aluko, et al., 2023) emphasised the importance of FDI in lighting up African countries between 2000 and 2017. Not only that, but they also highlighted how the interaction between governance and FDI could influence electricity access in the studied countries. Mainly, FDI has a higher effect on the level of electrification in countries with lower levels of governance.

In an attempt to study the drivers of energy poverty reduction and specifically the role of natural resources in Sub-Saharan Africa, (Nkoa, et al., 2023) employed the pooled Ordinary Least Squares (OLS) and the difference GMM on a sample of 45 African countries between 1997 and 2018. Their conclusions showed that natural resources do not increase electricity access, while per capita income, secondary education and employment help in reducing energy poverty by increasing electricity access to the local people. FDI also plays a vital role in providing electricity in Africa, particularly in rural areas. Employing different determinants including FDI in their analyses, (Khan & Majeed, 2023) focused on the financial sector development impact on energy poverty in developing countries. To empirically investigate the relationship between the different variables, they used several econometric methods such as pooled OLS, fixed and random effects and GMM. They concluded that financial development is important to alleviate energy poverty in the 110 studied economies between 1990 and 2020. The same positive impact was also found between FDI inflows and electricity access. According to the authors, foreign capitals are accompanied by advanced technology transfer that may reduce energy intensity and thus decrease energy poverty. Considering a more comprehensive financial framework, (Ajebe, 2024) examined the nexus between financial resources, energy poverty and CO2 emissions in 54 African countries. The study contributes to the literature on the relationship between FDI and energy poverty and found out that FDI, together with financial development and official development assistance, plays a significant role in the energy landscape in Africa and has a strong connection between them, energy poverty and GHG emissions.

The other channel through which FDI can contribute to energy poverty reduction is economic growth. It is agreed that FDI is an important driver for economic development through the transmission of capital and funds, access to new markets, expansion of production and technology transfer (Sunde, 2017). Moreover, higher economic growth is generally associated with higher government spending on energy infrastructure in different areas. In addition, economic growth may result in an improvement in income levels, and thus householders are likely to choose cleaner and sustainable sources of energy. Hence, FDI can promote access to energy through its effect on economic growth (Nguyen & Su, 2022; Nguea, et al., 2022).

4. Challenges

Considering the previous affirmations, FDI, being an importer of new technologies, able to create new job opportunities and a contributor to the host economy, represents a key driver in promoting energy access and reducing energy poverty. However, it is extremely crucial to join the debate on the FDI and energy poverty relationship, including a comprehensive empirical model to help policymakers, particularly in Africa.

The goal is to explore how African countries should structure their policies regards FDI regulations to reduce the number of people living without access to energy. This requires to carefully balance the timing of

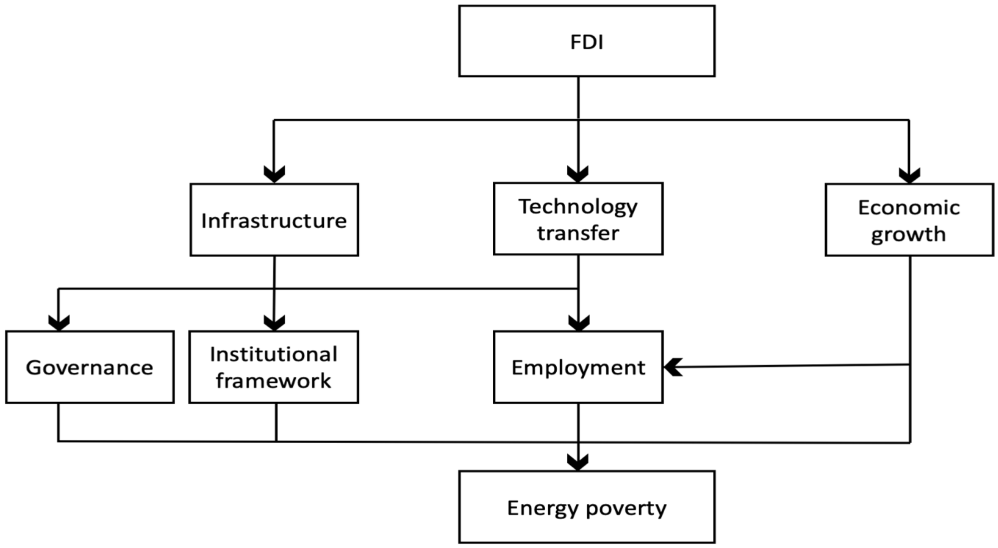


Figure 3: FDI and energy poverty nexus
Source: The authors, based on the literature review.

these interventions with their efficiency. Specifically, it is important to clarify the priority between addressing energy poverty in the short term or pursuing a longer-term strategy that achieves a higher percentage of people lifted out of poverty.

Moreover, policymakers must assess the relative impact of various channels through which FDI can alleviate energy poverty. Some channels may offer quicker solutions with immediate benefits, while others could require more substantial, long-term improvements. Therefore, finding an effective balance between short-term gains and long-term sustainability is essential to ensure both immediate relief and long-term progress in reducing energy poverty across Africa.

It becomes highly important to deepen the understanding of the economic processes that deeply connect different dynamics. Accordingly, further econometric analysis is needed to explore the conditions and the relations allowing to identify the balance between long-term and short-term investments. Also, it is required a deep understanding of the priorities of each territory, in order to better direct FDI.

5. Conclusion and Proposition

Understanding the relationship between foreign investments and the reduction of energy poverty in developing countries is crucial for driving sustainable progress. Foreign investments, particularly in energy infrastructure, have the potential to transform economies by providing access to clean, affordable, and reliable energy sources. This access can empower communities, improve living standards, and foster economic growth. However, the complexity of this relationship demands a deep, interdisciplinary exploration to assess both the positive impacts and the challenges that may arise.

A **call for research** is being proposed to establish a network of complementary studies aimed at collectively addressing the multifaceted connections between foreign investments and the reduction of energy poverty. By gathering diverse perspectives—spanning fields such as economics, environmental science, policy analysis, and social justice—this initiative seeks to create a comprehensive body of work.

The proposed goal is to compile these studies into a unified framework that, like pieces of a puzzle, will offer a clear and holistic understanding of how international funding can effectively mitigate energy poverty. This initiative will invite scholars and experts to contribute their research and insights, fostering collaboration across disciplines. The outcome of this collective effort is envisioned to inform and guide future policy-making and investment strategies, ultimately promoting equitable and sustainable development in regions most affected by energy poverty.

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Will Data Science and Artificial intelligence Significantly Impact Eliminating Energy Poverty?

BY KABIRAT NASIRU

Data science and artificial intelligence are crucial in tackling energy poverty by enabling precise identification of energy-vulnerable households, optimizing energy use, and fostering sustainable practices. This article explores how AI-driven insights can guide energy poverty alleviation, offering potential socio-economic benefits for both developed and developing nations.

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The focus on ensuring universal access to modern energy is a global conversation on energy poverty, especially as international organizations like the IEA, UN, and World Bank present it. It is also generally agreed that to lessen the effects of climate change, the global energy system must be decarbonized (Samarakoon, 2019). Scientists and entrepreneurs are focusing on carbon markets and renewable fuel solutions, amongst other things. Beckmann et al. (2020) explained how it is imperative to discern multiple pathways of association, particularly in oil exporting nations, with exchange rates to oil prices, keeping in mind how ethanol blending may or may not influence the uniformity of oil prices. The necessity to develop only supporting mechanisms within the net zero energy transition defeats the fact that energy poverty is a severe challenge in many countries and that energy poverty is prevalent all contribute to our growing capacity to anticipate homes and countries that are energy susceptible.

The Adoption of Data Science Techniques and Artificial Intelligence for Socio-economic Benefits

Lately, Artificial intelligence has been the talk of many fields, businesses, and organizations; it makes it possible to employ different types of machine learning algorithms for data analysis and other day-to-day assistance. AI can carry out tasks including data classification, pattern recognition, and predictions; it is a valuable tool for many industries and, lately, energy and sustainability (Chamola et al., 2020; Thamik et al., 2022). Regardless of the application areas, it will be highly relevant in solving problems considering the current trend. According to Allam and Dhunny (2019), metro areas have begun to employ new technology more frequently to address problems such as big data via the Internet of Things.

Recent research has focused on improving energy poverty schemes by applying artificial intelligence and machine learning techniques. This will ensure the prediction of energy-vulnerable homes using various objectives and publicly accessible data. However, what do we do when we cannot easily access data? I revel at the thought of treating instances of energy not just as a whole but on a need basis.

It is general knowledge that some countries highly depend on fossil fuels, and some have diverse sources based on several socio-economic factors. Will our models be based on standard variables that affect both, or will there be some wiggle room? (Roberts et al. 2015, Spandagos et al. 2023) Explained that no widely acknowledged criterion exists for identifying whether a person or household is energy-poor. Energy poverty measurements are divided into primary, secondary, and relative or absolute categories (et al., 2022; Spandagos et al., 2023). While secondary measures use aggregated data from utilities and weighted scoring of specific indices, primary metrics directly use consumer-level data. Moreover, relative measures offer comparison data across several households, nations, or regions, whereas absolute metrics quantify energy poverty through rigid thresholds.

There are a few examples of using AI methods, such as machine learning methods, to precisely guide the reduction of energy poverty (López-Vargas et al., 2022). Some research endeavors focus on pinpointing the most significant energy poverty indicators in one or more nations. The study on energy poverty predictors in the Netherlands conducted by Dalla Longa et al. (2021) is a recent example of work focusing on developed countries. The study's authors used machine learning to divide Dutch families into four risk groups for energy poverty. They found that factors like home ownership, value, age, income, and household size were significant predictors.

The machine learning techniques explored by Spandagos et al. 2023 offer promising directions for a better understanding of alleviating energy poverty. They suggest expanding the research to include additional data that could reveal more profound insights into factors like household supplier changes, which takes us to our questions. Keeping in mind that the focus is mostly on global potential, improvements should be focused on where the impact varies significantly to achieve a positive impact.

Since a growing trend of research is being done in that area, this increasing interest should be embraced and instead used effectively to solve the problems at the top level and the root. We want to start thinking outside the box and consider other variables and dependencies, such as the occupation of a farmer with a renewable energy plant that caters to its running cost and rural communities. In essence, do poverty alleviation schemes in both developed and underdeveloped countries follow up with practices? What do they do with the data and the project's success? Is there a follow-up with the recipients, and how does that fit into the larger perspective? These are the questions we should be asking.

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Poverty and Energy Poverty in Ecuador: Subsidised Electricity Tariffs and Clean Cooking Programs

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Abstract

In this article, we identify potential energy poverty patterns using poverty indicators in Ecuador. We discuss the extent to which the current subsidised electricity tariffs are efficient and might require improvements. We also address the potential impact of energy poverty on participation in clean cooking programs.

Disclaimer: The opinions expressed within the contents are solely the authors' and do not reflect the opinions of the institutions or companies with which they are affiliated. Daniel Davi-Arderius works at e-Distribución Redes Digitales, SLU and is part of the EU DSO Entity. Xavier Rodríguez-Cruz is an associate consultant at Econintsa.

1. Introduction

Ecuador is one of the few officially dollarized economies in Latin America and a net oil exporter. Its economy is characterized by a huge informal sector in both the labour and the housing markets (Matano et al., 2020; Obaco et al., 2021). Economically speaking, Ecuador is a developing country with high levels of inequality and poverty, but a high Human Development Index (HDI), which is around 0.765.

Ecuador is a highly subsidised economy (Gould et al., 2018). These subsidies include electricity tariffs, gas for general transportation, and liquefied petroleum gas (LPG). However, to our knowledge, the Ecuadorian Statistical Agency (INEC) does not report specific energy poverty indicators (Siksnelyte-Butkiene et al., 2021). Instead, INEC publishes poverty statistics such as Income Poverty, Unmet Basic Needs or the Multidimensional Poverty Index. Income Poverty considers household incomes. Unmet Basic Needs covers five household components: economic conditions, rights to basic education, rights to housing, rights to essential services (sewage and water), and housing overcrowding. Finally, the Multidimensional Poverty Index considers four dimensions (education, work and social security, health, water & food, and housing structure) and is made of twelve indicators (Añazco et al., 2016).

In 2023, Income Poverty, Unmet Basic Needs and the Multidimensional Poverty Index criteria were 23.9%, 28.4% and 36.9%, respectively (INEC, 2024b). In the next section, we analyse these indicators by province and identify potential patterns of energy poverty (González-Eguino, 2015).

2. Poverty in Ecuador

INEC classifies "poor", and "extremely poor" populations based on the monthly household income per capita. As shown in Table 1, the rate of poor households in rural areas is several times higher than in urban areas, which implies relevant socioeconomic differences between both areas. Rural areas and provinces in the Amazon also have accessibility problems (Obaco et al., 2020). Similar regional patterns are identified in the Unmet Basic Needs and in the Multidimensional Poverty Index (Matano et al., 2022; Obaco and Díaz-Sanchez, 2018).

Table 1. Main poverty indicators in June 2024

Poverty criteria assessment	Definition	Ecuador	Rural areas	Urban areas
Households monthly Income per Capita	Share of poor population (less than 91.55 USD)	25.5%	43.2%	17.2%
	Share of extremely poor population (less than 51.60 USD)	10.6%	24.1%	4.4%
Unmet Basic Needs	5 components	30.8%	52%	21%
Multidimensional Poverty Index	4 dimensions and 12 indicators	37.3%	67.9%	23%

Elaboration: Authors. Source: INEC (2024a).

Ecuador is made of four regions: the Coast (Northern Coast, Southern Coast), the Andes (Northern Andes, the Andes, Southern Andes), the Amazon and the Galapagos Islands (Figure 1). Geographical characteristics set important socioeconomic differences in consumption patterns. For instance, weather is different between regions and households in the Coast mostly use air conditioning, while heating water in the Andes. Amazon has less accessibility in general. Thus, housing structure is also different between natural regions (Obaco et al., 2022). Higher wages are presented in three main provinces, in Pichincha where the capital Quito is, in Guayas where the economic port city of Guayaquil is, and in Azuay due to its industrial activity.

When analysing the poverty indicators from Table 1 in provinces, we find interesting results. Figures 2, 3 and 4 depict the regional Income Poverty statistics, the Multidimensional Poverty Index and the Unmet Basic Needs, respectively. In all cases, the provinces with the highest poverty statistics are in the Amazon, while the lowest are in the Andes.

Despite INEC not providing energy poverty indicators, this might be quite well estimated with the rate of

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COD	PROVINCIA	REGION
01	AZUAY	Andean
02	BOLIVAR	Andean
03	CAÑAR	Andean
04	CARCHI	Andean
05	COTOPAXI	Andean
06	CHIMBORAZO	Andean
07	EL ORO	Coast
08	ESMERALDAS	Coast
09	GUAYAS	Coast
10	IMBABURA	Andean
11	LOJA	Andean
12	LOS RIOS	Coast
13	MANABI	Coast
14	MORONA SANTIAGO	Amazon
15	NAPO	Amazon
16	PASTAZA	Amazon
17	PICHINCHA	Andean
18	TUNGURAHUA	Andean
19	ZAMORA CHINCHIPE	Amazon
20	GALAPAGOS	Insular
21	SUCUMBIOS	Amazon
22	ORELLANA	Amazon
23	STO DGO TSACHILAS	Coast
24	SANTA ELENA	Coast

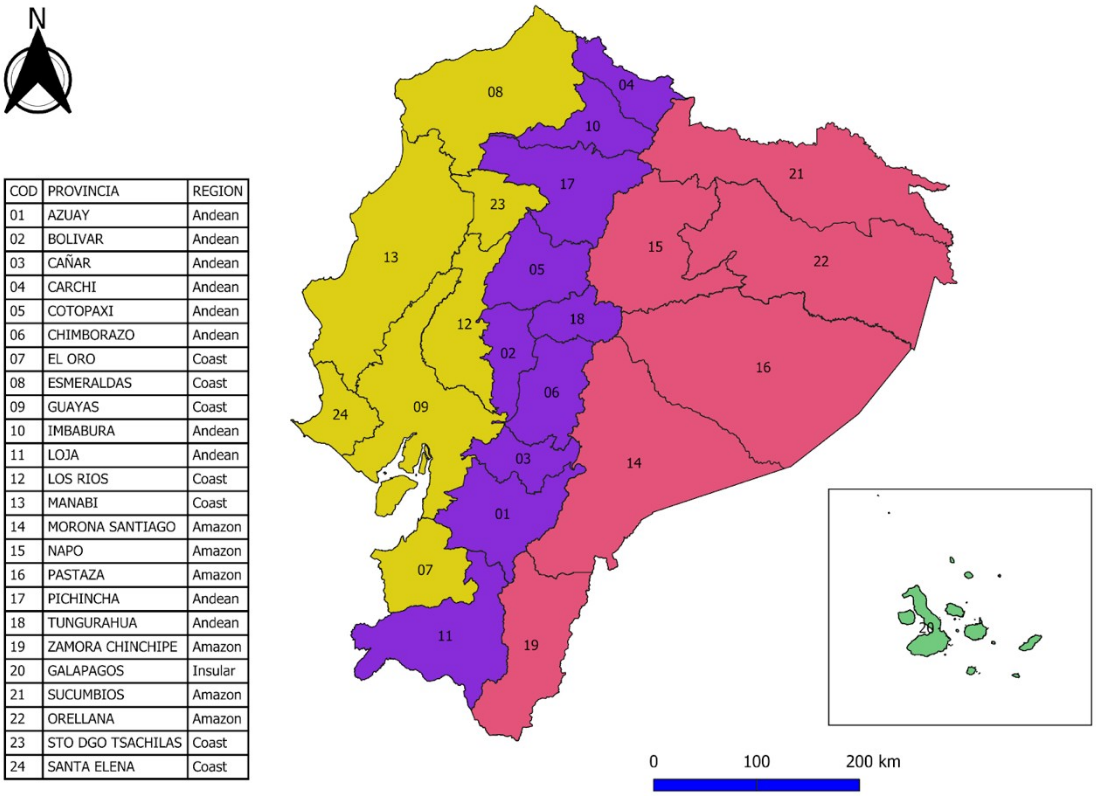

Figure 1. Provinces in Ecuador by regions. The Coast region is identified in yellow, the Andes in violet, the Amazon in purple, and the Galapagos Islands in green.
Elaboration: Authors. Source: Own elaboration based on INEC (2024a).

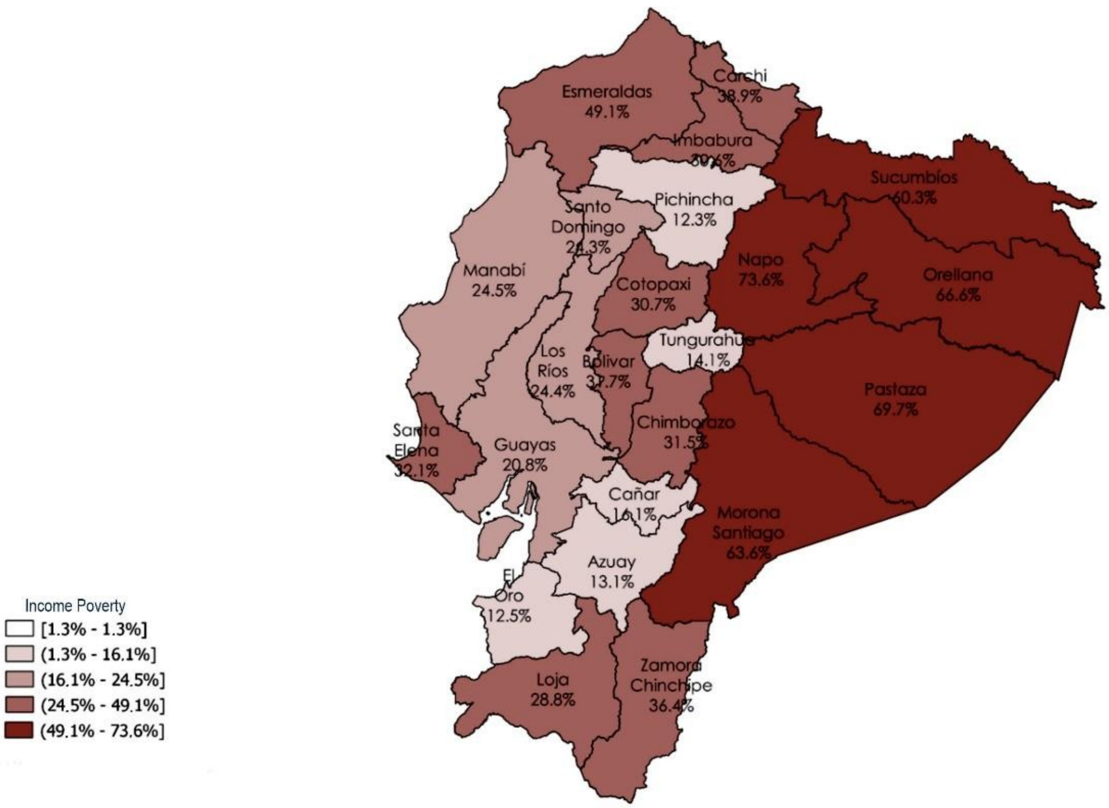

Figure 2. Income Poverty Index (in %) by provinces (2023).
Source: Principales resultados de la Encuesta Nacional de Empleo, Desempleo y Subempleo – Anual (INEC, 2024a; 2024b)

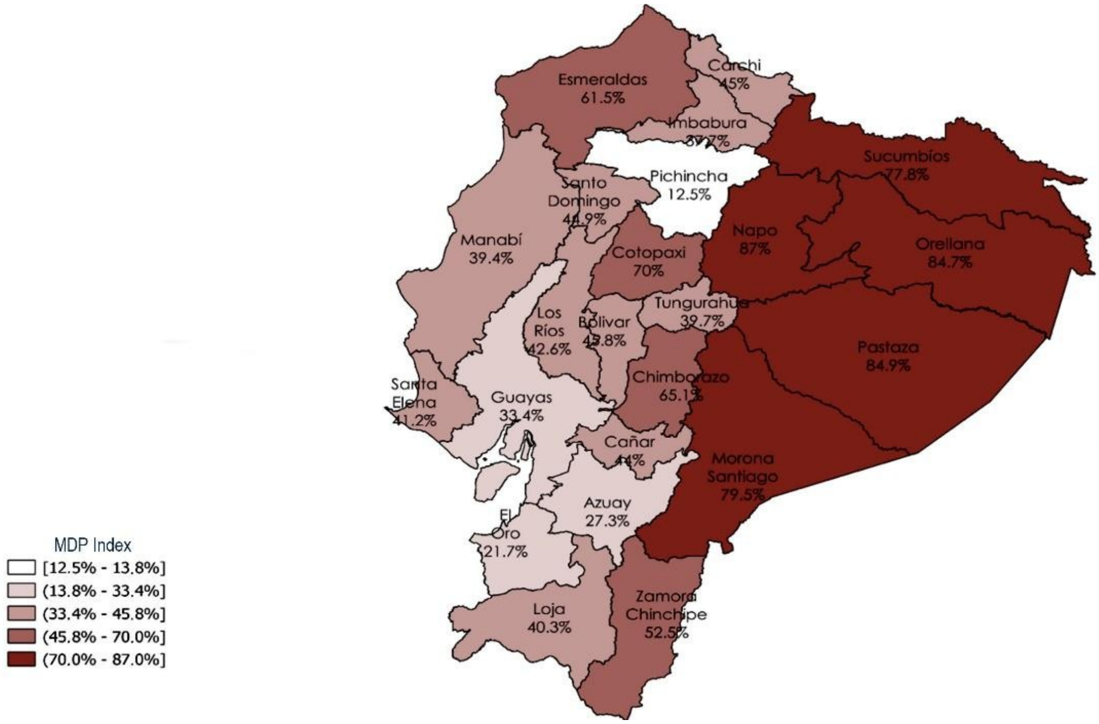

Figure 3. Rate of Multidimensional Poverty Index (in %) by provinces (2023).
Source: Principales resultados de la Encuesta Nacional de Empleo, Desempleo y Subempleo – Anual (INEC, 2024a; 2024b)

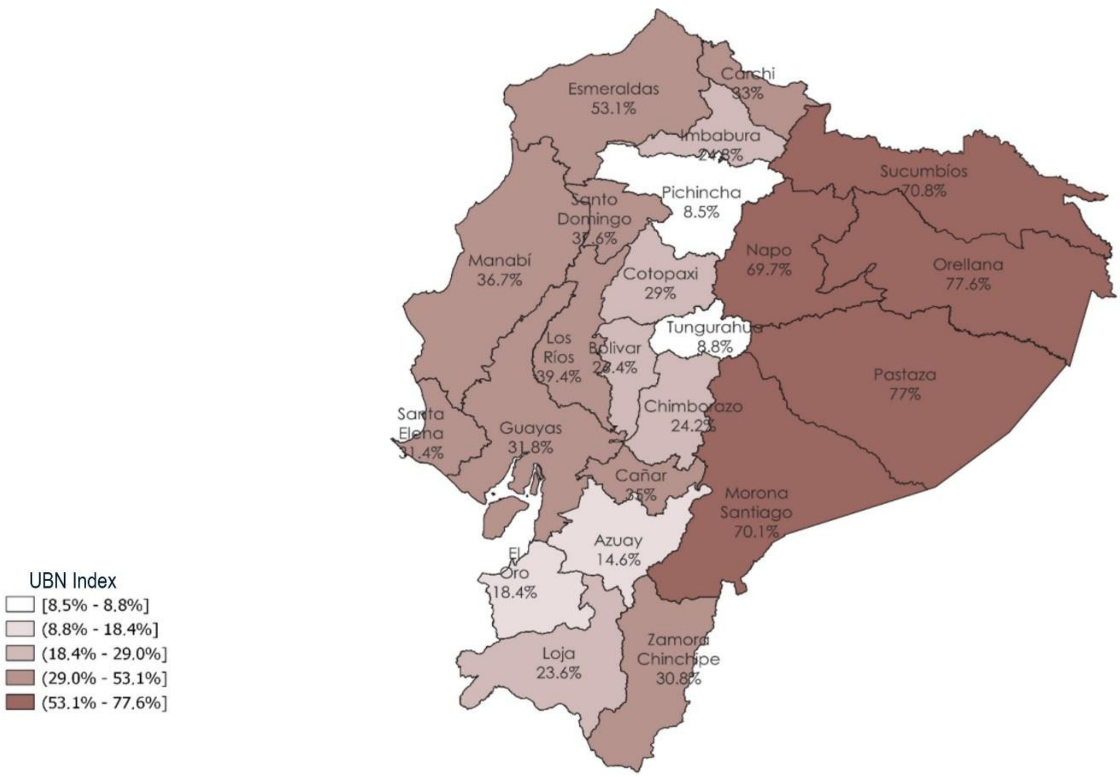

Figure 4. Rate of Unmet Basic Needs (in %) by provinces (2023).
Source: Principales resultados de la Encuesta Nacional de Empleo, Desempleo y Subempleo – Anual (INEC, 2024a; 2024b)

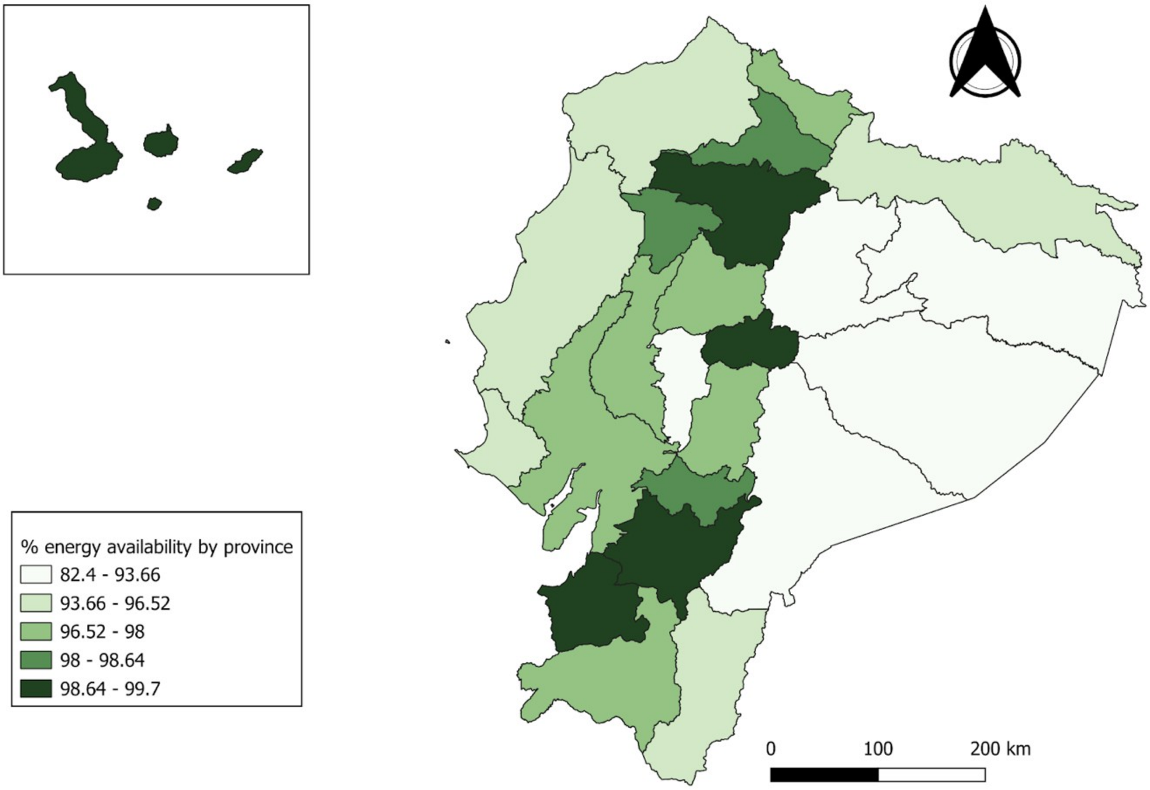

Figure 5. Rate of homes connected to the electricity public network by province (2023). Elaboration: Authors. Source: INEC (2024a).

homes connected to the electricity public network and the rate of homes owning a refrigerator. As shown in Figures 5 and 6, provinces in the Amazon have the lowest levels, while the opposite for provinces in the Andes. These results are relevant since the World Bank states that Ecuador has full access to electricity. These patterns represent potential regional poverty indicators (Figures 2, 3 and 4).

In the next section, we describe the electricity subsidies in Ecuador to show how the targeted population is benefiting from these subsidies. These subsidies in general coexist with other subsidies.

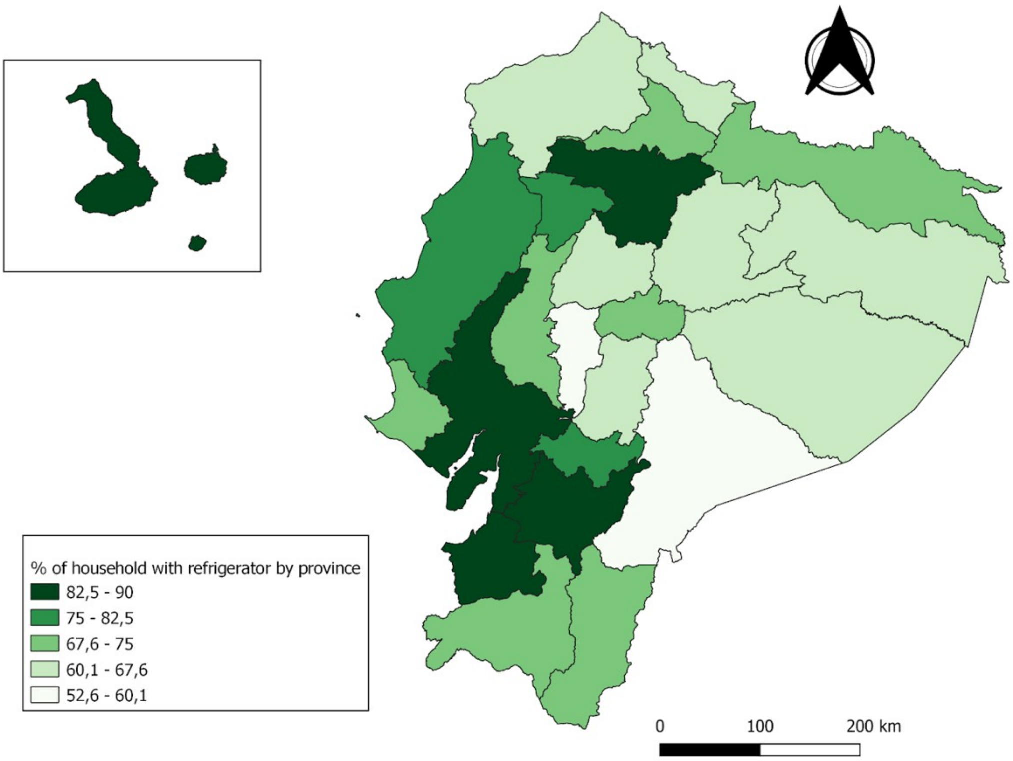

Figure 6. Rate of homes that have a refrigerator by province (2023) Elaboration: Authors. Source: INEC (2024a).

3. Subsidised electricity tariffs in Ecuador

Ecuador has several subsidised electricity tariffs: "*tarifa dignidad*" for low-income households, "*tarifa tercera edad*" for elderly people, and "*tarifa de la discapacidad*" for disabled people. In all cases, households also pay specific charges on their electricity bills, such as waste charges or fire services. See Table 2.

Table 2. Energy subsidies in Ecuador.

Energy source	Description	Target population	Subsidy	Participation requirements
LPG	Direct subsidy	General	Each LPG cylinder (15 kg) costs 1.65 USD	None
Electricity	Specific tariff identified as "tarifa dignidad"	Poor people	0.04 USD/KWh	Monthly electricity consumption lower or equal than 130 kWh during the last 12 months
Electricity	Specific tariff identified as "tarifa tercera edad"	Elderly people	50% discount on 138 kWh per month	Age > 65 years
Electricity	Specific tariff identified as "tarifa discapacidad"	Disabled people	50% discount and 225 USD maximum	Being a disabled person

Elaboration: Authors. Source: own elaboration based on ARCONEL (2024).

Access to the tariff for low-income households is conditional on the maximum monthly electricity consumption, which seems not to be the most efficient scheme since it does not consider the fact that poor households can't buy expensive energy efficient devices -led lights or low-consumption household appliances- or the higher number of people living in the house. Consequently, poor energy residential should opt for losing comforts if they want to receive the subsidy.

In 2014, Ecuador launched a clean-cooking program aimed at replacing LPG-fired cookstoves and LPG-fired boilers with electric devices. The main target of this program was to reduce the imports of highly subsidised LPG, reduce CO2 emissions and make a major use of new hydropower electricity generation (Davi-Arderius et al., 2024). The Ecuadorian government and the national regulator expected a participation of 3 million families in this program, and planned very ambitious investments in electricity networks and hydropower capacity. However, maximum number of houses participating was only 0.7 million. Economic benefits for the participants in the clean cooking program were the following (Obaco et al., 2025):

- Subsidy of electricity consumption: 20 KWh for water heating devices, 80 KWh for induction cooking, or 100 KWh for water heating and induction cooking.
- A tax exemption to purchase an induction stove.
- Government loans (between 150 USD and 600 USD) to purchase an induction stove.
- Agreements with national manufacturers of induction stoves and compatible pots and pans.
- Electricity grid connection to one's home.

Figures 7 and 8 depict the average consumption from tariffs for elderly and poor households between 2018 and 2021, respectively. Higher percentages represent a larger rate of the population covered by these tariffs. Moreover, Figure 9 shows the local participation in the clean cooking program.

When comparing regional patterns from subsidised electricity tariffs (Figures 7, 8 and 9) and the regional poverty patterns (Figures 2 to 6), we find some interesting conclusions:

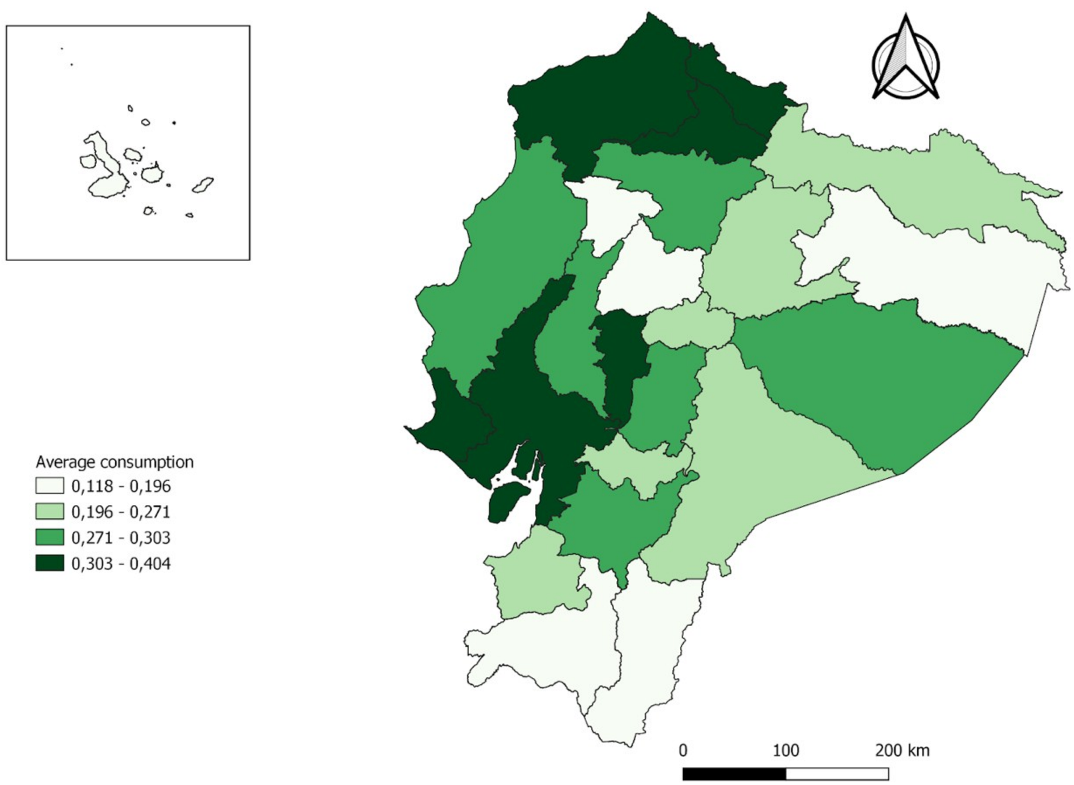

Figure 7. Average consumption for the elderly tariff (in USD/housing) by province (2018-2021) Elaboration: Authors. Source: ARCONEL (2024).

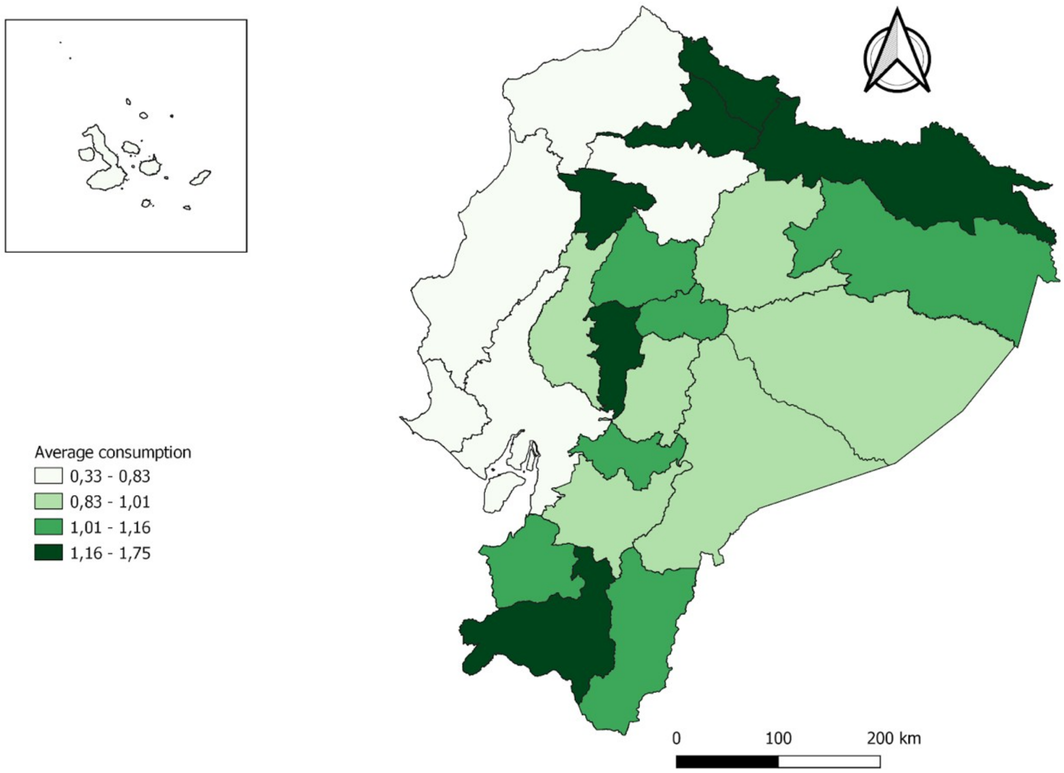

Figure 8. Average consumption for the poverty tariff (in USD/housing) by province (2018-2021)
Elaboration: Authors. Source: ARCONEL (2024).

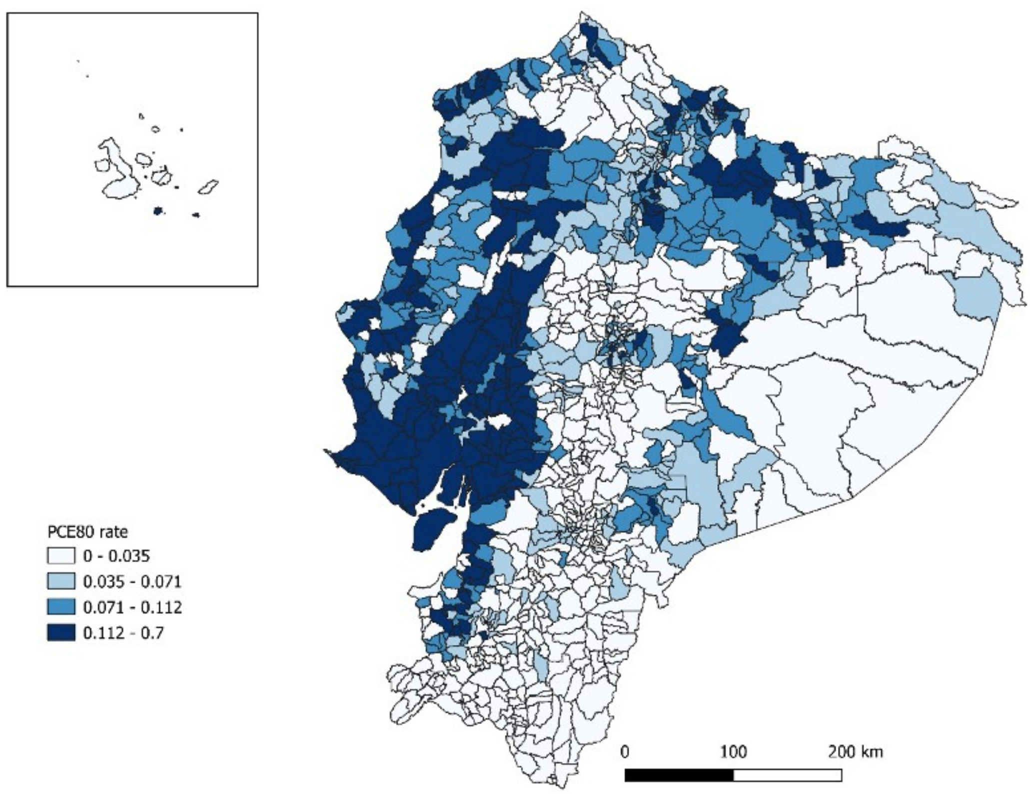

Figure 9. Average participation (p.u.) in the clean cooking program by parish (2015-2021).
Source: Obaco et al. (2024).

- **Elderly tariffs**: The highest use of this tariff is made in provinces in the Coast region. Guayas, the most populated province, has the highest consumption rate of this subsidised tariff (0.404 USD/housing). Pichincha, the second-most populated province, also has a high consumption rate (0.290 USD/housing). We also find provinces in the Amazon with significant consumption.
- **Poverty tariffs**: Regional consumption follows the opposite pattern than elderly tariffs. In this case, Guayas has the lowest consumption rate in this subsidised tariff (0.442 USD/housing) after Galapagos (0,333 USD/housing). Moreover, the province with the worst poverty indicators in Figures 2 to 4, Pinchicha, is the third on the list (0.520 USD/housing). On the other hand, Santo Domingo (1.75 USD/housing) and Bolivar (1.35 USD/housing) have the highest use of the poverty tariff. Bolivar is one of the provinces with the lowest rate of homes connected to the electricity public and homes that have a refrigerator (Figures 5 and 6).
- **Clean cooking program**: the highest participation in this program corresponds to the Coast and the most populated provinces, while it is very low in the Amazon.

4. Conclusions and Policy recommendations

From the above results, we identify some insights about poverty and the energy poverty:

- As expected, the poorest regions have higher consumption on the poverty-subsidised tariff. However, further analysis is needed at the parish level to confirm if the poorest population at the parish level is benefiting from them.
- There are concerning regional differences in the rate of homes connected to the public network. Additional programs could be implemented to improve this indicator, which could also cover improvements to housing conditions and subsidise household electricity installation or connecting it to the public grid.
- A subsidised electricity tariff for poor people whose participation is limited to a maximum consumption does not seem to be the best option, especially for people who might not have enough resources to buy efficient electricity devices. This characteristic should be assessed to consider potential improvements depending on the socioeconomic characteristics of the housing.
- INEC should perform specific studies in Ecuador to provide energy poverty indicators. They are essential to set efficient programs to deal with it.

Moreover, we identify interesting patterns of the electrification programs -clean cooking- and the energy poverty, which need to be considered in the future:

- Participation in this program follows the opposite pattern from the poverty tariff. Thus, income levels seem to increase the probability of adopting alternative energy sources to LPG. Education and location availability are also key factors (Karimu, 2015; Davi-Arderius et al., 2023; 2024).
- The effect of other energy subsidies, such as LPG, cannot be ignored. If participants do not have clear economic incentives to move from LPG to electricity, they don't participate in the clean cooking programs. Between 2010 and 2023, subsidies accounted for 53.9 billion USD of the public budget to subsidise fuel, which equals to almost 15 times the annual budget for health (3.7 billion USD). Nowadays, LPG remains the main cooking fuel in Ecuador: 93% of households used it in 2022 (ARCONEL, 2024).
- A uniform national approach for the clean cooking program might not be efficient when there are relevant socioeconomic differences between regions as we find (Obaco et al., 2025).

Nowadays, Ecuador is suffering from important electricity supply problems related to the lack of hydropower production. On one side, water reservoirs have drastically decreased due to climate change, and, on the other side, some generators and electricity lines are not fully operating due to technical problems. In some cases, these problems end with restrictions on electricity consumption or even blackouts. If this situation is not normalized soon, the consequences of poverty, and energy poverty in particular, may be significant in the future.

Recently, the Ecuadorian government announced that electricity bills for houses whose consumption is below 180 KWh will be zero for December 2024, January 2025 and February 2025. Its potential socioeconomic impacts need to be assessed in the future.

Finally, the development of renewables and the development of training and job retraining programs for workers in intensive sectors should be prioritized by the Ecuadorean government. This would reduce dependence on fossil fuels in line with the National Government's guidelines to advance the energy transition. This also includes facilitating the transition towards jobs in the renewable energy sector, promoting sustainable technologies, and setting stricter regulations on energy efficiency in industry, public buildings and the residential sector. All these recommendations might also have a positive effect on energy poverty through lower electricity consumption.

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Advancing SDG7 (“Affordable and Clean Energy”): Towards Ending Energy Poverty for Net Zero Emissions in the Middle East and North Africa

BY SARA ZAIDAN AND MUTASEM EL FADEL

Abstract

This article examines advancing the United Nations Sustainable Development Goal 7 (SDG7) pertaining to “Affordable and Clean Energy”, to address energy poverty (EP) and achieve the broader objectives of upcoming global agendas for the SDGs by 2030 and the Net Zero Emissions (NZEs) target under the Paris Agreement by 2050. We begin by exploring the relationship between EP and SDG7 through a comparative analysis of the six indicators monitoring SDG7 progress in the Middle East and North Africa (MENA) region. The drivers of EP and their subsequent impacts at national and regional levels are then discussed, followed by policy recommendations advocating the “right to energy”.

1. Energy Poverty and the Pursuit of SDG7

Energy lies at the heart of development and the backbone of a modern economy. In the coming decades, energy systems will undergo significant transformations triggered by current global challenges, particularly those related to climate change and socio-economic inequality, with energy poverty (EP) representing a key subset at the intersection of these issues. While various EP definitions have been recognized across multiple sources [1]–[7], no single universal or standard definition is followed. Insights to common EP definitions include the lack of an efficient supply and distribution systems for modern fuels, poor infrastructure or absence of power networks, no access to reliable and affordable supply of electricity, inability or low consumption of modern energy per capita, high reliance on traditional biomass for cooking, high share of income spent on energy needs, absence of physical opportunity to connect or acquire energy, absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services, absence of adequate safeguards to ensure a country’s energy demand and supply patterns are sustainable, among others. These definitions imply the issue of EP is relevant in both developed countries, where it is often linked to low income and high energy prices, and developing countries, where it is primarily associated with a lack of access to modern energy services [2]. In this article, we conceptualize EP as an interconnected and overlapping issue that touches on multiple critical and emerging aspects of sustainable energy development, including but not limited to energy “sustainability”, “access”, “security”, “justice”, “affordability”, “diversification”, “democracy”, “equity”, “resilience”, “reliability”, “inclusion”, “vulnerability”, “governance” among others. The boundaries between these dimensions are blurry and the underlying concepts are all similar, indicating they should not be viewed in isolation to be able to emphasize the complex dynamics of the energy system and its broader implications on the environment, economy, and society. As human development and climate agendas crossed paths following the adoption of the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement in 2016,[1] the fundamental importance of considering the interaction of energy systems with human development became increasingly emphasized given the intertwined nature of both global agendas. Accordingly, we argue that EP is closely interlinked with the aspirations envisioned by upcoming global agendas, short-term for the SDGs by 2030 and long-term for the Net Zero Emissions (NZEs) target of the Paris Agreement mainly centering around 2050. In particular, the most direct link is seen through the **SDG7 (“Affordable and Clean Energy”)** with the fundamental principles to propel sustainable poverty alleviation rooted in its definition that calls for ensuring access to affordable, reliable, sustainable and modern energy for all by 2030 through the achievement of five targets and six indicators reinforcing positive change as outlined in Table 1.

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Therefore, this article explores key questions regarding EP: *Where do we stand now, and where must we go next?*

We take the Middle East and North Africa (MENA) region as a case study, motivated by the ongoing political affairs and their disruptive impacts in exacerbating EP at both national and regional levels. To address these questions, we first examine the current state and emerging trends in EP, the underlying barriers and their impacts, and the strategic policy opportunities that lie ahead within the MENA context.

2. Current Energy Landscape and Emerging Trends in MENA

The MENA region has a high degree of intraregional heterogeneity owing to differences in energy infrastructure, political status, and socio-economic development, which lead to associated large disparities in access to affordable, reliable, sustainable, and modern energy. This makes EP a highly relevant issue to the region and its implications warrant far greater discussion at environmental, economic, social, and political levels. Table 2 provides a comparative analysis of 26 MENA coun-

Table 1: Definition of SDG7 as per the latest refinements of the United Nations global indicator framework (February/March 2024) [8] with the hierarchy labeling based on definitions by [9].

Macro-level: *Goal ("SDG") = 1*		Meso-level: *Targets ("T") = 5*		Micro-level: *Indicators ("I") = 6*		Impact of Goal-Target-Indicator (Increase or Decrease) on Energy Poverty (Decrease)	
Index	Description	Index	Description	Index	Description	Index	Description
SDG7	*"Ensure access to affordable, reliable, sustainable and modern energy for all"*	T.7.1	*"By 2030, ensure universal access to affordable, reliable and modern energy services"*	I.7.1.1	*"Proportion of population with access to electricity"* *(% population-electricity)*	(+, −)	*Increasing access to electricity ensures that more people have reliable and affordable power supply which enables better living standards by supporting essential needs like lighting, heating, cooking, and the use of electronic devices, and facilitating economic opportunities, education, healthcare, and overall social development.*
				I.7.1.2	*"Proportion of population with primary reliance on clean fuels and technology"* *(% population-clean cooking)*	(+, −)	*Increasing reliance on clean fuels and technologies offers safer, more sustainable cooking solutions that improve quality of life and support long-term well-being, particularly for vulnerable populations, by reducing health risks from indoor air pollution and easing the financial burden of using traditional, inefficient fuels.*
		T.7.2	*"By 2030, increase substantially the share of renewable energy in the global energy mix"*	I.7.2.1	*"Renewable energy share in the total final energy consumption"* *(% renewable consumption)*	(+, −)	*Increasing renewable energy in end-use sectors decreases greenhouse gas (GHG) emissions and provides affordable electricity to underserved populations in off-grid areas using decentralized solutions such as solar and wind energy.*
		T.7.3	*"By 2030, double the global rate of improvement in energy efficiency"*	I.7.3.1	*"Energy intensity measured in terms of primary energy and gross domestic product (GDP)"* *(megajoule per $2017 Purchasing Power Parity (PPP) GDP)*	(−, −)	*Decreasing energy intensity indicates improved efficiency (less energy used per unit of economic output) which reduces energy waste and associated emissions, eases strain on local resources and infrastructure, and reduces costs, making energy more affordable to a broader segment of society to meet growing demands.*
		T.7.a	*"By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology"*	I.7.a.1	*"International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems"* *(billions of constant 2021 US$)*	(+, −)	*Increasing international financial support accelerates research and development (R&D) and investment projects for the development of energy infrastructure, hybrid renewable systems, clean energy technologies, advanced energy efficiency solutions, and expansion of the green jobs market.*
		T.7.b	*"By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support"*	I.7.b.1	*"Installed renewable energy-generating capacity in developing and developed countries"* *(renewable watts per capita)*	(+, −)	*Increasing renewable power production goes in parallel with expanding electricity access, particularly in remote or rural areas, which in turn directly contributes to a larger share of renewables in the overall national energy mix and reduces the carbon footprint of the energy system.*

tries for SDG7 indicators related to access to electricity, access to clean cooking fuels, renewable energy share, energy intensity of economies, international finance for clean energy, and renewable electricity-generating capacity, respectively.

The *first part* of the analysis categorizes the MENA countries into respective geographical sub-regions and income levels. The boundaries of the MENA region, as defined by the World Bank [10][11], encompass the 22 member countries of the League of Arab States which we have grouped into four sub-regions – Gulf (A), Levant (B), North Africa (C), and Least Developed (D) – along with Iran, Israel, and Malta which have been considered under a fifth sub-region – Non-Arab (E). We have also included Türkiye in the latter due to its significant influence and close interconnections with the countries of the region. Of these 26 countries, a total of 8 are classified as high-income, 14 (9 lower- and 5 upper-) as middle-income, and the remaining 4 as low-income.

The *second part* of the analysis examines the existing and announced national plans that crosscut sustainable development and climate action objectives in the MENA region. This is given within the framework of the SDGs – monitored through Voluntary National Reviews (VNRs) – and the Paris Agreement – monitored through Nationally Determined Contributions (NDCs) and Long-Term Strategies (LTSs) for the NZEs target – to highlight policy gaps in current energy governance of the surveyed countries. For the 2030 agenda, all countries report progress toward sustainable development in a periodic cycle, except for Iran – Non-Arab (E) – which has not submitted any VNRs. Regarding the 2050 agenda, all countries have NDCs except Libya – North Africa (C) – with the most recent commitment submitted in November 2024 by the United Arab Emirates through its third NDC version. As for LTSs, only six countries (Gulf (A): United Arab Emirates and Oman, North Africa (C): Morocco and Tunisia, Non-Arab (E): Malta, and Türkiye) have made official commitments, with the most recent submission given in November 2024 by Türkiye. For the NZEs target, 11 countries (out of 26) have yet to make any form of net-zero commitment, including Gulf (A): Qatar, Levant (B): Iraq, Jordan, Syria, and Palestine, North Africa (C): Egypt, Libya, Algeria, and Morocco, Least Developed (D): Yemen, and Non-Arab (E): Iran. Meanwhile, the remaining 15 countries have made varying commitments, either through policy (Gulf (A): Saudi Arabia, United Arab Emirates and Oman, North Africa (C): Tunisia, and Non-Arab (E): Malta and Türkiye), pledges (Gulf (A): Kuwait and Bahrain), or ongoing discussions (Levant (B): Lebanon, Least Developed (D): Sudan, Djibouti, Somalia, and Mauritania), and Non-Arab (E): Israel), with Comoros – Least Developed (D) – being the only country that has declared reaching a state of NZEs. No NZEs target has been legislated across the region, meaning that no country within the MENA has formally established a legally binding commitment to achieve NZEs by a specific date. While many countries have made voluntary climate commitments, these are not backed by enforceable legal frameworks. This highlights a gap in the region's policies regime, where ambitious goals may lack the necessary legal structures to ensure long-term accountability and implementation, leaving them susceptible to future policy shifts or political changes.

The *third part* of the analysis calculates the Compound Annual Growth Rate (CAGR) for each indicator over a set period of two decades (2000-2021) to reflect the extent to which countries have progressed towards achieving SDG7. The overall trend is defined on the basis of the average CAGR across indicators, with positive values indicating growth and negative values signaling regression. Accordingly, the ranking of countries' performance is determined by a three-level scheme (sustained, neutral or declining progress) based on their attained scores, allowing for a comparative analysis of their progress relative to one another.

- ↑ A total of 13 (out of 26) countries – including Oman (58.07%), Kuwait (30.85%), Malta (29.90%), Libya (23.79%), United Arab Emirates (23.38%), Palestine (23.26%), Somalia (19.45%), Saudi Arabia (15.2↑0%), Jordan (12.08%), Israel (11.75%), Yemen (11.45%), Djibouti (8.03%), and Bahrain (7.57%) – scored the highest demonstrating *"sustained progress"* towards SDG7 with all countries showing a positive performance across the six indicators. The progress of high-income countries (Gulf states, Israel, and Malta) is primarily driven by advancements in renewable energy systems. For the remaining countries (Palestine, Jordan, Libya, Somalia, Yemen and Djibouti), progress is largely due to the expansion of renewable energy generation capacity followed by international financing to advance clean energy transitions.
- → A total of 11 (out of 26) countries – including Lebanon (4.93%), Egypt (2.46%), Tunisia (2.40%), Morocco (2.02%), Mauritania (1.88%), Türkiye (1.88%), Comoros (-0.55%), Iraq (-0.55%), Qatar (-1.83%), Algeria (-2.59%), and Sudan (-3.18%) – demonstrate *"stable progress"* towards SDG7. Rather than showing consistent advances in a particular domain, these countries experience a mix of positive and negative fluctuations across the various indicators. In many cases, minor improvements in specific indicators are offset by slower growth or weaker performance in others. This pattern suggests that while incremental progress is being made, none of these countries have achieved significant gains across all fronts, highlighting the need for more targeted interventions to enhance the overall performance of respective energy systems. In high-income countries like Qatar, decline in progress is primarily attributed to the limited integration of renewable energy into the national energy mix. For Mauritania, Comoros, Iraq, Algeria, and Sudan, the main factor driving the decline is the lack of green financing mechanisms for clean energy initiatives, followed by lack of renewables in energy mix and the persistence of high energy-intensity economies, respectively. For the remaining countries (Lebanon, Egypt, Moroc-

Table 2: Comparative analysis of MENA countries with respect to SDG7 as a measure to eradicate regional energy poverty (Source: Data referenced from [12]).

Part I – Geographical and Income Classification				Part II – Existing & Announced National Plans				Part III – SDG7: "Ensure access to affordable, reliable, sustainable and modern energy for all"																		
				SDGs	Paris Agreement			T.7.1						T.7.2			T.7.3			T.7.a			T.7.b			
Code	Geographical Sub-Regions	Country	Income Level	VNRs [13]	NDCs [14]	LTSs [15][16]	NZEs (Target Year and Status) [17]	I.7.1.1 (% population-electricity)			I.7.1.2 (% population-clean cooking)			I.7.2.1 (% renewable consumption)			I.7.3.1 (megajoule per $2017 PPP GDP)			I.7.a.1 (billions of constant 2021 US$)			I.7.b.1 (renewable watts per capita)			CAGR, % (Overall Trend)
								2000	2010	2021	2000	2010	2021	2000	2010	2021	2000	2010	2021	2000	2010	2021	2000	2010	2021	
1.		Saudi Arabia	High	☐ (2023)	☐ (2021)	☐	☐ (2060, Policy)	100.00	100.00	100.00	100.00	100.00	100.00	0.01	0.01	0.08	5.14	6.70	5.81	–	–	–	0.02	0.08	12.31	15.20% (↑)
2.		United Arab Emirates	High	☐ (2022)	☐ (2024)	☐ (2023)	☐ (2050, Policy)	100.00	100.00	100.00	100.00	100.00	100.00	0.08	0.11	1.01	4.13	5.36	5.48	–	–	–	0.00	1.28	320.70	23.38% (↑)
3.	Group A: Gulf	Oman	High	☐ (2024)	☐ (2023)	☐ (2022)	☐ (2050, Policy)	100.00	100.00	100.00	100.00	100.00	100.00	0.00	0.00	0.10	3.69	6.61	7.21	–	–	–	0.00	0.00	45.37	58.07% (↑)
4.		Kuwait	High	☐ (2023)	☐ (2021)	☐	☐ (2060, Pledge)	100.00	100.00	100.00	100.00	100.00	100.00	0.00	0.00	0.07	6.91	7.42	7.75	–	–	–	0.00	0.00	22.74	30.85% (↑)
5.		Qatar	High	☐ (2021)	☐ (2021)	☐	☐	100.00	100.00	100.00	100.00	100.00	100.00	0.08	0.13	0.03	8.91	6.26	7.20	–	–	–	0.00	0.00	8.96	-1.83% (→)
6.		Bahrain	High	☐ (2023)	☐ (2021)	☐	☐ (2060, Pledge)	100.00	100.00	100.00	100.00	100.00	100.00	0.00	0.00	0.02	10.43	9.59	9.23	–	–	–	0.00	0.56	8.20	7.57% (↑)
7.		Iraq	Upper-middle	☐ (2021)	☐ (2021)	☐	☐	96.81	98.36	100.00	70.50	95.10	99.30	0.36	1.67	1.10	13.05	5.17	4.96	0.00	158,120	980	27.20	72.74	36.62	-0.55% (→)
8.		Jordan	Lower-middle	☐ (2022)	☐ (2021)	☐	☐	99.01	100.00	99.90	99.60	99.90	99.90	2.09	2.95	11.50	4.61	3.62	3.39	0.00	6,930	24,710	2.85	2.44	194.55	12.08% (↑)
9.	Group B: Levant	Syria	Low	☐ (2024)	☐ (2018)	☐	☐	93.39	92.70	88.82	98.50	98.60	96.30	2.00	1.35	1.14	13.64	11.58	10.68	0.00	5,210	0.00	94.11	38.38	71.76	-17.19% (↓)
10.		Lebanon	Lower-middle	☐ (2018)	☐ (2020)	☐	☐ (2050, Discussion)	99.30	99.50	100.00	–	–	–	4.88	5.70	6.82	3.66	2.80	3.55	0.00	1,800	2,200	65.27	56.51	86.16	4.93% (→)
11.		Palestine	Lower-middle	☐ (2018)	☐ (2021)	☐	☐	99.70	99.90	100.00	–	–	–	17.52	14.06	15.40	2.85	2.61	3.13	40	1,500	25,270	0.00	0.00	34.71	23.26% (↑)
12.		Egypt	Lower-middle	☐ (2021)	☐ (2023)	☐	☐	97.70	99.36	100.00	82.80	99.20	99.90	8.26	5.37	6.11	3.16	3.51	3.06	11,430	1,089,830	160,440	41.01	39.39	57.27	2.46% (→)
13.		Libya	Upper-middle	☐ (2024)	☐	☐	☐	99.80	81.90	70.21	–	–	–	2.05	2.50	3.12	4.65	4.18	5.26	0.00	0.00	5,560	0.00	0.57	0.94	23.79% (↑)
14.	Group C: North Africa	Algeria	Upper-middle	☐ (2019)	☐ (2015)	☐	☐	98.64	98.91	99.79	96.90	99.20	99.70	0.43	0.26	0.12	4.25	4.49	5.61	0.00	430	100	8.99	7.04	13.29	-2.59% (→)
15.		Morocco	Lower-middle	☐ (2020)	☐ (2021)	☐ (2021)	☐	69.81	95.73	100.00	90.20	96.50	98.20	15.54	13.87	10.90	3.35	3.21	3.14	290	8,720	1,290	42.98	48.09	98.12	2.02% (→)
16.		Tunisia	Lower-middle	☐ (2021)	☐ (2021)	☐ (2022)	☐ (2050, Policy)	94.80	99.50	99.90	93.60	99.30	99.90	14.24	12.61	11.58	4.05	3.77	3.81	4,830	143,240	20,520	7.43	10.78	33.10	2.40% (→)
17.		Sudan	Low	☐ (2022)	☐ (2021)	☐	☐ (2050, Discussion)	23.00	35.99	61.77	7.40	31.90	62.80	80.42	61.31	60.98	4.51	3.26	4.83	0.00	93,380	290	14.79	42.06	39.79	-3.18% (→)
18.		Comoros	Lower-middle	☐ (2023)	☐ (2021)	☐	☐ (2050, Achieved)	39.79	69.66	87.94	0.50	3.20	11.30	69.87	66.02	41.19	2.79	2.78	4.27	0.00	0.00	40	0.00	2.21	1.76	-0.55% (→)
19.	Group D: Least Developed	Djibouti	Lower-middle	☐ (2022)	☐ (2015)	☐	☐ (2050, Discussion)	55.96	57.87	65.44	3.90	6.30	9.60	31.44	32.54	26.56	3.75	3.55	2.08	0.00	13,540	370	0.00	0.00	18.42	8.03% (↑)
20.		Somalia	Low	☐ (2022)	☐ (2021)	☐	☐ (2050, Discussion)	2.11	52.27	49.32	0.40	1.10	3.80	93.28	93.57	95.37	12.23	7.51	6.57	0.00	0.00	150,010	0.00	0.00	1.59	19.45% (↑)
21.		Mauritania	Lower-middle	☐ (2024)	☐ (2021)	☐	☐ (2030, Discussion)	19.15	34.20	47.70	29.40	41.50	48.30	44.41	34.00	22.08	2.55	2.81	3.54	0.00	0.00	20	0.00	0.00	26.42	1.88% (→)
22.		Yemen	Low	☐ (2024)	☐ (2015)	☐	☐	49.24	60.78	74.88	55.50	59.70	61.30	0.95	0.78	3.67	2.88	3.12	2.07	1,650	350	8,290	0.00	0.04	7.79	11.45% (↑)
23.		Iran	Upper-middle	☐	☐ (2015)	☐	☐	97.90	99.43	100.00	92.90	96.60	96.40	0.44	0.90	0.91	7.13	7.52	9.32	62,160	0.00	0.00	30.67	113.94	135.69	-15.02% (↓)
24.	Group E: Non-Arab	Israel	High	☐ (2019)	☐ (2021)	☐	☐ (2050, Discussion)	100.00	100.00	100.00	100.00	100.00	100.00	5.96	8.55	6.20	3.97	3.70	2.39	–	–	–	1.08	13.48	410.14	11.75% (↑)
25.		Malta	High	☐ (2018)	☐ (2023)	☐ (2021)	☐ (2050, Policy)	100.00	100.00	100.00	100.00	100.00	100.00	0.00	1.22	8.62	2.6	2.54	1.21	–	–	–	0.00	1.91	399.27	29.90% (↑)
26.		Türkiye	Upper-middle	☐ (2019)	☐ (2023)	☐ (2024)	☐ (2053, Policy)	99.90	100.00	100.00	90.20	94.10	95.40	17.29	14.21	12.02	3.25	3.03	2.48	142,400	311,220	414,960	176.06	237.29	627.25	1.88% (→)

Legend for Ranking Countries Performance:

Overall Trend	Progress Level	Defined Range (%)	Interpretation
↑	Sustained	CAGR > 5	Values in this range indicate strong positive performance and improvement.
→	Stable	-5 ≤ CAGR ≤ 5	Values in this range indicate relatively neutral performance with minimal growth or decline.
↓	Declining	CAGR < -5	Values show a significant negative trend indicating major performance deterioration.

Notes:

(1) World Bank's 2023 income classifications categorize countries based on GNI per capita: low (≤ $1,145), lower-middle ($1,146–$4,515), upper-middle ($4,516–$14,005), and high (> $14,005) [18][19].

(2) Palestine is commonly referred to as West Bank and Gaza (the non-occupied territories) by international organizations such as the World Bank [10].

(3) The "–" denotes that data for this indicator is either unavailable or not reported for this country.

(4) CAGR(%) for I.7.3.1 (Energy Intensity) has been inverted, as a higher CAGR(%) for this indicator signifies worse performance (higher energy use per unit of GDP), for consistency in interpretation with other indicators where a higher CAGR(%) reflects positive progress towards sustainable development.

(5) Renewable energy in indicators I.7.2.1 and I.7.b.1 includes solar (photovoltaic and thermal energy), wind, geothermal, hydropower, bioenergy, and marine (ocean, tidal and wave) sources.

(6) The year in brackets for the VNRs, NDCs, and LTSs represents the latest available versions of the strategies, and for the NZEs represents the target year and current target status.

co, Tunisia, and Türkiye), the primary contributors of declining performance are the limited share of renewable energy in end-use consumption. Nonetheless, all these countries show positive progress in improving access to electricity and clean cooking fuels and technologies.

- A total of 2 (out of 26) countries – including Iran (-15.02%) and Syria (-17.19%) – exhibit "declining progress" towards SDG7, primarily due to the lack of financial support for developing renewable systems and associated infrastructure. Energy intensity, a measure of energy efficiency, also remains a challenge across both countries. In fact, Syria scored the lowest progress for SDG7 across the MENA. Securing funds is critical for these territories given the destructive impact of past wars and ongoing political conflicts which have severely damaged energy infrastructure. The destruction of power plants, grids, and supply chains has left these countries heavily reliant on outdated and inefficient energy systems making it difficult to attract international investments, further hindering the development of clean energy solutions.

It can be observed that progress is being made across all indicators but to varying degrees across countries, inferring that the current rate of ambition may be insufficient and will likely fall short of reducing EP. Furthermore, the data of this analysis is based on the latest available figures for 2021 for all countries and does not account for the impact of the October 2023 Israel-Gaza war on national and regional levels, including neighboring countries such as Lebanon, Iran, and Yemen, nor the re-escalation of the recent intense conflicts in Syria since early December 2024. These ongoing conflicts may have introduced new challenges that could delay the region's progress towards eradicating EP and ultimately the broader objectives of the 2030 and 2050 agendas. Overall, each country has distinct performance patterns, underscoring the need for tailored strategies that address specific challenges within different local contexts.

3. Causes and Implications of Energy Poverty in MENA

EP is a result of the multifaceted challenges to current energy systems across the MENA region, influenced by several prohibiting factors as discussed below [5]–[7], [20]–[22]:

(1) Income Poverty and Inequality

EP in the MENA is most prevalent in countries with high rates of income poverty. Wealth is mainly concentrated in the oil-rich Gulf countries, while in other sub-regions, a small fraction of the population controls most of the wealth. Households with limited disposable income struggle to afford modern energy services, such as electricity, and the initial investment required to access these services, including the cost of an electricity connection, a new stove, or equipment for liquid fuel supplies. Income inequality further exacerbates unequal land ownership and reliance on precarious, informal employment in rural areas leading to volatile incomes that hinder energy access for many households. In many cases, illegal connections to the national grid or a neighbor's line at a low informal fee provide an alternative for households unable to afford formal services, potentially leading to a decline in electrification rates as infrastructure fails to keep up with the pressure of continuous high demand.

(2) Political Instability and Conflict

Virtually all MENA countries possess adequate energy resources that, if utilized, produced and distributed efficiently, could meet their population energy needs. However, the escalation of regional geopolitical tensions in past and recent years, particularly in countries like Libya, Egypt, Sudan, Syria, Iraq, Lebanon, and Yemen, along with the ongoing wars happening in Palestine, Lebanon and Syria (as of this writing), have severely damaged infrastructure, disrupted energy supply chains, and displaced millions. These conflicts reduce the availability and affordability of modern energy sources, and access to basic energy services for mundane activities such as cooking, heating, cooling, food refrigeration, lighting, and others. The reoccurring political uprisings, protests, and instability have impeded coordinated regional solutions for EP, as immediate humanitarian needs are prioritized over long-term energy planning and development objectives.

(3) Rural and Remote Geographies

Rural energy markets in the MENA region are small and geographically dispersed, correlating with overall poverty levels. Large rural populations in countries like Comoros, Sudan, Yemen, and Egypt are isolated from central energy grids, making network expansion technically and financially challenging. The high cost of extending transmission and distribution infrastructure to low-density areas often renders these projects economically unfeasible due to the significant investment needed. Transport and logistics, particularly across scarcely inhabited mountainous terrain, also raise the cost of local fuel supply which must either be borne by suppliers or local communities despite national price controls. This leaves many disadvantaged and energy-poor communities reliant on traditional energy sources like biomass and diesel generators, which are costly and have negative environmental and health impacts.

(4) Energy Supply Volatility

Despite over 90% of the MENA population having access to electricity in 2021, service disruptions in the electricity sector are common, especially in conflict-affected countries and those hosting large refugee populations. Insufficient generation capacity, underinvestment in maintenance/upgrading of outdated transmission and distribution infrastructure, and illegal grid connections overload the system and exacerbate frequent outages. In rural areas, access is limited and intermittent, with mini-grids supplying electricity for only a few hours a day. Recurring shortages force households and businesses to resort to backup noisy and polluting private generators fueled by diesel or fuel oil at substantial cost, where the additional burden to households' expenditure is more than twice that of normal grid-based electricity. Low-income households are the least able to afford backup generation and thus are left behind.

(5) Influence of Tradition and Custom

Custom and convenience significantly influence households' energy choices in the MENA region. Income gains and fuel availability do not automatically translate to a shift up the energy ladder due to factors that can dampen consumers' interest in modern fuels like personal preferences, perceived fuel supply unreliability, price volatility, and switching costs. In rural MENA areas, household time management and the distribution of household tasks are often shaped by time-honored traditions, including the ancestral division of labor that assigns women and children the responsibility of collecting biomass and firewood locally. These deeply ingrained customs contribute to the continued reliance on traditional fuels and a general perception that modern fuels like electricity necessitate changes in cooking habits and equipment. Households relying on traditional fuels, especially in areas with low education and limited media access, face severe health risks and environmental damage (such as deforestation), due to insufficient information. Cultural norms, combined with income barriers and a lack of public awareness about the long-term benefits of clean energy, prevent many households from transitioning to affordable modern fuels.

(6) Energy Demand Growth

The region has experienced an unprecedented surge in energy demand, with primary energy consumption increasing by over 112% from 2000 to 2021 [23], which is stimulated by multiple factors. The region's population has nearly doubled over the past few decades from around 341 million in 1990 to more than 658 million in 2023 [24]. The fast-growing population led to rapid urbanization which necessitates critical energy infrastructure investments in MENA countries over the next few years to meet future energy needs, but the slow pace of investment in infrastructure expansion projects poses significant long-term risks for EP. Concurrently, economic growth and industrialization, particularly in upper-middle- and high-income countries, led to rising living standards. Ineffective demand-side management, due to the lack of energy efficiency regulations and subsidized energy pricing, has also distorted energy dynamics and exacerbated EP levels across the region. Many MENA countries keep energy prices below market levels to fulfil national development objectives, without differentiating between user groups, causing high-income households to pay the same low rates as the poorest, widening the already existing social class gap. Regulated energy prices have also inhibited the adoption of efficient energy technologies where possible, causing wasteful consumption habits due to the perceived low value of energy and related products. In many countries, artificially low energy pricing schemes have led to the accumulation of fiscal burdens, which divert government spending of public funds away from pro-poor investments.

(7) Carbon-Intensive Energy Mix and Harsh Weather

The region heavily relies on fossil fuel-centered economies, primarily oil and gas, for domestic energy supply and as revenue streams, resulting in a lack of diversification in the energy mix and increasing vulnerability to persistent or even escalating levels of EP. The rising cost of hydrocarbon consumption raises concerns about the long-term affordability of the current energy mix, as depletable fossil fuels would either need to be imported in larger volumes from global markets, or hydrocarbon exports would need to be reduced which would threaten economic sustainability for many countries across the region. The high susceptibility of MENA countries to climate change risks stems from the arid conditions and extreme heat waves to which they are exposed, which impacts the structural integrity, operation, and lifespan of critical energy infrastructure. This includes a geometric rise in cooling demand which would place strain on electricity networks and lead to higher operational and maintenance costs for energy systems.

4. Policy Remedies to Eradicate Energy Poverty in MENA

The prevailing consensus is that while some progress has been made across the region, it is not enough, and we must accelerate policy efforts to advance further and faster. By rapidly accelerating progress in all components of SDG7, the MENA can eradicate EP while simultaneously moving towards NZEs for the 1.5°C pathway at the center of the Paris Agreement. This is a win-win proposition that warrants the "right to energy", asserting that every person has equitable access to affordable, reliable, sustainable, and modern energy services as a basic human right [25]. As such, the following series of policy recommendations are directed at government, business, and societal levels for the consideration of decision-makers, managers, and individuals, respectively [5]–[7], [20], [21]:

(1) Intraregional Energy Trade and Cooperation

A region-wide policy for energy system integration in MENA, aligned with international energy laws, can address growing energy demand, and enhance energy security through bilateral cross-border energy trade and cooperation. Examples include interlinking electricity grids and natural gas supply networks with neighboring countries, scaling up joint investments in clean energy technologies, and creating regional energy markets to optimize renewable potential across countries with diverse resources. These mechanisms help foster political stability and peace within the region through context-specific strategies that address security concerns by managing reliance on external energy sources and building the capacity of fragile governance structures. Establishing regional knowledge-sharing platforms and centers can also facilitate the exchange of best practices between countries. This can include benchmarks on energy efficiency, energy diversification, and advanced technology adoption to capture opportunities in the design and implementation of energy projects and advance efforts to monitor and make decisions on EP across the region.

(2) Strengthen Public-Private Partnership (P3)

MENA countries can implement clear and comprehensive P3 laws to leverage private sector expertise for investment in clean energy by de-risking projects through financial assurances such as loan guarantees and credit enhancements, and streamlining related processes through technical assistance and feasibility studies. The law could establish a central "one-stop shop" institution to simplify procedures for obtaining regulatory licensing/permits and investment approvals, while fostering intergovernmental coordination among public institutions involved in the execution and oversight of clean energy projects. Examples include energy efficiency and infrastructure development projects aimed at strengthening transmission networks, increasing installed generation capacity, and expanding off-grid solutions, particularly in rural, underdeveloped, or conflict-affected areas. The legal framework would also mandate resilience planning as a prerequisite, requiring project planners and stakeholders to integrate climate change mitigation and adaptation considerations into the design, operation, and maintenance of clean energy projects.

(3) International and Regional Green Financing

MENA countries must prioritize strategic investment in climate-smart infrastructure across the energy system, to improve society's ability to cope with climate-related risks. Effective finance mobilization enhances the share of grant or concessional financing, attracts additional private sector investments, and implements innovative financial instruments including blended finance, green bonds, credit lines, revolving funds, along with fiscal and tax incentives dedicated to EP. Subsequent laws are imperative to mobilize international green funding by encouraging global investors to finance clean energy projects through multilateral organizations like the World Bank and Green Climate Fund. This can also be achieved through regional help from high-income countries, such as the Gulf states, whose fiscal stability endows them with financial resources to address unsustainable development patterns in their own countries as well as other peer countries. The legal framework should clarify the country's energy requirements to financing bodies and participants for project approval including proofing processes, impact assessments, efficiency standards, eligible technologies, registration and certification, and the systems for verification, validation, reporting, and monitoring.

(4) Social Welfare and Energy Pricing Reforms

Strengthening energy governance and institutions in the MENA to support the expansion and improvement of social welfare and safety programs enables households to overcome income poverty which directly improves EP. This can be achieved by effectively registering households, assessing their socio-economic needs, and providing accountable responses. To promote an equitable and clean energy future, suggested pricing policies should involve the careful re-adjustment and re-distribution of energy pricing reforms considering the specifics of vulnerable social groups. Gradually phasing out fossil fuel subsidies encourages the adoption of renewable energy alternatives and re-invests the savings into sustainable energy projects. Improving the governance of targeted subsidies through innovative tools, such as smart cards and micropayment schemes, bridges the rural-urban divide by ensuring equitable energy access for low-income households while advancing clean energy solutions.

(5) Improve Energy Efficiency Regulations

Policies across the MENA should aim at sustainable management of natural resources and the adoption of energy-efficient practices and technologies across key sectors of the energy systems. This can include programs for retrofitting energy infrastructure to improve performance and promoting clean cooking technologies to reduce dependence on harmful traditional biomass fuels such as wood and charcoal stoves. Another key priority is rural electrification programs to provide quality electricity services to poor households using decentralized renewable solutions, such as solar photovoltaic generators, small hydro turbines, wind turbines, grid extensions and stand-alone systems, and avoid the price volatility of fossil fuels. Renewable energy applications should extend beyond power generation by setting national targets for integrating renewables into end-uses such as heating, cooling, and transportation, supported by financial incentives and infrastructure development. Additional measures can focus on promoting a circular economy by establishing standards for end-of-life management, mandatory take-back, and waste recycling schemes. Also, developing national clean hydrogen strategies with clear regulations, incentives, and infrastructure investments can diversify export earnings and aid in emissions reduction for decarbonization purposes.

(6) Develop Local Capacity Building

Renewable energy is associated with several challenges, including supply chain issues for critical materials, limited availability of suitable land, insufficient grid infrastructure, renewable waste management concerns, slow permitting processes, and profitability concerns. Policies should invest in research and development (R&D) and promote transparent reporting to foster the growth of local renewable energy industries, identify innovative recycling technologies for material recovery, and reduce reliance on imported technologies. Building local capacity through targeted training and education programs is imperative to develop clean energy skill sets and innovation. MENA countries with established electrical and mechanical industries can undertake feasibility assessments to explore the manufacturing potential of renewable energy equipment based on domestic capacities, which in turn helps create new employment opportunities. A parallel shift to increasing public awareness and incentivizing energy-saving behavior is equally important to overcome cultural preferences and scale up consumer motivation. Informational campaigns can protect vulnerable populations and mitigate the negative impacts of biomass use, such as poor indoor air quality and prolonged exposure to pollutants affecting women and infants. Expanding knowledge about inexpensive small-scale solutions, such as micro-hydro installations, biomass biodigesters, improved cook stoves, and guidance on proper house ventilation, can also significantly enhance consumption quality and improve energy access in local communities.

(7) National Databases and Monitoring Regimes

To effectively map and address rising patterns of EP across the region, national authorities should first develop clear, conceptual, and transparent national statistical databases that detect and outline specific landscapes of vulnerability through country-specific analyzes of the various environmental, economic, social, and political threats to energy security. Subsequent response programs can follow with definite objectives for energy access, coupled with monitoring regimes based on well-established metrics, expanding beyond the definitions governed by SDG7, to manage and track progress in EP levels throughout the MENA region. Some commonly used metrics to effectively measure EP include single indicators such as 10%, Twice the National Median (2M), Minimum Income Standard (MIS), Low Income High Cost (LIHC), After- Fuel-Cost Poverty (AFCP), and composite indicators such as the Multidimensional Energy Poverty Index (MEPI) and Multi-Tier Framework (MTF), among various others [2], [3], [26]–[28]. Such an operational framework effectively evaluates the practical efficiency of energy justice programs and monitors progress based on predetermined timelines. It also helps resolve conflicting or overlapping strategies and rules across the different governing sectors and institutions and allows for the development of coherent programs that eliminate inconsistencies.

To this end, the proposed policy solutions emphasize achieving SDG7, which in turn enables mitigation and adaptation action to combat climate change in favor of the Paris vision while also catalyzing progress towards the attainment of other SDGs. This is because strong interlinkages, both direct and indirect, have been proven between SDG7 and all the other goals [29]–[35], notably SDG1 ("No Poverty"), SDG3 ("Good Health and Well-being"), SDG4 ("Quality Education"), SDG5 ("Gender Equality"), SDG8 ("Decent Work and Economic Growth"), SDG9 ("Industry, Innovation and infrastructure"), SDG11 ("Sustainable Cities and Communities"), SDG12 ("Responsible Consumption and Production"), SDG13 ("Climate Action"), and SDG15 ("Life on Land"). This implies policy frameworks should be designed in an integrated fashion to maximize synergies and minimize trade-offs between and across the different SDGs for the effective and timely attainment of the objectives of approaching global agendas. The latter calls for coordinated action from all relevant stakeholders at national and regional levels to acknowledge these implications and seize opportunities for integrated energy policy planning, formulation, and management across the MENA.

Footnotes

[1] Following the Millennium Development Goals (MDGs) (2000-2015), the SDGs were adopted in September 2015, implemented on January 1, 2016, and are monitored through the Voluntary National Reviews (VNRs). Concurrently, the Paris Agreement was adopted on December 12, 2015, came into force on November 4, 2016, and is monitored through the Nationally Determined Contributions (NDCs)

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Energy Poverty in Africa

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Energy poverty in Africa is gendered; it disproportionately affects women and girl children. Studies on the intersection between energy poverty and gender are well researched; however, no studies investigate the percentage of women with electricity access in Africa, making target setting difficult.

In most African societies, it is the women and girl children who are tasked with fetching firewood and water, making fires, boiling water for baths, cooking, etc. A world without electricity places a heavy burden on girl children and women to fulfil these tasks. They get up as early as 3 am to start with these daily chores, which extend late into the evening. This removes women from income-generating activities despite their personal ambitions; it also keeps girl children illiterate, which necessitates them to marry as they have no education. In some countries, girls attend school in the afternoon to try to address this crisis. The lack of electricity, amongst other variables, keeps girls physically unsafe in public spaces and susceptible to abuses such as child marriage. This practice is so pervasive that even in polygamous marriages, it is common practice to get a young wife for the sole purpose of staying at the family home, looking after ageing parents and carrying out manual tasks around the home.

Energy poverty is characterised as a situation in which a household cannot attain adequate levels of energy use due to a lack of affordability, leaving them unable to satisfy their basic needs; it is when households spend more than 10% of their income on energy. This means that in some of these societies, electricity is only used at certain times of the month or year as electricity tariffs are exorbitant. The cost of electricity (if available) is prohibitive, forcing many families to use alternative and often dangerous heating, lighting, water heating and cooking methods.

Post-apartheid, South Africa adopted the user pay principle (UPP) for services such as electricity and water. This principle refers to the concept that the cost of electricity should be directly related to the amount of electricity a consumer uses. In simpler terms, those who use more electricity pay more. This principle aims to promote responsible electricity consumption and encourage energy efficiency.

However, the outcome has been less than favourable. It has resulted in energy poverty not just for the poor, but for every South African. This includes not just electricity but biomass, paraffin, lignite, gas, petrol and other forms of energy.

The UPP deployed in South Africa has left each member of society vulnerable to energy poverty. India and China both grapple with setting electricity tariffs that balance affordability for a large underprivileged population with the need to sustain and invest in the power sector. Both countries consider the cost of services, subsidies and cross-subsidisation when setting tariffs. India uses a flat tariff structure for most consumers; however, from 2025, time-of-use tariffs will be introduced. China, like SA, employs a tiered structure with increasing rates for higher consumption; however, electricity in China is heavily subsidised.

Key challenges to the UPP are the affordability of people living below the poverty line, the widening gap between social classes that will lead to social unrest, poor service delivery and limited access to affordable alternatives like solar panels. UPP prejudices a township dweller who lets out outside rooms for income or someone who cooks food from their home to sell or sews from their yard. UPP can create a situation of energy poverty, where people cannot afford the minimum amount of electricity needed for basic needs.

According to Good Governance Africa, 600,000 households live in extreme energy poverty in South Africa. These households heavily depend on paraffin, which is responsible for 5000 shack fires and 2000 deaths annually.

Contrary to popular belief, energy poverty does not just relate to the poor, as the rest of the world finds out. Wealthy nations like Germany are experiencing increased energy poverty due to high tariffs. Electricity consumers are increasingly using biomass to curb their electricity costs.

In Africa, grid access is costly, so in some countries, the grid will never reach remote areas. Thus, African utilities and governments are considering electrification models that are not reliant on the grid; one of these is microgrids. Microgrids are defined as a group of small, interconnected loads and distributed energy resources that are usually attached to a centralised national grid but can function independently.

Sierra Leone successfully launched microgrids during the Ebola outbreak in a spoke and wheel approach. They are attached to an anchor, i.e. clinic or school, and are powered using a combination of solar, battery and a diesel generator. Once the local clinic is electrified, there is an influx of people who set up homes in the direct vicinity in the hopes of being electrified too. These microgrid electrification efforts are always driven by the private sector with government support and foreign funding.

Microgrids aid in driving local economies. Women will buy freezers and stock them with fish from the market, they then sell this fish in the neighbourhood – this extends the working day of women for income-generating activities. Women also enter entrepreneurship by charging people a fee to charge their phones or opening a convenience store. It also allows street vendors to extend their trading hours when using streetlights. Distributors of solar home systems also use these convenience stores as distribution centres for solar equipment. Microgrids have allowed local clinics to store anti-venom and vaccines. They have also enabled women to give birth in well-lit, equipped rooms instead of candlelight.

Studies in sub-Saharan Africa suggest microgrid electricity costs might range from ZAR14 to ZAR16 per kWh (USD 80 – 90 cents). This is much higher than traditional utility tariffs in the region but perhaps potentially cheaper than alternative fuel sources like paraffin.

With over 60% of the population not electrified, Sub-Saharan Africa is fertile ground for deploying microgrids; however, they must be affordable, reliable and considerate of social and traditional contexts. Microgrids are not a one-size-fits-all solution; oftentimes, systems are deployed in rural areas with no operators, maintenance plan, or diesel availability for the backup generator. Those systems lie idle, and people return to using firewood. In other instances, systems are installed for nomadic people who are now indebted to the state, the private sector or the utility. These people cannot move as nomadic lifestyles require; they cannot find grazing land for their animals or water for their sustenance. Entire social systems can be disrupted if socio-techno-economic systems are not well considered.

As microgrids expand in the continent, it will be imperative to create a conducive environment. First, policies that encourage renewable energy and microgrid development are crucial. This can include feed-in tariffs for excess power generation and streamlined permitting processes; models around community ownership and revenue creation can be explored. Investing in battery storage research can reduce costs and improve microgrid reliability. Finally, leveraging Africa's strong mobile network infrastructure to integrate ICT into microgrid management can optimise efficiency. Combining these elements allows African countries to create a favourable landscape for widespread microgrid deployment.

On the Links between Energy and Housing Vulnerability

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ABSTRACT

Tackling energy poverty and promoting affordable quality housing are two key policy priorities. While the links between energy poverty and housing quality have been largely identified, those with housing affordability are less so. This paper calls for further exploratory work and improved data and metrics to inform future renovation policies.

1. ONGOING EFFORTS AND PROGRESS ON TACKLING ENERGY POVERTY

Addressing Energy Poverty, as the inability of households to access essential energy services (EC 2020), and fostering just energy transitions has been high on political agendas in the European Union (EU) and beyond. The Fit-for-55 package and the resulting recast of important EU directives is a remarkable example of how these have been integrated in current policies. For instance, the Energy Efficiency Directive recast shows increased ambition on the fair access to energy efficiency measures, with priority to vulnerable consumers; the Renewable Energy Directive acknowledges the role of collective solutions such as energy communities; the Energy Performance of Buildings Directive (EPBD) strives to decarbonize the building stock, notably through renovation and mandating the development of enhanced Building Renovation Plans, in line with national energy and climate plans (NECPs); and the ETS Directive with ETS2's revenues being used to support vulnerable households through the Social Climate Fund.

Nevertheless, in spite of current efforts energy poverty continues to increase at alarming rates, with the latest data pointing to a worsening of the situation in 2023 in relation to the past couple of years. In the EU27, it is estimated that 10.6% of the population was unable to keep their homes adequately warm (in relation to 9.3% in 2022 and 6.9% in 2021; Eurostat 2023); and 21.4% was living in a dwelling not comfortably cool during summer time (Eurostat, 2012). Energy Poverty is a multifaceted problem largely determined by the so-called triangle of drivers: low income, high energy prices, and low energy efficiency of the building stock (Boardman, 2010; Bouzarovski and Herrero, 2017). While significant attention has been given to low-cost, small-scale and punctual improvements (e.g. fuel subsidies), these have proven insufficient (Healy and Clinch, 2004) and fail at addressing the root causes of energy poverty. In this sense, improved building efficiency, through renovation, can somehow cushion the effects of economic drivers (after investment recovery), while ensuring access to adequate energy services.

2. HOUSING DEPRIVATION AND ENERGY POVERTY

In line with the above, affordable housing is also a key EU strategy, as part of its renovation wave. Housing affordability alongside quality are two important dimensions when analysing housing vulnerability. Still, the two are very distinct and should be dealt with as separate problems (The European Foundation for the Improvement of Living and Working Conditions, 2016). Housing quality, measured by the population exposed to leak, damp or rot in their dwelling, is considered an energy poverty indicator (EC, 2020a). Studies focused on housing quality have identified a strong association between energy poverty and indoor condensation, and an even stronger association with presence of damp (Healy and Clinch, 2004). However, while the links between energy poverty and housing quality have been well identified, those with affordability remain largely unexplored.

The EU's composite measure of severe housing deprivation considers both housing quality (leaking roof, no bath, shower and no indoor toilet or too dark dwelling) *and* limited space (overcrowding). Nevertheless, such composite measures may bring about important limitations due to bundling of different types of deprivation, potentially subject to different drivers. This may also have an important effect in somehow masking the linkages between energy and housing deprivation. Supporting this, it is found that these two key components of severe housing deprivation (quality and overcrowding) are weakly related and evidence different patterns across countries (Hick, Pomati, and Stephens 2022). These authors also found that housing deprivation may be underestimated based on these metrics. If any of the housing deprivation and overcrowding issues is considered, deprivation may exceed 50% in some countries.

3. BUILDING RENOVATION AS A COMMON SOLUTION AND AVENUES FOR FURTHER WORK

Buildings represent the largest energy consumer in the EU, accounting for 40% of energy consumption and 36% of GHG emissions (EC, 2020b). The continent is faced with an ageing stock, with 35% of buildings built over 50 years ago and 75% being considered inefficient. Despite a large-scale uptake and faster and deeper building upgrade and renovation can largely help meeting EU's targets, current renovation rates of 1% per year, and of 0.2% for deep-renovation still fall short of these (BPIE, 2021).

Nevertheless, building renovation can bring important benefits to both energy-poor and materially deprived populations. A better understanding of the links between energy and housing vulnerability is key to promote further renovation and ensure that those that most in need can benefit from improved living standards and housing conditions. The recent appointment of the EU's first ever Commissioner-Designate for Energy and Housing marks an important milestone in acknowledging the links between these two key areas and that strategies to tackle both challenges should go hand-in-hand.

Further exploratory work is needed and so is up-to-date and reliable background data and metrics on both energy poverty and housing vulnerability to inform future strategies in the pursuit of joint pathways to ensuring clean, reliable and inclusive energy and housing access for all.

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Policy Measures to Overcome Energy Poverty: An Assessment

BY ELISENDA JOVÉ-LLOPIS AND ELISA TRUJILLO-BAUTE

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Abstract

This article explores the effectiveness of Spain's bono social and energy efficiency measures on reducing energy poverty. By combining income support with long-term energy-saving solutions, the study reveals a significant reduction in energy poverty, highlighting the need for a holistic approach to address both immediate and structural challenges in the energy transition.

The global energy transition is shifting economies towards cleaner, renewable energy sources to combat climate change. However, while this shift is crucial, it presents new challenges, particularly for vulnerable populations. One of these challenges is energy poverty—when households struggle to afford basic energy services such as heating, cooling, and lighting. In the European Union (EU), this issue affects more than 40 millions of people, a problem that has been exacerbated by rising energy prices, socioeconomic disparities, and the ongoing energy transition (https://energy.ec.europa.eu/system/files/2023-10/SWD_2023_647_F1_OTHER_STAFF_WORKING_PAPER_EN_V5_P1_3016190.PDF).

In Spain, a nation with a strong push towards sustainability, the government has implemented two key policies to combat energy poverty: the *bono social*, which provides income transfers for energy bills, and energy efficiency measures that aim to reduce consumption through retrofitting homes. This article highlights the findings of a recent study (see Jové-Llopis & Trujillo-Baute, 2024) that evaluates these policies' effectiveness and provides insights into how governments can design better interventions to lift households out of energy poverty.

Understanding Energy Poverty in the European Context

Energy poverty is a multidimensional issue, driven by a complex interplay between income, energy prices, and household energy efficiency. While income support offers immediate financial relief to vulnerable families, it is often considered a short-term solution. On the other hand, energy efficiency measures promise a long-term reduction in energy consumption, potentially reducing the energy burden for households.

Spain has introduced both types of policies: the *bono social*, offering direct subsidies on electricity and heating bills for low-income households, and the Building Energy Rehabilitation Program (PREE), which provides support for improving energy efficiency in homes through retrofitting. Despite these efforts, energy poverty remains a persistent problem in the country, with around 10% of households estimated to be in energy poverty before policy interventions.

Policy Evaluation: Income Transfers vs. Energy Efficiency

The study evaluated the effectiveness of these two approaches by simulating their impact on Spanish households. The findings show that both policies can significantly reduce energy poverty, but their effectiveness varies (Figure 1).

1. Bono Social (Income Transfers):

—The *bono social* has the potential to helped lift 9% of energy-poor households out of poverty. However, this impact is relatively modest, as it only addresses the affordability side of the problem.

—The study shows that this income support, while crucial, does not tackle the underlying issue of high energy consumption in inefficient homes, limiting its overall effectiveness.

2. Energy Efficiency Measures:

—Retrofitting homes with energy-saving technologies can potentially lift 64% of energy-poor households out of poverty. Improvements to thermal insulation, heating

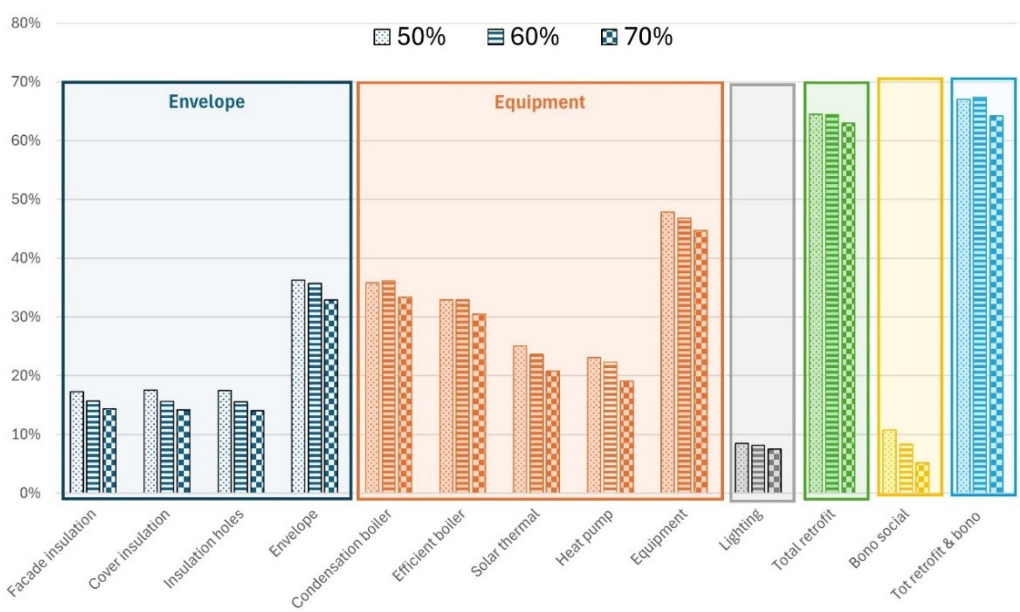

Figure 1: Households escaped from energy poverty after policies (% with different Low Income High Costs thresholds)

systems, and lighting can lead to significant savings in energy bills.

—These measures, though more costly upfront, offer a long-term solution by reducing energy consumption and making homes more resilient to fluctuations in energy prices.

(For a more detailed comparison of these interventions, refer to the full study on energy poverty policy effectiveness in Spain (Jové-Llopis & Trujillo-Baute, 2024))

The Power of Combining Policies

The most significant insight from the study is that combining income support with energy efficiency measures yields the greatest results. When both policies are implemented together, the reduction in energy poverty rises to 67.4%, as more households can benefit from both reduced energy bills and lower energy consumption.

However, the study also reveals a critical point: the incremental benefit of adding income transfers to households that have already undergone total retrofits is marginal. This suggests that energy efficiency should be prioritized as the more sustainable, long-term solution, with income transfers acting as a complementary measure to provide immediate relief in the interim. Nevertheless, it is important to recognize that the major challenge lies in ensuring that energy efficiency policies are affordable for the most vulnerable populations.

Policy Recommendations for a Just Energy Transition

This analysis has important implications for policymakers seeking to achieve a just energy transition. As governments design policies to reduce energy poverty, they must consider the long-term sustainability of their interventions:

1. Prioritize Energy Efficiency:

Energy efficiency improvements—such as retrofitting homes—offer the greatest potential to lift households out of energy poverty in the long run. Policymakers should increase funding and streamline access to these programs, particularly for low-income families who may face financial and bureaucratic barriers to participation.

2. Maintain Income Support:

While energy efficiency should be prioritized, income transfers remain crucial for addressing immediate needs. The *bono social* has proven effective in providing short-term relief, but policymakers should focus on simplifying the application process and raising awareness to ensure that all eligible households benefit.

3. Adopt a Holistic Approach:

Energy poverty is not just about reducing energy bills; it's about improving the overall quality of life for vulnerable populations. Governments must address behavioral barriers, such as awareness and understanding of energy-saving practices, alongside technical solutions like retrofitting.

Looking Ahead: Challenges and Opportunities

The findings from Spain can serve as a blueprint for other European countries facing similar challenges. As the EU pushes forward with its Green Deal and energy transition targets, policymakers must recognize that a one-size-fits-all approach will not work. Each country must tailor its interventions to address the specific needs of its population, combining short-term financial support with long-term structural improvements.

One potential obstacle is the rebound effect, where households that receive energy efficiency upgrades might increase their energy consumption, negating some of the benefits. To mitigate this, policies must include behavioral interventions that encourage households to adopt more sustainable energy practices.

Ultimately, tackling energy poverty requires multidimensional solutions that go beyond immediate financial relief. By integrating energy efficiency with targeted income support, governments can not only reduce energy poverty but also improve public health, increase energy security, and contribute to climate change mitigation.

Conclusion

The energy transition is not just about switching to renewable energy sources; it's about ensuring that all citizens can access affordable and reliable energy. Spain's approach to energy poverty—combining income transfers with energy efficiency improvements—offers valuable lessons for other nations. As we move towards a cleaner, more sustainable future, it is crucial to ensure that no one is left behind, and that energy policies are designed to benefit the most vulnerable in society.

For further reading on energy poverty policies and their impacts, visit the IAEE Energy Forum for more insights and research updates.

This article summarizes the key insights from the study while keeping the content accessible and engaging for the broader audience of the Energy Forum.

Energy Poverty and Subjective Well-being Revisited: Insights from the German Socio-Economic Panel

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Abstract

This paper examines the impact of energy poverty on life satisfaction, drawing on data from the German Socio-Economic Panel (2010–2021). The findings show that energy poverty significantly diminishes life satisfaction, particularly through subjective perceptions of household energy inadequacy. The paper highlights the importance of multidimensional strategies to tackle energy poverty and its profound impact on well-being.

1. Introduction

Energy poverty – a multidimensional concept describing the inability of households to secure adequate energy services – has increasingly captured attention in both policy and academic circles. Once seen as a developing-country issue, energy poverty is now a growing concern in advanced economies (Bouzarovski, 2014). Particularly for Germany, its ambitious commitment to the *Energiewende* – transition to a sustainable energy system – has significantly reshaped its energy landscape. While crucial for climate goals, this transition has raised challenges around energy affordability and equitable access. The integration of renewable energy sources, coupled with rising costs, disproportionately impacts low-income households, making energy poverty a critical social issue in Germany with significant implications for individual well-being.

The relationship between energy poverty and subjective well-being (SWB) is multifaceted. Energy poverty can contribute to material deprivation, social exclusion, and adverse health outcomes, all of which can negatively impact life satisfaction (Liddell et al., 2012). Moreover, the psychological burden associated with energy poverty – such as the stress and anxiety caused by high energy bills or the inability to maintain a comfortably warm home – can further diminish an individual's SWB.

This paper utilizes the German Socio-Economic Panel (SOEP) dataset to revisit the relationship between energy poverty and self-assessed life satisfaction, employing both objective and subjective measures. Analyzing data from approximately 70,499 individuals (2010–2021), we find that energy poverty significantly diminishes life satisfaction, with the reduction ranging from 0.02 to 0.29 points on an 11-point scale. The negative effect is more pronounced when measured subjectively, with self-reported energy poverty. Importantly, this impact persists even after controlling for income, indicating that energy poverty is a distinct issue, not merely a byproduct of income poverty.

Our analysis adds to the growing literature on the social implications of energy poverty in high-income countries, where energy affordability is an increasingly urgent concern. Unlike previous studies for Germany, such as Biermann (2016), which focused on heating expenditures from 1994 to 2013, our analysis incorporates more recent data and accounts for both electricity and heating costs. This approach provides a more comprehensive and up-to-date evaluation of energy poverty's impact on life satisfaction. Our findings highlight the need to address energy poverty through broader social and economic policies to improve overall quality of life.

2. Data & Empirical Strategy

We use data from the German SOEP, a nationally representative household survey covering 1984 to 2021, including households from all federal states, as well as foreigners, migrants, and refugees. The survey provides detailed information on socio-economic status, demographics, energy costs, education, and well-being. Its longitudinal nature enables the analysis of trends over time, such as changes in energy poverty. For the analysis, we focus on the period from 2010 to 2021, as 2010 marks the first year that electricity expenditure data was included.

Overall life satisfaction: We measure subjective well-being through overall life satisfaction, assessed by asking respondents to rate their satisfaction with life on a scale from 0 to 10, where 0 represents complete dissatisfaction and 10 represents complete satisfaction. Figure 1a shows the trend in average life satisfaction over time, suggesting that there are no significant differences between males and females, except in 2015-2017, where men report lower life satisfaction.

Energy Poverty Indicators Our main explanatory variables include both objective (expenditure-based) and subjective (consensual-based) indicators of energy poverty. The objective indicators are the *10% rule, 2-median share (2M), and low-income high-cost (LIHC)* (Meyer et al., 2018; Nie & Li, 2023). These expenditure-based indicators are calculated using monthly household income and energy costs, specifically heating and electricity expenses. We adjust for household size and composition using the OECD-modified equivalence scale, which accounts for economies of scale, allowing for more accurate comparisons across households of different sizes.

- **10% Rule**: classifies households as energy-poor if they spend more than 10% of their equivalized income on energy.

- **2M Share**: The 2M Share indicator, suggested by the European Poverty Observatory (Thema & Vondung, 2020), calculates the national median share of equivalized energy expenditure as a percentage of income for each year. A household is considered energy-poor if it spends more than twice this median share.
- **LIHC**: The LIHC indicator (Hills, 2012), identifies energy-poor households based on two criteria: low income (LI) and high energy costs (HC). A household is classified as low income if its disposable income, after energy expenses, falls below 60% of the national median income. High energy costs are defined as energy expenditures at or above the national median. A household is considered energy-poor if it meets both conditions, reflecting vulnerability due to both financial constraints and high energy expenses.
- **Consensual**: The consensual indicator is a subjectively-based measure, emanating from two questions which assesses whether households can adequately heat their home during cold months and if the reason for the inadequate warmth is due to financial reasons. These questions were introduced into the SOEP survey from 2016.
- **Composite**: We compute a composite indicator that combines both expenditure-based and consensual approaches to measure energy poverty more comprehensively. It is a binary indicator, coded as 1 if an individual is considered energy-poor by at least two indicators, such as the 10% Rule, 2M Share, LIHC, or subjective measures like difficulty in heating the home adequately.

Figure 1b shows the share of individuals identified as energy-poor across five indicators. The expenditure-based measures exhibit wide volatility and high levels of energy poverty over the years. In contrast, the Consensual indicator, based on subjective experiences, shows fewer individuals reporting an inability to heat their homes, and highlights a gap between subjective reports and expenditure-based measures, which may capture hidden forms of energy poverty. The Composite indicator combines multiple dimensions, and remains relatively stable around 10%, smoothing out fluctuations and reflecting long-term trends. These varying stabilities demonstrate the importance of a multidimensional approach to fully capture the complexity of energy poverty.

Table 1 presents the average monthly equivalized income, energy expenditure, and proportion of energy-poor individuals across income deciles, with D1 representing the lowest-income group, and D10 the highest. The results show stark contrasts between income classes. The top decile (D10) enjoys the highest income and spends only 3% on energy, reflecting a low financial burden. Conversely, the lowest decile (D1) spends about 13% of their income on energy, highlighting a substantial financial strain. These findings illustrate the disproportionate impact of energy costs on lower-income households, making them more vulnerable to energy poverty. While energy poverty is most prevalent among the lowest-income group, it also affects some higher-income households, indicating that the issue extends beyond income disparities.

Covariates: The literature on SWB suggests that individual well-being primarily depends on the "*big four* " factors: wealth, health, social relations, and genes. Accordingly, we include variables reflecting these determinants. Our explanatory variables encompass socioeconomic factors (log of income, income poverty indicator, log of peer income, employment status, and education level), demographics (age, household composition, location, and housing conditions), and health indicators (poor health, chronic illness, or disability) (Clark et al., 2008; Welsch, 2024).

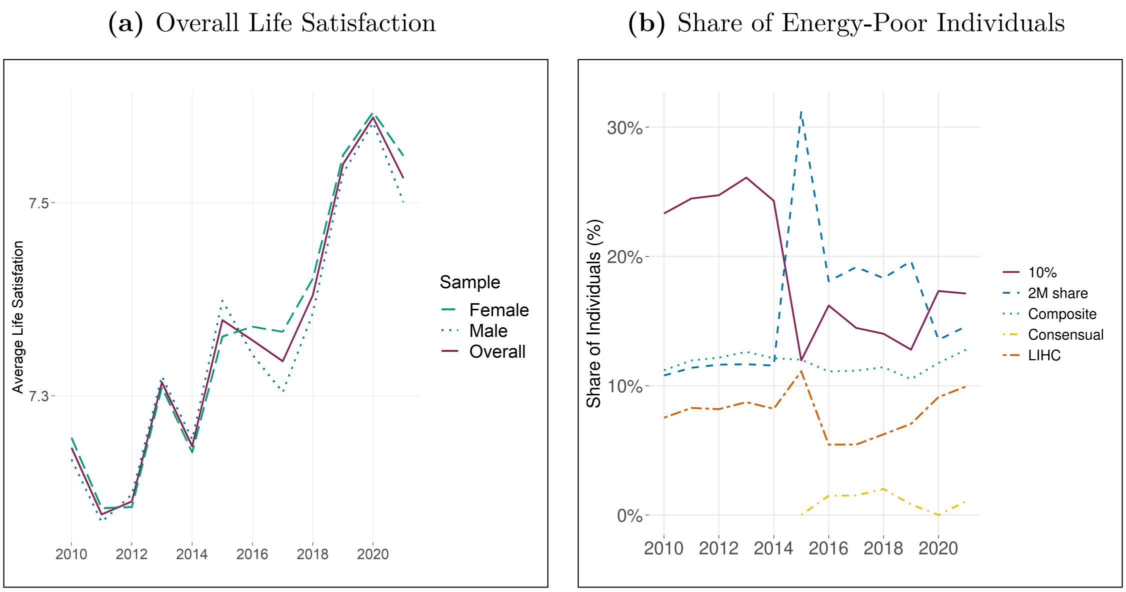

Figure 1: Trends in Overall Life Satisfaction and Energy Poverty Indicators

Table 1: Average Monthly Equivalized Income, Energy Expenditure, and Share of energy-poor across Income Groups (2010-2021 Pooled Sample)

Averages of Variables	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Monthly Equivalised Income	539.27	831.31	1025.17	1210.68	1405.29	1608.94	1872.87	2197.97	2659.63	4657.37
Electricity Cost	21.68	35.37	37.34	38.17	38.82	39.91	41.37	41.46	43.05	49.52
Heating Cost	27.91	47.17	51.01	53.77	55.64	55.95	59.90	60.42	63.78	76.42
Total Cost	49.59	82.53	88.36	91.94	94.46	95.86	101.26	101.88	106.83	125.94
Share of income spent on energy (%)	12.85	9.96	8.64	7.61	6.73	5.96	5.42	4.64	4.03	3.09
Energy Poverty Indicators	Percentage Share of Individuals in the Sample									
10%	44.59	49.50	33.85	23.30	14.79	9.55	6.56	2.96	1.81	0.65
2M Share	38.45	39.41	27.09	19.79	14.21	8.96	6.59	3.54	1.95	0.75
LIHC	27.41	42.38	9.52	0.76	0.03	0.00	0.00	0.00	0.00	0.00
Consensual	2.85	4.63	3.33	1.77	1.14	0.68	0.62	0.48	0.27	0.10
Composite	28.06	40.04	12.88	7.82	7.71	7.24	6.51	3.23	1.98	0.77

Notes: The total number of individuals in our sample is 70,499. For the Consensual indicator, the number of individuals is 45,694 ..

Empirical Strategy: We estimate self-reported life satisfaction *LS* of individual *i* in year *t*. The equation is as follows:

$$LS_{it} = \beta_{\mathbf{1}}^{\mathbf{a}}\mathbf{EP}_{it(a)} + \delta\mathbf{SE}'_{it} + \phi\mathbf{D}'_{it} + \lambda\mathbf{H}'_{it} + \theta\mathbf{TI} + \gamma_t + \gamma_r + \gamma_{ih} + \varepsilon_{it} \quad (1)$$

where *LS* represents the self-reported life satisfaction of individual *i* in year *t*. $EP_{it(a)}$ in Equation (1) captures the impact of energy poverty on SWB, with *a* representing different energy poverty indicators: *a* = {10%, 2*M, LIHC, Consensual, Composite*}. The vector $\mathbf{SE}'_{it}$ contains individual-level socio-economic controls such income poverty, log of income, log of peer income, employment status, and educational level. Vector $\mathbf{D}'_{it}$ denotes demographic variables including age, household types, and urban residence. The vector $\mathbf{H}'_{it}$ includes whether the individual has a poor health, disability or chronic illness, and $\mathbf{TI}'_{it}$ captures the presence of thermal insulation in the dwelling. γ_t represents survey year fixed effects while γ_r captures state-specific factors through state fixed effects. γ_{ih} includes individual *i* × household *h* fixed effects, accounting for unobserved heterogeneity both the individual level (e.g., personality traits) and the household level. ε_{it} is the idiosyncratic error term. Standard errors are clustered at the individual level for all regressions.

3. Results

Table 2 presents the fixed effects regression results, examining how various factors, including energy poverty, impact SWB, measured by life satisfaction. The analysis high-lights several important determinants of life satisfaction beyond energy poverty. Income plays a crucial role, with personal income positively correlated with life satisfaction. Additionally, being income-poor has a detrimental effect on life satisfaction.

Conversely, higher peer income – reflecting relative income comparisons – is associated with lower life satisfaction. Remarkably, the magnitude of this comparison effect is consistently larger than the positive effect of one's own income across different specifications. This suggests that absolute income plays a minimal role in determining life satisfaction, underscoring the significance of social comparisons in well-being. In terms of policy implications, these findings suggest that equal absolute increases in income – such as those implied by equal-per-capita rebates from carbon pricing revenues – are unlikely to enhance SWB. Instead, addressing relative income disparities may be more crucial for improving life satisfaction.

The results show that individuals with poor health, disability, or chronic illness report significantly lower life satisfaction, underscoring crucial role of health factors in well-being. Employment status also plays a significant role: unemployment consistently reduces life satisfaction by 0.108 to 0.118 points, likely due to the loss of social interactions at work, as income effects are controlled for. In contrast, retirement is linked to higher life satisfaction, likely due to financial security and increased leisure time, which can enhance social relationships and reduce stress.

We find mixed effects for education: individuals without a degree report higher life satisfaction than those with secondary education, while no significant difference is found between secondary and tertiary education levels. This suggests a more complex relationship between education and well-being. The results also show that household composition also matters for SWB. We find that individuals in partnerships or multi-generational households report higher satisfaction than those living alone. Conversely, single parents experience significantly lower life satisfaction, likely due to financial and caregiving burdens. Urban residents generally report higher life satisfaction than rural residents, likely due to better access to facilities, healthcare, and job opportunities. Interestingly, age shows no consistent impact on life satisfaction, and thermal insulation in homes does not consistently correlate with higher life satisfaction, except in one model, indicating that while it may add comfort, it is not a decisive factor in overall well-being. Turning to the central focus of this paper, energy poverty is shown to have a significant and

Table 2: Energy Poverty and Subjective well-being – Baseline Estimates

	(1)	(2)	(3)	(4)	(5)
	Dependent Variable: Life Satisfaction				
	10% Rule	2M Share	LIHC	Consensual	Composite
Energy Poverty	-0.0353***	-0.0217**	-0.0261	-0.2853***	-0.0486***
	(0.0098)	(0.0095)	(0.0171)	(0.0500)	(0.0116)
Income poverty	-0.0946***	-0.0995***	-0.0898***	-0.0667***	-0.0841***
	(0.0135)	(0.0134)	(0.0160)	(0.0238)	(0.0141)
ln(Income)	0.0989***	0.1019***	0.1077***	0.1108***	0.1054***
	(0.0128)	(0.0127)	(0.0126)	(0.0221)	(0.0126)
ln(Peer income)	-0.5152***	-0.5174***	-0.5222***	-1.888***	-0.5146***
	(0.1321)	(0.1322)	(0.1321)	(0.2410)	(0.1321)
Poor health	-0.7416***	-0.7415***	-0.7417***	-0.6988***	-0.7414***
	(0.0111)	(0.0111)	(0.0111)	(0.0179)	(0.0111)
Chronic illness	-0.0465***	-0.0467***	-0.0466***	-0.0638***	-0.0467***
	(0.0077)	(0.0077)	(0.0077)	(0.0136)	(0.0077)
Disability	-0.1058***	-0.1057***	-0.1057***	-0.0686**	-0.1054***
	(0.0204)	(0.0205)	(0.0204)	(0.0335)	(0.0204)
Education level					
Secondary	Ref	Ref	Ref	Ref	Ref
No degree	0.1795***	0.1796***	0.1794***	0.0347	0.1797***
	(0.0333)	(0.0333)	(0.0333)	(0.0695)	(0.0333)
Tertiary degree	-0.0493	-0.0496	-0.0491	0.0693	-0.0491
	(0.0357)	(0.0357)	(0.0357)	(0.0626)	(0.0357)
Employment status					
Employed (self)	Ref	Ref	Ref	Ref	Ref
Non-working	-0.1177***	-0.1178***	-0.1178***	-0.1082***	-0.1181***
	(0.0122)	(0.0122)	(0.0122)	(0.0216)	(0.0122)
Retired	0.1485***	0.1487***	0.1487***	0.0737**	0.1490***
	(0.0193)	(0.0193)	(0.0193)	(0.0328)	(0.0193)
Age	-0.5844	-0.5870	-0.5866	0.1752	-0.5722
	(669.9)	(670.2)	(670.4)	(1,384.3)	(669.5)
Household types					
Single Household	Ref	Ref	Ref	Ref	Ref
Couple without kids	0.2845***	0.2845***	0.2837***	0.3857***	0.2807***
	(0.0248)	(0.0248)	(0.0248)	(0.0436)	(0.0248)
Single parents	-0.1429***	-0.1439***	-0.1444***	0.0124	-0.1469***
	(0.0315)	(0.0315)	(0.0315)	(0.0568)	(0.0315)
Couple with kids	0.2109***	0.2105***	0.2091***	0.3440***	0.2054***
	(0.0265)	(0.0265)	(0.0265)	(0.0475)	(0.0265)
Other household	0.1067***	0.1069***	0.1054***	0.1696**	0.1008**
	(0.0399)	(0.0399)	(0.0399)	(0.0689)	(0.0399)
Urban	0.0815**	0.0815**	0.0817**	0.1948***	0.0817**
	(0.0412)	(0.0412)	(0.0412)	(0.0694)	(0.0412)
Thermal insulation	-0.0134	-0.0142	-0.0138	0.0334***	-0.0144
	(0.0087)	(0.0087)	(0.0087)	(0.0128)	(0.0087)
Number of Individuals	70,499	70,499	70,499	45,694	70,499
Number of Households	41,683	41,683	41,683	27,684	41,683
Within R^2	0.03634	0.03630	0.03629	0.03293	0.03637
Observations	331,071	331,071	331,071	133,900	331,071
Year FE	✓	✓	✓	✓	✓
State FE	✓	✓	✓	✓	✓
Household × Individual FE	✓	✓	✓	✓	✓

Notes: The data is from SOEP version 38. The dependent variable is Overall life satisfaction (scale 0-10: 0=Completely dissatisfied, 10=Completely satisfied). The column labels represents the measure for energy poverty. Each column comes from a unique regression.
Peer income is computed by first calculating the median monthly equivalence household income of reference groups based on age, gender, education level, and region. The mean (equivalised household) income of the four respective reference groups is then computed as an individual's peers' average income.
Clustered standard errors at the individual level are shown in parentheses. *: Significant at the 10% level. **: Significant at the 5% level. ***: Significant at the 1% level.

negative impact on life satisfaction. Most energy poverty indicators, including the 10% Rule, 2M Share, composite indicators show statistically significant negative effects on life satisfaction, with reductions ranging from 0.022 to 0.285 points on the 11-point scale. The Consensual indicator, which captures subjective experiences of difficulty in heating the home, has the most substantial impact, reducing life satisfaction by 0.29 points. This highlights the significant emotional and psychological toll of energy poverty, where subjective perceptions of energy deprivation are strongly linked to lower well-being. Notably, these effects remain significant even after controlling for income levels and income poverty, indicating that energy poverty imposes an additional burden on life satisfaction, beyond what can be explained by income poverty alone. This finding challenges the traditional view that energy poverty is merely a subset of income poverty, and demonstrate that it is a distinct and significant factor affecting individuals' well-being.

4. Conclusion

This paper revisits the relationship between energy poverty and subjective well-being using data from the German Socio-Economic Panel (2010–2021). The findings reveal that energy poverty significantly reduces life satisfaction, especially when measured subjectively through indicators like the Consensual measure, which captures self-reported difficulties in heating homes. This negative impact persists even after controlling for income, indicating that energy poverty is a distinct issue that profoundly affects well-being. These results highlight the importance of considering both objective and subjective dimensions when assessing energy poverty, as each offers unique insights into the lived experiences of those affected. Our findings also highlight the role of personal income and relative income comparisons in life satisfaction, emphasizing the importance of social comparisons. These results underscore the need for targeted policy interventions that address both income disparities and the specific challenges of energy poverty to improve the quality of life for vulnerable populations in Germany.

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