

Energy sustainability, vulnerability and resilience

Demetrio Panarello¹ · Andrea Gatto^{2,3,4,5} · Elkhan Richard Sadik-Zada^{4,6,8,9} · Luigi Aldieri⁷

Published online: 15 October 2024

© The Author(s) 2024 [OPEN](#)

Keywords Energy sustainability · Energy vulnerability · Energy resilience · Energy policy · Energy economics · Sustainable development

1 Confronting the complexities of energy sustainability in the face of global challenges

In an era marked by growing ecological challenges, geopolitical tensions, and widening socioeconomic inequalities, the quest for sustainable energy solutions emerges as a pivotal imperative for building resilience and promoting a fair and equitable future [1–3]. Grounded in the recognition that energy is fundamental to nearly every facet of human well-being and environmental sustainability, our shared mission is to explore the complex interplay of factors shaping energy resilience, vulnerability and transition pathways.

Amidst growing uncertainties, exacerbated by the COVID-19 pandemic and armed conflicts—above all the ongoing wars in Ukraine and the Middle East—the need for resilient, fair and equitable energy systems has become more critical than ever. At the heart of this endeavor lies the recognition of energy as a linchpin for addressing a wide range of interconnected challenges, from mitigating climate change to alleviating poverty and beyond [4, 5]. The global energy landscape finds itself at a crossroads, buffeted by a confluence of intersecting crises and transitions. The war in Ukraine has laid bare the fragility of our current energy systems, underscoring the need for diversification, decentralization, and decarbonization [6]. Indeed, the specter of supply chain disruptions and price volatility looms large, heightening concerns about energy security and resilience. Moreover, the COVID-19 pandemic has cast a harsh spotlight on the disparities and inequities that pervade our societies, exacerbating vulnerabilities and underscoring the imperative for inclusive and sustainable development pathways [7]. Hence, the imperative for energy sustainability has taken on added urgency, with far-reaching implications for environmental stewardship, socio-economic development and global stability.

From the corridors of academia to the halls of policymaking, there exists a shared responsibility to harness the transformative power of energy in service of people and the planet. The adoption of the 2030 Agenda for Sustainable Development and the Paris Agreement marked significant milestones in the global commitment to addressing climate change and fostering sustainable development [8]. However, the extent to which these international frameworks have influenced academic discourse and policy discussions in the realm of energy sustainability—specifically in terms of shaping research agendas, guiding policy decisions, and informing best practices—remains underexplored [9].

✉ Andrea Gatto, agatto@kean.edu | ¹Department of Human Sciences, Link Campus University, Rome, Italy. ²College of Business and Public Management Economics Department, Wenzhou-Kean University, Wenzhou, China. ³Division of International Studies, College of International Studies, Korea University, 145 Anam-ro, Seongbuk-gu, Seoul 02841, Republic of Korea. ⁴Centre for Studies on Europe, Azerbaijan State University of Economics, Baku, Azerbaijan. ⁵Center for Economic Development and Social Change, Naples, Italy. ⁶Institute of Development Research and Development, Ruhr University, Bochum, Germany. ⁷Department of Economic and Statistical Sciences, University of Salerno, Fisciano, Italy. ⁸BEU-Scientific Research Center, Baku Engineering University, Baku, Azerbaijan. ⁹Center for Environmental Management, Resources and Energy, Ruhr-University of Bochum, Bochum, Germany.



In this context, we here introduce a collection of articles that delve into the intricate interplay between energy sustainability, vulnerability and resilience, shedding light on both the pressing challenges and promising opportunities that lie ahead. The articles assembled in this topical collection provide valuable insights into the complexities of energy sustainability, drawing on rigorous scholarship and interdisciplinary inquiry to inform policy, inspire innovation and catalyze action toward a more resilient and equitable energy future.

2 Contextualizing energy sustainability

From the principles outlined in the Sustainable Development Goals (SDGs) to the commitments forged under the Paris Agreement, the international community has demonstrated its resolve to transition toward cleaner, more resilient energy systems, addressing the intertwined challenges of climate change, energy access, and socio-economic inequality. However, translating these lofty aspirations into tangible progress remains a formidable task, requiring concerted efforts across sectors and scales [10]. In particular, the intersectionality of energy sustainability with issues of equity, justice and resilience demands a holistic and inclusive approach to policy-making and practical implementation.

The nexus between energy and sustainability is well-documented in the literature, with scholars and practitioners alike grappling with the complexities of balancing competing priorities and interests. Indeed, energy sustainability encompasses a broad spectrum of concerns, ranging from environmental stewardship and resource conservation to social equity and economic development. At its core, however, lies a simple yet profound truth: the choices we make today will reverberate across generations, shaping the trajectory of our planet and the well-being of its inhabitants [11].

The ongoing conflict in Ukraine has deepened existing vulnerabilities in the global energy landscape, intensifying concerns about energy security and potential supply disruptions. Moreover, the war serves as a stark reminder of the geopolitical forces that shape energy markets, underscoring the urgency of diversifying energy sources and reducing reliance on fossil fuels. In addition to the conflict in Ukraine, ongoing instability in the Middle East, including disruptions caused by Houthi rebels, further exacerbates concerns about energy security and supply chain vulnerabilities. As countries grapple with these challenges, there is growing recognition of the need to strengthen domestic energy infrastructure, diversify supply chains, and enhance resilience to shocks and disruptions. In parallel, there is a growing need to invest in renewable energy technologies, as well as to improve energy efficiency and conservation.

3 Exploring emerging trends in academic discourse

The first article in this collection, by Mark M. Akrofi, Mahesti Okitasari and Richa Kandpal [12], offers a comprehensive synthesis of academic discourse on energy sustainability in the context of global agendas. Drawing on a systematic review of policy-based research publications, the authors illuminate the emergent trends and challenges shaping the pursuit of sustainable energy futures. Their findings underscore the predominance of predictive and prescriptive studies, which offer valuable insights into potential pathways for achieving international commitments such as the SDGs and the Paris Agreement.

However, the analysis also reveals notable gaps in the literature, particularly regarding the progress of policy implementation and its impacts on SDGs. Indeed, while the academic community has made significant strides in modeling future scenarios and assessing technological feasibility, there remains a pressing need for empirical research that evaluates the efficacy of existing policies and identifies barriers to implementation. By shedding light on these critical issues, the article sets the stage for deeper inquiry and informed policy action.

4 Revealing the determinants of renewable energy adoption

The second paper, written by Daniel Etongo and Harini Naidu [13], shifts the focus from global agendas to local contexts, examining the determinants of solar photovoltaic (PV) uptake in the Seychelles. Despite boasting high levels of electricity access, the Seychelles faces formidable challenges in transitioning to renewable energy sources, with over 90% of its energy derived from fossil fuels. Through a rigorous analysis of household surveys, the authors identify access to credit and household income as primary drivers of solar PV adoption, underscoring the role of financial incentives in overcoming adoption barriers.

In addition, the study highlights the motivations and barriers shaping household decisions regarding solar PV adoption, offering valuable insights for policymakers and practitioners alike. By elucidating the factors that influence adoption decisions at the household level, the article informs targeted interventions aimed at promoting renewable energy uptake and fostering energy resilience. Importantly, it underscores the need for holistic approaches that address both technological and socio-economic dimensions of energy transition.

5 Empowering communities for energy resilience

The third contribution, by Abigail Nana Ama Baidoo and colleagues [14], zooms in on the Cape Coast Metropolis of Ghana, where thermal power generation remains the dominant source of energy despite escalating electricity demand. Through a comprehensive analysis of household energy conservation practices and awareness levels, the authors uncover a complex interplay of socio-economic factors shaping energy behavior. Their findings underscore the importance of education, income level and household characteristics in influencing energy-efficient appliance usage, highlighting the need for targeted interventions to enhance energy literacy and promote sustainable practices.

Moreover, the study sheds light on the variability between social strata in terms of energy consumption patterns and conservation behaviors, underscoring the importance of equitable access to energy-saving technologies and information. By advocating for robust energy literacy programs and policy interventions, the article seeks to empower communities to take ownership of their energy futures and contribute to broader sustainability goals. In doing so, it offers a blueprint for fostering resilience and driving positive change at the grassroots level.

6 Uncovering the intricacies of fossil fuel subsidies in Nigeria

Delving into the intricate landscape of Nigeria's energy sector, the fourth manuscript—authored by Olusola Joshua Olujobi and Oshobugie Suleiman Irumekhai [15]—scrutinizes the payment of fossil fuel subsidies on petrol, coupled with an in-depth analysis of the regulatory framework governing such payments. With a keen eye on recent policy shifts, the study examines the rationale behind the removal of the petrol subsidy and evaluates the merits espoused by its proponents. Furthermore, it meticulously explores the array of pricing mechanisms employed for petroleum products.

Making use of a doctrinal legal research approach, the article synthesizes insights from primary and secondary legal sources to propose reform measures. Recommendations span a spectrum of domains, advocating for the adoption of a mixed economic system, bolstering trade, consumer protection and competition laws, enhancing transparency and accountability, stimulating investments in local refineries and embracing cleaner energy alternatives. The findings underscore the tangled web of challenges surrounding petrol subsidy payments, including corruption, rent-seeking practices and a lag in embracing cleaner energy sources compared to other countries. By offering a roadmap for policy reform, the study equips policymakers and stakeholders with actionable insights to foster transparency, accountability and sustainability within Nigeria's downstream petroleum industry, thereby contributing to global energy security endeavors.

7 Addressing energy poverty in South America

The fifth article, by Walter Leal Filho and colleagues [16], delves into the persistent issue of energy poverty in Latin America, where inadequate energy systems exacerbate socio-economic inequalities and impede sustainable development. By employing a bibliometric analysis and survey methodology, the authors explore the critical barriers that hinder access to reliable energy sources in the region and examine the implications for achieving the SDGs. The study highlights how energy poverty disproportionately affects low-income households, who spend a significant portion of income on basic energy needs, further entrenching poverty cycles.

The findings suggest that reducing dependence on coal, expanding access to renewable energy and implementing government-subsidized energy programs are pivotal to improving living conditions and fostering economic growth. This manuscript contributes valuable insights into how targeted energy policies can play a key role in alleviating energy poverty and promoting broader social and economic development across Latin America.

8 Conclusion: navigating the road ahead

Reflecting on the insights gleaned from these articles, it becomes evident that the journey toward sustainable energy futures is fraught with challenges but also rich with possibilities. From the geopolitics of energy to the intricacies of local energy transitions, the challenges we face are both complex and multifaceted. Yet, amidst the challenges lie opportunities for innovation, collaboration and transformation.

As we navigate the uncertainties of a rapidly changing world, the need for bold and decisive action to address the interlocking challenges of climate change, energy insecurity, and socio-economic inequality has never been more urgent. By questioning prevailing narratives, challenging entrenched assumptions, and forging new pathways forward, we can unlock the full potential of renewable energy and chart a course towards a more resilient, equitable and sustainable world for all.

Author contributions Not Applicable.

Funding The research was funded by the Internal Faculty Start-Up Research Grant of Wenzhou-Kean University Project No. ISRG2023014.

Data availability No data was used in this study.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

1. Gatto A, Mattera R, Panarello D. For whom the bell tolls. A spatial analysis of the renewable energy transition determinants in Europe in light of the Russia-Ukraine war. *J Environ Manag.* 2024;352:119833. <https://doi.org/10.1016/j.jenvman.2023.119833>.
2. Mattera R, Panarello D, Gatto A. What does EU energy policy mean to you? Regional differences in EU citizens' sentiments on energy transition—socio-economic, political and environmental factors. In: Mišík M, Figulová A, editors. *EU energy and climate policy after COVID-19 and the invasion of Ukraine*. Milton Park: Routledge; 2024. p. 33–47.
3. Roos M. *Principles of Complexity Economics: Concepts, Methods and Applications*. Cham: Springer; 2024.
4. Pagliuca MM, Panarello D, Punzo G. Values, concern, beliefs, and preference for solar energy: a comparative analysis of three European countries. *Environ Impact Assess Rev.* 2022;93:106722. <https://doi.org/10.1016/j.eiar.2021.106722>.
5. Gatto A, Drago C, Panarello D, Aldieri L. Energy transition in China: assessing progress in sustainable development and resilience directions. *Int Econ.* 2023;176:100450. <https://doi.org/10.1016/j.inteco.2023.08.001>.
6. Mišík M, Oravcová V. Policy persistence vis-à-vis a crisis: the curious case of Slovak energy policy after the Russian invasion of Ukraine. *Energy Effi.* 2024;17(4):1–13. <https://doi.org/10.1007/s12053-024-10216-x>.
7. Mišík M, Oravcová V. Ex ante governance in the European Union: energy and climate policy as a 'test run' for the post-pandemic recovery. *Energy Policy.* 2022;167:113076. <https://doi.org/10.1016/j.enpol.2022.113076>.
8. Wiebe KS. A global perspective on sustainable development. In: Murray J, Owen A, Simas M, Malik A, editors. *A triple bottom line analysis of global consumption*. New York: Jenny Stanford Publishing; 2022. p. 3–11.

9. Schneider F, Kläy A, Zimmermann AB, Buser T, Ingalls M, Messerli P. How can science support the 2030 agenda for sustainable development? Four tasks to tackle the normative dimension of sustainability. *Sustain Sci*. 2019;14:1593–604. <https://doi.org/10.1007/s11625-019-00675-y>.
10. McCollum DL, Zhou W, Bertram C, De Boer HS, Bosetti V, Busch S, Riahi K. Energy investment needs for fulfilling the Paris agreement and achieving the sustainable development goals. *Nat Energy*. 2018;3(7):589–99. <https://doi.org/10.1038/s41560-018-0179-z>.
11. Panarello D. Economic insecurity, conservatism, and the crisis of environmentalism: 30 years of evidence. *Socioecon Plann Sci*. 2021;73:100925. <https://doi.org/10.1016/j.seps.2020.100925>.
12. Akrofi MM, Okitasari M, Kandpal R. Recent trends on the linkages between energy, SDGs and the Paris agreement: a review of policy-based studies. *Discov Sustain*. 2022;3:32. <https://doi.org/10.1007/s43621-022-00100-y>.
13. Etongo D, Naidu H. Determinants of household adoption of solar energy technology in Seychelles in a context of 100% access to electricity. *Discov Sustain*. 2022;3:38. <https://doi.org/10.1007/s43621-022-00108-4>.
14. Baidoo ANA, Danquah JA, Nunoo EK, Mariwah S, Boampong GN, Twum E, Amankwah E, Nyametso JK. Households' energy conservation and efficiency awareness practices in the Cape Coast Metropolis of Ghana. *Discov Sustain*. 2024;5:2. <https://doi.org/10.1007/s43621-023-00154-6>.
15. Olujobi OJ, Irumekhai OS. An analysis of the abolition of premium motor spirit (PMS) subsidies in Nigeria: a breach of social contract or climate change action? *Discov Sustain*. 2024;5:71. <https://doi.org/10.1007/s43621-024-00252-z>.
16. Leal Filho W, Begum H, Anholon R, et al. Addressing the challenges posed by energy poverty in Latin American countries. *Discov Sustain*. 2024;5:262. <https://doi.org/10.1007/s43621-024-00426-9>.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.