Extended Abstract

Assessing Energy Vulnerability in the EU: A Capability-Based Energy Vulnerability Index (EVI)

Giuseppe Pellegrini Masini, ENEA, Italy

Maria Rosaria Seminara, ENEA, Italy

1. Introduction

Energy poverty poses a significant challenge throughout the European Union (EU), affecting millions of households and intensifying underlying social inequalities (Bouzarovski and Petrova, 2015; Thomson and Bouzarovski, 2018). Traditionally, energy poverty has been understood in terms of economic hardship—for instance, spending a large portion of income on heating, cooling, or electricity (Sovacool, 2015). However, such definitions often overlook broader dimensions, including social exclusion, health consequences, and energy injustice (Walker and Day, 2012; Day et al., 2016). The capability to participate in society fully—whether that means working, accessing education, or maintaining a healthy living environment—goes well beyond the sheer cost of energy.

Recent EU initiatives, such as the Clean Energy for All package and the European Green Deal, emphasize a fair and inclusive energy transition, echoing the assertion that no individual should be left behind. Nevertheless, around 50 million people in Europe remain unable to afford essential energy services (Thomson & Bouzarovski, 2018). This urgency has only heightened in the face of the COVID-19 pandemic and recent geopolitical tensions, which contributed to rising energy prices across Member States (Eurostat, 2023).

Scholars and policymakers are thus re-evaluating how energy poverty is measured, proposing multi-dimensional indices that consider not only economic but also social, environmental, and even political dimensions (Pye et al., 2015; Dobbins et al., 2019). Within this discourse, the concept of energy justice offers an integrative framework: it focuses on the fair distribution of resources (distributive justice), inclusive decision-making (procedural justice), and the recognition of specific vulnerabilities (recognition justice) (Jenkins et al., 2016; Sovacool et al., 2017). Grounded in Amartya Sen's capability approach (Sen, 1979; 1999), energy justice encourages a broader perspective on what individuals can actually do and be—rather than merely examining income or expenditure metrics (Pellicer-Sifres et al., 2021).

Against this background, this extended abstract presents the Energy Vulnerability Index (EVI), an analytical tool developed to capture the multiple facets of energy deprivation across Europe. By distinguishing between maintenance indicators (reflecting access to

basic energy services) and growth indicators (opportunities for socio-economic development), and by including transport energy in addition to household energy, the EVI provides a holistic assessment of how individuals experience and cope with energy poverty.

2. Energy Poverty and Energy Justice

Traditional energy poverty metrics (e.g., the percentage of income spent on energy or the Low Income-High Costs indicator) do offer insight into financial burdens but fail to capture the complexity of the problem (Faiella and La Vecchia, 2014; Pye et al., 2015). Such an economically oriented view overlooks the broader set of well-being deficits—social exclusion, hindered educational opportunities, and health risks—that people living in energy poverty may endure (Day et al., 2016; Carley and Konisky, 2020).

Energy justice, by contrast, places these concerns at the forefront. It promotes fairness in resource allocation, emphasizes the inclusion of marginalized communities in policy formation, and focuses on recognizing distinct vulnerabilities (McCauley et al., 2013; Jenkins et al., 2016). When energy justice principles are applied, energy deprivation is viewed not merely as a budgetary issue but as a form of social injustice rooted in unequal resource distribution, lack of procedural inclusivity, and inadequate recognition of at-risk groups (Sovacool and Dworkin, 2015; Heffron and McCauley, 2017).

Recent studies have built upon the idea of capability-based energy justice (Pellicer-Sifres et al., 2021). Inspired by Sen's (1979) argument that the essence of poverty lies in restricted freedoms or opportunities, a capability-based indicator examines whether individuals can maintain comfortable homes, access essential transport, and engage meaningfully in society. In other words, it extends energy poverty research to investigate how lack of energy can shape broader life choices (Walker and Day, 2012).

3. Broadening the Definition: Transport Energy

A key innovation in the EVI is the inclusion of **transport energy** alongside household energy services. Traditional discussions often focus on indoor heating, cooling, and lighting, with only tangential references to how people power their vehicles or access public transportation (Thomson and Bouzarovski, 2018). Yet, in many parts of Europe, the ability to travel—whether by car or via well-funded public transit—is crucial for employment, education, healthcare, and overall societal participation (Koukoufikis and Uihlein, 2022).

Scholars increasingly recognize that low-income households can suffer from what is termed a "double energy vulnerability," struggling to afford both household and

transportation energy costs (Boyd et al., 2023; Del Rio et al., 2023). Households in semi-rural or rural areas lacking public transport infrastructure are forced to rely on private vehicles, escalating their overall energy expenses (Sovacool et al., 2023). The consequence is not just a chilly home but also restricted mobility that limits social interaction and job opportunities (Day et al., 2016).

Thus, capturing **transport energy** within the EVI is imperative for assessing how vulnerable households truly are. By highlighting these dual burdens, the EVI gives policymakers a clearer sense of where targeted interventions—like affordable public transport or incentives for electric vehicle adoption—may be most needed.

4. The Capability Approach Applied to Energy Vulnerability

Underlying the EVI is the notion that energy poverty is best understood within a capability framework. Amartya Sen posited that measuring poverty merely through income or expenditure fails to address whether people can lead lives they have reason to value (Sen, 1979, 1999). In parallel, Martha Nussbaum (2000) enumerated specific "central capabilities" such as bodily health, bodily integrity, practical reason, and affiliation, all of which can be hindered by limited access to energy.

Yet operationalizing capabilities into measurable indicators can be challenging (Day, Walker, & Simcock, 2016). Scholars have turned to empirical needs theories—like Maslow's (1954) hierarchy—that parallel the concept of differentiating between basic (maintenance) and advanced (growth) needs (Tay and Diener, 2011). Applied to energy studies, the distinction underscores that while some households struggle to secure minimal comfort levels (maintenance), others are constrained in opportunities for personal or professional advancement (growth). By bridging these theoretical concepts, the EVI resonates with earlier evidence that persons lacking essential energy services can see multiple facets of life compromised (Bouzarovski and Petrova, 2015).

5. Constructing the Energy Vulnerability Index (EVI)

5.1 Maintenance vs. Growth Indicators

In line with Maslow's "maintenance" and "growth" framework, the EVI separates indicators into two categories:

- **Maintenance indicators:** Basic housing conditions (e.g., ability to keep homes adequately warm), risk of poverty, existence of utility bill arrears, and minimal transport costs (Pye et al., 2015). These aspects underscore immediate well-being—ensuring that an individual or household meets day-to-day energy needs for survival and dignity.

- **Growth indicators:** Access to transport that enables social participation, ability to invest in energy-efficient measures, and resource allocation toward personal or family development (Tay and Diener, 2011). These reflect the capacity to move beyond mere survival, focusing on autonomy, mastery, and self-direction in daily life.

5.2 Indicator Selection and Data The EVI relies on publicly available data from Eurostat and the EU Statistics on Income and Living Conditions (EU-SILC). Maintenance indicators track phenomena like severe material deprivation, inability to afford adequate heating, or presence of damp or rot in dwellings (Bouzarovski and Petrova, 2015). Growth indicators center on expenditures related to vehicle ownership, personal transport equipment, or advanced housing improvements. Importantly, the chosen indicators also reflect data availability and cross-country comparability, ensuring the EVI remains both practical and replicable (Walker and Day, 2012).

5.3 Normalization and Aggregation To ensure comparability across indicators with different scales, the EVI employs min-max normalization (OECD, 2008). After each indicator is normalized, the Maintenance (M) and Growth (G) components are calculated separately and combined into a single index.

A higher EVI score signifies elevated vulnerability: households must devote more resources to meeting basic energy demands, hindering their capacity for personal or social development (Pellegrini-Masini et al., 2020). While min-max normalization is sensitive to outliers, no severe anomalies were identified in the dataset, making this method appropriate for the EVI's needs.

6. Results

6.1 High, Medium, and Low Vulnerability The EVI reveals considerable disparities across Europe. Greece (52.93), Bulgaria (43.28), and Spain (39.53) occupy the upper end of the spectrum, reflecting heightened difficulty in providing or affording sufficient household and transport energy. Meanwhile, Finland (16.40), Luxembourg (17.95), and the Netherlands (20.49) display relatively low vulnerability, likely attributable to robust infrastructures, effective policy interventions, and higher living standards.

Most countries cluster around a middle range, such as Italy (27.87), Germany (26.05), and Ireland (25.78). Here, vulnerabilities exist—e.g., a subset of the population faces substantial energy costs—but are moderated by policy frameworks that partly buffer households from extreme hardship (Pye et al., 2015).

6.2 Maintenance vs. Growth Findings Maintenance results highlight that countries like Greece and Bulgaria struggle to ensure even minimal thermal comfort, reflecting subpar housing stock and socio-economic strains (Sovacool, 2015). Meanwhile, growth

indicators capture whether households can invest in improving their circumstances. For instance, Spain shows relatively widespread coverage of basic needs yet scores poorly on growth measures. The inability to afford a vehicle or upgrade to energy-efficient appliances can stunt economic mobility and social participation (Del Rio et al., 2023).

6.3 Transport Energy Insights Transport emerged as a pivotal factor distinguishing household experiences. Countries with reliable, affordable public transport (e.g., the Netherlands) rank lower in overall vulnerability; rural regions forced to rely on private vehicles (e.g., parts of Greece) see additional financial burdens on already strained incomes (Lowans et al., 2023). This underscores that focusing exclusively on residential energy risks underestimating the full extent of deprivation (Koukoufikis and Uihlein, 2022).

---

7. Policy Implications

High-vulnerability Member States—such as Greece, Bulgaria, and Spain—require multi-pronged strategies. Housing retrofits can reduce household bills, while expanded public transit can alleviate transport poverty (Day et al., 2016; Sovacool, 2015). Direct income support or utility discounts may also assist those at immediate risk.

Middle-tier nations, including Italy and Germany, can learn from lower-EVI countries by promoting deeper energy efficiency programs, incentivizing renewable energy adoption, and improving existing social safety nets (Bouzarovski and Petrova, 2015). Low-vulnerability states like Finland serve as instructive models, demonstrating how integrated social policies and stable infrastructure can create synergy between equity and economic growth (Walker and Day, 2012).

9. Conclusion

This extended abstract has presented the Energy Vulnerability Index (EVI) as a holistic framework for evaluating energy poverty across EU member states. Building on Sen's capability approach and incorporating transport energy alongside household energy needs, the EVI speaks directly to the core concerns of energy justice—distributive equity, procedural involvement, and recognition of diverse vulnerabilities (Jenkins et al., 2016). By highlighting variations in both maintenance and growth indicators, the EVI demonstrates that energy poverty is not a one-dimensional issue but a multi-faceted challenge that impacts social inclusion, economic mobility, and personal well-being.

Policy strategies should therefore move beyond conventional income-based measures. Addressing energy poverty from a capability-based perspective means ensuring that households can achieve a decent standard of living and the freedom to pursue upward mobility. Specific interventions—ranging from housing retrofits and improved public

transit to targeted financial assistance and inclusive policy processes—will depend on local contexts, but all must be guided by the principles of energy justice.

Looking ahead, future research could adapt the EVI for non-European contexts, accounting for disparate climates, infrastructures, and socio-economic frameworks (Bouzarovski, 2014). Additionally, augmenting the EVI with indicators that track community engagement in policy decisions may offer a fuller reflection of procedural justice. By continuing to refine the EVI, policymakers and researchers can work toward a truly fair and inclusive energy transition—one that safeguards immediate well-being while promoting opportunities for social and economic advancement.

References

- Bouzarovski, S. and Petrova, S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. *Energy Research & Social Science*, 10, 31–40.
- Boyd, K.S., Calvillo, C., Mueller, T., Mu, X. and Zhu, T. (2023). The intersection of fuel and transport policy in Scotland: a review of policy, definitions and metrics. *Energies*, 16(13), 4978.
- Carley, S., & Konisky, D. M. (2020). The justice and equity implications of the clean energy transition. *Nature Energy*, 5(8), 569–577.
- Day, R., Walker, G., & Simcock, N. (2016). Conceptualising energy use and energy poverty using a capabilities framework. *Energy Policy*, 93, 255–264.
- Del Rio, J. F., Del Rio, D. D. F., Sovacool, B. K., & Griffiths, S. (2023). The demographics of energy and mobility poverty: Assessing equity and justice in Ireland, Mexico, and the United Arab Emirates. *Global Environmental Change*, 81, 102703.
- Dobbins, A., et al. (2019). *Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures*. INSIGHT_E.
- Eurostat (2023). People unable to keep their home adequately warm, 2022. [online] Available at: https://ec.europa.eu/eurostat
- Faiella, I. and La Vecchia, L. (2014). La povertà energetica in Italia. *Questioni di Economia e Finanza*, 240.
- Heffron, R. J. (2022). Applying energy justice into the energy transition. *Renewable and Sustainable Energy Reviews*, 156, 111936.
- Heffron, R.J. and McCauley, D. (2017). The concept of energy justice across the disciplines. *Energy Policy*, 105, 658–667.

- Jenkins, K., McCauley, D., Heffron, R.J., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science*, 11, 174–182.
- Koukoufikis, G., & Uihlein, A. (2022). *Energy poverty, transport poverty and living conditions: JRC Technical Report*. European Commission.
- Lowans, K., Calvillo, C., & Zhu, T. (2023). The intersection of fuel and transport policy in Scotland: A review of policy, definitions and metrics. *Energies*, 16(13), 4978.
- Maslow, A.H. (1954). *Motivation and Personality*. Harper & Row.
- McCauley, D., Heffron, R., Stephan, H., & Jenkins, K. (2013). Advancing energy justice: The triumvirate of tenets. *International Energy Law Review*, 3, 107–110.
- Nussbaum, M. (2000). *Women and Human Development: The Capabilities Approach*. Cambridge University Press.
- OECD (2008). *Handbook on Constructing Composite Indicators: Methodology and User Guide*. OECD Publishing.
- Pellicer-Sifres, V., Simcock, N., & Boni, A. (2021). Understanding the multiple harms of energy poverty through Nussbaum's theory of central capabilities. *Local Environment*, 26(8), 1026–1042.
- Pellegrini-Masini, G., Pirni, A., & Maran, S. (2020). Energy justice revisited: A critical review on the philosophical and political origins of equality. *Energy Research & Social Science*, 59, 101310.
- Pye, S., Dobbins, A., Baffert, C., Brajković, J., Grgurev, I., & Deane, P. (2015). *Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures*. INSIGHT_E.
- Sen, A. (1979). Equality of what? *The Tanner Lecture on Human Values*. Stanford University.
- Sen, A. (1999). *Development as Freedom*. Knopf.
- Sovacool, B.K. (2015). Fuel poverty, affordability, and energy justice in England: Policy insights from the Warm Front Program. *Energy*, 93, 361–371.
- Sovacool, B.K. and Dworkin, M.H. (2015). Energy justice: Conceptual insights and practical applications. *Applied Energy*, 142, 435–444.
- Sovacool, B.K., Burke, M., Baker, L., Kotikalapudi, C.K., & Wlokas, H. (2017). New frontiers and conceptual frameworks for energy justice. *Energy Policy*, 105, 677–691.

- Sovacool, B.K., Upham, P., Martiskainen, M., Jenkins, K.E.H., Torres Contreras, G.A., & Simcock, N. (2023). Policy prescriptions to address energy and transport poverty in the United Kingdom. *Nature Energy*, 8(3), 273–283.
- Thomson, H. & Bouzarovski, S. (2018). *Addressing energy poverty in the European Union: State of play and action.* EU Energy Poverty Observatory.
- Walker, G. & Day, R. (2012). Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. *Energy Policy*, 49, 69–75.
- Tay, L. & Diener, E. (2011). Needs and subjective well-being around the world. *Journal of Personality and Social Psychology*, 101(2), 354–365.