From Hydrogen Risk to Hydrogen Justice: Building a UK Hydrogen Transition Vulnerability Index

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Extended Abstract:

Green hydrogen has become a central pillar of the UK's net-zero strategy, with growing expectations that it will help decarbonise hard-to-electrify sectors and support industrial renewal. Yet most projects remain at the planning or early funding stage. This creates a practical problem for researchers and policymakers who want to evaluate "hydrogen justice": there is not yet enough realised deployment to measure who is actually exposed to hydrogen infrastructure, who benefits, and who bears costs. Survey evidence is also limited because many communities have not encountered hydrogen projects directly, and perceptions captured in advance are often abstract and difficult to connect to specific places. As a result, conventional ex post evaluation tools—based on observed exposure, outcomes, or public attitudes—risk arriving too late to inform fair design. This paper responds by developing an ex ante approach: a spatially explicit Hydrogen Transition Vulnerability Index (HTVI) for the UK that identifies communities and households likely to experience unfair burdens or exclusion if hydrogen development accelerates nearby, given existing social, environmental, and governance conditions.

The objective of the paper is to create a practical and interpretable screening tool that can inform place-based governance before large-scale hydrogen build-out occurs. The core contribution is both methodological and conceptual. Methodologically, we provide a replicable way to operationalise hydrogen justice when deployment is still emerging using open UK datasets. Conceptually, the HTVI is grounded in a mechanism-based understanding of justice risks. Rather than relying on generic deprivation metrics, our framework specifies how hydrogen transitions generate distributional and procedural injustices through three distinct pathways in literature: exclusion, enclosure, and externalization. Exclusion refers to limited participation in decision-making and weak voice in planning, consultation, and benefit negotiation. Enclosure describes competition over land, water, and energy resources, alongside pressures that can worsen affordability for households already facing energy insecurity. Externalization captures the shifting of environmental, health, or nuisance costs onto particular communities. We organise these mechanisms using a Capability Approach, which shifts the focus from purely economic resources to the substantive freedoms

communities have to live well—such as the ability to participate in decisions, maintain well-being, and avoid concentrated harms. In this framing, justice risk rises when communities have limited capabilities to respond to or shape transitions, particularly when those same places face concentrated development pressure.

Empirically, the HTVI is constructed at local-area scale using open UK datasets. The specific spatial unit is chosen to balance policy relevance with data coverage; in practice this can be implemented at Local Authority District level or at a smaller unit such as MSOA depending on the final data pipeline. The baseline vulnerability component combines indicators that reflect socioeconomic sensitivity, energy and heat exposure, local demand pressures, environmental burdens, and procedural capacity. Socioeconomic sensitivity is captured through measures related to deprivation and economic insecurity, which affect communities' ability to absorb shocks and benefit from new investment. Energy and heat exposure is represented through variables such as fuel poverty and housing energy efficiency, which are directly relevant to household vulnerability in the context of changing energy infrastructures and costs. Local energy demand and infrastructure context are proxied using indicators that reflect the intensity of local energy needs and the potential friction of transition. Environmental burdens include measures such as air quality and cumulative exposure proxies, intended to capture baseline conditions that may amplify the perceived and actual costs of additional infrastructure. Procedural capacity uses available proxies for communities' ability to participate, organise, access information, and influence decision processes, reflecting that weak procedural capacity can turn even well-intentioned development into real injustice.

The index construction follows transparent steps designed to be replicable and interpretable. Indicators are cleaned, harmonised across geographies using consistent area codes, and oriented so that higher values correspond to higher vulnerability. Variables are then normalised to allow aggregation across different units and distributions. The baseline HTVI is aggregated using an entropy-weighting method, which assigns weights based on the informational variation of each indicator across places. Entropy weighting is attractive in this context because it provides a consistent rule for combining heterogeneous data while still allowing the researcher to clearly explain what drives the index. Because index results can be sensitive to methodological choices, we implement robustness checks that compare entropy weights with alternative weighting schemes such as equal weights and principal-components-based weights, test alternative normalisation approaches, and examine rank stability through correlations.

A key innovation of the paper is to incorporate early-stage deployment dynamics through a hydrogen transition pressure score. Vulnerability alone does not imply that hydrogen development will occur locally; some highly vulnerable places may see little hydrogen activity in the near term, while other areas may experience high development pressure despite lower baseline vulnerability. To capture this, we may use machine learning to estimate transition pressure from observable siting fundamentals and policy pipeline signals. Siting fundamentals include measurable characteristics that make hydrogen projects more likely, such as industrial structure and heat demand proxies, proximity to ports and logistics corridors, and indicators related to relevant infrastructure contexts. Policy pipeline signals are derived from publicly observable markers of hydrogen momentum, such as project announcements, cluster programme signals, and related indicators that capture near-term plausibility rather than long-run theoretical potential. The pressure model is trained using a target variable that reflects the presence or intensity of hydrogen development indications (for example, project counts or announced capacity where data allow), with cross-validation used to assess out-of-sample performance. We then combine baseline vulnerability and transition pressure to map expected justice risk.

The tentative results expected from this framework are a set of empirically grounded patterns about where justice risks may become concentrated under plausible deployment dynamics. We expect hotspots to emerge where industrial transition pressure intersects with socioeconomic vulnerability, particularly in places that combine high energy demand signals, existing environmental burdens, and lower procedural capacity. We also anticipate that different mechanisms will dominate in different regions: in some places, exclusion and procedural capacity may be the binding constraint, implying a need for stronger engagement design and community capacity support; in others, externalization risk may be more pronounced due to cumulative environmental burdens, implying a need for monitoring and impact assessments. The paper’s conclusions emphasise that hydrogen justice can and should be addressed before large-scale deployment, not only after conflicts emerge or harms are realised. The HTVI offers a practical tool for early planning: it highlights places where engagement should be strengthened, where benefit-sharing design may be particularly important, and where environmental protections and monitoring should be tightened given baseline burdens. In practice, this means the HTVI can directly inform emerging UK governance frameworks, such as Local Area Energy Plans and national cluster sequencing criteria. By integrating this spatial data, policymakers can ensure that community benefit guidelines and targeted resilience funding are deployed precisely where transition pressures and systemic vulnerabilities collide. Looking ahead, the HTVI can be extended as hydrogen deployment matures. As better project-level data become available, transition pressure can be updated and validated against realised build-out, and the vulnerability component can incorporate more direct measures of participation processes and outcomes. The framework can also be linked to regional energy system and investment models to examine how alternative policy pathways might shift pressure across space, potentially allowing not only hotspot identification but scenario comparison of justice implications.