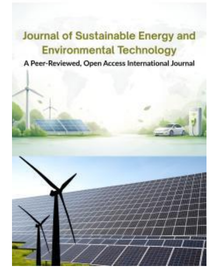
Journal of Sustainable Energy and Environmental Technology

E-ISSN: 3122-0630
P-ISSN: 3121-9454

Volume 2, Issue 1, March, 2026
(An Academians Publishers of Research & Academic Resources)



Review Article

The Readiness Gap: Institutional Capacity and the Governance of Sustainable Energy Deployment

Majid Bakkar*[1], Miqdam Tariq Faroq[2],
[1]*K.N. Toosi University of Technology, Iran*
[2]*Energy and Renewable Energy Technology Center, University of Technology – Iraq*

Abstract: The global energy transition has been widely characterized as a race between technological innovation and climate change. This framing has driven substantial investment in research and development, resulting in dramatic cost reductions for renewable energy technologies and the emergence of promising new materials and processes across chemistry and engineering. Yet the persistent gap between technological availability and deployment at scale suggests that innovation alone is not the binding constraint on sustainable transitions. This article argues that a "readiness gap" separates technological maturity from institutional capacity, and that closing this gap requires reorienting transition governance away from technology-centric approaches toward frameworks attentive to coordination, equity, and place. Drawing on evidence from European energy system analyses, national-scale typological studies of renewable energy projects, and research on emerging sustainable technologies, the analysis develops an institutional readiness framework identifying four dimensions essential for effective deployment: coordination capacity, regulatory coherence, distributive fairness, and adaptive learning. Each dimension is examined in relation to empirical patterns of renewable energy deployment, revealing how institutional deficits manifest in spatial inequalities, policy instability, and public resistance. The article concludes by proposing governance reforms that treat deployment not as an implementation detail but as a distinct and demanding policy challenge requiring institutional capacities that cannot be assumed to emerge spontaneously from technological progress.

Keywords: *energy transition governance, institutional readiness, deployment capacity, renewable energy, spatial justice, adaptive governance*

1. Introduction

Few policy challenges have attracted as much scholarly attention or political commitment as the transition to sustainable energy systems. The urgency of decarbonization is widely recognized, the technological pathways are increasingly clear, and public support for renewable energy remains high in most countries. Yet progress toward climate targets continues to lag, not because the necessary technologies are unavailable or unaffordable, but because the processes through which technologies are integrated into existing systems, landscapes, and institutions are far more complex and contested than dominant transition narratives acknowledge.

This article examines what might be called the "readiness gap" — the persistent disconnect between technological capability and actual deployment at scale. While substantial literatures address technological innovation, on one hand, and policy instruments, on the other, less attention has been paid to the institutional capacities that mediate between them. The argument advanced here is that sustainable energy transitions are constrained less by technological immaturity than by institutional deficits: insufficient coordination across sectors and scales, fragmented regulatory frameworks, unresolved distributive questions, and weak mechanisms for learning and adaptation. Closing the readiness gap requires treating deployment not as a straightforward implementation of technical solutions but as a distinct governance challenge requiring institutional capacities that cannot be assumed to emerge automatically from technological progress.

Received 22 January, 2026; Accepted 25 February, 2026; Available Online: 31 March, 2026
Corresponding Author: Majid Bakkar

The analysis draws on multiple strands of recent research to develop this argument. Empirical studies of energy system evolution in European countries reveal how structural complexity changes during transitions and what this implies for coordination. Typological analyses of renewable energy projects illuminate the diversity of deployment configurations and their relationships to socio-ecological contexts. Research on emerging sustainable technologies demonstrates the breadth of innovation relevant to sustainability while highlighting the challenge of moving from laboratory to landscape. Together, these sources support a reconceptualization of transition governance that places institutional readiness at its center.

The article proceeds in four main parts. Section 2 develops the concept of the readiness gap, distinguishing technological from institutional readiness and explaining why the latter is often the binding constraint. Section 3 examines four dimensions of institutional readiness — coordination capacity, regulatory coherence, distributive fairness, and adaptive learning — in relation to empirical evidence on renewable energy deployment. Section 4 explores the spatial and social dimensions of deployment, showing how institutional deficits manifest in particular places and communities. Section 5 concludes by outlining a research and policy agenda oriented toward closing the readiness gap.

2. The Readiness Gap: Conceptual Foundations

2.1 Technological Readiness and Its Limits

The concept of technological readiness has become central to innovation policy, providing a framework for assessing how close technologies are to commercial deployment and where public investment is most needed. Renewable energy technologies have advanced dramatically along this scale over the past two decades. Solar photovoltaic costs have fallen by nearly 90 percent since 2010, wind turbines have grown larger and more efficient, and grid integration technologies have matured substantially. By conventional measures of technological readiness, the tools needed for deep decarbonization are largely available.

The field of sustainable chemistry offers a parallel narrative of technological progress. New catalysts eliminate the need for scarce and toxic metals, novel materials enable more efficient energy conversion, and advanced separation processes reduce the resource intensity of industrial production (Droescher et al., 2021). These innovations demonstrate that the scientific community continues to generate solutions to sustainability challenges. Yet the translation of such innovations into widespread practice remains slow and uneven, suggesting that factors beyond scientific discovery govern the pace of change.

The limits of technological readiness as a guide to policy become apparent when one considers what deployment actually requires. A solar panel that performs well in laboratory conditions must be integrated into a grid with specific characteristics, sited in a landscape with existing uses and meanings, financed through instruments matched to investor expectations, permitted by regulatory frameworks with particular requirements, and accepted by communities with legitimate concerns about impacts. Each of these requirements involves institutional arrangements that are not given by technology but must be developed, negotiated, and maintained.

2.2 Institutional Readiness as the Binding Constraint

Institutional readiness refers to the capacity of governance systems to manage the complex processes through which technologies are deployed, integrated, and sustained. This capacity has multiple dimensions — coordination across sectors and scales, regulatory coherence and predictability, mechanisms for distributing costs and benefits fairly, and processes for learning from experience and adapting to new information. When these capacities are absent or underdeveloped, even mature technologies may fail to achieve anticipated deployment levels.

The distinction between technological and institutional readiness helps explain a puzzle that has puzzled analysts of energy transitions: why does deployment vary so dramatically across countries with similar resource endowments, comparable incomes, and access to the same technologies? The answer appears to lie not in differences in technological availability but in differences in institutional capacity. Countries that have developed coherent planning frameworks, aligned regulatory incentives, addressed distributive concerns, and created mechanisms for adaptive management have achieved much higher deployment rates than those that have not.

This insight has implications for how transitions are studied and governed. A techno-centric approach treats deployment as a function of cost and performance, assuming that once technologies are competitive, adoption will follow. An institution-centric approach recognizes that deployment is a governance challenge, requiring active management of coordination, distribution, and uncertainty. The latter perspective suggests that policy attention must shift from supporting innovation to building the institutional capacities that enable deployment.

2.3 Why Institutional Readiness Is Difficult to Achieve

If institutional readiness is so important, why is it so difficult to achieve? Part of the answer lies in the nature of the challenge. Energy transitions involve coordinated change across multiple sectors — electricity, transportation, industry, buildings — each with its own actors, regulations, and path dependencies. They require action at multiple scales, from international agreements to local land-use decisions. They unfold over decades, spanning multiple electoral cycles and requiring sustained commitment despite changes in government.

And they generate winners and losers, creating political conflicts that must be navigated.

Another part of the answer lies in the characteristics of institutions themselves. Institutional capacity is not something that can be purchased or imported; it must be built through practice, learning, and adaptation. The skills of coordination, regulation, and conflict management are developed over time through experience. Institutional change is typically incremental and path-dependent, constrained by existing arrangements and vested interests. Building institutional readiness for energy transitions is therefore a long-term project that cannot be shortcut by technological progress.

These observations suggest that the readiness gap is not a temporary condition that will resolve itself as technologies mature. It reflects structural characteristics of governance systems and the challenges they face. Closing the gap requires deliberate attention to institutional development as a core element of transition strategy.

3. Dimensions of Institutional Readiness

3.1 Coordination Capacity

The first dimension of institutional readiness is coordination capacity: the ability to align decisions and actions across multiple actors, sectors, and scales. Energy transitions require coordination between national governments setting targets and local authorities making land-use decisions, between energy regulators and environmental agencies, between grid operators and project developers, between industry and civil society. Where coordination mechanisms are weak, transitions stall or proceed in inefficient and inequitable ways.

Empirical research on European energy systems reveals how coordination challenges manifest in practice. Analyses of energy flow networks show that transitions involve changes not only in the composition of energy sources but also in the structure of relationships between activities and carriers (Abadi et al., 2025). As renewable sources are introduced, new pathways emerge that connect production activities to final uses in different ways than fossil fuel systems. This structural change creates coordination demands: new connections must be established, new intermediaries must be created, and existing arrangements must be reconfigured.

The complexity of coordination is compounded by the diversity of transition configurations. Typological studies of renewable energy projects identify multiple distinct types of energy-land systems, each with its own characteristics, actors, and governance arrangements (Buchadas et al., 2025). Utility-scale wind projects in mountainous regions, for example, typically involve different actors and face different coordination challenges than rooftop solar installations in urban areas. Effective governance must be capable of addressing this diversity without imposing uniform requirements that ignore local conditions.

Coordination failures are particularly visible in the spatial dimension of transitions. Renewable energy resources are unevenly distributed, and grid infrastructure often does not align with where new generation is needed. Resolving such mismatches requires coordination between energy planning and land-use planning, between transmission and distribution, and between different jurisdictions. Where such coordination is lacking, projects may be sited in locations that are suboptimal from a system perspective, contributing to inefficiency and, potentially, to social conflict.

3.2 Regulatory Coherence

The second dimension of institutional readiness is regulatory coherence: the extent to which rules, standards, and incentives are consistent, predictable, and aligned with transition objectives. Energy transitions involve multiple regulatory domains — energy markets, environmental protection, land use, building codes, tax policy — each with its own logic and objectives. Where regulations conflict or change unpredictably, investment is discouraged and projects are delayed.

The empirical record reveals significant variation in regulatory coherence across countries and over time. Some countries have developed integrated frameworks that align energy and climate objectives with land-use and environmental regulation, providing clarity for investors and communities alike. Others have relied on overlapping and sometimes conflicting instruments, creating uncertainty and inefficiency. Changes in regulatory frameworks — whether through policy shifts, revised targets, or new requirements — can undermine confidence and delay deployment even when the underlying technological and economic conditions remain favorable.

Regulatory coherence is particularly important for the spatial dimensions of transitions. Renewable energy projects must comply with a range of requirements — environmental impact assessment, land-use permits, grid connection agreements — administered by different authorities with different timelines and criteria. Where these requirements are not coordinated, projects can face years of delay and significant uncertainty. Where they are well coordinated, as in some jurisdictions that have streamlined permitting for renewable energy, deployment proceeds more rapidly and predictably.

The challenge of regulatory coherence is illustrated by tensions between climate objectives and environmental protection. Renewable energy projects, while essential for decarbonization, can have significant ecological impacts — displacing wildlife, fragmenting habitats, or altering hydrological systems. Resolving such tensions requires regulatory frameworks that can weigh competing objectives and provide clear guidance rather than forcing project-by-project negotiation. The absence of such frameworks creates uncertainty for developers and can lead to outcomes that satisfy neither climate nor conservation goals.

3.3 Distributive Fairness

The third dimension of institutional readiness is distributive fairness: the extent to which the costs and benefits of transitions are distributed in ways that affected communities consider legitimate. Energy transitions generate significant distributional consequences. Some regions gain economic activity and revenue; others experience landscape change and disruption. Some communities benefit from local energy production; others bear burdens without comparable benefits. Where such distributions are perceived as unfair, opposition can slow or block deployment.

Research on socio-ecological marginalization reveals troubling patterns in the distribution of renewable energy impacts. Large-scale projects are frequently sited in regions characterized by economic decline, demographic loss, and limited political influence (Buchadas et al., 2025). While this pattern may reflect the availability of land and favorable resource conditions, it also raises concerns about whether the burdens of energy transition are being concentrated on communities least able to resist them. The concept of "sacrifice zones" captures this dynamic, highlighting the risk that marginalized places will bear disproportionate costs of the transition to a low-carbon economy (Scott & Smith, 2017; Zografos & Robbins, 2020).

Addressing distributive concerns requires institutional arrangements that ensure affected communities share in the benefits of energy development. This may involve direct compensation, local ownership, revenue sharing, or community benefit agreements. The effectiveness of such arrangements depends on their design and implementation. Research on community acceptance of renewable energy projects suggests that procedural justice — the extent to which communities are involved in decisions — is often as important as distributive outcomes in shaping attitudes (Batel, 2020; Enserink et al., 2022).

The challenge of distributive fairness is complicated by the multi-scalar nature of energy systems. Benefits often accrue at national or global scales — through reduced emissions, energy security, or economic growth — while costs are experienced locally. Bridging this scalar mismatch requires institutional mechanisms that translate aggregate benefits into local gains. Without such mechanisms, communities may reasonably conclude that they are bearing the costs of transitions that primarily benefit others.

3.4 Adaptive Learning

The fourth dimension of institutional readiness is adaptive learning: the capacity to monitor outcomes, evaluate effectiveness, and adjust strategies in light of experience. Energy transitions unfold under conditions of deep uncertainty. The pace of technological change, the evolution of energy markets, the trajectory of climate impacts, and the responses of social and ecological systems cannot be predicted with confidence. Governance frameworks must therefore be capable of learning and adapting as new information becomes available.

The importance of adaptive learning is evident in the experience of renewable energy policy. Feed-in tariffs that successfully stimulated early solar deployment became unsustainable as costs fell and deployment accelerated, requiring transition to auction mechanisms and market-based approaches (Sareen, 2024). Support schemes that worked well in some contexts proved less effective in others, requiring adjustment to local conditions. Approaches to community engagement that seemed promising in theory often required revision in practice as unexpected challenges emerged.

Adaptive learning requires institutional arrangements that support experimentation, monitoring, and feedback. It also requires a willingness to acknowledge and learn from failure — to recognize when policies are not achieving their objectives and to adjust accordingly rather than persisting with approaches that are not working. This orientation can be difficult to sustain in political systems that reward consistency and punish apparent reversals, suggesting that institutional design must create space for learning that is insulated from short-term political pressures.

The spatial dimensions of transitions create particular challenges for adaptive learning. Because energy-land systems are diverse and context-dependent, lessons from one place may not transfer directly to another. Adaptive governance must therefore be attentive to local conditions while also capturing and disseminating generalizable insights. This requires mechanisms for horizontal learning across jurisdictions and for vertical learning that connects local experience to national and international policy frameworks.

4. The Geography of Deployment

4.1 Spatial Patterns and Their Drivers

The spatial distribution of renewable energy deployment reflects both natural conditions and institutional factors. Solar resources are concentrated in southern regions, wind resources in coastal and mountainous areas, and hydroelectric potential in river basins. But the actual pattern of deployment is also shaped by grid infrastructure, land availability, regulatory frameworks, and the political economy of local opposition and support. Understanding the geography of deployment requires attention to both natural and institutional determinants.

Empirical research on European energy transitions reveals distinctive spatial patterns. In Portugal, wind development was initially concentrated in the mountainous northern regions, areas characterized by favorable wind resources but also by economic decline and demographic loss (Delicado et al., 2017). Solar development subsequently expanded in the south, where high irradiance and large land parcels facilitated utility-scale projects. More recently, hybrid projects combining wind and solar have begun to appear, driven by grid availability and the economics of co-location (Buchadas et al., 2025).

These patterns reflect the interaction of resource conditions with institutional factors. The concentration of wind development in northern Portugal was not simply a matter of wind resources but also reflected the availability of communal lands that could be leased for wind development, the presence of protected areas that required co-governance arrangements, and the weakening of traditional agricultural uses that might have competed for land. Similarly, the shift toward solar in the south reflected not only superior solar resources but also larger land parcels, lower land prices, and fewer competing uses.

4.2 Marginalization and Justice

The spatial patterns of renewable energy deployment have important implications for justice. Where projects are concentrated in marginalized regions, they may reinforce existing patterns of inequality or create new forms of disadvantage. Where they are located in more prosperous areas, they may contribute to further concentration of benefits. The distributional consequences of deployment depend not only on where projects are located but also on the terms under which they are developed and operated.

Research on Portuguese energy-land systems reveals that large-scale projects are frequently located in areas characterized by socio-ecological marginalization (Buchadas et al., 2025). These areas exhibit lower income levels, higher energy poverty, limited access to services, and degraded environmental conditions. The presence of large-scale renewable energy projects in such contexts may bring economic activity and revenue, but it also may reinforce patterns of extraction in which resources flow from peripheral regions to centers of consumption. The concept of "green sacrifice zones" captures the risk that renewable energy development will perpetuate rather than remedy spatial inequalities (Scott & Smith, 2017).

The justice implications of deployment extend beyond the location of projects to encompass the terms of their development. Projects that incorporate community ownership, local benefit-sharing, and meaningful participation are more likely to be perceived as fair and to contribute to local development than those that are developed by external actors with minimal local involvement. Yet research suggests that even projects that nominally incorporate such measures often fail to achieve meaningful community benefits, either because the measures are inadequate or because they are implemented in ways that reproduce rather than challenge existing power relations (Oliveira et al., 2025).

4.3 The Scale Question

The relationship between project scale and justice outcomes is complex and contested. Large-scale projects may benefit from economies of scale and more rigorous environmental review, but they also have larger absolute impacts and may be sited in more marginalized areas. Small-scale projects may be more easily integrated into local contexts, but they may escape regulatory oversight and fail to generate sufficient benefits to justify their impacts. The "few big versus many small" trade-off has no universal resolution; the appropriate balance depends on local conditions and priorities (Buchadas et al., 2025).

The scale question is further complicated by the diversity of small-scale configurations. Decentralized systems — rooftop solar, community energy projects, micro-grids — represent a fundamentally different model of energy production than utility-scale installations. They are typically located in populated areas, integrated with existing land uses, and governed through different arrangements. Research suggests that such systems may be more multifunctional and more readily integrated into local contexts than large-scale projects, but they face their own barriers — regulatory complexity, financing challenges, and limited technical capacity (Buchadas et al., 2025).

4.4 Toward Place-Based Approaches

The spatial dimensions of energy transitions suggest the need for place-based approaches to governance: approaches that are attentive to the specific characteristics of particular places rather than relying on uniform national policies. Place-based governance recognizes that the challenges and opportunities of energy transitions vary across contexts and that effective responses must be tailored accordingly. It also recognizes that transitions unfold through the decisions and actions of multiple actors at multiple scales, and that governance must therefore operate across scales rather than being confined to any single level.

Place-based approaches require institutional capacities that differ from those needed for centralized planning. They require the ability to understand local conditions, to engage diverse stakeholders, to negotiate context-appropriate arrangements, and to learn from experience. They also require mechanisms for coordinating across places, ensuring that local decisions are consistent with broader objectives while respecting local autonomy. Building such capacities is a long-term project, but one that is essential for closing the readiness gap.

5. Conclusions and Implications

This article has argued that sustainable energy transitions are constrained less by technological readiness than by institutional readiness. The readiness gap — the disconnect between technological capability and deployment at scale — reflects deficits in coordination capacity, regulatory coherence, distributive fairness, and adaptive learning. Closing this gap requires reorienting transition governance away from technology-centric approaches toward frameworks that treat deployment as a distinct governance challenge requiring institutional capacities that cannot be assumed to emerge automatically.

The analysis has several implications for research and policy. For research, it suggests the need for greater attention to the institutional dimensions of energy transitions — the arrangements through which decisions are made, conflicts are managed, and learning is enabled. It also suggests the value of comparative research that examines how different institutional configurations shape deployment outcomes across contexts. And it points to the importance of research that connects the spatial and social dimensions of transitions to the systemic and technological dimensions that have received more attention.

For policy, the analysis suggests that supporting technological innovation, while necessary, is insufficient. Governments must also invest in the institutional capacities that enable deployment: coordination mechanisms that align decisions across sectors and scales, regulatory frameworks that provide clarity and consistency, benefit-sharing arrangements that ensure affected communities share in transition gains, and monitoring and evaluation systems that support adaptive management. These are not peripheral concerns but core elements of transition strategy.

Finally, the analysis suggests a reframing of how transitions are understood. Rather than viewing them as technical problems with identifiable solutions, it may be more accurate to view them as ongoing processes of institutional development and adaptation. Transitions do not end when technologies are deployed; they continue as systems evolve, contexts change, and new challenges emerge. Governance must therefore be oriented toward continuous learning and adaptation rather than toward a fixed endpoint. This perspective suggests that the readiness gap is not a problem to be solved but a condition to be managed — an ongoing challenge of aligning institutions with the demands of sustainability transitions.

The stakes are high. The pace of climate change demands rapid decarbonization, but the institutional changes needed to support it cannot be achieved overnight. Navigating this tension requires both ambition and realism — recognition of what is at stake and acknowledgment of what is required to achieve it. The readiness gap framework developed here offers a way of thinking about these challenges that avoids both techno-optimism and despair, pointing toward practical steps that can be taken while recognizing the scale of the task.

References

Abadi, N., Mastrandrea, R., Ruzzenenti, F., & Diaz, A. (2025). Energy pathway variety and the progress of the energy transition in European countries. *JRC Working Papers*. European Commission, Joint Research Centre.

Batel, S. (2020). Research on the social acceptance of renewable energy technologies: Past, present and future. *Energy Research & Social Science*, *68*, 101544.

Boudet, H., Hazboun, S., Haggett, C., & Batel, S. (2025). Going slow to go fast: Public response and engagement in renewable energy projects. *Nature Reviews Clean Technology*, *1*, 877–889.

Buchadas, A., Alves, A., Sequeira, M. M., Silva, R. A., Ferreira, V., & Lambin, E. F. (2025). A multiform energy transition: Typifying wind and solar energy-land systems in Portugal. *Manuscript submitted for publication*.

Campos, I., Brito, M., & Luz, G. (2023). Scales of solar energy: Exploring citizen satisfaction, interest, and values in a comparison of regions in Portugal and Spain. *Energy Research & Social Science*, *97*, 102952.

Delicado, A., Figueiredo, E., & Silva, L. (2016). Community perceptions of renewable energies in Portugal: Impacts on environment, landscape and local development. *Energy Research & Social Science*, *13*, 84–93.

Delicado, A., Truninger, M., Figueiredo, E., Silva, L., & Horta, A. (2017). A blot on the landscape: Consensus and controversies on wind farms in rural Portugal. In *Transforming the Rural: Global Processes and Local Futures* (Vol. 24, pp. 179–199). Emerald Publishing Limited.

Diaz, A., Tchung-Ming, S., Diaz Vazquez, A., Matei, N. A., Moreno Cruz, E., & Fosse, F. (2022). Understanding sectoral integration in energy systems through complex network analysis. In *International Conference on Complex Networks and Their Applications* (pp. 481–493). Springer.

Droescher, M., Garcia-Martinez, J., & Shuai, Z. (2021). Emerging technologies for a more sustainable future. *Pure and Applied Chemistry*, *93*(12), 1347–1350.

Dunlap, A., Sovacool, B. K., & Novaković, B. (2025). 'A dead sea of solar panels': Solar enclosure, extractivism and the progressive degradation of the California desert. *The Journal of Peasant Studies*, *52*(3), 539–573.

Enserink, M., Van Etteger, R., Van den Brink, A., & Stremke, S. (2022). To support or oppose renewable energy projects? A systematic literature review on the factors influencing landscape design and social acceptance. *Energy Research & Social Science*, *91*, 102740.

Garcia-Martinez, J. (2021). Chemistry for a sustainable future. *Angewandte Chemie International Edition*, *60*(10), 4956–4960.

Hernandez, R. R., Armstrong, A., Burney, J., Ryan, G., Moore-O'Leary, K., Diedhiou, I., Grodsky, S. M., Saul-Gershenz, L., Davis, R., Macknick, J., Mulvaney, D., Heath, G. A., Easter, S. B., Hoffacker, M. K., Allen, M. F., & Kammen, D. M. (2019). Techno-ecological synergies of solar energy for global sustainability. *Nature Sustainability*, *2*(7), 560–568.

Naumann, M., & Rudolph, D. (2025). From the "right to energy" to the "right to the countryside" and back again: Contextualizing rural energy transitions. *The Professional Geographer*, 1–8.

Oliveira, F. G., Campos, I., & Moreira Alves, F. (2025). A quiet public? Procedural justice in Portuguese wind energy governance. *Energy Research & Social Science*, *126*, 104147.

Sareen, S. (2021). Drivers of scalar biases: Environmental justice and the Portuguese solar photovoltaic rollout. *Environmental Justice*, *14*(6), 424–433.

Sareen, S. (2024). *The sun also rises in Portugal: Ambitions of just solar energy transitions*. Bristol University Press.

Scott, D. N., & Smith, A. A. (2017). "Sacrifice zones" in the green energy economy: Toward an environmental justice framework. *McGill Law Journal*, *62*(3), 861–898.

Smil, V. (2015). *Power density: A key to understanding energy sources and uses*. MIT Press.

Sovacool, B. K., Geels, F. W., Andersen, A. D., Grubb, M., Jordan, A. J., Kern, F., Kivimaa, P., Lockwood, M., Markard, J., Meadowcroft, J., Meckling, J., Moore, B., Raven, R., Rogge, K. S., Rosenbloom, D., Schmidt, T. S., Schot, J., Sharp, D., Stephenson, J., Vormedal, I., & Yang, K. (2025). The acceleration of low-carbon transitions: Insights, concepts, challenges, and new directions for research. *Energy Research & Social Science*, *121*, 103948.

van Zalk, J., & Behrens, P. (2018). The spatial extent of renewable and non-renewable power generation: A review and meta-analysis of power densities and their application in the U.S. *Energy Policy*, *123*, 83–91.

Zografos, C., & Robbins, P. (2020). Green sacrifice zones, or why a Green New Deal cannot ignore the cost shifts of just transitions. *One Earth*, *3*(5), 543–546.