

New political ecologies of renewable energy

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Abstract

The critique of fossil fuel regimes has been a foundational concern for the field of political ecology, in its drives to expose the injustices and harms of energy extractivism and its early warnings of the climate crisis. However, it is increasingly evident that renewable energy sources and their infrastructures will carry their own costs and trade-offs, and that critique, resistance and alternative movement-building are needed to forge a truly just renewable energy transition. This theme issue underlines the many ways in which political ecology is well-positioned to lead critical and engaged scholarship in support of energy/climate justice. In this introduction and survey, we draw on new research collected here to reflect on political ecology's distinctive analytical capacities and forms of praxis for this task. We argue that the collection advances political ecology's intellectual and political purchase on renewable transition in several crucial ways. These include (1) *Theorizing Renewables-Driven Land Transformations*, (2) *Advancing Industrial Political Ecologies of Renewables*, (3) *Locating Power within Technical and Artifactual Politics* and (4) *Generating Knowledge and Tools for Just Transitions*. We conclude with reflections on further pressing concerns for the field: for example, rising debates over scale, ownership and accountability models within renewable energy justice and democracy movements and critical conversations growing around renewable energy's own extraction geographies and diverse forms of racialization.

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Introduction

The 21st century is seeing profound transformations in the energetic basis of societies, equaling or exceeding the sweeping changes which embedded large-scale fossil energy use in the 19th and 20th centuries. Progressive voices have advanced calls for the accelerated retirement of fossil fuels and rapid deployment of renewable and low-carbon energy technologies for decades, protesting the social and ecological costs of fossil energy and warning of the mounting climate crisis. Work in cultural and human ecology on the energetic bases and dynamics of myriad human societies was an important inspiration and foil alike for early political ecology (Watts, 2015; Huber, 2015). Some of the field's earliest works sounded early warnings of climate impacts and uneven vulnerabilities on the ground (Blaikie and Brookfield, 1987; and see Watts, 2015). Likewise, the critique of fossil fuel regimes became a central exemplar of political ecology's foundational concern with the injustices and harms associated with extraction, commodification and forced integration into global markets (e.g. Le Billon, 2001; Watts, 2004).

However, it is increasingly evident that renewable energy sources and their infrastructures will carry their own costs and trade-offs, and that critique, resistance and alternative movement-building are needed to forge a truly just renewable energy transition (Newell and Mulvaney, 2013; Levenda et al., 2021; Sovacool, 2021). The need for political ecological critique and engagement around such trajectories grows particularly urgent as renewable energy becomes a priority for private capital as well as governments, leading to strong and manifest preferences for forms of renewable energy development most conducive to new accumulation. Worldwide investment in utility-scale renewable projects is booming, with over USD 322 billion invested in 2018, much of this private (IRENA, 2020). Meanwhile, many governments are procuring and subsidizing renewable energy deployment and targeting renewable technologies in their R&D and industrial policies—a growing locus of inter-state competition and geopolitical maneuvering in a new era of energy crisis (e.g. Knuth, 2018; Mulvaney, 2019; Williams et al., 2020; Harlan, 2021). In crucial areas like power generation, renewable energy sources are now consistently cheaper than fossil fuels (IRENA, 2021). Although it is easy to regard such developments as positive—and indeed they are, in many ways—it is critical to bear in mind that a transition to renewable energy is no panacea for the ills of global capitalism. Likewise, it is critical to build and maintain political pressure to ensure that the rapid growth of renewable energy is actually displacing and leading to a reduction in the total use of fossil fuels, rather than simply adding to an ever-larger total energy supply for an ever-expanding global capitalist economy. Although many firms and governments rushing to invest in renewable energy projects pay lip service to that goal, their actions elsewhere often belie such claims (see, e.g. van den Bold, 2021).

This special issue underlines the many ways in which the field of political ecology is well-positioned to lead critical and engaged scholarship in support of a more just renewable energy transition. As contributions here demonstrate, calls for greater justice and democracy in conceptualizing and developing renewable energy forms, infrastructures and production geographies are gaining strength in many places worldwide. This rising consciousness and movement organization is complex and multi-sided. Like energy transitions of the past, renewable energy transitions today will at once be material, ecological, power-laden and culturally meaningful—and deeply geographical, realized in specific situated contexts and meaningfully differentiated across them. Papers included here explore some of the many site-specific relations which will inflect experiences of renewable energy transition on the ground. These include, for example, preexisting legacies of

racialized extraction, land dispossession and rural transformation in new frontiers of renewable energy expansion; prior programs of energy development and maneuverings of incumbent political economic interests, fossil-based and beyond; and other extant political struggles, left and right.

Political ecology is growing its engagement with such crucial lines for questioning and rethinking renewable energy transition. This collection consolidates and advances that capacity in key ways. Political ecological inquiry builds here on long traditions of energy geography and sociotechnical analysis of energy transitions, contemporary and historical (e.g. Verbong and Geels, 2007; Pasqualetti, 2011a). This work includes previous collections in these important trading zones for political ecology. Relevant early special issues and collections have, for example, advanced energy geography as a field (Zimmerer, 2011). Scholars have continued to explore the political economy of energy (De Graaf et al., 2016), including fossil energy regimes and “lifeworlds” (Appel et al., 2015). More recent special issues have examined energy infrastructure and the political economy of national development (Bridge et al., 2018) and the geographical political economy of energy transition (Bridge and Gailing, 2020). These collections have featured a number of individual contributions that critically examine the shifting geographies of renewable energy (e.g. Bailis and Baka, 2011; Finley-Brook and Thomas, 2011; Pasqualetti, 2011b; Kennedy, 2018; Knuth, 2018) and the political ecology of energy (Sovacool, 2016). These collections, alongside important survey essays such as Bridge et al. (2013) Calvert (2016) and Baka and Vaishnava (2020), have done important work to consolidate critical energy studies within and beyond the discipline of geography.

However, the current collection is novel in advancing dedicated scrutiny of renewable energy and more closely considering political ecology’s distinctive analytical capacities and forms of praxis for this endeavor. The field’s critical facility and mandate are particularly vital as renewable energy technologies and lineaments of energy transition become highly visible in everyday lifeworlds, politics and cultural conversations. Like climate change, energy has too often historically been marginalized as a niche area of concern and expertise—and often thereby “rendered technical” in anti-political ways (Li, 2007, and see Ferguson, 1994), a legacy that several contributions here confront directly. Indeed, many scholars have called for translational work to highlight energy relations (and, frequently, associated greenhouse gas emissions) as underlying, enabling and (co-)constitutive of today’s social practices, institutions and political problems and possibilities (Shove and Walker, 2010; Cohen, 2017; Bulkeley, 2019; Knuth et al., 2020). As this recalibration unfolds in practice, it increasingly means that no one field or discipline can or should “own” social studies of energy. However, it likewise means that these expanding explorations are not necessarily critical. Social and humanistic studies may instead take up today’s shifting energy relations in an observational and interpretive way, as a phenomenon of far-reaching material, ecological, social and cultural significance in a broader unfolding Anthropocene.

It matters in this sense that a (arguably *the*) central tenet of political ecology remains, after Marx, that “the point is to change it.” Critical attention to power relations and structural injustice is foundational to the field’s distinctive contributions to the energy transition, and political ecologists frequently position their work within today’s growing movements for energy/climate justice and democracy. Such critically engaged scholarship is needed to maintain a focus on renewable energy transition’s ongoing possibilities as well as its emerging problems in practice—balancing the undoubted socioecological necessity of decarbonizing energy systems and societies with an imperative to resist unjust, maladaptive versions of those transitions. This dual mandate of critique and reimagination, often developed via engaged scholarship and movement praxis, has long characterized political ecology as a field, what Robbins (2004) described as its “hatchet” and “seed.” Papers in the collection take up this multisided charge in various ways, across diverse international cases. Some sharpen critiques of problematic sociotechnical imaginaries, discursive strategies and practices emerging within renewable energy spaces, or further our understanding of complex,

fast-shifting terrains of energy politics and power relations on the ground. Others more explicitly advance resistive praxis, the development of alternative models and movement-facing tools and strategies. Some do all of the above.

More specifically, contributions collected here advance political ecology's intellectual and political purchase on renewable transition in several significant ways. These include (1) *Theorizing Renewables-Driven Land Transformations*, (2) *Advancing Industrial Political Ecologies of Renewables*, (3) *Locating Power within Technical and Artifactual Politics*, and (4) *Generating Knowledge and Tools for Just Transitions*.

Key contributions

(1) *Theorizing Renewables-Driven Land Transformations*

In investigating today's rapidly evolving geographies of renewable energy development, many political ecologists have embraced the calls to "study up" that have gained strength in the field since the 2000s (Robbins, 2002). Important early political ecological theorizations of renewable energy transition speculated on how large-scale investment in renewable technologies and infrastructures might serve as a novel socio-temporal or "socioecological" fix for capitalist crisis, particularly amid the protracted turbulence following the 2008 financial collapse (Castree and Christophers, 2015; McCarthy, 2015). Subsequent investigations have explored more concrete workings-out of such fixes in practice (Behrsin, 2019; Spivey, 2020; Palmer, 2021), within unfolding international geographies of renewables investment and development (e.g. research on renewable power from Carton, 2016; Rignall, 2016; Yenneti et al., 2016; Avila-Calero, 2017; Lennon, 2017; Shen and Power, 2017; Curley, 2018; Dunlap, 2018; Cantoni and Rignall, 2019; Mulvaney, 2019; Chien, 2020; Alonso Serna, 2021; Stock and Birkenholtz, 2020; van den Bold, 2021). Other work has taken a more granular view on financial practices and accumulation strategies in renewable project development, including widespread financial exclusion and favoritism, extraction and rentierism. These financial geographies are contributing to rising transnational corporate monopolies in the sector (Baker, 2015, 2021; Kennedy, 2018; Knuth, 2018, 2021; Bridge et al., 2020; Harrison, 2020; Klagge and Nweke-Eze, 2020; Christophers, 2022a).

Studying up remains important within this collection. However, contributions here equally emphasize such centers' connections to—and co-constitutive relations with—geographies of renewable development on the ground. In the accounts that follow, mainstream interests variously "see" the grounded socioecological relations that populate their would-be development frontiers, overlook them or render them invisible; each with consequences. Political ecologists have theorized the distinctive qualities of renewable energy forms, particularly the large-scale land transformations involved in moving "beyond the subterranean energy regime" of fossil fuels (Huber and McCarthy, 2017). Given the high surface land demands of key renewable energy technologies, many new development sites will be rural. Key early analyses in energy geography (e.g. Pasqualetti, 2001, 2011b) focused on particular Northern experiences of these renewables-driven land transformations and their politics. They observed resistance to renewable energy projects rooted in culturally specific conceptions of rural amenity and aesthetics, more and less compatible with differing rural "working landscapes" (Buck, this volume). More broadly, such competing visions of rural futures were a foundational concern for "First World" political ecology as the field has expanded its global Northern analysis since the 2000s (McCarthy, 2002; Robbins, 2002; Walker, 2003). Calvert et al.'s contribution to the collection advances this questioning in new ways.

However, as renewable energy expands across the global North and South, its development is encountering more diverse rural politics, extant land transformations and power geometries. All

are preexisting concerns of political ecology, alongside cognate work in peasant studies. For example, Avila et al. situate their contribution within broader scholarship on land grabbing and “green” grabbing, particularly the wave of international capital flight and farmland buy-ups that followed the 2008 financial crash (e.g. Borras et al., 2011, Fairhead et al., 2012) as well as new renewable resource mapping initiatives by the World Bank (McCarthy and Thatcher, 2019). Avila et al.’s paper speaks to important interpretive moves within that literature, as scholars have conjoined “thick” geographically situated interpretation with participatory movement praxis; working within global indigenous, environmental/climate justice and peasant movements.

Viewed collectively, the contributions here argue that political ecology needs to further develop its theories of power in these diverse renewables-driven land transformations, particularly as renewable energy continues to “mainstream.” In the early days, rural lobbies in key Northern contexts wielded considerable power to shape the trajectory of the renewable sector overall, not just within their specific regional and national contexts. Notably, in enabling or blocking the siting of many land-intensive renewable energy projects, often capturing significant rents for landowners in the process (Hughes, 2021), agrarian interests and their political allies affected how fast many renewable technologies such as wind and solar could scale up, develop mass production geographies and, frequently, become dramatically cheaper (Knuth, 2018; Westgard-Cruice and Aoyama, 2021). As the renewable sector has grown internationally and key technologies “mature,” the influence of particular rural sites has arguably diminished, precisely because and as a rapidly maturing and globalizing industry looks to an ever-larger set of rural areas around the world, and increasingly in the global South, as potential sites of investment and development.

However, the ways in which rural power continues to resist or shape the evolution of renewable energy trajectories demand scrutiny, as does the extent to which this power remains distinctively land-based. Certainly, rural resistance to renewables in major polluting economies like the United States remains a key concern for climate imperatives, in blocking or slowing needed decarbonization. Beyond that, contributions in this collection suggest important ways in which land politics continue to matter for newer technologies—and, as the final section of this introduction explores, in advancing alternative models of renewable transition. For example, Buck’s paper argues that proposals for large-scale carbon capture, utilization and storage (CCUS) from fossil energy production, at the contested borderlands of a low-carbon energy transition, may ultimately be defeated by failure to consider the equally sizable land requirements of many of these interventions. Novel energy storage and transmission technologies are increasingly central to a renewable energy transition and present similar questions (Turley et al., 2022, Spivey this volume). Conversely, Behrsin et al.’s contribution suggests that land-based industries like forestry and agriculture may incubate newer—if controversial—renewable energy forms like biomass waste.

(2) *Advancing Industrial Political Ecologies of Renewables*

In this sense, a second major contribution of the collection is to continue to advance work across political ecology’s trading zones, particularly its deepening interrelations with (geographical) political economy and Science and Technology Studies (STS). This expansion is appropriate to the multifaceted nature of renewable energy transition, which is at once a major force for land transformation, a complex set of evolving technologies and material infrastructures as well as a growing industrial block and locus of economic strategy.

First, one important conversation advanced by the collection is a developing “industrial political ecology” (after Huber, 2017, though see also cognate work in “political-industrial ecology” from Newell et al., 2017 and others). This research seeks to deepen political ecology’s empirical analysis and theorization of industrial spaces and processes. These arenas have more historically been associated with political economy than political ecology, though since the latter’s founding the two

fields have been interrelated in many ways (McCarthy, 2012). Such moves are particularly important as renewable energy has become an important target for industrial policy (Knuth, 2018), and energy transition becomes a major concern for financial regulators in the form of “transition risks,” “stranded” fossil energy assets and infrastructures and prospective uncontrolled devaluation and crisis (Knuth, 2017; Christophers, 2017, 2019, 2021; Langley and Morris, 2020). Indeed, as the collections discussed above demonstrate, geographical political economy has become another important home for critical studies of the renewable energy transition, including vital questions around industrial incumbency, the “disassembly” of fossil energy industries and related social relations (Bridge, 2018; Bridge and Gailing, 2020).

Contributions to this collection highlight the porosity of the political economic/ecological boundary in advancing their own takes on these questions of incumbency and transition—often conjoined with ongoing political ecological insights on land politics and land-based industries. For example, Buck (this volume) does so in her analysis of emerging sociotechnical imaginaries of CCUS. Late 2010s proposals to reimagine carbon capture as “circular carbon” play into fossil sector strategies for avoiding disassembly via new forms of hybrid industrial positioning (Christophers, 2022b). In Buck’s case, they do so within broader discourses of a “circular economy.” Buck notes that in addition to framing fossil energy as a potential net-zero emitter, these imaginaries are materially enabled by newly cheap renewables as a support technology. As discussed above, Buck also suggests that these speculative visions will live or die not necessarily on their contested low-carbon bona fides, but rather on their under-examined reliance on land-intensive infrastructures like carbon dioxide pipelines.

Behrsin et al. investigate other forms of incumbent industrial entry into the U.S. renewables space, in their case a range of “dirty” land-based industries’ efforts to recast their wastes (coal byproducts, agricultural waste, forestry litter) as renewable energy forms. They suggest that incumbents’ efforts to shape renewables classification in their favor may help these industries rebrand, provide them fresh lines of accumulation and reshape their regional economies—though frequently with problematic environmental justice outcomes on the ground. Meanwhile, Vaishnav and Baka analyze a different, though no less controversial, kind of land-intensive incumbent: hydropower as a long-contested renewable energy form. They explore new hydropower development initiatives as the sector sees fresh life in a number of ways. These include the emergence of “run of the river” technologies, new calls for pumped storage hydropower around rising energy storage needs in a renewables-dominant grid (see also Turley et al., 2022) and the demands of regional development strategies—in their case, the Indian Government’s promotion of geologically unstable development frontiers in the Himalayas.

(3) *Locating Power within Technical and Artifactual Politics*

How such new industrial strategies are being advanced matters. Spivey (this volume) argues that in answering this kind of question political ecology requires a better theory of technology, including through deepening its conceptual engagements with STS. Spivey particularly considers tools needed to investigate understudied transition technologies and technological concerns such as networked transmission infrastructures and power load balancing (see also Kennedy and Stock, 2021; Turley et al., 2022). However, his argument speaks also to longer discussions across political ecology, political economy and STS. The broader social scientific turn to the study of markets and marketization in the 2000s (see, e.g. Callon, 1998; Mackenzie, 2008; Berndt and Boeckler, 2009) furthered the analysis of technical politics in many ways—for example, via the social study of expertise, devices, performative narratives and practices of calculation and classification. In political ecology as well as political economy, this “cultural economic” turn provoked early tensions with the Marxian roots and production focus of both fields (see Boyd et al., 2001 vs Smith,

2007; Robertson, 2012). The current collection demonstrates the usefulness of strategically synthesizing these approaches, or using their toolkits in complementary ways within projects (see Peck, 2012; Christophers, 2014). Many contributions here put scrutiny of technical politics into conversation with situated political economic analysis, furthering more nuanced understandings of political power within renewable energy transition.

For example, the renewable classification strategies that Behrsin et al. analyze become meaningful in and through their incorporation in state-level renewable portfolio standards (RPSs), the United States' chief policy instrument for procuring renewable energy. States' regional political economic bases are significant here in influencing regulators' attitudes toward important incumbent industries. However, the United States' available technical policy instruments also shape these outcomes: for example, that states are free to adopt RPSs which sponsor a wide range of renewable energy forms, and that their state-level scaling makes them particularly susceptible to "capture" by regionally important industries. This multidimensional theory of power—a combination of situated political economic analysis and attention to the politics of particular instruments, classification schemes and other technical dimensions of renewable energy transition—runs across papers in the collection.

In another example, both the power of the Indian state and specific state-backed discourses and classification strategies are crucial to Vaishnava and Baka's interpretation of how Himalayan hydropower development has been maintained in the face of high risks and costly project failures. Particularly, they examine state narratives and practices that have been used to insulate private hydroelectric developers from the financial risks of project failures, while displacing these costs onto power users and communities exposed to harm. Meanwhile, Buck considers the "double unseeing" of CCUS experts and under-examined but necessary constituencies on the ground. Spivey's analysis problematizes the seemingly neutral technical category of transmission "grid capacity" in Japan's post-Fukushima energy transition. He explores how national regulators privilege certain forms of technical expertise (and marginalize competing "counter-expertise") in defining this capacity, and how this "rendering technical" (Li, 2007) conceals support for particular incumbent interests. In his case, incumbency is demonstrated in Japan's embedded nuclear power lobby, which has sought to maintain a foothold for the technology despite the post-disaster national moratorium and major public interest in renewable alternatives. It also encompasses certain regulators willing to privilege the perceived stability of the transmission grid, challenged by the rapid entry of variable renewable sources and the withdrawal of nuclear baseload power, over the demonstrated risks of nuclear energy in a tectonically active country.

Across the collection, other contributions explore similar questions of how mainstream political power works in and through the deployment of certain technical instruments—more particularly, how a specific version of renewable transition attractive to international investors is being privileged in many regional and national governments' deployment programs. As others have explored (Baker, 2015, 2021; Kennedy, 2018; Knuth, 2021; van den Bold, 2021) that vision is characterized by very large "utility scale" projects, alongside other characteristics to bolster projects' profitability and lower their perceived risks to investors. In this light, Sareen scrutinizes sustainability metrics, particularly solar transition metrics used in Portugal's national renewable energy program. Particularly, he critiques dominant national metrics for failures of legitimation and accountability, in ignoring how community-scale renewables might contribute to meeting national energy/climate goals. Similarly, Calvert et al. consider the rural land-use plan as an instrument, particularly how Canadian regional attempts to "upscale" large-scale renewables planning and bypass municipal authority have backfired and heightened local resistance. Finally, Avila et al. consider the Mexican national government's recent history of mapping initiatives to define renewable resource potential, and the forms of mainstream power reified—and alternatives rendered invisible—in this technical practice.

In a related theoretical vein, and with Mitchell's (2011) *Carbon Democracy* as a frequently cited exemplar and inspiration, several contributions here work to integrate attention to materialities,

assemblages and “artifactual politics” that has long been advanced by STS—with similar histories too of contestation and evolving synthesis with political economy and political ecology (e.g. Kirsch and Mitchell, 2004; McFarlane and Anderson, 2011 vs Brenner et al., 2011 and Appadurai, 2015, but then Ranganathan, 2015; Demaria and Schindler, 2016; Baker and McGuirk, 2017 and others). In expanding this toolkit for analysis of renewable energy transition, authors contend with such pre-existing critiques of these approaches. Critics frequently have warned of their capacity to flatten power relations and sacrifice structural political analysis—both foundational concerns for political economy and political ecology. In a different sense, artifactual forms of explanation contend with longer histories of “technological determinism” and “energy determinism” in mainstream social and historical explanation, which exerted their own artifacts-led flattening of complex causation and power relations.

In response, Vaishnava and Baka take up Barry’s (2013, p. 152) useful note on such questions that “materials acquire more-than-local political agency only occasionally, not in general.” This interpretation suggests that political ecology’s task then becomes to investigate these contingent moments of potential power—and, notably, to situate them within grounded power relations and forms of structural inequality. Such contextually specific dynamics shape both the realization of these moments and their consequences; for example, in the form of infrastructural failures produced, but then also structurally uneven risk exposures and reparations in the wake of these disasters. In furthering this line of investigation, Vaishnava and Baka consider Himalayan run of the river hydropower projects as assemblages. They argue that theories of the assemblage are valuable not only for emphasizing the heterogeneous human and more than human constituents of hydropower systems but, more particularly, the again-contingent nature of these projects and development programs: in a highly challenging geological and developmental context, it is instructive to ask how such initiatives have (so far) been reassembled despite their risks. The authors draw on STS’s concept of boundary objects to further theorize the holding-together work performed by regulatory narratives of “geological surprise.” Regulators thereby classify failures and harms created by development in an unstable environment as unknowable “Acts of God” (in a legal sense) rather than foreseeable and preventable outcomes. Simultaneously, they help the political economy of hydropower development pencil out in the ways discussed above.

In a similar vein, Spivey (this volume) takes up theories of technopolitics as a vehicle for reconciling the study of artifactual politics derived from STS with political ecology’s more structural and historical accounts of power. Spivey emphasizes that artifacts such as transmission grids exert important power in the imagination and conduct of social life but that “acknowledging this does not require subscribing to an ahistorical technological determinism...[r]ather, it means recognizing that a kind of hidden legislative work [and durable ordering] takes place in the design and material construction of those systems.” He argues that technopolitics emerge out of these processes of design and construction, as well as in anti-political bodies of expertise produced through their operation and governance thereafter—including the tactics for delegitimizing critiques and alternatives that become a central feature of his analysis. Simultaneously, this interpretation brings in political economic concerns for networked infrastructures as fixed capital themselves, and as vehicles for devaluing or extending the economic life of *other* fixed capital such as power generation facilities. Artifactual expertise is being deployed in this case precisely in service of such concerns for stranded assets and economic loss in an energy transition.

(4) *Generating Knowledge and Tools for Just Transitions*

Finally, the collection does important work to advance a more just renewable transition. Contributions do so in political ecology’s more critical vein—particularly in developing a sharper analysis of the terrain of political power in renewable energy development, rising areas

of contention and alternative visions of renewable transition emerging in the field (Bollman, 2022; Hudlet-Vazquez et al., 2022). Some also make creative interventions in political ecology's more engaged and praxis-oriented mode, working with movement partners to hone engaged approaches and toolkits. In both, it is vital to consider how movements against exploitative forms of renewable energy may acquire power beyond the local. These are classic questions for political economy and ecology: how can diverse place-based mobilizations and "militant particularisms" (Harvey and Williams, 1995) translate their wins, build their power collectively, and "jump scale" (Smith, 1992)? Furthermore, how can movements advance not only models of effective resistance but qualitatively different *versions* of development? In the case of the renewable energy transition, how can they make renewable energy models more just and democratic?

One way in which contributions help answer these questions returns to land-based concerns, in underlining the diverse land transformations that new renewables' development inherits and furthers. As Calvert et al. (this volume) argue: "for the foreseeable future at least, the energy transition is yet another moving part in a broader and ongoing process of rural transformation." Widespread trends include legacies of land-based industrial development and change, and often rural depopulation and land abandonment (Behrsin et al., Buck, Spivey). Incumbency also encompasses prior episodes of land-intensive energy extraction and development, from fossil fuels (Behrsin et al.) to hydropower and nuclear regimes (Vaishnava and Baka, Spivey). Crucial here are embedded agrarian patterns of racialized and classed land dispossession, historical and ongoing; unequal access to sociotechnical goods; and disproportionate exposure to compounding harms, now including from climate change (Avila et al., Bedi, Vaishnava and Baka). Papers draw on these insights to interpret the site-specific rural politics that new renewable energy projects encounter.

For example, Calvert et al. draw out new insights on rural protectionism and "defensive localism" around renewables' development, sometimes embedded in extant processes of "rural gentrification" and amenity migration (Calvert et al., and see Walker, 2003). They note that political ecologists must "ask questions about the 'kind' of rural landscapes that are protected and for whom/what purpose." These mobilizations are taking on diverse political orientations as they join extant land struggles and preexisting resistance to fossil fuel infrastructures such as pipeline projects. These complex politics include both right and left populisms (e.g. Knuth, 2019; McCarthy, 2019; Bosworth, 2022) and myriad variants of "resource nationalism" (Koch and Perreault, 2019; Riofrancos, 2022). As other recent work has shown (Cantor and Knuth, 2019), they also include complex invocations of classic environmental justice concepts like the "sacrifice zone" (Bullard and Wright, 2009). Contributions here underline that renewable energy's new resource frontiers and "working landscapes" may indeed create or reify extractive geographies and sacrifice zones. In this sense, disempowered rural places and populations are asked to bear direct costs of new generation, transmission and energy storage development, while most of the energy produced goes to serve cities, wealthy and middle-class households and other more powerful interests (and see Bedi, this volume). These new axes of sacrifice and exclusion may worsen older forms along lines of race and gender (Lennon, 2017; Lohmann, 2020) caste (Bedi), indigenous identity and/or sovereignty (Avila et al.) and beyond. Meanwhile, in some rural sites of renewable energy expansion, largely white settler colonial populations have taken up narratives of sacrifice and the sacrifice zone to defend their own interests (Cantor and Knuth, 2019). Parsing these differentiated claims on reparative justice is no easy task (though also not unfamiliar terrain for political ecology; e.g. McCarthy, 2002).

Part of political ecology's contribution to advancing a more just transition is in building better tools and approaches, across these rural sites and beyond. These contributions may be useful for generating more nuanced pictures of political resistance to renewables, as well as in helping justice movements advance their goals. Buck provides a useful example of the former, in taking

up the “social transect” as a method; in her case, along a proposed interstate carbon dioxide pipeline for CCUS in the United States. This approach draws from the study of fossil energy infrastructures, including important work on pipeline geographies and resistance tactics (e.g. Barry, 2013; Appel et al., 2015; Bosworth 2022). These network studies have important insights into renewables. Beyond Buck’s example, this is particularly so amid calls to modernize transmission grids for renewables (Spivey), as the siting of new and expanded transmission corridors becomes a rising site for contestation. Buck’s case suggests that the use of the social transect method is particularly promising in its ability “to surface a diversity of perspectives that may not have been surfaced if the method was simply contacting pre-defined stakeholders...[and to] hear situated perspectives from inside the landscape which may not otherwise be heard.” The method does not try for a perfect representation of all perspectives, but “can be a check against assuming who is an important ‘stakeholder,’ as is often done in public engagement around new infrastructure.”

Other contributions to the collection similarly work in this movement tool-building mode. For example, Sareen’s paper generates translatable models and rubrics for evaluating deliberative justice and legitimation in programs of renewable energy development. Similarly, Avila et al. work with movement partners to advance countermapping techniques and strategies that can be used across diverse sites targeted for renewables deployment. The authors situate this resistive project in (counter-)relation to official mapping strategies that the Mexican Government uses to attract investors to the sector, and the ways in which these resource mapping tools render invisible complex landscapes and land politics. The project creates databases and maps to “fill” these spaces and relations, speaking to existing struggles by rural and indigenous communities to claim recognition for their land rights. Moreover, it responds to a long-standing challenge for political ecology and environmental justice in “go[ing] beyond the ‘case study-based approach’...[by presenting] a useful research tool to identify patterns, reveal relationships among multiple cases and actors as well as describe how such conflicts are shaped by the larger political economy.” They argue that “[w]hile countermapping practices operate, by definition, with localized concerns, discourses and tactics, a focus on these approaches could simultaneously integrate ongoing struggles over indigenous lands, with larger citizen movements pushing to de-commodify the production of electricity in different territories.” In this important way, the technique stands to advance both political ecological interpretation and movement-building across diverse contexts, while the project itself advances a useful model of scholarly praxis.

Further directions

Finally, to this important point on praxis, the collection captures an important moment in energy justice and democracy movements. This moment includes significant points of disjuncture, though hopefully also new areas for generative discussion and the emergence of differentiated and context-responsive strategies. All of these questions require more sustained engagement from political ecology.

This rising debate centers around how more just models of the renewable energy transition are conceived, and diverging visions for making renewables live up to their potential as liberatory “technologies of existence” (Powell, 2006). Consistent with much energy democracy organizing to date, alternatives to the kind of large project favored by mainstream investors and governments have often been imagined to lie in local solutions and distributed energy models such as rooftop solar and community energy (see, e.g. van Veelen and van der Horst, 2018). Many contributions to the collection note this advocacy, a commentary on its international scope today (and see other important critical interventions such as Luke and Heynen, 2020). For example, Sareen explores community-scale renewables as an important absence in Portuguese strategy, while Vaishnava and Baka consider the “technological reclamation” potential of micro-hydropower

alternatives in the Himalayas. Spivey tracks advocacy that positions small-scale solar power as a more “grassroots transformation of Japan’s energy system.”

However, the collection also advances growing critiques and qualifications of this proposed scalar solution. Notably, while Bedi suggests energy cooperatives as one model for a more just transition in Kerala, India, she also finds many problems in the way distributed energy has been deployed in the state. After widespread protests against utility-scale solar projects, the state of Kerala turned to rooftop solar as a favored solution—but simultaneously rolled back its prior commitment to addressing energy poverty in favor of prioritizing uptake of renewables by middle- and upper-class households. This shift reproduced class and caste exclusions, as it privileged a renewable technology (rooftop solar) unaffordable to the poor and those without stable access to electricity, by either improving access to cheap power from big projects or a focus on smaller-scale technologies such as cell phone charges, lamps or water heaters. Critical scholars have critiqued other rooftop solar initiatives for these potential class-race exclusions (Aronoff et al., 2019). Meanwhile, other interventions have warned of distributed energy’s growing attractiveness to would-be tech “disruptors” (including large companies like Tesla) and vulnerability to emerging forms of financialized extraction (Knuth, 2018). Neither is the cooperative model a panacea, despite its promise (Hanna et al., 2022).

Rather, crucial questions of ownership and democracy in a renewables transition are essentially *political* rather than narrowly technological. No one renewable technology or scale of deployment can in and of itself ensure a just and democratic transition. That depends significantly on political movements to connect diverse renewable energy forms to geographically specific needs and justice struggles. Deeper political questions around ownership and democratic accountability must also necessarily arise here. For example, Calvert et al.’s intervention argues for the importance of the democratic process: communities ignored versus deliberatively brought into planning may have very different attitudes toward renewables across scales—including, potentially, larger scale projects. Similarly, Avila et al.’s contribution speaks to broader movements both to decarbonize and decommodify energy. Calls for decommodification and public power encompass a range of scalar visions, including varying project sizes and diverse scales of public ownership. Models include community-based energy, cooperatives and other distributed energy forms but also the regional and national visions embedded in progressive and radical proposals for a Green New Deal (see, e.g. Aronoff et al., 2019; Bozuwa et al., 2021).

In conclusion, this collection makes many important advances in political ecology’s scope for critical analysis and praxis around renewable energy transition—in deepening understanding of land transformations driven by renewables, furthering insights and approaches in political ecology’s trading zones with political economy and STS as well as advancing practical insights and tools for movement-building. However, it is likewise important that the collection does not represent the totality of political ecology’s developing explorations and interdisciplinary conversations around renewable energy transition—itsself reflective of the field’s now robust, diverse and fast-growing engagements with the topic.

Future work might usefully pick up these other important threads. Some involve ongoing conversations with already-significant political ecological research on biofuels and the bioeconomy (e.g. Bailis and Baka, 2011; Fairhead et al., 2012; Carton, 2016; Palmer, 2021). Others pose newer questions for the field—or old questions returned in new technological forms. For example, enthusiasm for renewable energy’s potential and its genuine advantages over fossil fuels too often obscures most current renewable energy technologies’ reliance on a variety of strategic minerals that remain finite, geographically specific stocks rather than widely distributed flows, and whose extraction and processing often replicates some of the worst elements of fossil fuel extraction (see, e.g. Klinger, 2018; Black, 2018; Mulvaney, 2019; Riofrancos, 2022). These concerns apply to the production of renewable technologies and provoke questions of the varying extractive demands posed by different technologies and preferred scales of implementation. They also encompass necessary

questions about processes of maintenance, repair and end-of-life disposal. Despite its necessary centrality to any Marxian or political economic analysis of the sector, analysis of the labor geographies of renewable energy similarly remains in its infancy. As noted above, the same could be said of the political ecologies of renewable energy transmission and storage, as opposed to generation (though see Spivey this volume, Turley et al., 2022)—whether through a lens of value theory, access to and control over land, emergent extraction geographies or political and economic tensions between integration and autarky central to potential futures for renewable energy systems.

A major development in political ecology was the turn toward Foucauldian and Gramscian attention to micropolitics, identities and subjectivities. Inasmuch as we are all arguably thoroughly interpellated into fossil capitalism, major questions remain about what identities and subjectivities might be produced with and through energy systems dominated by renewable sources. Political ecology offers important opportunities to more deeply situate renewable energy transitions within everyday life fabrics, as well as emergent pathways for political consciousness and organizing. One pathway for doing so is expanding critical lines of questioning within urban political economy/ecology—for example, on the retrofitting and remaking of built environments for energy efficiency and distributed energy resource formation, or in new mobilities, transportation technologies and flows within urban space (Knuth, 2019; Stehlin, 2019; Knuth et al., 2020; Thoyre, 2021). Contributions to the current collection track some forms of difference inflecting uneven experiences of renewable energy transition. However, more work is needed to advance political ecology's growing engagements with gendered difference and feminist methods, as well as the many forms of racialization and racial capitalism deeply embedded in today's energy systems—and, without intervention, energy systems to come. Legacy injustices must better inform existing organizing for energy transition (Lennon, 2017, 2020; Sunter et al., 2019; Lohmann, 2020). Likewise, emerging scholarship (e.g. Luke and Heynen, 2020; Lennon, 2021) argues that broader antiracist movements will play a key role in driving more just and reparative low-carbon futures. All are core concerns for a 21st-century political ecology.

Highlights

- The rapid growth and “mainstreaming” of renewable energy demands critical appraisal and engagement to drive a just low-carbon energy transition.
- Political ecology is well-positioned to lead critical and engaged scholarship in support of energy/climate justice.
- Issue contributions advance key analytical pathways in (1) Theorizing Renewables-Driven Land Transformations and (2) Advancing Industrial Political Ecologies of Renewables.
- Further contributions include (3) Locating Power within Technical and Artifactual Politics and (4) Generating Knowledge and Tools for Just Transitions.
- Further research directions include debates over scale, ownership and accountability models for energy justice; and new renewables-related extractivism and racialization/s.


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