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Who are the victims of low-carbon transitions? Towards a political ecology of climate change mitigation

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Abstract: This study critically examines 20 years of geography and political ecology literature on the energy justice implications of climate change mitigation. Grounded in an expert guided literature review of 198 studies and their corresponding 332 case studies, it assesses the linkages between low carbon transitions—including renewable electricity, biofuel, nuclear power, smart grids, electric vehicles, and land use management—with degradation, dispossession and destruction. It draws on a framework that envisions the political ecology of low-carbon transitions as consisting of four distinct processes: enclosure (capture of land or resources), exclusion (unfair planning), encroachment (destruction of the environment), or entrenchment (worsening of inequality or vulnerability). The study vigorously interrogates how these elements play out by country and across countries, by type of mitigation option, by type of victim or affected group, by process, and by severity, e.g. from modern slavery to organized crime, from violence, murder and torture to the exacerbation of child prostitution or the destruction of pristine ecosystems. It also closely examines the locations, disciplinary affiliations, methods and spatial units of analysis employed by this corpus of research, with clear and compelling insights for future work in the space of geography, climate change, and energy transitions. It suggest five critical avenues for future research: greater inclusivity and diversity, rigor and comparative analysis, focus on mundane technologies and non-Western case studies, multi-scalar analysis, and focus on policy and recommendations. At times, low-carbon transitions and climate action can promote squalor over sustainability and leave angry communities, disgruntled workers, scorned business partners, and degraded landscapes in their wake. Nevertheless, ample opportunities exist to make a future low-carbon world more pluralistic, democratic, and just.

Keywords: political economy; political ecology; low-carbon transitions; energy transitions; climate change mitigation; renewable energy; mobility

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1. Introduction

Low-carbon sources of energy are often framed as more equitable, egalitarian, and just than their fossil-fueled or carbon-intensive counterparts (O’Sullivan et al. 2020; Lacey-Barnacle 2020; Crow and Li 2020; Jenkins et al. 2019; McCauley et al. 2019; Szulecki 2018; Alister 2017; Hernández 2015; Sovacool and Dworkin 2014). These academic findings are bolstered by recent investment and finance scenarios which anticipate a truly massive expected uptake of low-carbon technologies in the years to come. The International Energy Agency (2014) predicts that \$48 *trillion* will need invested to meet global energy needs by 2035, and updated their projections to suggest at least *half* of these amounts will need to be funneled into renewable electricity sources and energy efficiency efforts (International Energy Agency 2019). Such investment is increasingly guided not only by public funds but private banks, state investment banks, and even multilateral development banks (Geddes et al. 2018; Steffen and Schmidt 2019). Correspondingly, anticipated adoption and diffusion

rates for renewables and other climate mitigation options are expected to grow exponentially (IRENA 2018; McKinsey & Company 2019).

Nevertheless, such a low-carbon revolution could usher in not only significant changes in energy markets, investment flows, buildings, and power plants; it could also directly affect the vitality and vulnerability of particular communities and marginalized spaces (Bumpus and Liverman 2008; Sovacool et al. 2019). Yet the literature on energy and sustainability transitions has generally avoided discussing issues of power and vulnerability (Lawhon and Murphy 2012; Geels 2014; Kohler et al. 2019; Hulme 2008).

It is with these possible lacunae in mind that the present study systematically examines the political ecology and injustice of climate change mitigation and low-carbon transitions. It does so by examining not only sources of renewable electricity such as wind, solar, and hydropower, but also broad range of mitigation efforts including nuclear power, biofuel, changes in land use, and end use devices such as electric vehicles, fuel cells, and energy efficiency improvements. It undertakes an interdisciplinary and expert guided critical review of 198 studies over 20 years. As a guiding lens, it uses a political ecology framework of that examines the potential for climate mitigation to perpetuate enclosure (capture of resources), exclusion (unfair planning), encroachment (destruction of the environment), or entrenchment (worsening of inequality or vulnerability). Its primary aims are twofold: to offer a comparative, comprehensive, and global review of the political ecology of climate mitigation that moves away from single country cases; and to look one-step further and more deeply at how injustice becomes embedded in specific economic, political, ecological and social processes.

Going forward, the review first summarizes its political ecology framework before explicating the particular research methods utilized to examine the literature. It then proceeds to discuss its results (organized by geographic and technological case studies, political ecology processes, and vulnerable groups) and a discussion of five critical avenues of research before concluding. Better grappling with the political ecology of climate mitigation is vital if our global energy future is to be fairer, more equitable, and more just.

2. A political ecology framework for climate mitigation

To both ground the review in the existing literature, and also offer a heuristic for analyzing the results of the review, this study applies a political ecology framework developed by Sovacool et al. (2015) and Sovacool and Linnér (2015). Of course, this framework is not the only one drawing from political ecology or political economy to discuss

power relations or vulnerabilities in climate mitigation or energy transitions. At an even broader level, more scholars are coming to recognize how processes of sustainable development or climate change mitigation can become complicit in condoning ecological degradation or perpetuating violent conflicts (Dunlap and Fairhead 2014; Hunsberger et al. 2017; Mirumachi et al. 2020). Other frameworks within this body of political ecology or political economy work include Martinez-Alier and O'Connor's (1996) "ecological distribution conflicts," Gramsci's (1971) notion of "hegemony," and even Foucault's (1982) notion of "disciplinary power." These frameworks all share a concern with critically analyzing some degree of power relations and vulnerabilities, as well as unjust patterns of colonialism, racism, patriarchy, militarization and structural violence.

What is unique is that this particular framework envisions four different processes that can shape social climate responses across the economic, political, ecological, and social dimensions shown in Table 1. The table also reveals the broad interdisciplinary foundations for the framework as well as the multiple sub-processes which are identified conceptually within these various literatures. As an additional novelty, so far the framework has been applied to climate change adaptation (Sovacool et al. 2017; Sovacool 2018), as well as disaster recovery (Sovacool et al. 2018; Lin 2019) but not yet climate mitigation.

Table 1: A political ecology framework encompassing enclosure, exclusion, encroachment, and entrenchment

Concept or process	Dimension	Explanation	Sub-processes	Disciplines
<i>Enclosure</i>	Economic	<i>Capturing resources or authority:</i> transferring public assets into private hands, or the expansion of private roles into the public sector	Territorial accumulation, privatization, market stretching, parallel bureaucratization, land grabbing	Political geography, environmental geography, public policy, public administration, neo-Marxism
<i>Exclusion</i>	Political	<i>Marginalizing stakeholders:</i> limiting access to decision-making processes and fora, unfair planning or policymaking procedures or access to recourse	Dispossession, accumulation by dispossession, tyranny	Political ecology, climate policy, development studies

<i>Encroachment</i>	Ecological	<i>Damaging the environment:</i> intruding on biodiversity areas or other areas with predisposed land uses, interfering with ecosystem services, shifting emissions sources (but not reducing them)	Commodification, subordination, forum shopping	Ecology, environmental science, biodiversity conservation, consumption studies
<i>Entrenchment</i>	Social	<i>Worsening inequality:</i> aggravating the disempowerment of women or minorities, exacerbating vulnerability, and/or worsening concentrations of wealth	Comparative advantage, elite capture, sexism, racism, ethnic discrimination	Welfare economics, environmental justice, gender studies, political economy

Source: Author, modified from Sovacool et al. (2015) and Sovacool and Linnér (2015)

2.1 Enclosure

The process of “enclosure” refers to when public assets are transferred into private hands, the roles of a private actor are expanded into a formerly public sphere. It relates in part to how private institutions, especially corporate actors, intensify their efforts to penetrate into more remote or peripheral areas from which they can derive revenue (McCarthy 2009). It incorporates actions into a strategy of “territorial accumulation” (Hoogvelt 1987: 3) or the expansion of capital as it “stretches” the reach of markets to encompass remote areas, and “deepens” capitalism by allowing it to penetrate into the provision of more goods and services (Prudham 2009). Activities become “enclosed” as part of the strategy of accumulation for capitalism and those it serves (Harvey 2003; Bridge 2011; Bond 2012), or part of a process of “accumulation by decarbonisation” (Bumpus and Liverman 2008).

These types of enclosure can have many causal mechanisms (White et al. 2012). In some cases, corporate actors can invest in solutions that are land-intensive, such as genetically engineered crops or the growing of feedstocks, and forcibly displace people. In others, land and natural capital might be directly appropriated for environmental ends, such as circumventing restrictions on logging in an old-growth tropical forest to expand the

production of biofuel. In still others, national or corporate “land deals” or “green grabbing” may legally set aside land for other uses such as economic development or the creation of jobs (Benjaminsen and Bryceson 2012). Enclosure can also occur whenever industrial scale renewable energy relies upon “the appropriation and enclosure of new elements of nature, and the displacement and dispossession of economically and politically marginal populations, particularly in the global South” (McCarthy 2015: 2497).

2.2 Exclusion

The process of “exclusion” occurs frequently in tandem with enclosure (Heynen and Robbins 2007). It refers to unfair planning, policymaking, or lack of representation, recognition, and due process. Exclusion amounts to a strategy of containment, a way to prevent and manage other actors from interfering with one’s interests. The process of exclusion enables resources to be appropriated or consolidated by state authorities, private firms, or social elites (Robbins 2012). In other cases, small countries or indigenous people have seen their social systems, ways of knowing, and values marginalized or ignored in the formulation of policy (Barnett and Campbell 2010; Adger et al. 2009). In still other cases, local decision-makers, inland towns, and small farming communities may be excluded from influencing the institutions with the most sway over the distribution of resources. Anguelovski et al. (2016) add that exclusion can be engrained further in selective land use regulations, resettlement procedures, or even infrastructure plans and building codes.

The process of “exclusion” is close to the notions of “dispossession” and “accumulation by dispossession” (Harvey 2004) affiliated with capitalism, or that of the “new tyranny” affiliated with unfair decision-making processes (Cooke and Kothari 2001). Government actors and others involved in the policy processes can deliberately underprovide public support to avoid creating green constituencies (Aklin et al. 2013), or put forth confusing or poorly formed regimes of accountability that can render low-carbon initiatives contestable while locking in unfair transitions dynamics (Sareen and Grandin 2020). As a result, decision-making becomes exclusionary to particular groups of people or spatial communities.

2.3 Encroachment

The process of “encroachment” puts the “ecology” of political ecology into the framework. It refers to when climate mitigation projects damage the natural environment via pollution, carbon emissions, or other ecological insults. Mitigation efforts can intrude or infringe upon protected areas, national parks, wildlife reserves, or other areas with

predisposed uses, or interfere with the healthy functioning of an ecosystem. Climate mitigation can, because it is primarily concerned with building human resilience, undermine the resilience of natural ecosystems (Turner et al. 2010: 304). Examples here include the land-use requirements for wind farms, the mineral inputs for batteries and solar panels, the fertilizers needed to cultivate crops for biofuels, the fugitive methane emissions linked to manufacturing hydrogen, or the widespread environmental impacts of uranium mining for nuclear power.

Encroachment need not always be so obvious or direct, however. It can operate as part of a sub-process of commodification, one that transforms biodiversity and other protected assets into “productive” uses that we can utilize to combat climate change while generating profit (Castree 2003). It can also operate as a sub-process of subordinating other policy or societal goals—such as protecting the sovereignty of indigenous peoples, or the wishes of rural communities—to climate goals, putting climate action ahead of other desirable goals. Encroachment can lastly occur as part of a sub-process of “forum shopping” where perceptive investors or firms look for areas amenable to encroachment to keep costs low and socialize externalities to parts of society with little protection from them (Biermann et al. 2010).

2.4 Entrenchment

“Entrenchment” refers to when climate mitigation activity results in uneven patterns of development, or are not affordable or fairly accessible to all affected groups. A climate project may aggravate structural inequalities and the disempowerment of disadvantaged or vulnerable groups. It “entrenches” inequities by interfering with egalitarian systems of distribution, by further concentrating wealth within a community, or by hurting vulnerable members of a community, such as artisanal fishers, women, children, refugees, or ethnic minorities. It is typically wealthier households, members of majoritarian groups, or national and global elites that possess the requisite assets to maintain resilience in the face of climate change, or in extreme situations take advantage of vulnerable groups. Poorer actors, by contrast, cannot generally afford to undertake these activities. Anguelovski et al (2016) emphasize that entrenchment can occur both by acts of omission—such as diverting investments from poor communities, failing to engage poor communities, or creating enclaves around wealthy districts—as well as acts of commission such as displacing the poor from settlements, relaxing standards, or disbursing funds to wealthier groups rather than communities. Climate mitigation projects thus become an elemental part of “risk

transference” between communities, e.g. the one that benefits from a wind farm or the jobs from ethanol, whereas another does not, which can introduce or heighten inequality. Low-carbon transitions pathways can thus entrench or cement particular social relations, including those among powerful groups, advocates, political parties or governments (Rosenbloom et al. 2019).

Sub-processes closely linked to entrenchment include “comparative advantage” and “elite capture.” Comparative advantage refers to the way in which climate projects can disrupt existing distributions of products and services that result in uneven distribution of benefits. Climate action may catalyze local, national, and even global regimes that comparatively benefit some and hurt others. Elite capture refers to when resources appropriated to the masses or poorer stakeholders become captured or usurped by politically or economically powerful groups (Dutta 2009; Platteau 2004).

2.5 Caveats and synthesis

In applying this framework, it is apparent that its connections with energy justice and political economy are just as salient as those with political ecology. However, the “political ecology” framing is apt because the author views political ecology as less a set of prescribed tenets or concepts, and more a loosely backed collection of themes. Rather than always offering a coherent or synthetic theoretical agenda, political ecology encompasses a celebration of diverse sets of inquiries with a common focus or shared concern for addressing inequality, injustice, and asymmetric power relations at the nexus of people and the environment. It is here that the framework seeks to identify the “base propositions” or “common denominators” that negatively shape climate change mitigation.

The framework does have a particular *take* on political ecology which situates the processes of enclosure, exclusion, encroachment, and entrenchment at the nexus of human ecology, political economy, and vulnerability shown in Figure 1. From this vantage point, political ecology sits at the nexus of political economy and human ecology, conceived as potentiality and resilience to shocks. The framework also has strong elements of energy justice, which is conceived as transcending capacity and class relations. The framework lastly has elements of human capabilities, the agency and entitlements afforded to particular groups that have (or do not have) ecological or human assets to address or minimize vulnerability.

Figure 1: Conceptualizing the political ecology framework of enclosure, exclusion, encroachment, and entrenchment

Source: Author, with inspiration and substantial modification from Bohle et al. (1994).

As also indicated in Figure 1, each of the four processes “sits” closest to a core thematic area. Encroachment reflects the human and ecological impacts of climate projects, connecting closest with *human ecology*. In line with Bohle et al. (1994), human ecology is conceived as the ways in which perturbations to nature intersect with human labor as well as specific ecosystem properties. Human ecology is not merely the application of ecological concepts to the inquiry of society, but instead a recognition of how social organizations directly implicate sustainability and environmental risks. Entrenchment connects most closely with *vulnerability*, and how particular individuals, households, communities, or other groups of people are exposed to possible damage from climate projects. Vulnerability here is not only shaped by exposure and the extent of human capabilities, it is also shaped by social relations and the reproduction of ethnicity, class, caste, gender and heritage. It is possible to depict both vulnerable areas (spaces, regions) and vulnerable groups (social actors) within this conception of vulnerability. Enclosure and exclusion reside most closely to *political*

economy, which is envisioned as the mutual shaping of resource endowments and class relations. Implicit here is the notion of regimes of accumulation, which configure class processes, and market failures and crises of overproduction, which often create pressures that motivate the rationales behind enclosing new resources or excluding stakeholder groups.

In Figure 1, the four processes occur at the intersection of these axes and produce three parallel analytical concepts which are central to our explanation of injustice and exposure to low-carbon energy or mitigation. As is perhaps obvious, the three sides of the analytical triangle— as human ecology, vulnerability, and political economy—can be understood as a jumble of social relations and therefore each point of triangulation represents a dynamic network of ideas and literatures that often overlap with the other two coordinates. The triangle also reflects the interconnected and system-wide aspects of these analytical categories, as perturbations in one point of the triangle can cascade and affect the entire map of interests or processes—something confirmed later in the study by the frequency by which each of the four processes of enclosure, exclusion, encroachment, and entrenchment occur together.

3. Research methods: An expert guided literature review

With the framework in place, this section briefly overviews how climate change mitigation is conceived, the contours of the expert guided review, and limitations with the approaches taken.

3.1 Conceptualizing climate change mitigation

The study focuses on the political ecology of climate change mitigation, rather than the political ecology of fossil fuels, because much of the latter is already well known. Seminal work includes Healy et al.'s exploration (2019) of the “embodied injustices” of fossil fuels or Sundqvist's (2004) meta-survey of the social harms (externalities) of fossil fuels. Other notable studies have looked at the way fossil fuels promote violence, authoritarianism and the resource curse, and otherwise reconfigure space and social identity in problematic ways (Daggett 2018; Huber and McCarthy 2017; Parenti 2011).

Climate mitigation refers to activities that reduce or stop the emissions of greenhouse gases into the atmosphere. Mitigation is distinct from geo-engineering (greenhouse gas removal, solar radiation management) or adaptation (building resilience to the impacts of climate change) as shown in Figure 2. For the purposes of this review, climate mitigation efforts were clustered into three broad categories:

- Land use and management, including agriculture and forestry;
- Energy demand and end use devices, including energy efficiency, electric vehicles, hydrogen fuel cells, and smart meters;
- Low-carbon energy supply, including solar energy, wind power, hydroelectricity, waste to energy, and biofuel as well as nuclear power.

Figure 2: Conceptualizing climate change mitigation, geoengineering, and adaptation

Source: Author

3.2 Expert guided literature review

The author wanted a research method that was comprehensive enough to capture a wide range of comparative sources and studies, but rigorous enough to capture only studies that were regarded as first-rate or seminal in the field. An expert guided literature review seemed well suited to this task.

The author contacted 50 prominent scholars working in the space of the geography of climate mitigation or the political ecology and economy of energy transitions in early 2020 (see Appendix I). These experts were asked to recommend “highly cited” or “seminal” work on low-carbon energy transitions or climate change mitigation that also discussed some element of political economy or ecology (broadly defined). No restrictions were placed on what these experts could recommend except that studies had to satisfy the four core criteria of:

- Being a peer reviewed academic article (nothing non-peer reviewed, unpublished, or in non-article form such as books, conference proceedings or PhD dissertations);
- Dealing with climate mitigation (and not other areas such as adaptation, geo-engineering, or disaster recovery);
- Being published in the past 20 years, i.e. between 2000 and 2020;
- Being published in English, unfortunately the only language comprehended by the author.

No studies were filtered and excluded as long as they met the four criteria, and all recommended studies were treated as equally valid. Experts were given one month to complete their task, with one reminder, and they were welcome to nominate their own work alongside others. The resulting corpus included 198 studies (see Appendix II) and collection of studies from the disciplines of geography and political ecology, but also energy justice, climate justice, environmental science, and political economy.

3.3 Limitations

Admittedly, the nonrandom sample relied upon for the expert review is limited in several ways. First, although the experts listed in Appendix I come from over two dozen disciplines, the sample was limited primarily to researchers in the social sciences, with an emphasis on geography and political ecology. Second, the experts represented diversity in terms of institutions—coming from 38 separate universities and a few research institutes spread across ten countries—but the sample focused mostly on more senior and eminent researchers. Third, the sample is limited demographically and moderated by the personal

networks of the author. Thus, the expert review should not be interpreted as representing the full diversity of scholarship on the political ecology of climate mitigation; rather, it is an analysis of what a nonrandom or “convenience” sample of leaders of the field, or a network of people with prominent field positions, perceive to be important contributions.

Additionally, the expert guided review did explicitly narrow its focus to “first-rate” or “seminal” studies. Although some could critique this as biased or subjective, the author would retort that such biases almost always exist, implicitly, in most non-systematic literature reviews, with authors choosing a sample of literature based on familiarity, convenience, or other hidden criteria. The difference between this review and those types is that the study is fully transparent about its possible biases, and it is also grounded in what 50 prominent experts identified as critical works, rather than a single author. So at least the research design is more robust, and in essence “distributes” and “mitigates” potential bias by surveying such a large number of expert participants.

Furthermore, there is an element of “grounded theory” to the expert guided review in that only articles shared by the respondents are included. The aim was not to examine all possible studies on the topic, of which there are probably thousands, but instead to represent those argued as most relevant or useful by the experts. Moreover, the coding strategy for analyzing the corpus of literature was inductive and co-constitutive: it began with a few analytical categories before expanding to match the scope of the examined literature as the review progressed.

Because the author performed full content analysis of the corpus of articles, they needed contributions of roughly equivalent size. Books were excluded because they were incongruent in the sense they were too long and incomparable with shorter articles. Also, pragmatically, they would have taken much longer to code, as this was all done by a human with no machine learning or automation to assist them. This means the corpus excludes some noteworthy books documenting the political ecology of climate mitigation, especially Masco (2005), Zehner (2012), Hecht (2012), Franquesa (2018), Dunlap (2019), Dunlap and Jacobsen (2019), and Mulvaney (2019), or the political economy of energy, e.g. Boardman (2010), Ockwell and Byrne (2016), Van de Graaf et al. (2016), and McCauley (2018). Some of these authors are still in the sample of studies based on their articles. The focus on a 20 year window of studies also prohibits earlier work that paved the way for current scholarship.

Finally, what the study refers to as “climate change mitigation” is in reality a series of diverse innovations and options, which may more-or-less directly associated with climate change mitigation efforts. The risk of talking about such diversity under the banner of climate

change mitigation is that it loses – or does not pay sufficient attention to - difference and heterogeneity. However, the author believes including such a diverse sample is justified by three reasons: it reflects the true scope of options available to society, rather than narrowing (artificially) to only a handful; it reflects the locus of energy and climate policymaking, which are duly concerned with translating technical options (such as all of those covered in the study) into policy or location action; it also enables one to evaluate the extent to which different mitigation options interfere with or tradeoff with each other, a characteristic that would be missed or obscured by a narrower focus.

What, then, is the justification for including such a diverse sample?

4. Results: Three trends in the political ecology of climate mitigation

This section of the study divides its results into three inductive themes or trends.

4.1 The geographies and technologies of injustice

Within the 198 articles, there were 332 distinct case studies, although 33 of these were to general technologies and 11 were to global institutions (such as the Roundtable on Sustainable Palm Oil, or the European Union). The remaining 288 case studies were of a given country location, or a subnational location such as a state or a city within a country. These at one level showed a striking diversity of distinct political systems, cultures, and energy and climate markets, from New Caledonia to New Zealand, or China to Chile. Still, Figure 3 depicts a strong concentration of cases among the United States (34 cases), United Kingdom (19), Mexico (19), India (15), Germany (15) and South Africa (10). Put another way: these six countries account for more than *half* (56.6%) of the case study content when counted by number of articles rather than number of cases.

Figure 3: Case study location by region and country for academic research on political ecology and climate mitigation (n=198 studies)

a. Case study location by region

b. Case study location by country

c. Case study counts by country

Source: Author. Note: the legend for Panel B reflects the number of times a country was chosen as a case study, from 1 to 30. Grey countries represent 0 cases.

In terms of technological coverage, there was an equal amount of diversity and heterogeneity, with no less than sixteen distinct types of climate change mitigation being discussed (see Table 2), but also a fair amount of concentration. The most prominent three technologies examined were wind energy (appearing in almost *half* of the articles), solar energy (about 38% of articles) and hydroelectricity (about 20% of articles), a fair number, but one that doesn't not account for the fact that about 85% of global renewable electricity comes from hydropower each year. In contrast, hardly any articles (less than 5%) discussed smart grids or meters, geothermal energy, mundane technology such as bicycles or cookstoves, hydrogen fuel cells, energy transport nodes, clean coal, or mobility—a theme we will return to later.

Table 2: Case study technology for academic research on political ecology and climate mitigation (n=198 studies)

<u>Technology</u>	<u>No. of articles</u>	<u>% articles</u>	<u>% cases</u>
Wind (including onshore, offshore)	97	49.0%	28.9%
Solar (including solar PV, CSP, solar thermal)	75	37.9%	22.3%
Hydro (including big dams, small and micro hydropower)	40	20.2%	11.9%
Bioenergy & waste (including refuse, biomass, residues, wood, crops)	20	10.1%	6.0%
Nuclear (including uranium mining and processing)	19	9.6%	5.7%
Biofuel (including ethanol, biodiesel, Jatropha, palm oil)	17	8.6%	5.1%
Land (including biochar, forest management, soil, smart agriculture, mining)	17	8.6%	5.1%
Housing (including energy efficiency, heating, retrofits)	15	7.6%	4.5%
Electric mobility (including EVs and PHEVs)	12	6.1%	3.6%
Smart grids (including smart meters and homes)	8	4.0%	2.4%
Geothermal (including conventional and advanced)	6	3.0%	1.8%
Mundane (e.g., bikes, cookstoves, light bulbs)	4	2.0%	1.2%
Hydrogen (including fuel cells)	2	1.0%	0.6%
Energy transport nodes (including T&D for electricity, biofuel pipelines)	2	1.0%	0.6%
Clean coal (including CCS and CCUS)	1	0.5%	0.3%
Mobility (including congestion charging, ridesharing, MaaS)	1	0.5%	0.3%

Source: Author. Note: PV = Photovoltaics. CSP = Concentrating Solar Power. EVs = electric vehicles. PHEVs = plug-in hybrid electric vehicles. T&D = transmission and distribution. CCS = carbon capture and storage. CCUS = carbon capture utilization and storage. MaaS = mobility as a service.

4.2 Recurring political ecology processes

As perhaps unexpected, given the diversity of countries and technologies examined, all four political ecology processes of entrenchment, encroachment, exclusion and enclosure

were frequently evident (see Figure 4). All of them were present in at about half of the articles and some such as exclusion and entrenchment were present in more than 70% of the articles. For example, Alborgh and Nightingale (2018) show how electrification efforts promoting small hydropower in Tanzania only worsened the *entrenchment* of local elites in positions of power who could exploit the energy and revenues to better themselves; norms about gender also curtailed the space for action of women in ways that only worsened social inequality and reproduced existing hierarchies. German et al. (2011) discuss the *encroachment* effects of biofuel expansion (e.g., sugarcane, soybean, oil palm, jatropha) and how it includes a staggering land footprint for crop cultivation, immense water consumption, massive inputs of agrichemical fertilizers, pesticides and fuels for operating machinery, and the devastation of species-rich rainforests in the Amazon, Indonesia, Malaysia, Congo, and many other developing nations. Gorayeb et al. (2018) document the presence of *exclusion* in the unfair and arguably illegitimate way that plans for a wind farm in Ceará state, Brazil, proceeded. Fairhead et al. (2012) showcase the complex ways in which land use management and forestry techniques to mitigate climate change end up perpetuating *enclosure* and the forced dispossession and relocation of communities from their land.

Figure 4: Processes of entrenchment, encroachment, exclusion and enclosure in the political ecology of climate mitigation (n=198 studies)

Source: Author.

Compellingly (and in a way tragically), we also see numerous examples of where *all* four processes of political ecology operate in tandem, something that occurred in almost a

third (28.3%) of cases. To offer just a few examples, Argenti and Knight (2015) reveal how the development of wind farms and solar energy facilities in Greece enabled enclosure via the appropriation and grabbing of farming land, exclusion of local concerns from the planning process, encroachment of environmentally sensitive sites with endangered fauna and flora, and the entrenchment of inequality with no project benefits distributed to local communities. Baka (2017) similarly notes that tree plantations for fuelwood or the cultivation of jatropha for biofuel in India has led to the dispossession of communities living near forests (enclosure), a government process of target setting that marginalized stakeholders (exclusion), diversion of water for irrigation (encroachment), and unfair patterns of property rights, land tenure, and power (entrenchment). In addition to reducing the amount of energy available for rural use throughout Tamil Nadu, biofuel development also had a net reduction in the number of regional jobs available (entrenchment). Same with climate smart agriculture in places such as Cambodia and Myanmar, which Borras and Franco (2018) write germinated in a land rush for plots that have displaced people from community forests (enclosure), been connected with top-down policy and planning such as REDD+ (exclusion), exacerbated biodiversity loss (encroachment), and worsened rural poverty (entrenchment). Sovacool and Bulan (2011) lastly showed how the construction of a large hydroelectric dam in Malaysian Borneo involved the forced resettlement of thousands of indigenous peoples and forest dwellers (enclosure), facilitated elitist and unfair planning processes (exclusion), destroyed thousands of acres of precious tropical rainforest (encroachment), and aggravated community inequality and conflict (entrenchment).

4.3 Vulnerable groups and violent conflict

Another theme related to those who were the active victims or vulnerable groups suffering or experiencing the political ecology of climate mitigation. Here, 24 distinct groups emerged as being vulnerable to climate mitigation (see Table 3), a number far beyond the five categories of vulnerable groups identified by Bohle et al. 1994 (e.g. rural smallholder agriculturalists, wage laborers, destitute groups, the urban poor, and refugees). Interestingly, and connected intimately with the process of encroachment, the single most frequent group (apparent in 77.3% of articles) to suffer impacts was non-human species—e.g. flora and fauna, forms of biodiversity, and other sentient and non-sentient life. Seven other groups were most frequently impacted by climate mitigation efforts: host communities or households (76.8% of articles); farmers, agriculturalists, or pastoralists (37.4%); the rural poor (36.9%);

occupational workers, wage laborers, or their unions (36.4%); indigenous groups or ethnic minorities (35.9%); future generations (35.9%); and fishers and water resource users (25.8%).

Table 3: Vulnerable groups mentioned in academic research on political ecology and climate mitigation (n=198 studies)

<u>Vulnerable group</u>	<u>No. of articles</u>	<u>% of articles</u>
Non-human species	153	77.3%
Local communities, host communities, adopters or households	152	76.8%
Farmers, agriculturalists, or pastoralists	74	37.4%
Rural poor	73	36.9%
Occupational workers, wage laborers, or their unions	72	36.4%
Indigenous/aboriginal groups, ethnic/racial minorities, or members of a lower caste	71	35.9%
Future generations (e.g., nuclear waste)	71	35.9%
Fishers and water resource users	51	25.8%
Environmental groups, civil society, wildlife reservists, land managers or nature conservationists	38	19.2%
Urban poor	36	18.2%
Women (including gender roles)	27	13.6%
Recreationists, campers, hikers, forest users	27	13.6%
Banks, financiers, investors (including fossil fuel incumbents)	27	13.6%
Elderly	13	6.6%
Students	13	6.6%
Disabled individuals	12	6.1%
Forced labor or modern slaves	10	5.1%
Coastal homeowners (e.g. offshore wind energy)	10	5.1%
Prostitutes	10	5.1%
Children or youth (including health impacts)	5	2.5%
Local businesses (including tourism)	5	2.5%
Refugees (including displaced persons and forced migrants)	3	1.5%
Alcoholics	3	1.5%
Affluent suburban homeowners	1	0.5%

Source: Author

Some of the most vulnerable groups, oddly, were those that actually owned, operated, or used the climate mitigation option in question, or those working on the manufacturing of those options at mines, processing facilities, or factories. For instance, many communities hosting wind farms, residing on land being proposed for biofuel crop cultivation, living in shared forests or nature reserves, or sitting adjacent to solar parks bear the brunt of negative and often concentrated social and environmental impacts. Furthermore, it is the low-wage

factory workers inhaling toxic fumes and exposed to hazardous materials in places such as in China (see Figure 5), Malaysia, and elsewhere that see their lives shortened and environments degraded so that climate mitigation options can be used or exported elsewhere. Finally, it is not always the poor or marginalized who “lose out” from low-carbon transitions: in some cases, it can be affluent coastal homeowners (especially for offshore wind energy), banks and financial firms (who may invest in fossil fuels), or local businesses (such as tourism) that are severely impacted by climate mitigation efforts.

Figure 5: Legacies of occupational hazards and toxic pollution from solar panel manufacturing in China

- a. Low wage workers at Top Solar, Qinghai, China working 18 hour shifts in the dark to assemble solar photovoltaic systems*

b. Waste streams behind a solar energy factory in Dobden, Qinghai, China

Source: Author.

Horrifyingly, acts of violence were reported in 62 of the cases, with the most severe being murder or torture. Dunlap (2018a) documents how Mexican military forces formally trained in torture and other unsavory techniques were placed in charge of subduing local opposition to wind farms in Oaxaca. Carruthers and Rodriguez (2009) chronicle police abuse and torture against Mapuche community members in Chile opposing hydropower. Other studies mention the murder of campaigners against hydroelectric dams in Borneo (Sovacool and Bulan 2011), the murder of a protestor against a dam in France (Dunlap 2010), repeated acts of murder over those opposing industrial tree plantations around the world (Gerber 2011), and multiple assassinations of those opposing copper mining in Peru (Dunlap 2019). Lohmann (2009) reports how paramilitary gangs formerly associated with antidrug operations went on a campaign of seizing Afro-Colombian land in South America to facilitate palm oil biofuel conglomerates, killing dozens of farmers in the process. Caneppele et al. (2013) reveal how wind energy development in Italy is prone to violence from the mafia if particular construction firms or planners do not expedite wind energy projects that benefit organized crime networks.

Other cases discuss compelling and at times shocking links between climate mitigation and prostitution, alcoholism, and slavery. Lohmann (2005) writes that the

development of biomass power plants in Thailand's central region have facilitated increases in male prostitution. Calzadilla and Mauger (2018) show how the Lake Turkana Wind Project in Kenya resulted in substantial increases in alcoholism and prostitution among both the host communities and the camps full of job seekers. Gorayeb et al. (2018) catalogue how wind farms in northeastern Brazil have also brought increases in child prostitution. Green et al. (2015) warn of the likelihood that construction of the Grand Inga Dam in central Africa would spread HIV among the prostitutes that would come to service construction workers. Sovacool et al. (2020) discuss the use of forced labor and modern slaves in the backbreaking work needed to mine copper and cobalt for a variety of low-carbon technologies, or to handle their hazardous waste streams, especially at electronic waste scrapyards in Ghana.

Finally, Table 4 reveals 61 distinct minority communities mentioned within the literature at being disrupted, dispossessed or damaged by climate mitigation efforts. This included:

- Indigenous peoples such as the Sami in Sweden, Adivasis forestland users in India, Saharai groups in Morocco, members of the Six Nations in Canada or Native Americans and tribal groups in the United States;
- Aboriginal communities including the Wayuu communities in Colombia, the Penan in Malaysia, or the First Nations peoples in Australia;
- Ethnic minorities such as African Americans or Hispanics in North America.

Also, as Table 4 reveals, some of these communities are under perpetual threat from *multiple* climate mitigation options at once, especially the Mapuche-Williche indigenous leaders in Chile (facing wind energy, hydropower, forestry and tree plantations), forest dependent minorities around the world (connected with climate smart agriculture, forestry, land use pressures), or people living on indigenous lands under threat to land grabbing and appropriation (connected with biofuel, climate smart agriculture, forestry, biochar, carbon funds, and solar energy parks).

Table 4: Indigenous peoples and ethnic communities marginalized or displaced by climate mitigation efforts

<u>Reference(s)</u>	<u>Technology/ies</u>	<u>Particular group(s) negatively effected</u>
Avila 2018; Lawrence 2014	Wind energy	Sami herding community in Sweden
Avila 2018	Wind energy	Zapoteco and Huave coastal and agricultural communities in Mexico
Avila 2018	Wind energy	Traditional fisheries and pastoralists in India
Avila 2018	Wind energy	Adivasis forestland users in India
Avila 2018; Rignall 2016	Wind energy, solar energy	Saharai contested territories and other indigenous groups in Morocco

Avila 2018	Wind energy	Lenca communities in Honduras
Avila 2018; Calzadilla and Mauger 2018	Wind energy	Turkana, Randile and Borana communities in Kenya, especially ranchers and cattle stewards
Avila 2018	Wind energy	Traditional fisheries in Brazil
Avila 2018	Wind energy	Quilombola communities in Brazil
Avila 2018; Carruthers and Rodriguez 2009; Gerber 2011; Kelly 2019; Sánchez De Jaegher 2018	Wind energy, hydropower, forestry, tree plantations	Mapuche communities and Mapuche-Williche indigenous leaders in Chile
Avila 2018	Wind energy	Wayuu communities in Colombia
Avila 2018	Wind energy	Koyna Sanctuary traditional pastoralists in India
Avila-Calero 2017; Calzadilla and Mauger 2018; Dunlap 2017a; Dunlap 2017b; Dunlap 2018c; Howe and Boyer 2015; Siamanta and Dunlap 2019; Sovacool et al. 2019; Zárate-Toledo et al. 2019	Wind energy	Indigenous peoples of the Isthmus of Tehuantepec in Mexico
Barandiarán 2019; Revette 2015	Electric vehicles, smart grids, renewable energy storage (lithium for batteries)	Indigenous communities living near lithium mines and salt flats in Bolivia's Uyuni
Barandiarán 2019	Electric vehicles, smart grids, renewable energy storage (lithium for batteries)	Indigenous communities living near lithium mines and salt flats in Chile's Atacama
Bednar et al. 2017; Reames 2016; Reames et al. 2018	Energy efficiency, heating, lighting	African Americans in urban Michigan
Bednar et al. 2017; Reames 2016	Energy efficiency, heating	Hispanics in urban Michigan
Bonds and Downey 2012; Sovacool and Bulan 2011	Biofuel (palm oil), hydropower	Erosion of land tenure of the Penan, Kayan, Kenyah, Kajang, and Ukit groups in Malaysia
Bonds and Downey 2012	Biofuel (palm oil)	5 million indigenous people displaced by palm oil development in Indonesia
Borras and Franco 2018	Climate smart agriculture	Indigenous peoples and ethnic minorities in Myanmar
Borras and Franco 2018; Poffenberger 2009	Climate smart agriculture, forestry, land use	Indigenous peoples and forest dependent minorities in Cambodia
Borras et al. 2010; Fortin and Richardson 2013; Leach et al. 2012; Lohmann 2005	Biofuel (ethanol), land use (biochar)	Dispossessed indigenous peoples in the Amazon
Brady and Monani 2012; Mulvaney 2017; Powell 2006	Wind energy, solar energy	American Indian tribal lands and Native American tribes
Brannstrom et al. 2017	Wind energy	Territories of indigenous peoples and traditional communities in Brazil
Cram 2015; Cram 2016	Nuclear power (waste)	Yakama Nation, the Nez Perce Tribe, and the Confederated Tribes of the Umatilla Indian Reservation in the United States
Curley 2018	Wind energy, solar energy	Navajo Nation in the United States
Desbiens 2004	Hydropower	Crees Nation in Canada
Dolter and Boucher 2018	Solar energy	First Nations and Indigenous Peoples in Saskatchewan Canada
Dunlap 2018a; Dunlap 2018b; Dunlap 2019b; Pasquetti 2011; Sovacool et al. 2017a; Sovacool et al. 2019	Wind energy	Indigenous peoples of Juchitán de Zaragoza in Oaxaca Mexico
Dunlap 2018d; Dunlap 2019a	Wind energy	Zapotec Indigenous community in Mexico
Fairhead et al. 2012; German et al. 2011; Leach et al. 2012; Lohmann 2005; Mirumachi et al. 2020; Newell and Bumpus 2012; Sikor and Lund 2009; Stock and Birkenholtz 2019	Biofuel, climate smart agriculture, forestry, land use (biochar), carbon funds, solar energy (solar parks)	Global indigenous communities and ethnic groups affected by land grabbing or appropriation of resources
Finley-Brook and Thomas 2011	Hydropower	Naso and Ngobe indigenous territories in western Panama
Furnaro 2019	Renewable energy (broadly)	Indigenous communities in Chile
Gerber 2011	Bioenergy (tree plantations)	Dayak communities in Borneo
Gerber 2011	Bioenergy (tree plantations)	Tupinikim, Guarani and Pataxo' communities in Brazil
Gerber 2011	Bioenergy (tree plantations)	Maisin communities in Papua New Guinea
Graetz 2015; Marsh and Green 2020	Nuclear power (uranium mining, nuclear waste)	Aboriginal Australians and Torres Strait Islander "First Peoples" in Australia
Hommes et al. 2016	Hydropower	Ethnic minorities and indigenous peoples in Turkey
Islar et al. 2017	Solar energy, wind energy, hydropower	Dalits (often viewed as the lowest social caste) and indigenous people in Nepal

Martinez and Castillo 2016	Hydropower	Peasant, indigenous, and Afro-Colombian rural communities
Newell and Mulvaney 2013	Solar energy, wind energy, smart grids, electric vehicles	Trade unions and indigenous peoples movements
Richards and Lyons 2016	Bioenergy, land use, forestry (plantation forests)	Indigenous and subsistence farmers in Uganda
Scott and Smith 2017	Wind energy, solar energy	Six Nations communities in Canada
Siciliano et al. 2018; Sovacool and Bulan 2011	Hydropower	Orang Ulu peoples and indigenous peoples from the upper Balui River, including some semi-nomads in Sarawak, Malaysia
Sovacool et al. 2017a	Biofuel	Indigenous communities such as the Dene, Cree, and Metis in Canada
Sovacool et al. 2017b	Smart meters	Exclusion of rural and Scottish communities
Sovacool et al. 2020	Electric vehicles, solar energy, wind energy (waste streams)	Discrimination against ethnic groups and minorities in Ghana
Sovacool et al. 2020	Electric vehicles, smart grids, renewable energy storage (cobalt for batteries)	Discrimination against ethnic minorities in Democratic Republic of the Congo
Stock and Birkenholtz 2019; Yenneti and Day 2015; Yenneti and Day 2016; Yenneti et al. 2016	Solar energy (solar parks)	Indigenous minorities or those of a lower caste in Gujarat India
Sunter et al. 2019	Solar energy (rooftop PV)	African Americans neighborhoods in the United States
Sunter et al. 2019	Solar energy (rooftop PV)	Hispanic neighborhoods in the United States
Temper 2018	Tree plantations (pine and eucalyptus), biofuel (sugarcane plantations)	Farmers and indigenous groups in Uganda
Temper 2018	Biofuel (Jatropha)	Indigenous groups and pastoralists in Ghana
Temper 2018	Biofuel (ethanol)	Indigenous groups and traditional communities in Senegal
Temper 2018	Biofuel, forestry, land use	Mukaya Diaspora in Juba in South Sudan
Temper 2018	Biofuel (ethanol)	Indigenous groups, traditional communities, and landless peasants in Mozambique
Temper 2018	Biofuel (palm oil)	Indigenous groups in southwest Cameroon
Temper 2018	Forestry, land use	Indigenous groups in Rio Negro Argentina
Temper 2018	Forestry, land use	Indigenous groups and communities in San Martin Peru
Velasco 2016	Hydropower	Embera' Katio indigenous community
Walker et al. 2019	Hydropower	Munduruku people in the Tapajo's River Valley

Source: Author.

5. Discussion: Critical avenues for future political ecology and geography work

The corpus of studies reveals not only thematic perspectives into the political ecology of climate mitigation; it also offers insights on the way the community designs and executes its research. With this in mind, the author advances five recommendations for future research: more inclusivity and diversity, more rigor and comparative analysis, focusing on more mundane technologies as well as non-Western case studies, more multi-scalar analysis, and more focus on policy and recommendations.

5.1 More inclusive, diverse and interdisciplinary research teams

The first recommendation is for the community of scholars working at the nexus of political ecology and climate mitigation to reach out to non-social scientists (and possibly the

life sciences), especially those in the arts and humanities, and to create more interdisciplinary teams.

Using a six-fold classification of academic disciplines drawn from the *Times Higher Education* (utilized for university categorization and rankings), the 454 authors from the corpus of 198 articles fall into six different areas: the arts and humanities; the social sciences; economics, business and management; engineering and technology; life sciences and medicine; and the natural, physical and environmental sciences (see Figure 6). Perhaps surprisingly, very few authors fall into the arts and humanities and life sciences. Affiliations were instead dominated by the social sciences (including geography and political science), business and management (including economics), the environmental sciences (including ecology and sustainability science), and engineering (including energy studies). In terms of gender, we see a slight tilt in the balance towards men (268 male authors and 186 female authors). In terms of location, we see a dominance of authors from the Global North. North America, Europe, and Australia and New Zealand accounted for 88.1% of the location of authors, with only 5 authors writing from within Africa and only 31 writing within Asia.

Figure 6: Author demographics, locations, and institutional affiliations for academic research on political ecology and climate mitigation (n=198 studies)

a. Author disciplinary affiliation

b. Author gender (n=454 authors)

c. Author location (n=454)

Source: Author. Note: if multiple affiliations for an author were given, in different countries, the author only coded the first and primary affiliation.

Although in a way this diversity of affiliations buttresses the idea that political ecology remains an interdisciplinary endeavor, very few authoring teams had what the author would term “deep” interdisciplinarity that cuts *across* the six different categories of academia. Only 33 studies were deemed interdisciplinary in this manner, which is only 7.3% of the sample. The most common form of this interdisciplinary collaboration was someone in environmental science partnering with someone in geography or public policy.

This paucity of interdisciplinary authoring is a possible shortcoming given that deeply interdisciplinary research tends to stimulate new approaches to problems that no single

discipline would have explored in isolation (Gardy and Brinkman 2003). Interdisciplinary teams can also enhance the relevance, explanatory power, and practical applicability of research (Caruso and Rhoten 2001). Moreover, interdisciplinary research can lead to synthetic theories or conceptual frameworks as well as an awareness and appreciation of alternative paradigms, viewpoints, and methods. This appreciation of interdisciplinarity could improve the effectiveness and scope of political ecology research terms.

5.2 More rigorous and comparative research designs

Political ecologists may do well to consider becoming more rigorous in their research designs and more comparative in their assessments.

Apart from coding and analyzing the attributes of authoring teams, the author also examined the extent that the corpus of research employed mixed methods research designs, or even had research designs or methods explicated. Based on this coding, 112 studies had a research methods section or an easily identifiable method, but only 42 studies employed mixed methods designs (see Figure 7). The lack of a research method was especially true for studies rooted in political science, anthropology, political ecology and geography departments, and less common in other areas. Most of this research lacked comparative analyses as well: only 54 (11.9%) studies were comparative in their case study design for countries, and slightly more (14.3% or 65 studies) were comparative in the climate mitigation technologies they examined.

Figure 7: Research designs and comparative research strategies for academic research on political ecology and climate mitigation (n=198 studies)

However, there were a few large-scale comparative assessments in the corpus such as Gerber's (2011) examination of conflicts over 58 cases of industrial tree plantations, Bulkeley et al.'s (2013) collection of 100 cities conducting urban climate action plans, or Avila et al.'s (2018) 20 case comparison of wind energy conflicts across five different continents. These more comparative studies likely have a greater degree of generalizability than their single case counterparts, and comparative work is generally more useful at model or theory building (Berg-Schlosser and Meur 2009). Going further, Mills et al. (2006) write that comparative work is essential for research questions or designs that seek to examine underlying patterns of similarity and variance, and critical for researchers that seek to separate or isolate regularities from the context laden environment. Comparative work also enables one to juxtapose "positive" or "successful" cases alongside "negative" or "failed" cases, enabling a greater range of variables to be examined and tested (Mahoney and Goertz 2004). These all suggest that more comparative political ecology work would deepen and advance the field.

5.3 More emphasis on mundane technologies and novel locations

As depicted in Section 4.1, most articles in the corpus focused on the highly visible or "high tech" cases of wind farms, solar panels, hydroelectric dams, or nuclear reactors. In contrast, fewer articles discussed more modular forms of mitigation such as smart meters,

fuel cells, or e-bikes, or systems such as geothermal energy or clean coal/carbon capture and storage. There could thus be a promising future research agenda on:

- Smart homes, especially the ways in which they intersect with surveillance capitalism or are used to monitor bodily functions (menstrual surveillance) or people (including digital abuse and domestic violence);
- The domestic politics of geothermal heat pumps or the community resilience concerns surrounding deep reservoirs and the siting of advanced geothermal power plants;
- Segregated access and knowledge to mitigation options such as more efficient electric bicycles or improved cookstoves;
- The shifting regimes of accumulation or enclosure that may arise with industrial hydrogen infrastructure, or with carbon capture and storage (“clean coal”);
- Land grabbing and green dispossession associated with high voltage electricity transmission and distribution networks or transnational biofuel pipelines;
- Connections between elites and labor, or the global production networks, with emerging mitigation options such as automated mobility, ridesharing, mobility-as-a-service and eco-driving or even active modes of transport such as walking or cycling;
- The political economy of biomass, kerosene, or charcoal, which even become intertwined with criminal networks, smuggling rings, and organized military violence (Branch et al. 2018).

Furthermore, some of these options, especially energy-efficient lighting, automobiles, or cooking devices, affect a far greater range of people in a more immediate manner than remote or centralized technologies. For example, there are an estimated eight billion light bulbs in use around the world’s homes and offices compared to only a few hundred thousand power plants; there are similarly 2 billion automobiles, bicycles, and scooters and about three billion cookstoves (Sovacool and Dworkin 2014). Kammen and Done (1997) argue that it is therefore a “virtue” to study “mundane” technologies that are commonly utilized around the world, rather than the more sophisticated and capital intensive forms of climate mitigation.

In addition, political ecologists may need to focus more on the Global South. Across the sample of 288 national cases, Australia and New Zealand, Europe and North America accounted for almost half (45.8%) of coverage. Thus, most political ecology research, despite pursuing critical analysis, is WEIRD: focused on Western, Educated, Industrialized, Rich, and Democratic spaces (Henrich et al. 2010). This narrowness in populations may

cause researchers to miss important dimensions of variation and to devote undue attention to analytical tendencies that are truly unusual in a global context.

Perhaps this dominance of the Global North in case study selection is not totally surprising, and even justified by the resources available for research in those locations, and the fact that a larger share of low-carbon mitigation technologies are installed there. China, however, would be a notable exception to this trend (with only 3 cases), given it is the world leader in terms of renewable electricity capacity (including hydro and non-hydro) as well as in electric vehicle adoption. Other very important energy markets, suppliers, or importers such as South Korea (3 cases), Japan (2 cases), and Nigeria (2 cases) seem under-examined, and it is glaring there were *no* reported cases in the corpus on Russia or the entire Middle East.

5.4 More whole systems and multi-scalar approaches

Lastly, greater whole systems or multi-scalar thinking within geography and political ecology work is warranted. For the justice impacts of climate mitigation not only unfold across different countries and technologies, they also involve different lifecycle stages of a given technology, sociotechnical system or global production network as well as distinct spatial scales.

As shown in Figure 8, some studies centered their focus on upstream processes of resource extraction and mining, such as palm oil plantations for biofuel or the material and metal inputs for electric vehicle batteries (Bonds and Downey 2012). Some focused on the manufacturing of a low-carbon technology, such as the impacts that befall workers exposed to cadmium in the manufacturing and assembly of thin-film solar panels (Mulvaney 2014). Some focused on the construction or installation of climate mitigation efforts, such as the erection of wind farms in Mexico (Dunlap 2018) or the impacts of building large-scale dams that impound the world's rivers (Siciliano et al. 2018). Some focused on the policy, planning, or financing processes behind the technology or infrastructure in question, such as McCarthy and Thatcher's (2019) analysis of the World Bank's efforts to better map renewable energy resource potential. Some—a great multitude of studies, in fact—looked at the actual deployment, diffusion, or use of climate mitigation technologies and practices, such as the uptake of energy efficiency retrofits (Willand et al. 2020) or the utilization of hydrogen fuel cells (Scott and Powells 2020). Some focused all the way downstream on the disposal and waste arising from climate mitigation efforts, including the recycling complexities surrounding discarded solar panels in Kenya (Cross and Murray 2018), the

waste streams created by electric vehicle batteries (Skeete et al. 2020), or the difficulty of handling long-lived nuclear waste (Barron and Hill 2019).

Figure 8: Lifecycle stages and spatial scales in academic research on political ecology and climate mitigation (n=198 studies)

Source: Author

However, Figure 8 reveals that most studies center narrowly on only a few of these scales—the mean number of scales across the entire corpus was 2.08, and the two most examined scales were operation and use and policy and planning. Some studies discussed transport or construction (especially of dams or wind farms) or resource extraction (such as mining), but far less discussed disposal and waste (only 27) or manufacturing (only 20). Truly multi-scalar approaches that examined all six scales was rare and limited to only four studies in the corpus: Burke and Stephens 2018, Sovacool et al. 2019a, Sovacool et al. 2019b, and Sovacool et al. 2020.

Perhaps this rarity of multi-scalar analysis is understandable given that multi-site research is more expensive and time consuming to do, and it does require expertise that cuts across the six lifecycle scales (extractive industries and mining, manufacturing and construction, policy and finance, use and adoption, and waste and recycling)—expertise that may only exist within large groups. For example, Sovacool et al. (2020) relied on a team of almost 20 researchers and assistants, and the costs behind that study reached about \$500,000. But such multi-scalar work is pivotal to get a whole systems view of climate mitigation, to make sure that downstream and upstream processes, such as mining or waste flows, are properly connected with patterns of policy planning or technology deployment. Without such multi-scalar foci, critical components and salient synergies could be missed, distorting the view of system properties connected to climate mitigation, and masking broader implications for efficiency or sustainability (Bridge et al. 2018; Castan-Broto and Baker 2018).

5.5 More prescriptive recommendations and policy implications

The reality is that most political ecology research involves reflections or investigations of policy, policy actors and policy outcomes but relatively few engage with policy in the sense of “how can policy regimes be improved.” Although 193 of 198 studies mentioned the word policy or a phrase using policy (see Table 5) at least once in the text or reference list, they did so theoretically or critically. For example, such studies might offer critical perspectives and narratives on policy, or advance a critical analysis of policy, or discuss the dynamics of resistance or dispossession to policy. Sometimes, political ecology research within the sample attempts to offer implications for “how we think” (Borras and Franco 2018) or “doing research” (Boahmah et al. 2020) or “challenging old economics” (Brady and Monany 2012) or “mobilizing experimentation” (Bulkeley et al. 2014) or “reworking commodification” (Bumpus 2011)—and that’s just studies with authors starting with “B”. Other studies might reveal configurations and practices, or identify emergent and

hegemonic regimes, or interrogate uneven development that connect with policy. Still other studies discussed the effects of policy, or the making, unmaking, and remaking of policy.

Table 5: Terms and dimensions of policy in academic research on political ecology and climate mitigation (n=198 studies)

Term or dimension of policy discussed	Number of studies in the sample that discuss it (N=198)	% Studies mentioning this term (N=198)
Policy actors	6	3.0%
Policy attention	4	2.0%
Policy autonomy	1	0.5%
Policy context	9	4.5%
Policy decisions	4	2.0%
Policy design	11	5.6%
Policy discourse	9	4.5%
Policy documents	3	1.5%
Policy domain(s)	4	2.0%
Policy experiment(s)	2	1.0%
Policy focus	5	2.5%
Policy fora	2	1.0%
Policy fluctuation	1	0.5%
Policy framing	2	1.0%
Policy framework	17	8.6%
Policy hostility	1	0.5%
Policy incentive	5	2.5%
Policy influence	1	0.5%
Policy initiative(s)	2	1.0%
Policy innovation(s)	4	2.0%
Policy instrument	3	1.5%
Policy measures	1	0.5%
Polycymaking or policy-making	105	53.0%
Policy objective	2	1.0%
Policy outcome	4	2.0%
Policy planning	15	7.6%
Policy position	3	1.5%
Policy process	11	5.6%
Policy regime	6	3.0%
Policy response(s)	17	8.6%
Policy stringency	1	0.5%
Policy support	12	6.1%
Policy tool(s)	8	4.0%
Policy trends	2	1.0%
Policy vacuum	1	0.5%

Although these sorts of findings may have implications for policy, they are not necessarily translatable into policy or actionable. But as Figure 9 indicates, surprisingly few studies actually offered prescriptive recommendations or policy suggestions—only about 20% of articles in the sample articulated actual policy recommendations. If policy recommendations are the key mechanisms by which policy decisions are informed at most levels of government, then this lacuna is striking—and a lost opportunity for the community to more proactively seek to remedy many of the ills identified in their research. Such recommendations need not be directed only at government—suggestions could also include how to influence or prescribe courses of action for other actors, notably businesses and industry, local planners and administrators, community groups, and even investors and financial managers.

Figure 9: Policy recommendations in academic research on political ecology and climate mitigation (n=198 studies)

Source: Author

6. Conclusion

Low-carbon transitions and climate mitigation efforts can be viewed as power struggles and processes of exacerbating vulnerability. This review of 20 years of political ecology literature has confirmed the persistent presence of four processes—enclosure, exclusion, encroachment, and entrenchment—across technologies as diverse as wind energy, hydroelectric, electric vehicles, household solar panels, building retrofits, climate smart agriculture, land use management, and forestry. Across all of these diverse technical

configurations (centralized and decentralized, supply-side and demand-side), contexts (energy markets, political economies, distinct cultures), and countries (Africa to Asia, Europe to North America), climate mitigation creates a fulcrum for elitism, discrimination and the consolidation of wealth. Every form of climate mitigation is linked to at least one process of enclosure, exclusion, encroachment, and entrenchment, and many are linked repeatedly and persistently. Almost one third (28.3%) of cases in the corpus are linked to *all four* processes, suggesting that climate mitigation efforts consistently exclude others, concentrate assets, and harm communities. The implication here may be that while issues of inequality and exclusion are extrinsic to a given technology, they are intrinsic to the current regime of low-carbon energy.

The tragic impacts arising from climate mitigation are not distributed equally, however, nor are they experienced by a uniform sect of actors. Although the most common to suffer from climate mitigation were non-human species (habitats, plants, animals) and host communities or households themselves, there were a broad spectrum of other impacted groups. The evidence identified no less than 61 different vulnerable groups of indigenous peoples, aboriginal collectives, or ethnic minorities negatively impacted by climate efforts, some of them under threat via multiple processes or mitigation options at once. Moreover, the impacts differentially cut across: scales (spanning local-community divides or urban-rural locations or even implicating global actors such as unions, financiers, or investors); temporality (present vs. future generations); and recognition (affecting very specific and highly vulnerable groups including child prostitutes, slaves, smallholder farmers, coastal property owners, etc.). Climate mitigation thus engenders not only green on green conflict—with civil society groups sometimes pitted against each other over the varying tensions between climate mitigation and social vitality—but poor on poor conflict, with some poor communities dispossessed in order to help other poor communities (e.g., a poor Congolese cobalt miner living a life of misery so that low-carbon options can become more affordable for fuel-poor households in the United Kingdom). The impacts differ meaningfully, and at times shockingly, in their severity. Sixty-two cases of climate mitigation resulted in violence, including severe violence, murder, and torture. Others resulted in the threat of irreversible species loss, the degradation of cultural icons, or the permanent alteration of ecosystems and landscapes.

Five critical avenues for future research emerge alongside these empirical findings. One is to pursue more inclusive research teams, especially a greater appreciation for the arts and humanities, as well as perhaps the life and medical sciences. More rigorous research

designs are called for, for they can enable replication and also enhance transparency. More comparative analysis would be better suited at building models and theories, or translating research into generalizable and actionable findings. Less emphasis on “high technology” such as smart grids or nuclear power and more emphasis on “mundane” technologies such as light bulbs, cookstoves, or bicycles is warranted, especially as these latter options are more immediately useful and widespread amongst the world’s poor. Hydropower also dominates the global supply of renewable energy, providing about 85% of renewable electricity, but is less studied by political ecologists, as it accounted for only about 20% of studies—with far more focusing on wind energy and solar energy. An implicit bias towards WEIRD case studies (in Western, Educated, Industrialized, Rich and Democratic societies) may also be constraining the global reach of political ecology endeavors. More attention to multi-scalar and whole-systems thinking would better appreciate how climate mitigation efforts depend on resource extraction and mining, manufacturing, transport and construction, policy and planning, operation and use, *and* disposal and waste streams. Whole systems approaches would ensure that the suffering of others is no longer obscured or distorted by distance. More attention and detail to reflective *solutions* is also called for, with far too few studies actively engaging with policy recommendations, at any scale; most studies (about 80%) identify problems only, with no prescriptive guidance offered for how to ameliorate them. Political ecology research all too often critiques policy, but does not expressly inform policy, or actively seek to provide actual recommendations for improving policy. This implies the research community needs to aim for more policy relevance, and perhaps less arcane (and at times baroque and inaccessible) theorizing.

Ultimately, a future low-carbon world may very well become more pluralistic, democratic, and just. But the sobering results from this review also indicate without proactive governance it could be more antagonistic, exclusionary, violent, and destructive. Low-carbon transitions and climate actions currently pull not only avoided and displaced emissions from the sky, but people into turbulent crosscurrents of suffering and exploitation. Their impacts are not only written in the clouds and expressed in the atmosphere, but spilled in blood, sweat, and tears. As climate mitigation actions become more integral in future resource planning discussions, attract more investment, and become more instrumental to economies, we must collectively ensure its rise in prominence is not accompanied by an inexcusable tragedy of equally compelling problems.

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