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Water throughout the green energy transition: Hydrosocial dimensions of coal, natural gas, and lithium

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Abstract

Energy transitions are reshaping hydrosocial relations. How they will be reshaped, however, depends on location and water's material relationship to other resources and industrial activities embedded within energy transitions. To highlight this, we focus on three different resources—coal, natural gas, and lithium—to signal how the water–energy nexus will be reworked in a transition away from fossil fuels. We examine the water–coal nexus as an example of a resource relationship that is transitioning *out*, or that is being moved away from in the green energy transition. Natural gas represents the "bridge fuel" used *through* the transition. Lithium illustrates a resource *inside* the green transition, as it is a fundamental material for green technologies *in* the transition to a low-carbon future. Coal, natural gas, and lithium each have their own material impacts to water resources that stem from their industrial life-cycle and different implications for communities shaped by coal, natural gas, and lithium activities. To explore this, we review each of these resources' connection to water, their legal and regulatory dimensions, and their impact on communities and water justice. We argue that the energy transition is also a hydrosocial transition that will create uneven water-related benefits and burdens. To maximize sustainability and equity, efforts to decarbonize energy systems must examine the localized, place-based hydrosocial relations that differentially affect communities.

This article is categorized under:
- Engineering Water > Planning Water
- Human Water > Water Governance
- Human Water > Rights to Water

KEYWORDS
coal, energy transition, hydrosocial, lithium, natural gas, water justice, water–energy nexus

1 | INTRODUCTION

The current climate crisis underscores the fundamental need to rapidly transition away from a carbon intensive economy. This involves shifting toward renewable energy sources, such as wind and solar, and away from fossil fuels, including coal, oil, and gas. This realignment of the energy sector, however, will also reorganize energy's interdependence with other resources, namely *water*. The interwoven relationship between water and energy resources, or the water–energy nexus, reflects how energy production and use is also tied to water production and use. A just energy transition also needs to attend to the potential water-related conflicts, equity concerns, and justice issues that might arise in the pursuit of decarbonization (Newell & Mulvaney, 2013).

While much has been written about energy and the just transition (Cha, 2020; Harrahill & Douglas, 2019; Healy & Barry, 2017; McCauley & Heffron, 2018), our aim in this review is to highlight how a just energy transition is also a hydrosocial transition. The just transition involves a political ecological focus on the power dynamics and inequalities that arise around struggles over resource access, control, and distribution—from sites of production to consumption. The emphasis of the just transition on the full lifecycle of energy resources also reflects concerns in industrial ecology on dematerializing resource stocks and flows and creating more sustainable energy systems. Water is a clear and important part of this social and material transition.

The broader political–industrial ecology of water–energy transition creates an uneven and interwoven landscape that connects the flow of water, energy, and social relations across space (Cousins & Newell, 2015; Newell et al., 2017). The production of "new energy spaces" (Bridge & Gailing, 2020) or extractive zones (Marston, 2017) also reshapes the hydrosocial territories they are embedded in, reconfiguring spatial relationships between people, institutions, technology, and the biophysical environment through the control of water. Meanwhile, in what has been termed a "mid transition" phase in which fossil fuels and renewables co-exist (Grubert & Hastings-Simon, 2022), fossil fuel hegemony may continue to entrench and reproduce itself alongside renewables, even in the face of opposition (Behrsin et al., 2022). With the lurking possibilities that an energy transition might shift costs and lead to the production of "green sacrifice zones" (Zografos & Robbins, 2020), any strategy needs to unpack and address questions about who experiences water-related burdens of energy transitions, where, and why.

In this paper, we focus on three different resources—coal, natural gas, and lithium—and their relationship to flows of water. To represent the transition away from fossil fuels, we use coal as an example of a resource *outside* of a green and just transition. In this regard, we use it to discuss how societal transitions away from fossil fuel resources create new hydrosocial relations. In contrast, we use lithium as an example of a resource *inside* the green transition, as it is a fundamental material for green technologies *in* the transition to a low-carbon future. Natural gas is sometimes framed as a "bridge fuel" *through* the transition. For each of these three resources, we describe their material connection to water, then discuss some of the water-related legal and regulatory dimensions (which, notably, vary considerably around the world), along with community impacts and water justice issues. We argue that as societies move away from fossil fuels, the water–energy nexus will be re-worked in fundamentally new ways—opening up opportunities in some cases and presenting difficult political, environmental, and ethical challenges in others.

2 | WATER AND COAL

According to the International Energy Agency (IEA), coal accounted for nearly 40% of global energy in 2019 (IEA, 2019). Behind this number is an incredible burden on water resources. While coal's undeniable material impact on air quality, carbon emissions, and human health is well known, nearly every stage of coal's lifecycle—from extraction to combustion—relies upon water and impacts local water resources. At sites of extraction, communities and local waterways can be impacted by acid mine drainage, which happens when water contaminated with heavy metals flows from active or abandoned mines. This is in addition to extractive processes of mountaintop removal and the storage of coal slurry, which destroy headwater streams and present water quality hazards. Water is also essential for coal plants to function, accounting for 48% of all fresh surface water withdrawals (Smyth, 2020). As coal plants retire, large quantities of water will be available for other uses (Smyth, 2020). This situates questions about water rights alongside questions about shifting relations between labor, political economic processes, and the material flow of resources across space.

The material impacts of coal on water resources are often observed and felt locally, but the transition away from coal will create a geographically expansive impact beyond extractive peripheries. Sites along the entire supply chain and through the entire lifecycle of coal will observe different material impacts on human and environmental health and the local economy. The questions are not only about newly available water within critical watersheds. Coal dust blowing off rail cars during transportation pollutes local waterways and train derailments have severe environmental impacts (Epstein et al., 2011; Trimming, 2012). Some communities receive their water supplies from the coal companies and the infrastructure they provide locally (Jakobsen, 2022). This creates a multifaceted set of material politics that influence access and control of water resources and unevenly distribute benefits and burdens of a transition away from coal.

2.1 | Legal and regulatory dimensions

Various legal and regulatory structures influence responsibility for remediation and for any damages to water quality at coal mine sites. The rules and strategies vary by region, country, and jurisdiction and depend on each country's law-making system (e.g., common law, the United States; or civil law, Chile). In the United States, the Clean Water Act and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) can authorize the US Environmental Protection Agency (US EPA) to respond to pollution at mine sites. In Europe, payments for remediating damages go through the Environmental Liability Directive. Enforcement of laws can also come from a Ministry (e.g., Colombia, China, Vietnam), a National Commission (e.g., Chile CONAMA), or other rule-making and enforcing bodies. Most places, however, have some type of permitting process to regulate discharges of effluent and wastewater.

While these rules are important for regulatory action and litigation, research on the coal–water–energy nexus also shows how law and policy enable dispossession. Andrew Curley (2021), for example, shows how decades of legal concessions constructed Arizona's coal–water–energy nexus at the expense of Indigenous lands and livelihoods. This is not the only case of water agreements and leases for extractive industries creating new mechanisms of dispossession that heighten inequality over time. Others have shown how modifications to zoning laws have facilitated coal plant construction in protected areas (Borgias, 2018) and how the absence of energy policy on coal transitions can impact local tax bases and their ability to maintain water infrastructure (Roemer & Haggerty, 2021). In many of these scenarios the flows of water and energy are tied to financial flows as well, where fiscal dependence on the coal industry undermines local resiliency and impacts local drinking water and wastewater systems (Grubert & Hastings-Simon, 2022; Roemer & Haggerty, 2022). Both the presence and absence of legal and policy frameworks are at play in reshaping hydrosocial relations to energy.

As places move beyond peak coal consumption and production, many legal and policy questions at the water–energy nexus remain underexplored. Questions will continue to persist around legal disputes over water access and consumption during drought, but emerging questions center on who has access to water rights as coal plants retire. Some of these disputes will likely be between local and Indigenous communities and utilities, while others may include the water needs of new technologies, such as carbon capture and storage. Major resource corporations and fossil fuel actors will likely continue to play a role in shaping the local political ecologies of resource extraction and water use, even as they face resistance (Grubert & Hastings-Simon, 2022; Nyberg et al., 2022; Wright et al., 2021). This might include the delay in phasing out fossil fuel use, such as coal, by reasserting their central role in maintaining middle class ways of life (Huber, 2013; Wright et al., 2022). With respect to the overall impact of a phase-out of coal fired power plants on hydrosocial relations across the entire supply chain; however, there is a need to evaluate how different legal and regulatory mechanisms shape future access and control over water resources through the energy transition.

2.2 | Community impacts and water justice

The lasting environmental justice impacts and impairments to water quality in both surface and groundwater that coal mines and plants generate are well established (Scott et al., 2011). What is less explored are the community impacts and water justice implications that arise as coal fired plants retire and coal mines shut down. Social movements create opportunities to rework the possibilities of water–energy transitions away from coal (Dao, 2022; Kelly & Negroni, 2021; Yoon & Saurí, 2019). Coal mines and plants have long been generative sites for social justice movements to push back against fossil fuel development and to advocate for labor rights and alternative futures (Broto & Carter, 2010; Bustos et al., 2017; Kopas et al., 2020; Mehmood & Cousins, 2024).

How social movements impact coal phase-out policies, however, is complex and reflects place-based differences within water–energy transitions and the ability of communities to counter corporate control over water and resources (Mohr & Smits, 2022). For example, in Craig, Colorado a coal fired power plant is slated to retire in 2030 and the community is grappling with how to replace the lost jobs and economic revenue (Nieberg, 2022). Attention has turned to converting coal plant water rights to instream flows to support a new economy based on recreation and tourism. This shift in water rights supports goals of reducing consumptive water use aligned with the Upper Colorado River Basin's Drought Contingency Plan (Rep. Grijalva, 2019), but it also presents a new hydrosocial relationship between the community and the river. Similar dynamics can be found in other countries, including Poland, Czech Republic, Australia, Indonesia, Canada, and Germany, where community actors and social movements leverage different policy tools and types of evidence to shape struggles over the future of water resources impacted by coal (Currell et al., 2017; Dragan & Zdyrko, 2023; Gürtler et al., 2021; Svobodova et al., 2021; Toumbourou et al., 2020; Weller, 2019). As coal production continues to decline in many rural communities these shifts in the hydrosocial dynamics of the energy transition will play a critical role in shaping community resilience.

3 | WATER AND NATURAL GAS

In 2020, global natural gas production was at 4014 billion cubic meters—a decline from its peak in 2019 (IEA, 2020). The United States remains the world's top natural gas producer, with Russia situated as the second largest producer and top exporter of natural gas (IEA, 2023). Meanwhile, the European Union (EU) is the top gas importing region and new gas projects are being proposed and built across Asia and Africa (Global Energy Monitor, 2024). This global mix of natural gas production and distribution creates a mix of water impacts across the supply chain.

Historically, natural gas was harvested from shallow shale deposits using hydraulic fracturing and vertical wells, known as "conventional" extraction. Deeper deposits became more affordable and accessible with the combination of high-volume hydraulic fracturing and horizontal drilling (Braun, 2019), which allowed deeper and larger deposits to be fracked from a single well. Burning natural gas emits less carbon dioxide than coal, and as such, transitioning coal-burning power plants to natural gas has been characterized as a "bridge" to a lower-carbon energy system. As a bridge, natural gas ostensibly serves as a step toward a decarbonized energy future; however, many question this notion and have demonstrated that natural gas does not necessarily displace any carbon emissions (Chen, 2020; Greiner et al., 2018; Levi, 2013).

The transition to natural gas from coal reduces some types of water use but presents new water quality challenges. Water use for cooling natural gas power plants is an estimated four times less than for coal fired power plants (Kondash et al., 2019; Larson & Gupta, n.d.). However, the process of extraction via unconventional fracking is particularly water intensive. Anywhere from 1.5 to 16 million gallons of water is required to frack a gas well (Kondash et al., 2018). In the fracking process, fresh water is mixed with various chemicals and propellants and is forcefully pumped into deep shale to release the gas. This water and chemical mixture returns to the surface along with the gas. The wastewater, called "produced water," can either be recycled and used to frack additional wells, treated at facilities that filter out the brines, or disposed of in underground injection wells (Kondash et al., 2018). In general, this water–chemical mixture cannot be returned to source water or used for any human consumption purposes.

The material characteristics of natural gas create many risks and challenges as it is extracted, transported, processed, and intermixed with water (Kaup, 2008). Studies show evidence of surface water contamination and instances of methane contamination in water (Harkness et al., 2017). Meanwhile, scientific and popular debates persist about whether fracking natural gas can contaminate water and how widespread are the risks. Transportation of natural gas requires costly infrastructure with potential impacts on water quality, and a regulatory system that seeks to differentially allocate risk across the supply chain (Balmaceda et al., 2019).

3.1 | Legal and regulatory dimensions

Regulation of natural gas extraction is heterogeneous across countries and states (Sangaramoorthy, 2019), including a handful of countries and states choosing a moratorium on natural gas exploration and production (Sangaramoorthy, 2019; Vesalon & Crețan, 2015). France, for example, passed a landmark ban in 2011, which the courts upheld, on fracking for natural gas due to concerns over impacts to water quality (Jolly, 2013). As the top natural gas producer in the world, US natural gas extraction is largely permitted and regulated at the state level. This regulation across state lines, combined with regulation at the federal level, has been described as heterogenous (Baka, Forthcoming) and as "regulatory confusion" (Young, 2023). Notably, at the federal level, the Energy Policy Act of 2005 exempts fracking fluid from regulation under the Safe Drinking Water Act, as long as the fracking fluid does not contain diesel (Wylie, 2018). Additionally, produced wastewater is not classified as hazardous by the US EPA (Lave & Lutz, 2014; A. Willow & Wylie, 2014). Moreover, produced water contains proprietary chemical mixtures that most companies are not legally required to disclose (Kinchy & Schaffer, 2018; Young, 2023).

At the state level in the United States, multiple states have "presumed liability" legislation that states that water contamination is presumed to be the fault of well drilling activity when predrill and postdrill tests show that water quality has been affected (Kinchy, 2020). This process is complicated by a lack of baseline water testing (predrill), as well as company self-reporting (Turley & Caretta, 2020). A report from 2016 concluded that it is difficult to assess water contamination due to fracking because there is a lack of baseline water quality data and lack of data in general (US EPA, 2016). Similar regulatory gaps exist across Europe as well, with some countries imposing outright bans and others issuing permits and tax breaks to the natural gas industry. This has created a situation where many regulations are "not fit for purpose" or do not address many of the primary concerns of fracking (Tawonezvi, 2017). For instance, some of the chemicals used in the fracturing process are categorized as nonpollutants, which means that their injection into groundwater is not regulated despite potential impacts to groundwater quality (Hawkins, 2015).

The transmission of natural gas across state and international lines in large diameter, high-pressure pipelines are also unique to the country and region. In Europe, the European Union established several directives that each member state remains responsible for implementing. In the United States, natural gas transmission is permitted and regulated by the Federal Energy Regulatory Commission. In the US context, the permitting and construction of many pipelines, such as the Mountain Valley Pipeline or the Atlantic Coast Pipeline that would transport gas from the Marcellus shale to export terminals on the east coast, have been mired in delays and cancellations due to failure to secure environmental permits, particularly because of water quality violations around stream crossings (Stump, 2018; Ward, 2020). Similar issues exist across Europe and Africa; for example, the EU seeking to import gas from Africa would require investment into liquified natural gas pipelines (Global Energy Monitor, 2022), building a network of inland and offshore pipelines with an array of environmental impacts (World Bank Group, 2004).

3.2 | Community impacts and water justice

Natural gas extraction is controversial across the world primarily for its carbon intensity and contribution to global climate change and because of its potential to contaminate fresh water. Climate activists in Europe and Africa have mobilized against multinational corporations for their continued investments into producing and burning natural gas fossil fuels (Gayle, 2024; Rawoot, 2024).

Set in the United States, the documentary *Gasland* aimed to show the potential for water contamination due to hydraulic fracturing, and this documentary has spurred opposition based on water justice around the world (Fox, 2010). In the United States, natural gas drilling and fracking is often carried out in residential settings requiring gas companies to secure a lease to frack privately owned mineral rights to shale as well as a lease to the surface. Natural gas extraction has resulted in extensive rural and suburban land use change (Caretta et al., 2021). Because land and mineral owners are subject to both the benefits (gas royalty payments) and harms (environmental disturbances) of this arrangement, a myriad of community responses have emerged since the beginning of unconventional natural gas extraction. Studies have documented both support of gas extraction (Jerolmack & Walker, 2018) and the public outcry and protest around water contamination risks (Turley & Caretta, 2020; A. J. Willow, 2017). In US residential settings and across the world, communities have mobilized counter-expertise about how hydraulic fracturing impacts water, which runs counter to the dominant assertion that hydraulic fracturing cannot contaminate groundwater sources (Cantoni, 2022). The enduring issues around water in relation to natural gas extraction include how to manage large amounts of water used for fracking, and the risks to groundwater contamination from gas wells.

4 | WATER AND LITHIUM

Lithium is an ideal material for batteries because of its excellent ability to conduct electricity. As demand for electric vehicles (EVs) increases, lithium demand has grown worldwide, setting off a boom in extraction projects (Jerez et al., 2021). However, lithium extraction, typically spearheaded by multinational corporations, is water intensive and negatively impacts sensitive ecosystems and water quality (Blair et al., 2024), and as such has generated community opposition in lithium extraction hotspots around the world, particularly in South America (Blair et al., 2022; Bustos-Gallardo et al., 2021; Jerez et al., 2021; Sanchez-Lopez, 2019). Lithium extraction uses significant quantities of water, often in places already experiencing freshwater scarcity (Schomberg et al., 2021). Most of the world's lithium is currently extracted from Australia, China, and South America: Chile, Argentina, and Bolivia represent ⅔ of the world's mineable lithium resources (Schomberg et al., 2021). Brine extraction (common in South America and China) involves extraction of large amounts of groundwater into evaporation ponds (Liu & Agusdinata, 2020), leaving behind brine with higher concentrations of lithium, which is treated to extract lithium. In Chile, for example, producing 1 ton of lithium involves evaporation of 2 million liters of water (Dorn & Huber, 2020). The saline ecosystems where lithium is found often have unique biodiversity value (Gajardo & Redón, 2019), and lithium extraction is a major contributor to local environmental degradation (Liu et al., 2019). Other extraction methods also involve water: hard rock mining (common in Australia) involves mining, crushing, and roasting ore, then treating it with water, and technologies to extract lithium from geothermal brines are being explored in the United States at California's Salton Sea. Lithium can be toxic to humans and aquatic species (Bolan et al., 2021). Water pollution comes from trace amounts of lithium in waste storage ponds, along with processing chemicals and evaporation pond liners that leach chemicals into groundwater (Kaunda, 2020; Wanger, 2011).

Research on localized impacts of lithium extraction, including water impacts, has been fairly limited until recently (e.g., Agusdinata et al., 2018). However, the past few years have seen a marked increase in scholarship on hydrosocial and local community impacts of lithium extraction (Blair et al., 2024), as growing EV demand has sparked interest and awareness of lifecycle impacts, particularly in South America (Blair et al., 2022; Bolan et al., 2021; Bustos-Gallardo et al., 2021; Dorn & Gundermann, 2022; Hernandez & Newell, 2022; Jerez et al., 2021; Kaunda, 2020).

4.1 | Legal and regulatory dimensions

Laws and regulations around lithium extraction, water use and water quality, environmental protection, and community impacts vary widely from place to place (Dorn & Gundermann, 2022). Transnational mining companies often hold significant power and evade meaningful regulatory restrictions (Blair et al., 2022; Lunde Seefeldt, 2022). Complicating regulation, lithium brines can be considered water, mineral, or both. For example, in Argentina, lithium brines are regulated both as water resources and minerals (Steinmetz & Fong, 2019). Chilean law, however, considers lithium brine a mineral resource (despite its water intensive nature) and does not regulate it under the Water Code (Hernandez & Newell, 2022). Researchers have noted a need for more consistent and proactive approaches to regulation, including minimizing pollution, since retroactive cleanup of pollutants is expensive and difficult (Chow, 2022). Researchers have also described how scientific uncertainty and lack of data around, for example, groundwater impacts of mining, contributes to difficulty implementing regulations (Babidge & Bolados, 2018).

Beyond direct regulation (or lack thereof), several other types of interactions between law, lithium, and water occur. Legal permitting processes and tax credits are being used to incentivize lithium production in the United States. Seeking to increase domestic supply, the United States is fast-tracking permits and offering tax credits under the 2022 Inflation Reduction Act (Frazin & Budryk, 2023). In the United States and globally, proposed and existing extraction sites are being actively contested through legal means as communities use legal protections for water and endangered species to slow, stop, or regulate lithium development. Although legal protections exist in many places, they are not always effectively implemented (Dorn & Gundermann, 2022).

4.2 | Community impacts and water justice

While lithium is viewed as an important part of renewable energy transitions, vocal community opposition to lithium extraction has emerged globally, largely related to water impacts. This opposition challenges the premise of the "green" energy transition as a universally beneficial one, as sacrifice zones emerge (Cantor & Knuth, 2019). Given lithium's extensive water use, some scholars are seeking to reframe electro-mobility transitions explicitly in terms of water justice (Jerez et al., 2021). Global attention on the negative water impacts of lithium mining on communities, especially in Chile and Argentina, has expanded significantly in recent years (Blair et al., 2022; Bustos-Gallardo et al., 2021;

Riofrancos, 2022). Water in this arid region is foundational for life. Water scarcity and pollution caused by lithium extraction have forced communities to migrate and abandon their homelands (Agusdinata et al., 2018). Indigenous communities are particularly vulnerable, and companies have frequently failed to enact required consultation processes (Dorn & Huber, 2020). As mining proposals expand in the United States, issues of environmental justice and resistance are also emerging.

There is increasing interest from communities and researchers in contesting "the colonial shadow of green electromobility" (Jerez et al., 2021). Some have proposed to minimize lithium extraction by prioritizing its use for efficient transportation like e-bikes and e-busses, rather than inefficient SUVs (Riofrancos et al., 2023). Broader policy decisions around transportation, electro-mobility, and decarbonization thus have crucial connections to water.

5 | CONCLUSION

Hydrosocial relationships are being reworked through efforts to transition away from fossil fuels toward renewable energy. In conjunction with material changes, a host of water-related legal and community justice issues emerge in relation to decarbonization. In this paper, we have examined three different energy-related resources with markedly different hydrosocial relationships (Table 1). We purposely kept a narrow focus on these three specific resources to demonstrate water issues associated with different energy regimes and technologies, but we note that many other energy production technologies—for example, hydropower, biofuels, nuclear, and solar—also have unique and dynamic hydrosocial relationships. Moreover, in a mid-transition phase in which fossil fuels and renewables exist side-by-side (Grubert & Hastings-Simon, 2022), various water–energy relationships associated with different resources are likely to overlap and intersect.

As types and sites of extraction shift, water consumption and pollution patterns shift as well: for example, water use for energy is likely to intensify in already-drought-prone lithium mining areas even as it decreases in coal mining areas. "Virtual water" use patterns may shift as well: for example, the United States and other Global North countries currently import lithium while offshoring the localized impacts on water resource consumption and pollution (Peer & Chini, 2020). These international relationships and geopolitical trends should be a focus for scholars interested in energy transitions, water, and global equity.

Many questions remain to be explored within new geographies of the water–energy nexus. As our examination of three resources—coal, natural gas, and lithium—illustrates, a resource's materiality shapes hydrosocial relations within the water–energy nexus. Importantly, geography matters: not only in terms of where the resource exists for extraction, but also its relative location vis-à-vis consumers, nearby residents, and laborers along the supply chain. These geographical and material differences create contrasting perceptions of risk, uneven distributions of burdens and benefits, and

TABLE 1 Comparison of some key water issues associated with different energy resources.

	Coal	Natural gas (NG)	Lithium
Position in energy transition	"Out"—in decline.	"Through"—framed as "bridge fuel."	"In"—expanding.
Water quantity impacts	Less coal production and fewer coal-fired power plants can "free up" water.	Less water is used for NG power plants than coal, but NG production is water intensive.	Significant water use differs based on specific production method.
Water quality impacts	Abandoned mines can present significant water quality hazards even after mining operations close.	Significant potential for water quality impacts through fracking. Also, water quality concerns around transport including pipelines.	Significant water quality impacts in mining and extraction communities.
Summary of water–energy nexus around resource	Moving away from coal production may result in more water availability in coal-producing regions, but water quality remains a problem.	While NG power plants use less water, fracking presents significant concerns around water quality and quantity, and pipelines present water quality concerns.	Shifting toward lithium moves water burdens to communities where mining/extraction occurs, currently mostly in South America, China, and Australia.

different forms of regulation and resistance. Benefits and burdens are unevenly and inequitably distributed, particularly in regard to water resource impacts. For example, North American and European consumers who largely benefit from electric cars do not experience the associated burdens of groundwater over extraction or pollution associated with lithium extraction in South America. On the other hand, natural gas extraction often occurs within and adjacent to residential communities within the United States (Kroepsch, 2018). This could influence how different communities mobilize around different threats that new energy regimes present to water resources and community health. Place and scale are key: for example, water is freed up from closing coal power plants, but used and polluted in new ways via lithium. While this may amount to net zero in a global sense, in practice these impacts are place-based, localized, and felt in different ways by communities.

Each resource, with its unique materiality and set of hydrosocial relations, faces a host of different legal and regulatory landscapes in different places around the world. Many gaps and inconsistencies exist within current regulatory and legal systems. Some of these relate to how water is defined within existing rules. For instance, fracking wastewater is frequently not considered hazardous (Hammer & VanBriesen, 2012). Regulatory difficulties emerge with lithium brine and what it is legally classified as water or mineral (Flores Fernández & Alba, 2023). Then there are challenges in assigning rights and transfers, for example, as coal plants are decommissioned (Smyth, 2020). Looking ahead, water–energy transitions will create many legal and regulatory issues to track.

Finally, we argue that the energy transition is also a hydrosocial transition. Different energy regimes have distinct hydrosocial footprints and relationships, which involve material aspects, a variety of legal-regulatory contexts, and community impacts. Scale and geography are key, as uneven water-related benefits and burdens shift from one place to another through energy transitions, emphasizing the importance of a political-industrial ecology approach to explore impacts across the supply chain and entire lifecycle of resources. To maximize sustainability and equity, efforts to decarbonize energy systems must take into consideration the localized, place-based hydrosocial connections and impacts on communities via water.

AUTHOR CONTRIBUTIONS

Joshua J. Cousins: Conceptualization (equal); writing – original draft (equal); writing – review and editing (equal). **Alida Cantor:** Writing – original draft (equal); writing – review and editing (equal). **Bethani Turley:** Writing – original draft (equal); writing – review and editing (equal).

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

RELATED WIREs ARTICLES

Visualizing water-energy nexus landscapes

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