What Makes a Megaproject?

A Review of Global Hydropower Assemblages

Grant M. Gutierrez, Sarah Kelly, Joshua J. Cousins, and Christopher Sneddon

ABSTRACT: This article reviews how global hydropower assemblages catalyze socio-ecological change in the world's rivers. As a quintessential megaproject, massive dams and the hydropower they generate have long captivated the modernist development imaginary. Yet, despite growing recognition of the socio-ecological consequences of hydropower, it has recently assumed a central role in supporting renewable energy transitions. We highlight three trends in hydropower politics that characterize global hydropower assemblages: mega-dams as markers of nation-state development; river protection by territorial alliances and social movements opposed to hydropower; and transitions from spectacular, centralized hydropower installations to the propagation of small and large hydropower within climate mitigation schemes. We offer insights on how global hydropower assemblages force examination beyond traditional categories of "mega" through more holistic and grounded analyses of significance.

KEYWORDS: assemblages, climate change, development, energy transitions, hydropower, megaprojects

Introduction: Mega-Transformations of Hydropower

Few would question that early hydropower development represents a quintessential type of megaproject. Traditionally, a megaproject signified a massive, singular unit requiring extensive material and economic inputs (Flyvbjerg et al. 2003). Projects like the Aswan High Dam on the Nile or the Guri Dam in Venezuela, both towering more than one hundred meters, invoke such an image. Hydroelectric megaprojects are as impressive in scale as in scope. In 1950, large dams totaled around five thousand globally, with most of them located in Global North countries; 15 years later, that number jumped to 45,000, spanning more than 140 countries (ICOLD 1998), and this number now exceeds 59,000 (ICOLD 2019). This jump in dam development catalyzed the displacement of an estimated 40–80 million people, which prompted international organizations to seriously question the benefits versus costs of dams for local populations (WCD 2000). Indeed, the "concrete revolution" of large dam construction worldwide is one of the most notable trends in human-environment relations in the twentieth century (Sneddon 2015), contributing significant electricity and rapidly transforming human control over water resources.

Throughout the late twentieth century, large dams increasingly ignited opposition from networks of transnational social movements and nonprofit organizations on varying social and

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ecological grounds (Goldsmith and Hildyard 1984).[1] Yet financing for large dam development continues to increase (Ahlers et al. 2015; Richter et al. 2010), particularly in much of the Global South where nation-states and the global hydropower industry deem hydroelectric potential underdeveloped. Hydropower's "boom" is not only an artifact of the twentieth century but also a contemporary political challenge. Studies from the International Renewable Energy Agency (IRENA 2018) estimate that globally, hydropower jumped from producing 960,540 MW in 2008 to 1,270,496 MW in 2017; hydropower is currently undergoing a worldwide renaissance with capacity expected to grow 50 to 100 percent by 2050 (IHA 2015). Governments, international financers, and industry representatives successfully diffuse criticism by reframing hydroelectricity as renewable energy and now pitch hydropower projects as crucial to one hundred percent renewable energy goals.

Reframing hydropower as a viable renewable energy strategy currently manifests most prominently as the rapid development of small hydropower[2] and the resurgence of large hydropower. Many international developers and national governments push small hydropower because they consider it a lower-impact technology than large hydropower. As Christine Zarfl and coauthors (2015) show, there are 3,700 proposed dams worldwide, potentially increasing global hydropower by 73 percent. More than 2,700 will be small- to medium-scale hydropower (1 to 100 MW), with large dams supplying most of the electricity. At the international scale, climate change mitigation policies encourage adoption of both small and large hydropower, yet small hydropower tends to be more loosely regulated and often manifests as multiple, cascading projects in the same watershed. The global proliferation of small hydropower highlights the conceptual and political limitations of focusing on a single "project" or the size of the dam itself.

In this review, we emphasize how global hydropower assemblages help us understand the significance of socio-ecological change occurring in the world's rivers. We find that certain critical dimensions of hydropower development—sociotechnical imaginaries,[3] conflicts, and impacts—constitute a more holistic evaluation of the significance of megaprojects and global hydropower assemblages than the problematic labels "small" or "large." A focus on significance is not arbitrary. As a central feature of environmental impact assessments, significance is determined by the context and intensity of a proposed action. Considering hydropower projects as global assemblages (see Ogden et al. 2013) draws attention to the multiple scales, locations, and contingent relationships entangled with hydropower development.

We organize our review around three political elements that characterize global hydropower assemblages: large hydropower as symbolic of national development; hydropower as a locus of resistance that sparks transnational political activism; and small and large hydropower's ongoing alteration of river systems organized according to the purported logic of renewable energy transitions. We focus on the slippage and connections between large hydropower's history with small and large hydropower's present.[4] By questioning "mega," we also question what is labeled as small, demonstrating the need for analytical specificity and interdisciplinary inquiry for hydropower futures beyond the empirically loose category of "mega."

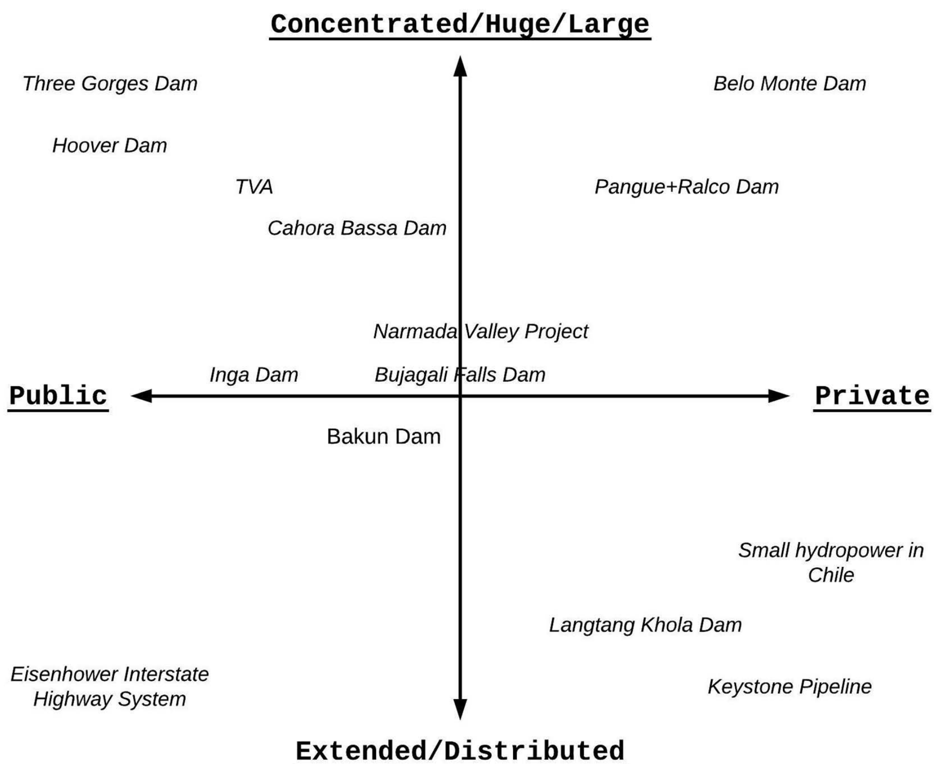
A Typology of Global Hydropower Assemblages

Hydropower's transformation of the world's rivers creates what Paul Robbins and Brian Marks (2010) term "assemblage geographies" that are both intimate and metabolic. They transform intimate human-nonhuman relationships in diverse socio-ecologies and produce profit in wide-reaching political-economic constellations. Analyzing hydropower as a global assemblage brings into sharp relief hydropower's multiplicity. As both river intervention and political-economic development endeavors, global hydropower assemblages consist of numerous financial, ideological, socio-ecological, and techno-political elements. Their geographies span World Bank boardrooms, concrete shipping routes, and subterranean mines where rare earth minerals for turbines are extracted.

The hydropower industry employs typologies when categorizing different types of projects; these are often based on a dam's specific use type and operation status (IHA 2015). In this section, we provide a typology that maps the reach of global hydropower assemblages and reframes how we analyze their significance. Our typology suggests an alternative way to examine the significance of megaprojects in contrast to more traditional, or apolitical, approaches such as cost-benefit analyses. Evaluating small hydropower alongside large hydropower reveals the historically contingent, and politically linked, ways that "mega" is hegemonic in terms of how academics, activists, and practitioners analyze the significance of current hydropower assemblages. As we suggest, "megaprojects" are a limiting conceptual and political category for thinking about development.

When applied to dams and hydropower, "mega" can refer to several different properties: physical characteristics, the expenditures needed to complete the project, the associated megawatts, the length of time necessary for construction, and the socio-ecological impacts, among others (Ansar et al. 2017). A common way to think about megaprojects is through their spatial reach, as well as the role of public and private actors in designing, financing, and constructing dams. In Figure 1, we mark these simplified attributes of megaprojects along two axes to

Figure 1. Characteristics of hydropower development activities. The x-axis highlights the continuum from public to private, in terms of financing, implementation, and participation. The y-axis directs attention to the spatial reach and material characteristics of infrastructure. Neither axis is necessarily linear, but together they offer a useful typology to examine and compare across cases.



designate their significance and allow for the comparison of different projects. The x-axis situates megaprojects horizontally along a spectrum from public to private and can refer to how megaprojects are financed, designed, and differentially beneficial to society. On the public side of the spectrum, megaprojects are marked by their symbolic importance for the public good. These projects receive public funds such as taxes or bonds for their construction, seek to include multiple stakeholders through the development process, and are owned and operated by governments or public utilities. In the United States, these public work projects represent about 32 percent of all dams (FEMA 2018). On the private end of the spectrum, megaprojects can take on similar development meanings among the public, but the infrastructures tend to serve private sector interests over the public good through their ownership and operations. For example, a hydropower project might power a local company or industry. Some projects that involve public-private endeavors do not easily chart on this axis; the center includes public-private endeavors that benefit each party.

The y-axis refers to the extent, spatial reach, and form of the megaproject. At one end of the pole, projects can be described as concentrated, huge, or large. This type of project is typically understood as a dense, large, and massive infrastructural agglomeration defined or scoped around a particular site. For example, these include large development projects in cities (e.g., Olympic grounds, stadiums, skyscrapers; see Fainstein 2008) or huge singular developments or structures with strong symbolic significance, such as the Three Gorges Dam in China. At the other end of the pole, megaprojects can be defined by their *extended* features and forms.[5] These are spatially distributed, far-reaching, and networked infrastructures and projects that span landscapes and territories and are part of larger development schemes characterized by their complexity, their heterogeneous components (e.g., interstate highways, submarine cables), and their near-to-distant impacts.

While Figure 1 offers a useful rubric to compare and orient megaprojects, we caution that these axes are neither static nor linear representations of megaprojects, but instead function as a simplified heuristic to show how projects emerge and exert influence. The matrix can help scope different components of the megaproject to be understood or studied (e.g., the transmission lines versus the dam). Our primary intent is to show how a simplified model of analysis that exclusively focuses on singular aspects of development, such as concentrated or extended features, is too narrow to understand how megaprojects produce social, technological, and ecological transformations and how their significance varies greatly by scale. Hydropower development, for example, exists along multiple continua that complicate the use of "mega" as a prefix, or its opposites of "micro," "mini," and "small," to describe projects.[6] Large or mega-hydropower projects typically involve large capital investments in the billions of dollars, take years to complete, enroll a complex set of actors, affect a large number of people, and pose major threats to terrestrial and freshwater biodiversity (Ansar et al. 2014; Benchimol and Peres 2015; Flyvbjerg 2007). Hydropower's resurgence foreshadows a massive increase in the number of hydroelectric dams, both large and small, and attendant socio-ecological impacts and transnational geopolitics.

Recent reports by the International Energy Agency (IEA 2010) and the World Bank (WB 2009) claim 70 percent of global hydropower potential remains untapped (1,330 gigawatts), primarily in regions of Africa and Asia-Pacific (Merme et al. 2014). A diverse array of nation-states—particularly those in regions with large segments of untapped hydropower potential such as West and East Africa, Central and Southeast Asia, and South America—garner multiple sources of financial and technical assistance to accelerate hydropower development (Zarfl et al. 2015). These activities are abetted by donor governments and their state-owned enterprises—prominently China, but also Iran and others—to establish advantageous economic relations and promote geopolitical aims (McDonald et al. 2009). Some of these projects, such as the series of Inga projects on the Congo River in Central Africa, are colossal and involve electricity transmission schemes on a continental scale (Showers 2011). In the Mekong and Himalaya regions, scholars argue international financial institutions now act as intermediaries in large hydro and small run-of-river projects for actors to make use of new financial instruments that disperse project funding with less transparency (Ahlers et al. 2015; Erlewein and Nüsser 2011; Merme et al. 2014). The complex political, economic, social, and ecological dimensions of global hydropower assemblages demand more holistic analyses.

We suggest the *significance* attributed to hydropower development by different actors is a more grounded way for social and physical scientists to measure the outcomes of a megaproject and the reach of its assemblage (Table 1). For example, incorporating how the residents of a site interpret project magnitude allows us to grapple with how massive infrastructural undertakings are remaking the world and how communities who live and hold interests near the site attach meaning to a project. The *extent* of a project in physical landscapes via road and transmission line infrastructure, and in networks of finance and resistance, is a key indicator to compare hydro-transformations. Significance also varies greatly based on scale, particularly from watersheds to state-making projects and geopolitical negotiations. The concept of significance shifts scholarly attention on hydropower to the work these projects do as assemblages in the world, and not just their material, or solely symbolic, components. In recognition of the politicized nature of hydropower development (Nüsser 2003), we suggest symbolism, conflicts, and impacts are perhaps more fruitful categories to capture significance than traditional ones such as size, spatio-temporalities, and functionality (Table 1).

Table 1. Categories of Significance for Hydropower Assemblages

Symbolism	Nationalism; mastering nature; renewable energy transitions; high modernism; scientism; sustainability
Conflicts	Geopolitical (e.g., transboundary rivers); international financing and ownership; grassroots resistance; Indigenous rights; transnational social movements; globalization
Impacts	Dispossession of local and Indigenous peoples; habitat fragmentation; altered stream flow and sediment disposition; inundating and harming sacred territory; affecting agricultural land and irrigation

Note: These categories and their associated examples are not exhaustive and not necessarily fixed outcomes. There is variation within the conflicts they generate, the types of symbolism underlying a project(s), and the social-ecological impacts of projects.

Next, we will expand on hydropower's significance by focusing on three political elements of global hydropower assemblages. Our emphasis focuses on how global assemblages and socio-ecological processes across sites transcend local, place-based dynamics (Ogden et al. 2013). Hydropower assemblages call in to effect multiplicity—of temporalities, of spatial scales, of political actors, and ecological relations (DeLanda 2006; Sneddon 2015).

Political Elements of Global Hydropower Assemblages

Global hydropower assemblages are multiple, and we focus on three of their characteristic features: hydropower as a vehicle for nation-state development, hydropower as a catalyst for social movements to organize against the proliferation of dams, and hydropower's central role in renewable energy development. Within each of these elements, the symbolism, conflicts, and impacts—our metrics for significance—associated with global hydropower assemblages call into question the efficacy of traditional metrics of "mega," like size, boundaries, inputs, and so on. We also contend the proliferation of small hydropower development in the era of renewable energy transitions captures contemporary reconfigurations of global hydropower assemblages.

Dams, Development, and the Project of Modernity

Interacting political-economic, geopolitical, and ideological forces combined to fuel the proliferation of hydroelectric generation systems across the planet over the past eight decades. For most of their history and continuing to the present, large hydropower projects have been bolstered by the hegemonic idea that "mastering" rivers was the most effective pathway toward using water resources to develop and modernize. Since their advent in the first half of the twentieth century, the dissemination of hydroelectric systems has become ensconced in national economic policies and state-driven ideologies of modernization (Isaacman and Isaacman 2013; Kaika 2006; Mitchell 2002; Sneddon 2015). This modernist project signifies the early history of global hydropower assemblages, as hydroelectric development activated global networks of techno-political power (Sneddon 2015).

The construction of Hoover Dam on the Colorado River in the 1930s and its attendant networks of water and electricity delivery across western US landscapes have rightly received intense scrutiny as seminal moments in the history of hydropower development (Hiltzik 2010; Worster 1985).[7] Additionally, Hoover construction established a model of mega-hydropower development that circulated throughout the world (Sneddon 2015). This style of exporting development also has antecedents in the Tennessee Valley Authority (TVA). Originally occurring in the name of "democratic" hydroelectric production (Ekbladh 2002), the transformation of the Tennessee Valley in the 1930s and 1940s offered an idealized framework for river basin development that rapidly proliferated across the planet in subsequent decades (Adas 2006; Baghel 2014; Barrow 1998; Klingensmith 2007; Molle 2009).

Both the Hoover Dam and the TVA cases underscore the geopolitical and imaginative aspects of hydropower development. Once the technological requirements of constructing massive structures and delivering electricity across vast distances were met, the dissemination of hydropower development to Asia, Africa, and Latin America was enveloped within Cold War geopolitics and the technological, political, and economic "sublimes" common to megaproject development (Flyvbjerg 2014). As in the United States, hydroelectric development in the USSR was a key component of its leaders' modernization and industrialization programs throughout the middle of the twentieth century, a period when the "display value" of megaprojects reached a zenith in the Soviet era (Josephson 1995). The foreign relations apparatuses of the US and Soviet states used hydroelectric dams as a means of maneuvering the leaders of emerging postcolonial nation-states into the defined ideological spheres of the Cold War. The leadership of many postcolonial regimes perceived the construction of hydroelectric projects as vital to both industrialization-led economic growth and as potent symbols of modernization (Sneddon 2015). India is a case in point, where the administration of Jawaharlal Nehru embraced damming, such as the Bhakra Dam for irrigation purposes in the context of the Green Revolution, as well as other hydroelectric endeavors to enhance their political legitimacy and stoke industrial activities. Dams, according to Nehru in a 1964 speech, were the "temples of the new age" (Klingensmith 2007).

As developers and governments promoted large dams around the world in the twentieth century, their implementation followed high-modernist ideals that placed an unquestioned faith in science and engineering—a vision that subordinated nature and people under state ideals of progress and development (Scott 1998). This scientism influenced Franco's rhetoric of *regeneracionismo* in twentieth-century Spain (Swyngedouw 1999, 2007) as much as it did during India's postcolonial turn to nation-building (Klingensmith 2007). Hydropower as a state-making technology, however, is as current as ever. For instance, the Bhakra and Hirakud dams in India, the Volta Dam in Ghana, the Kariba Dam in Zambia, the Bhumibol Dam in Thailand, and the Aswan Dam in Egypt were all considered potent symbols of development by national and international organizations. Currently, scholars examine how hydropower and state-making require and generate new forms of subjectivity and citizenship, all bound to modernist understandings of the nation-state (Anand 2017; D. Hughes 2006; Lord 2014). While hydropower serves to bolster nation-building, multiple visions of the state emerge unevenly across state space, which complicate a universal nation-state imaginary (Akhter 2015; Harris 2012). Across cases, scale provides a key analytic for understanding the relationships between state-making, hydropower, and political negotiations.

Hydropower development relies on scalar narratives that entangle a suite of actors, both human and nonhuman within complex networks, to assert power or a particular worldview (Sneddon 2003). Dams are used as tools to govern and manage new geopolitical units, as well as biophysical units such as the basin and watershed (Bakker 1999). In his early environmental history of the damming the Columbia River, Richard White points out that dams, being "the same machines that masked labor also created new opportunities for labor . . . [and] this new work depended on precise organization of humans and nature, and this organization was spatial" (1995: 38). Oftentimes, the concept of river basin and watershed are used interchangeably (Barrow 1998; Molle 2009), and James Wescoat (2000) shows how the watershed concept becomes used within regional planning in the United States. Moreover, the notion of watershed often assumes the idea of a stakeholder within the bounds of the watershed, all of whom, it is assumed, seek common solutions because of their shared experiences in the watershed (Orlove and Caton 2010). Yet, the history of responding to watershed interventions demonstrates multiple configurations of problem solutions that are codified in different programs, legal documents, and government reports.

The United Nations Conference on the Human Environment in Stockholm in 1972 established the United Nations Environment Programme, whose creation exemplified the increasing calls from environmental scientists, anthropologists, dam-affected communities, and pro-poor development NGOs that even the most well-designed schemes generated negative social and ecological effects (see Farvar and Milton 1972). More recently, the comprehensive review of hydropower impacts carried out by the World Commission on Dams (WCD 2000) overwhelmingly found significant cost overruns and unmet promises of economic returns for many of the world's major dam projects. As Maria Kaika (2006) notes, large dams embody the geographical imaginations and material practices of modernization, as well as infrastructures that conquer nature and reconfigure spatial relationships. For example, Hoover Dam eventually became a potent symbol of both aesthetic achievement within civil engineering practices (Wilson 1985) and human domination over the natural and social worlds (Worster 1984). Slowly, physical and social scientists caught up with large hydro's trend in development, documenting the significant impacts across large swaths of space and long durations of time (McCully 2001).

In the Zambezi Valley of Mozambique, the massive Cahora Bassa Dam's meaning shifted over time in relation to nation-state and colonial politics and varying interpretations of the natural environment. Alan Isaacman and Barbara Isaacman (2013) uncover a politics of nature that involves differentiated understandings of the environment: one where the colonial regime viewed the dam as a technological marvel to control and regulate a wild and dangerous nature contrasted with the local worldviews of the Zambezi as a place that provides wealth and a multiplicity of lifeworlds. The transformation of the Zambezi also touches on geopolitical and energy sovereignty, since more than 87 percent of the "displaced energy" is sold for export to South Africa. During the Portuguese colonial regime (1961–1974), guerilla and FRELIMO forces viewed the dam as an extension of white hegemony in the African continent because of its transnational energy regime. After colonial collapse, the FRELIMO government mobilized the dam as a technology of liberation. This discursive framing mobilized specific categories of nature, the state, and economy to dispossess people of the possibility of other worlds, displacing more than 30,000 residents dependent on the Zambezi River and its floodplains.

Overall, these development projects produced massive impacts. Large dams are likely to have significant, long-term social and ecological effects that frequently engender conflicts over displacement, the loss of cultural heritage sites, and competing uses (Chowdhury and Kipgen 2013; Huber and Joshi 2015; Scudder 1973; Sneddon and Fox 2008). The different functions of multipurpose dams (e.g., flood control, irrigation, electricity production) can also spark conflicts such as those between water suppliers and flood control managers (Cousins 2017). As large dam construction proliferated throughout the world, researchers interrogated the nature of hydropower impacts on upstream and downstream channel dynamics. Yet most of these studies were conducted in the Global North, where there is a longer track record of collecting consistent hydrological and ecosystem data. Large dams with artificial reservoirs impact a variety of processes and structures, from channel morphology (Brandt 2000; Chien 1985; Williams and Wolman 1984) to flow regulation and habitat fragmentation (Dynesius and Nilsson 1998; Nilsson et al. 2000) to floodplain morphology (Marren et al. 2014) to river and riparian ecology (Richter et al. 1996) through changes in the hydrology of rivers, such as the frequency of high and low flows, their magnitude and at what time of year and season they occur (Graf 1999; Power et al. 1995). For example, morphological changes in the river channel impact sediment load, creating "hungry waters" that erode the bed and banks of rivers to recapture the lost sediment load (McCully 2001). In general, the effects of dam impoundment on river processes are intimately linked to climate conditions, regional geography, types and operations of dams, and environmental conditions, though observed impacts tend toward homogenization and channelization of flow regime (Magilligan and Nislow 2005; Poff et al. 2007). Given this degree of physical intervention to the world's rivers, it is not surprising dams are connected to a noteworthy global example for networked grassroots resistance in defense of free-flowing rivers.

Dams and Their Discontents

In stark contrast to the imagining of dams as a potent modernizing force, hydropower also provokes enduring social conflicts across networks of locally disaffected peoples and their multiple global collaborators. These social movements draw attention to the multiple scales of impacts that hydropower intervention instigates in river systems and bring into sharp relief the widespread international alliance of anti-dam activists. Throughout the 1990s, roughly 640,000 MW of installed hydroelectric capacity provided almost 20 percent of the world's total electricity, revealing the scope to which large dams form part of the invisible infrastructure of everyday life for people across the planet (Gleick 1998). Recently, a diverse array of communities engaged in contentious politics began to invoke the phrase "water is life." For some, this rallying call against development interventions and dispossession reveals a powerful and complicated truth. These words, "water is life," bring to the fore the intersections between water and power, emphasizing that protecting water also protects life in its many forms. Water conflicts can also involve struggles for Indigenous self-determination and territorial sovereignty. Understanding the intersections between water and regimes of power is timely, yet long before this current moment, scholars of anti-dam social movements documented the ways water becomes a locus for political organizing.

While megaprojects such as large hydropower development have historically received push-back, it was not until the 1970s that directly affected people organized into formal movements to resist these projects in their territories (Garandeau et al. 2014; Omvedt 1987). Anti-dam movements rose parallel to the incipient environmental and conservation movements and gained traction as dams proliferated throughout the developing world (Cummings 1990; McCully 2001). These anti-dam social movements call attention to the variegated potential impacts from megaprojects, such as compromised Indigenous claims to land and territory (Athayde 2014; Ghosh 2006) or the social and economic impacts of resettlement and loss of livelihood (Katus et al. 2016; Nilsen 2008). These social movements are inspired by diverse sets of values for what constitute nature and society, such as the movement against hydropower in Patagonia, which produce geographic regions as exceptional "places of concern" (Schaeffer and Smits 2015).

Moreover, conflicts involving hydropower often involve conflicts in modes of development (Ahlers et al. 2014; Chowdhury and Kipgen 2013) and the politics of coloniality (Mitchell 2002). Early on, the World Bank was a major institution supporting hydropower (Omvedt 1987) and became a locus of anti-dam sentiments. For example, India's Narmada Valley project received World Bank support until it became a hotbed of political contestation in the early 1990s (Dwivedi 1998), at which point funding was partially retracted. The Narmada Valley became a focal point of international scrutiny because of a hotbed of issues: subversion of the environmental impact assessment process (McCully 2001), ties to state corruption (Omvedt 1992), and institutional epistemological bias (Erlewein 2013).[8] Over time, large dams also became embroiled in conflicts around water scarcity, and scholars have shown how the discourse of dams produces both the need for water supply and its perceived scarcity (Phadke 2002).

Indeed, increased environmental awareness at the international policy level over the Narmada projects in India helped spark what Gail Omvedt (1987) argues is the Third World's first "grassroots ecological movement." The anti-Narmada campaign Narmada Bachao Andolan (NBA), which arose to resist the displacement of people in the Narmada Valley because of large-scale dam development, is an exemplar of this organizing across scales (Dwivedi 1998; Nilsen 2008). Further, Omvedt (1993) argues this anti-dam campaign helped crystallize a formal environmental politics in India. Anti-dam social movements, as scholars show, become moments of knowledge brokering through different modes of political protest that incorporate science and other forms of knowledge in overlapping forms (Phadke 2005). These overlapping knowledges are part of an extensive circulation of local-global articulations as social movements gain size and momentum. Pablo Bose (2004) discusses the role of popular and public intellectuals in the rise of NBA, showing how activists like Medha Patkar and Arundhati Roy become embroiled in the conflict and garner mass media attention. Along similar lines, Jim Glassman (2002) analyzes the Thai Assembly of the Poor to demonstrate the global connections between anti-globalization protests following the WTO meeting in Seattle in 1999 and solidarity organizing with labor unions and communities resisting the Pak Mun Dam in Thailand.

Within Latin American water politics, few would dispute that the magnitude of the Ralco and Pangue dam projects (generating 690 MW and 450 MW, respectively) on the Upper Biobío River of south-central Chile was anything if not "mega."[9] For more than 10 years, a heated conflict involving the displacement of at least 42 Mapuche-Pehuenche Indigenous families and their sacred sites simmered alongside ecological and democratic concerns in post-dictatorial Chile. Under the Pinochet dictatorship (1973–1990), Chile's constitution and resource laws, including the Water Code (1981), were rewritten according to a neoliberal, pro-market ideology (Bauer 1998). Initially, the projects attracted the World Bank's financing arm, the International Finance

Corporation (IFC), continuing a history of World Bank investment in the country.[10] The Alto Biobío conflict in Chile embroiled actors at multiple scales (local, national, international) and crystallized a suite of inflecting concerns about development and the recognition of Indigenous rights in environmental assessments (Morales 1998).[11] Then, in 2007, Patagonia Sin Represas (Patagonia without Dams) famously cohered in protest of a proposed 1,912-kilometer transmission line and five hydropower projects (2,750 MW total) in southern Aysén, forming an international and transversal movement concentrated in Santiago and the Aysén region of Chile. The vast territory dragged into the conflict reflects in part the extent of the massive energetic undertaking. Popular imaginary of Patagonia as an untouched nature arguably motivated actors, as did the desire for democratic institutional proceedings (Borgias and Braun 2017; Schaeffer 2017). Conflicts involving hydropower, and water more broadly, proliferate throughout the country (Bauer 2015). How hydropower is imagined in Chile, and internationally, has shifted over time.

Small Hydropower in the Era of Renewable Energy Transitions

As we have discussed, large dams often served governments as symbols of national development and modernization. Today, governmental and industry actors promote hydropower generation in the name of renewable energy and mitigating the production of greenhouse gas emissions alongside economic development, despite the concerns of scientists, NGOs, and a variety of social movements that hydropower is neither renewable (because of reservoir emissions; see Deemer et al. 2016; Fearnside 2002) nor socially just (see Ahlers et al. 2015; Fletcher 2011; Maeck et al. 2013). In the past, the boosters of hydropower development in government, international finance, and business pointed out the sector's capacity to generate relatively cheap electricity to fuel industrialization.[12] An important discourse around hydropower as renewable energy—articulated across a range of geographical and political-economic contexts—emerged more recently through planetary concerns over global warming.

Overall, small and large hydropower are buoyed by the symbolism, and the discursive purchase, of a 100 percent renewable energy future (Ahlers et al. 2014; Frey and Linke 2002; Harlan 2018; Kelly-Richards et al. 2017). Small and micro-hydropower, for example, are often hailed as "green" or eco-friendly solutions, with limited environmental impacts, that can foster renewable energy transitions and provide rural electrification in less developed countries (Egré and Milewski 2002; Okot 2013; Paish 2002; Premalatha et al. 2014). The assumption that small hydropower is more benign is based on little evidence and runs the risk of repeating large hydropower's history to the detriment of affected populations (Premalatha et al. 2014).

Emergent literature on small hydropower identifies a variety of negative impacts and social conflicts across case studies (Couto and Olden 2018; Jumani et al. 2017; Kelly 2019; Kelly-Richards et al. 2017; Shaw et al. 2015; Silber-Coats 2017). This has major implications; an estimated 82,891 small hydropower projects are in phases of construction and operation in more than 150 countries (Couto and Olden 2018). In some cases—such as certain renewable energy portfolios like Chile's, cumulative impacts of cascade design in China, or Clean Development Mechanism (CDM) financing—small hydropower represents a contemporary articulation of global hydropower assemblages. As we demonstrate here, small hydro's current boom articulates with the past two political constellations of hydropower, particularly in terms of how its symbolism, conflicts, and impacts are framed and understood.

This point is made even more relevant by the reimagination of both small and large hydropower as integral to the transition to renewable energy. While small hydropower projects grow, climate change policies also promote the development of large hydropower (Moore et al. 2010). Climate change agreements like the Kyoto Protocol and the CDMs have spurred hydropower development to replace fossil fuel development (Erlewein and Nüsser 2011). Industry representatives encourage large hydropower as a means to transition into a renewable energy future by providing a less intermittent source of electricity than solar and wind while generating less carbon dioxide emissions per lifecycle than other sources (IHA 2018). Hydropower promotion as part of global climate change policy is evident in the CDM financing for hydropower, which funded large *and* small hydropower, producing a concentration of projects in the Himalayas of China and India, some of which did not meet CDM standards (Erlewein and Nüsser 2011).

Geographically, small hydropower's quick growth in mountainous regions worldwide concentrates projects in certain river basins as rural development schemes (Kelly-Richards et al. 2017). Thus, renewable energy development expresses locally as rapid socio-ecological change in mountainous rivers. As of 2014, China had roughly 48,000 small hydropower projects and 40 percent of the world's small hydropower installations (Couto and Olden 2018; Ptak 2014). Regionally, projects are boasted for their contribution to rural electrification and socioeconomic development, but minimal research documents the outcomes (Kibler and Tullos 2013; Ptak 2014, 2019). In the Yunnan Province, Tyler Harlan (2018) traces how interaction between government goals, private actor development, and climate mitigation funding have resulted in the regional transition from "rural utility to a low carbon industry," effectively shifting from micro hydro to "small" hydro installations (defined in China as generating 50 MW or less). A growing tendency in China to use the cascade design provokes considerable social and ecological impacts (Hennig and Harlan 2018). Scholars agree that small hydro's ecological and social impacts require more investigation (Couto and Olden 2018; Fung et al. 2019; Kelly-Richards et al. 2017; Kelly 2019; Lange et al. 2018). Currently, it appears that regulation for small hydropower stands to repeat the history of underestimating large hydro's impacts.

Within the discourses surrounding small hydropower, there tends to be a categorical conflation between "small" and "good," which leads decision makers to overlook negative impacts such as the cutting off of local access to water resources (Silber-Coats 2017). Confusion lingers regarding what actually constitutes small hydropower among policy makers and developers (Abbasi and Abbasi 2011; Kelly-Richards et al. 2017; Premalatha et al. 2014). This definition holds political implications: a persistent imaginary of small hydro as environmentally friendly (Premalatha et al. 2014) enables actors such as project developers to minimize the spatial extent and reporting of impacts. Here, hydropower's recasting as renewable energy interacts with its past: the emergent phenomenon of small hydro is regulated in relation to large hydropower, thus leading to inadequate regulation. In Chile, for example, operating up and downstream from the Pangue and Ralco dams on the Biobío River are multiple "nonconventional renewable energy" hydropower projects labeled as small hydropower. In Mapuche-Williche Indigenous territory of southern Chile, small hydropower's geographic preference for areas of cultural significance generates significant impacts, infringing on Mapuche-Williche territorial rights (Kelly 2019). In countries such as Chile and India, the cumulative socio-ecological change of these projects is not being considered in environmental impact assessments, in part because small hydropower is believed to be less invasive (Erlewein 2013; Kelly 2019).

Parallels exist in the imaginaries and discourses surrounding both small and large hydropower development, yet there are critical differences as well. For example, large hydropower's history has led to the transformation of the world's rivers—continuing to frame hydropower as green energy overlooks how hydropower's continued development substantially intervenes in the world's freshwater cycle (Nüsser and Baghel 2010). One of the most notable impacts of impoundment by dams is on a river's natural flow regime, or the diversity in magnitude, frequency, duration, rate of change and timing of discharge, and low and high flow events (Poff et al. 1997). The ecological integrity of a river system is dependent on heterogeneity in both process and form. Francis Magilligan and Keith Nislow (2005) analyzed pre- and post-impoundment data on dams across the United States, demonstrating a decrease in maximum flow and an increase in occurrence of minimum flows. More recently, scholarship has brought attention to hydropower's significant contribution to greenhouse gas emissions primarily through methane (and carbon dioxide) released in shallow and tropical reservoirs (Fearnside 2002; Guérin et al. 2006; Gunkel 2009; Steinhurst et al. 2012).

Small hydropower draws attention to a similar history of impacts, but one where symbolism in relation to size leads decision makers to overlook or downplay negative impacts. For example, the amount of megawatts generated is not directly proportional to hydropower's impacts (Bakken et al. 2014; Kelly-Richards et al. 2017; Kibler and Tullos 2013; Premalatha et al. 2014). To the contrary, megawatts can "mask impacts" for small hydropower projects that produce outsized impacts (Kelly 2019). Their disproportionate effect on biodiverse mountains streams and local landscapes can be severely detrimental in affected areas (Bakken et al. 2012; Pinho et al. 2007; Tang et al. 2012). Additionally, scholars are calling for examination of cumulative impacts of multiple small hydro projects at the watershed scale, particularly in terms of biodiversity (Couto and Olden 2018; Kelly-Richards et al. 2017; Kibler and Tullos 2013; Lange et al. 2018). Emphasis on size in hydropower projects, coupled with hydropower's looming history of megaprojects and simmering conflict, overlooks the significance and extent of hydropower's transformation of the world's rivers.

Conclusion: Hydropower Futures

In this article, we highlight the conflicts, impacts, and sociotechnical imaginaries entangled in hydropower development to draw analytic focus to how hydropower development activates global assemblages and networks of power, rather than being a singular infrastructure installation fixed by spatial and historical boundaries. The new global push for hydropower development following hydropower's recasting as renewable energy underscores the malleability of hydropower as a technological intervention and as a hegemonic notion for structuring hydro-social relations. Additionally, hydropower's history signals the vitality of water. Water is inextricably implicated in hydroelectric undertakings: its properties of flow invariably extend hydropower's reach. Tracking the materialities involved in megaprojects is critical to understanding the work each project does as an assemblage generating socio-ecological transformations.

"Mega" can be read in hydro-politics in multiple ways. Hydropower's historical interventions in the world's rivers are massive in scale and scope. Large conflicts and impacts left in hydro's wake do not necessarily correspond to one infrastructural project. All over the world, conflicts involving rivers run deep, typically involving human rights and significant costs. Conflicts over rivers present conflicts over life. A noteworthy portion of conflicts involve struggles for Indigenous self-determination. Despite its conflictive nature, hydropower projects are slated on development dockets all around the world. And it is ongoing river interventions that catalyze enduring socio-ecological change. This development occurs even amid uncertainty about hydropower's efficacy under changing precipitation regimes (Tarroja et. al. 2016).

Future research must trace hydropower's growth, particularly what appears to be the emergent trend of hydropower being developed with the 1–100 MW range. Scholars can address how environmental social movements against dam development, and alongside dam developers, become entangled in hydropower's emerging political economy as a renewable energy. Relatedly, scholarly examination could follow the ways hydropower as renewable energy resource gets bound up within contemporary nation-state politics and nation-building, which represents emergent geopolitics of the Anthropocene. Further, research on the ways rural people and people living at the margins of urban society come to understand alternative energy transition politics can shed light into the emerging subjectivities of hydroelectric development and climate change citizenship. A final direction for research, given the violent and colonial history of much of hydroelectric development, lies in continuing lines of research like Christine Folch's (2016) into movements toward energy sovereignty and the push for decolonizing energy politics through defending watersheds and waterways.

Hydropower's re-signification indicates how capitalism appropriates, and then reinterprets, its modes of resistance into new forms of encroachment and expansion (Gramsci 1971). Indeed, large and small hydropower continue to catalyze the transformation of the world's rivers, arguably diminishing resilience. Hydropower's history and current moment prompt us to think beyond megaprojects, to instead empirically assess the significance and reach of the assemblages that involve socio-ecological change, global environmental policy, and complex private-public arrangements. Transitions to renewable energy futures should not transpire at the expense of the world's river systems.

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GRANT M. GUTIERREZ is a PhD Candidate in Ecology, Evolution, Ecosystems and Society at Dartmouth College. His research examines the relationships between climate change and watershed conservation politics in Chile. Email: grant.m.gutierrez.gr@dartmouth.edu

SARAH KELLY is a postdoctoral researcher in the Department of Anthropology at Dartmouth College. She is also a postdoctoral researcher associated with the Centro de Investigación para la Gestión Integrada del Riesgo de Desastres at the Universidad Católica de Chile in Santiago Chile. Her research addresses the intersection of hydropower development, Indigenous rights recognition, knowledge politics, and collaborative research methodologies. Email: sarah.kelly@cigiden.cl

JOSHUA J. COUSINS is Assistant Professor in the Department of Environmental Studies at the State University of New York College of Environmental Science and Forestry. His teaching and research focus on issues of resource governance, sustainable urban systems, the political ecologies of water and energy, and the social dimensions of science and engineering. Email: jcousins@esf.edu

CHRISTOPHER SNEDDON is Professor of Geography and Environmental Studies at Dartmouth College. His research examines how conflicts over water emerge at multiple scales

and are linked to human alteration of river systems. His book *Concrete Revolution* (2015) explores the global geopolitical forces that contributed to the rapid spread of hydropower dams across the face of the planet throughout the twentieth century.
Email: christopher.s.sneddon@dartmouth.edu

NOTES

1. For an understanding of a river's natural flow regime, see Poff et al. (1997). For discussion of how hydropower disrupts ecosystem productivity and the impacts of sediment retention in rivers, among other social and ecological impacts, see Binger (1978), WCD (2000), Vörösmarty et al. (2003, 2004).
2. Definitions for the size of hydropower project vary by country and by reporting agency. A growing global consensus states that small hydropower generates 1 to 10 megawatts (MW), but the definition varies by country (Kelly-Richards et al. 2017; Lange et al. 2018). According to the International Commission on Large Dams, large dams are typically measured by the size of the concrete curtain (higher than 15 meters) and the amount of area inundated.
3. According to Jasanoff (2015: 4), socio-technical imaginaries are "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology." Within social and political theory, imaginaries have spanned from producing idealized political communities (Anderson 1983) to the intersubjective relations of individuals to broader networks (Taylor 2002). Nüsser and Baghel (2017) extend the sociotechnical imaginaries framework to hydropower through their framing of technological hydroscapes.
4. Our review does not address micro- or mini-hydropower because these are primarily low-impact projects that divert flows through pipes and bypass channels and have different turbine designs, costs, and efficiencies than small and large hydropower projects (Paish 2002).
5. The use of the terms extended and concentrated parallels theorizations of urbanization drawn from Lefebvre (2003) and further developed by Brenner (2014), Schmid (2018), and Soja (2013), among others.
6. In this article, we focus on small hydropower projects, since they are significantly larger than micro projects; Hoffken (2016) documents that some imagine micro-hydro a "beautiful" technology as they draw on different understandings of nature and science. These micro-hydropower projects, however, are context specific and entail different social and ecological impacts, maintenance needs, and exposure to extreme events (Arnaiz et al. 2018, Kusakana 2014).
7. Thomas Hughes (1983: 262–284) argues the coproduction of large-scale hydroelectric dams and long-range transmission lines in California during the late nineteenth and early twentieth centuries, made possible by a conjuncture of technological innovations, political, and economic interests, and the particular geographies of the region, was a similarly pivotal moment.
8. Other dam projects in India have been studied for both their connection to global flows of capital and exported/imported schemes of development (Biswas and Tortajada 2001) and for understanding the production of environmental subjects and subjectivity (Birkenholz 2009; Ghosh 2006).
9. Today, Ralco sits 30 kilometers upstream from the Pangue Dam. Built with a concrete curtain of 155 meters, the Ralco Dam meets the international agreed status of a mega-dam.
10. As read in WBG (2016): "The International Bank for Reconstruction and Development announced on March 25, 1948 that two loans were approved for Chile totaling $16 million (Loans 0005 and 0006); one for the development of electric power and water resources and the other for the importation of agricultural machinery and equipment. These were the Bank's first development loans and the first loans the Bank made to a country in Latin America."
11. These conflicts drew the attention of the Committee for Human Rights of the American Anthropological Association, whose "Pehuenche Report" denounced the IFC's suppression of anthropological knowledge detailing human rights violation and the forced resettlement of Indigenous communities (Johnston and Turner 1999).

12. This remains a crucial rationale for hydropower development and is often coupled to electric power targeted at specific industries such as mining. This is the case for the long-term plans to carry out hydropower development in the rivers basins of Sarawak, Malaysia—including the massive Bakun Dam—where nearly all the electricity produced is designated for the region's aluminum smelters (Sovacool and Bulan 2011).

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