



Infrastructuring environmental (in)justice: green hydrogen, Indigenous sovereignty and the political geographies of energy technologies

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Abstract. Against the backdrop of ongoing planetary crises, this paper discusses the ambivalent relationship between large-scale material infrastructure, particularly energy technologies, and environmental justice. Inspired by relational and practice-oriented understandings of infrastructure, it develops a conceptual approach for energy-related environmental justice research, which is exemplarily applied to the emerging issue of green hydrogen, drawing on brief insights from the hydrogen frontrunner countries Colombia and Canada and associated struggles over Indigenous sovereignty. This “infrastructural lens”, based on three epistemological shifts – from infrastructure to “infrastructuring”, from social imaginaries to “sociotechnical imaginaries” and from human infrastructuring to “planetary infrastructuring” – provides deeper insights into how patterns of justice and injustice are practically infrastructured and what kinds of imaginaries they evoke or are entangled with. Moreover, it makes tangible how practices of infrastructuring can themselves become part of a broader political ontology, that is, of struggles over ways of being and ways of relating to planet Earth.

1 Introduction

Not least since the recent “infrastructural turn” in the social sciences (Amin, 2014; Harvey et al., 2017b), critical scholars have increasingly debated the political dimensions of material infrastructure. In this regard, there is a growing consensus that, for example, dams, roads and bridges and energy technologies such as pipelines, transmission lines or wind farms are not neutral entities or inert material things but are imbued with power relations and normative orders, as well as social meanings and imaginaries of the future (Anand et al., 2018; Boyer, 2014; Harvey et al., 2017a; Jasanoff, 2022; Jasanoff and Kim, 2015). At the same time, there is an increasing awareness that infrastructure plays a critical role in driving planetary crises, prompting scholars to focus more thoroughly on the relationship between infrastructure and sustainability (Degens et al., 2022). Within these debates, large-scale infrastructure projects are seen as “the production mills of the Anthropocene” (Alejandro Esguerra cited in Berger et al., 2022:15), leading to massive CO₂ emissions, socio-ecological destruction, and struggles over

land and resources (Dunlap, 2021). Others, however, argue that infrastructure or, more specifically, the transformation of existing infrastructure can become an important leverage point for socio-ecological change (Neckel, 2022). While acknowledging the relevance of infrastructure in causing socio-ecological harm, these authors emphasize its transformative and revolutionary potential to enable societal alternatives and address the multiple planetary crises (Boyer, 2022; Schiller-Merkens, 2022). Thus, one of the central characteristics of infrastructure is not only that it is fundamentally paradoxical, in the sense that it can be simultaneously generative and destructive (Howe et al., 2016), but also that it is normatively ambivalent: on the one hand, it is the material means by which unjust and undemocratic regimes of unsustainability are being enabled, maintained and legitimized; on the other hand, it can also be understood as a “promise” (Anand et al., 2018; Kemmer and Simone, 2021) and a possible starting point for justice, re-democratization and more sustainable futures.

Building on this ambivalent and paradoxical nature of infrastructure, this article theorizes the role of large-scale mate-

rial infrastructure, more specifically of energy technologies, in contributing to and causing forms of environmental justice and injustice. Building on this discussion, through short vignettes from Canada and Colombia, it addresses the emerging issue of so-called green hydrogen, i.e., hydrogen produced with renewable electricity and fresh water, which has become one of the most vibrant and important issues within energy policy and decarbonization agendas in recent years. Although most green-hydrogen initiatives and projects are still at a very early stage and despite the fact that green hydrogen is currently quantitatively insignificant in terms of global hydrogen production, it is already foreseeable that this new economy will entail an enormous expansion of energy infrastructure (especially wind, solar power, transmission grids). These developments will not only shape socio-ecological path dependencies (Hanusch and Schad, 2021) and transform geoeconomic and geopolitical relations (van de Graaf et al., 2020), but also create multiple “hydrogen injustices” manifesting around issues such as forced evictions of local and Indigenous communities, limited energy access, rising authoritarianism, the reinforcement of neocolonialism, or water-related grievances (Müller et al., 2022). At the same time, however, if these injustices are properly addressed, green-hydrogen infrastructures could also open up avenues for emancipatory and more democratic energy futures (Kalt and Tunn, 2022), not only but especially with regard to struggles for Indigenous sovereignty. The aim of this paper is therefore to show both theoretically and exemplarily how infrastructure as a dynamic socio-material practice is entangled with issues of exclusion, maldistribution and misrecognition as well as struggles for emancipation, decolonization and autonomy. Contrary to common understandings of infrastructure as a research object, however, this paper draws on and further develops conceptualizations of infrastructure that understand it as a specific perspective that allows for deeper insights into its political geographies and justice implications. In doing so, it draws on existing relational and practice-oriented approaches to infrastructure and carves out an “infrastructural lens” that focuses both on the materiality of infrastructure projects and on the social practices and imaginaries that simultaneously shape them and are shaped by them.

As indicated, this aim stems from a desire to contribute to two emerging fields of research: first, this paper aims to contribute to theoretical discussions within energy geographies about the relationship between material infrastructures and justice and about the role of energy infrastructures in creating “new energy spaces” (Bridge and Gailing, 2020). While existing studies from political ecology are valuable contributions, they tend to emphasize the dark side of energy infrastructure: how it functions as a territorial weapon, colonizing landscapes and ecosystems and normalizing socio-ecological damage and plunder (Dunlap, 2021). Even beyond the field of energy, research on infrastructure and justice tends to focus on how infrastructure creates patterns of injustice, for ex-

ample, in the form of exclusionary migration politics through border infrastructure (Kathiravelu, 2021) or oppression and marginalization through urban infrastructure (Rodgers and O’Neill, 2012). In contrast, the questions of how infrastructure is intertwined with and can become a starting point for justice, re-politicization and democratization and how it can shift power relations remain underexplored. Second, this paper aims to contribute to a body of recent scholarship that calls for the need for a critical research agenda on the emerging hydrogen transition that focuses on its socio-ecological risks as well as on the potential for emancipatory and democratic hydrogen futures (Hanusch and Schad, 2021; Kalt and Tunn, 2022; Müller et al., 2022). In doing so, and as a complement to this call, the article will focus particularly on the role of struggles for Indigenous sovereignty in relation to green-hydrogen transitions. On the one hand, this emphasis is due to the fact that Indigenous communities have very often been, and continue to be, displaced or otherwise negatively affected by energy-related infrastructure developments, particularly in the context of settler colonialism (Whyte, 2019). On the other hand, as Baka and Vaishnav (2020) argue, there is a general research gap in energy geography regarding Indigenous knowledges and the role of Indigenous communities in energy transition processes, which this article, albeit limited in its empirical scope, seeks to address.

The paper is organized as follows: the first section provides a selective, but not arbitrary, overview of research on material infrastructure within the burgeoning field of energy geographies. It also identifies points of contact for further research. The second section represents the main conceptual part of the article and develops an infrastructural lens for energy-related environmental justice research, drawing on insights from anthropology and science and technology studies. In the third section short vignettes on recent green-hydrogen-related developments in the hydrogen frontrunner countries Colombia and Canada, based on a review and content analysis of the gray literature (online accessible reports, interviews and strategy papers), are used as examples to illustrate what kinds of insights the infrastructural lens developed in this paper can provide. In the last section the arguments will be summarized and critically reflected upon. In addition, starting points for future research are identified.

2 Infrastructural research within energy geographies

For more than a decade now, energy has emerged as a new key topic within critical human geography. In contrast to earlier geographical work on energy, which approached the topic from a more positivist and managerial perspective (Calvert, 2016), the sub-discipline has recently expanded in scope and conceptual plurality, opening the field to the inherently political nature of energy systems (Bridge et al.,

2018a). Accordingly, Calvert (2016:105) characterizes energy geographies as a “fertile academic borderland” that allows for the bringing together of different geographic disciplines to focus on one cross-cutting issue. Interestingly, however, the topic of infrastructure, or more precisely a critical, non-essentialist perspective on infrastructure, has been of relatively small concern for energy geographers, despite the increasing pluralization of energy-related research and the great interest in infrastructure within the wider social sciences, including other areas of human geography such as resource governance (Bruns et al., 2022). According to a recent energy geography literature review, created by Baka and Vaishnav (2020), analyses of energy infrastructure represent only 3% of 348 articles, compared to studies on energy extraction and production as well as consumption. Baka and Vaishnav (2020) therefore point to the need to expand research in this area and emphasize the lack of geographic analyses on issues such as transmission planning or electricity grid expansion, as well as on key infrastructural projects. However, this under-representation does not mean that there is no substantial literature on energy infrastructure. Notable are works (also mentioned by Baka and Vaishnav, 2020) such as the analysis of Bouzarovski et al. (2015) on the political geographies of gas infrastructure in Europe and Knuth’s (2018) study on the financial aspects of energy infrastructure. Equally important is the special issue of Bridge et al. (2018b) on the role of large-scale energy infrastructure in the (re)production of national state power.

Yet, whilst these analyses – broadly defined – focus either on the role of infrastructure in producing and reconfiguring political space or on the political economies that shape energy infrastructure, there are other studies that theorize in more depth its inherent political dimension, that is, how energy infrastructure *itself* becomes a site not only of contestation, but also of progressive experimentation. In this regard, fossil fuel pipelines have been of particular interest to energy geographers. One of the most influential works is Barry’s (2013) study of the controversies surrounding the Baku–Tbilisi–Ceyhan oil pipeline. Drawing on post-structuralism and science and technology studies, he shows how the emergence of respective publics and new political subjectivities, such as affected communities and other stakeholders, is not a purely social dynamic but deeply intertwined with the materiality of the pipeline itself. Yet, Barry argues that the pipeline project represents not only a matter of dispute through its materiality and its potential consequences for affected communities, but also an example of how the politics of transparency have a huge impact on the emergence and the governance of political conflict, leading to a fostering and intensification of conflict rather than to its harmonization.

While Barry’s analysis focuses on the co-production of infrastructure with social conflict, political-ecology-influenced investigations of energy infrastructure tend to emphasize its embodied socio-ecological dimensions and neocolonial logics. In particular, Hornborg’s theorization of energy tech-

nologies as embodiments of environmental load displacement and asymmetric global exchange challenges their framing as neutral instruments that put nature to work, as is often done in mainstream transition discourses. Instead, he conceptualizes them as “socio-natural strategies for appropriating embodied labour and other biophysical resources from less affluent sectors of world society” (Hornborg, 2020:9). Doing so makes it possible to understand how the distributive injustices of a given energy technology, e.g., the spatially uneven socio-ecological harms of photovoltaics, such as displacements and exploitation of labor in peripheral regions, are not unintended side effects but “fundamental to its underlying but mystified rationale” (Hornborg, 2020:10). Hornborg thus emphasizes the need for social scientists to de-fetishize infrastructure and to acknowledge that energy technologies are in essence nothing other than embodiments of the unjust capitalist world system.

A similar, but differently grounded, approach is taken by Dunlap and Laratte (2022) in their “necropolitical” critique of the European Green Deal, which focuses on the deadly implications of green transition agendas mediated through “infrastructural colonization”. Claiming that “the extraction necessary for low-carbon infrastructures is far worse than researchers realize” (Dunlap and Laratte, 2022:15), they point to the destruction of ecological habitats; the spread of toxic substances; and the colonization of landscapes, villages and entire regions through so-called green infrastructure. Moreover, a core argument of their critique is that green transition agendas essentially rely on and reinforce neocolonial power relations and resource extraction in the Global South. Using Morocco as an example, they show how concentrated wind and solar power for European energy markets generates green land grabs and violent repression of civil society. At the same time, the potential benefits of these infrastructures for the local population are absent, while the myth of green energy (i.e., that it is inherently sustainable and just) is framed as without alternative. Therefore, as Dunlap puts it in an earlier publication,

“infrastructural colonization” contends that infrastructure is a “modality of conquest”, serving as “territorial weapons that, to various intensities, dispossess populations and ‘roll out’ an apparatus of spatial, economic and psychosocial management”. (Dunlap, 2021:6)

Parallel to these reflections on the destructive properties of energy infrastructure, there is also work influenced by political ecology that focuses more on its progressive character. A good example is the study of Bulkeley et al. (2014) on “urban infrastructural regimes”, in which they show how urban responses to climate change in the city of London are governed by “new low-carbon modalities” and emerging experimental infrastructural networks (e.g., municipal photovoltaic projects). Rather than being merely niches of innovation that enable transitions from one sociotechnical system to another,

the authors argue that these infrastructural experiments function as “critical junctures through which new sociotechnical configurations take place, are maintained, contested and may be undone” (Bulkeley et al., 2014:1472). Thus, they offer an empirically grounded study that seeks to reconceptualize energy infrastructure as a central locus through which existing sociotechnical regimes are being re-politicized, contested and potentially reconfigured.

As this non-exhaustive overview demonstrates, research on infrastructures within energy geographies is diverse, but it still offers significant potential for further analysis. What’s more, it also reveals the political ambivalence of energy infrastructure, emphasized in the Introduction, albeit with a certain bias: while most geographical research tends to focus on the destructive properties and unjust consequences of energy infrastructure, its potential to open up avenues for social change and environmental justice remains rather under-explored (see also Bruns et al., 2022). This is especially true for the role of Indigenous knowledges in energy transition processes, which, as Baka and Vaishnav (2020) point out, represents a general gap within the energy geographies literature. The following section seeks to address these issues by reconceptualizing infrastructure as a specific research perspective.

3 Adopting an infrastructural lens

In the 1990s, scholars of science and science and technology studies initiated a paradigm shift in the study of infrastructure. Thanks largely to the work of Bowker (1994) and Star and Ruhleder (1996), critical social science began to see infrastructure not as an inert material object and the result of a certain political and/or engineering process but as a web of relationships between technological artifacts and social actors, infused with power, moral orders and the complexity of the social (Harvey et al., 2017b). As Larkin (2013:329) puts it,

Infrastructures are matter that enable the movement of other matter. Their peculiar ontology lies in the facts that they are things and also the relation between things

This shift in perspective towards a relational, non-essentialist approach has led social scientists to conceive of infrastructure as a specific analytical lens to gain deeper insights not only into infrastructure itself, but also into further topics that are intertwined with infrastructure, such as sustainability (Degens et al., 2022), security politics (Hentschel and Schröder, 2020), right-wing populism (Naumann, 2021), governance of the water–energy–food nexus (Bruns et al., 2022), emerging publics (Korn et al., 2019) or the spatialities of democracy (van Veelen et al., 2021). Inspired by and complementary to these approaches, I will elaborate in the following a further approach of an infrastructural lens that is

particularly applicable to energy-related environmental justice issues and is intended to provide conceptual support for respective empirical research. It relies on three epistemological shifts: from infrastructure to “infrastructuring”, from social imaginaries to “sociotechnical imaginaries” and from human infrastructuring to “planetary infrastructuring”. I will first briefly introduce these shifts. Second, I will discuss their normative, spatial and ontological implications.

3.1 Infrastructuring, sociotechnical imaginaries and the planetary

The first shift from infrastructure to infrastructuring urges researchers to abandon the common understanding of infrastructure as the generally invisible backdrop of society, i.e., the material things and connections that make social life possible. Rather, it suggests what Bowker (1994) calls an “infrastructural inversion”, which means focusing on the often hidden and mostly invisible inner workings of infrastructures, that is, on the social practices, norms and classification systems through which they come into being and function as such. In doing so, it can be shown that (im)material infrastructures, e.g., health systems, borders, supply infrastructure and road infrastructure, are in many cases powerful and highly normative instruments of justice and injustice, as they generally tend to privilege certain social groups while excluding and discriminating against others (Bowker and Star, 1999). Moreover, as Niewöhner (2015) argues, this reconceptualization of infrastructure as a material–semiotic practice, i.e., as infrastructuring, makes infrastructure more accessible to ethnographic research on the ways in which actors, technical things and moral orders are entangled and on how spatial relations between them are created. Seen through the lens of infrastructuring, then, spatial relationships, such as those between center and periphery, are not given but emerge through multiple processes of planning, designing, altering and maintaining of, e.g., supply, road or energy infrastructure.

The second shift from social imaginaries to sociotechnical imaginaries directs the researchers’ gaze to the visions, affects and knowledge systems that make sense of infrastructuring practices and that give them their legitimacy. However, in contrast to common understandings of social imaginaries as merely ideational constructs (Taylor, 2004), the notion of sociotechnical imaginaries, coined by Jasanoff and Kim (2015), focuses more explicitly on the material, technological and scientific underpinnings of social imaginaries, i.e., on ways in which visions, technical objects and the associated scientific knowledges are co-produced in practice. Sociotechnical imaginaries are thus “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” (Jasanoff, 2015:4). This approach therefore allows for an understanding of how the creation of energy infrastructures, such as those

associated with, e.g., green hydrogen, is intertwined not only with the ways in which society *is* reflected in technological things, but also with how it *aspires to be* in the future. Moreover, despite the focus on dominant and nation-specific visions (Jasanoff and Kim's focus in previous publications), Jasanoff (2015:4) argues that “[m]ultiple imaginaries can co-exist within a society in tension or in a productive dialectical relationship”. The concept of sociotechnical imaginaries therefore also helps to understand how competing imaginaries relate to each other and, more importantly, how – possibly in response to dominant ones – counter-hegemonic imaginaries emerge and gain power (Longhurst and Chilvers, 2019). In doing so, the concept is highly significant for political geographers and for the analysis of the construction of space. For, as Chateau et al. (2021:1) argue, “spatiality is both constituted by and constitutive of sociotechnical imaginaries (STIs), as they encode specific imaginations of socio-spatial order”. This is particular evident in energy transitions: a community energy project builds on and reproduces a different spatial imaginary (e.g., proximity, regional identity) than projects that are driven forward by national or supranational actors (e.g., nationhood, Europe as a political entity). The construction and legitimation of political scales, spatial identities and associated territorialities, as well as their contestation, are thus inextricably intertwined with the formulation and pursuit of particular sociotechnical imaginaries.

In addition to shifting the focus to the practices and sociotechnical imaginaries of infrastructure, the third epistemological shift consists in understanding infrastructuring not only as a purely socio-material activity – i.e., as processes by which humans shape technologies and vice versa – but also as a dynamic that is both contingent on and part of the non-human forces of the Earth system. In particular, the notion of planetary infrastructuring, developed by Szerszynski (2022), urges researchers to understand human-made infrastructure as a “variation on a more general phenomenon in the ongoing self-organization of planets” (Szerszynski, 2022:207). In this regard, planetary infrastructuring means considering infrastructuring not only taking place at different spatial scales, but also being characterized by different agencies and temporalities of the Earth system, e.g., seismic, geological and all kinds of biological activities; oceanic and atmospheric circulation; hydrologic dynamics; and, most importantly, the multiple and ever-increasing impacts of climate change. In emphasizing these intersections, Szerszynski's intention is therefore to focus on the causal relations between these dynamics: on the “interconnected meshwork of causation... that involves processes on different timescales modulating each other in ways that give rise to function and purpose” (Szerszynski, 2022:208–209). This more-than-human approach, therefore, treats the multiple, self-organizing agencies of the Earth system as more than the material base upon which human infrastructuring depends; rather, it treats them as active, unruly and often unpredictable participants in the processes of planning, creating, maintaining, modifying and

deconstructing infrastructure (see also Barry, 2017; Kropp, 2018; Maguire and Winthereik, 2017).

3.2 On normativity, space and ontological pluralism

As it turns out, these three epistemological shifts have not only analytical but also normative, as well as spatial, implications, some of which have already been touched upon: the first, and most obvious, is that by approaching infrastructure as a practice, it becomes possible to reflect more thoroughly on its inherent quality to produce spatially unevenly distributed winners and losers, i.e., to privilege certain groups while excluding and disadvantaging others. Rather than seeing these justice implications as unintended or external consequences of infrastructure, an infrastructural lens brings to the fore that they are inherent in the making, planning, maintaining, modification, etc. of infrastructure itself and contingent on actor constellations and power relations. From this perspective, then, material infrastructures and practices of infrastructuring are *always* generative of specific constellations of justice and injustice, and they cannot be separated from their normative implications. However, the nature, intensity and quality of the (in)justices can of course vary according to the specific socio-material context, which is precisely what an infrastructural lens aims to reveal: following the common three-dimensional approach to environmental justice as distributional, recognition-based and procedural justice (Schlossberg, 2007; Walker, 2012), it raises the question, for example, of the extent to which potential socio-ecological harms (e.g., environmental degradation due to the mining of rare-earth minerals that are needed for energy infrastructures) that negatively affect certain groups are taken into account in planning and construction processes of infrastructures (distributional justice). It also draws attention to issues of exclusion and inclusion of colonized and historically marginalized groups, especially Indigenous communities, and their knowledges and worldviews (recognition-based and epistemological justice), which is especially important when infrastructure projects are implemented on Indigenous land. Closely related to this are legal and political issues, such as the consideration of minority rights, international conventions, and informal or traditional rights (procedural justice), e.g., when energy infrastructures are created without the consent of those who are most affected by them. Therefore, these questions are matters not only of *environmental* justice but also of *spatial* justice, as practices of infrastructuring play a crucial role in determining which places become, e.g., “green sacrifice zones” (Zografos and Robbins, 2020); which are privileged in terms of, e.g., utility infrastructure; and which are neglected. Moreover, seen through the lens of infrastructuring, it also becomes possible to trace the networked spatial causalities of infrastructure-related environmental injustices. As Hentschel and Schröder (2020) argue, an infrastructural lens is particularly well suited to examining the multiplicity of agencies across geographical scales and established po-

litical institutions through which infrastructures are planned, created and deployed.

The second normative implication is derived from the notion of sociotechnical imaginaries, which urges researchers to understand processes of infrastructuring as being co-produced with visions of desirable futures. However, the questions of what constitutes a desirable future and for whom it will be realized are obviously contested and a matter of competing hegemonies. What's more, these questions are also questions of justice, since the pursuit of a particular version of the good life, e.g., the expansion of green infrastructures combined with the intensification of neoliberalism, can lead to new injustices and exclusions. At the same time, infrastructure projects and associated imaginaries often evoke particular affects such as anger, fear, anxiety or grief (Hentschel and Schröder, 2020:193). These can amplify feelings of injustice, transforming them into indignation and outrage as well as counter-hegemonic resistance and anti-democratic tendencies (van Veelen et al., 2021). In this context, it seems only appropriate, when Naumann (2021) speaks of "infrastructural populism", to argue that the expansion of infrastructure (e.g., green infrastructure) or the deterioration of public infrastructure (transportation, utilities) plays a crucial role in the loss of trust in democratic institutions and in the rise of right-wing populism. As a result, infrastructure often represents a key issue in right-wing agendas and a tool for populist mobilization and spatial domination.

The third normative implication is also ontological. Following Szerszynski's suggestion to think of infrastructuring as a planetary phenomenon in essence means abandoning some of the most fundamental assumptions of Western modernity, namely that human civilization can control the forces of nature through technological fixes (see also Clark and Szerszynski, 2021). A fruitful approach to sharpening and expanding this argument and translating it into environmental justice research is Escobar's (2018) decolonial design theory. Combining insights from Latin American social movements with design theory, Escobar develops an approach called "autonomous design". In doing so, he claims that designing practices are always ontological; i.e., through the creation of material things, such as infrastructure, people create worlds and ways of being that in turn are the pre-conditions for designing. This does not mean, however, that this cycle is inescapable or unchangeable. Rather, Escobar argues that in situations where communities are struggling for autonomy, i.e., against colonial domination and political, cultural and economic heteronomy (e.g., through neoliberal reforms or extractive industries), they engage not only in political resistance, but also in diverse practices of experimentally designing new decolonial and autonomous worlds. At the core of these struggles, then, is the pursuit of justice, self-determination and sovereignty, both discursively and materially, through the creation of self-governed infrastructures of, for example, reproduction, care and basic provisioning,

which in turn derive from and enable relational, non-Western and place-based ways of being (see also LaDuke and Cowen, 2020).

It is precisely here that Szerszynski's notion of planetary infrastructuring and Escobar's design theory meet: both emphasize the need to move beyond anthropocentrism and to focus more thoroughly on modes of infrastructuring (or designing) that rely on Indigenous knowledges and the collaboration of human and non-human agencies and which have historically been devalued as inferior to Western modernism. Planetary infrastructuring, then, does not mean dealing with planet Earth in a control-oriented and techno-utopian mode, as proponents of the "planetary stewardship" approach propose (Steffen et al., 2011). Rather, it means "facing the planetary" (Connolly, 2017), that is, dealing with the multiplicity of planetary forces by embracing ontological pluralism and situated, place-based approaches (Nightingale et al., 2020). It also means – and here the notion of Bulkeley et al. (2014) about infrastructures as experiments comes back into focus – seeing planetary infrastructuring as a world-making and world-changing dynamic through which alternative modes of living together may emerge. Accordingly, as Jensen and Morita (2017:620) note,

Viewed as open-ended experimental systems that generate emergent practical ontologies, infrastructures hold the potential capacity to do such diverse things as making new forms of sociality, remaking landscapes, defining novel forms of politics, reorienting agency, and reconfiguring subjects and objects, possibly all at once.

Using the emerging issue of green hydrogen as an example, the following section will now illustrate through vignettes from Colombia and Canada how the infrastructural lens and the three epistemological shifts discussed in this section can be applied and what empirical insights they may provide.

4 Green hydrogen: fueling environmental (in)justice

Green hydrogen is increasingly being discussed as a key issue in achieving the goal of carbon neutrality (IEA, 2022). Produced using renewable energy and electrolysis (the splitting of fresh water into oxygen and hydrogen), it is seen as a viable solution for decarbonizing hard-to-electrify sectors, such as heavy industry and heavy transportation. At the same time, it can contribute to increasing energy independence through replacing fossil fuels in industrial sectors and its ability to store stranded energy from renewable energy sources. However, the transition to green hydrogen is controversial, particularly from a justice perspective: while some argue that green hydrogen can contribute significantly to a just transition and environmental justice, e.g., by improving air quality for marginalized communities in industrialized zones or by creating green jobs (Stelpstra, 2020;

Yellen and Castillo, 2021), critics point to its multiple socio-ecological risks, especially as several countries in the Global South, such as Chile, Namibia, Morocco or Colombia, are currently developing ambitious green-hydrogen strategies. These developments therefore carry the risk of creating and reinforcing neocolonial dependencies between the Global North and Global South (van de Graaf et al., 2020). At the same time, the required massive expansion of hydrogen infrastructure (renewable energy, pipelines, production and desalination plants) risks displacing marginalized, colonized and Indigenous communities, triggering conflicts over land and the expansion of extractive industries, such as mining (Cuenca Berger, 2021).

In addition to this, the materiality of green hydrogen itself poses various challenges and risks. Most importantly, its raw material – fresh water – is a scarce and contested resource, especially in producing countries such as Chile, Morocco, Spain, Australia, Namibia and Colombia. Green-hydrogen production will therefore potentially impact on limited regional water supplies and fuel simmering water conflicts. In the case of using desalinated seawater, which is being discussed as an alternative to fresh water, it can also pose a threat to marine life and coastal communities, as the desalination process has several negative environmental impacts due to the generation of brine and the use of toxic chemicals (Jones et al., 2019). Another major concern is transportation. To make hydrogen transportable, it must be cooled and liquefied or converted into derivatives such as ammonia, which are costly and very energy-intensive processes. In addition, transporting hydrogen and ammonia through pipelines carries the risk of leakages, which could lead to explosions and the toxifying of humans and ecosystems (Patonia and Poudineh, 2022).

Given these multiple challenges of “hydrogen justice at the nexus of energy, water and climate justice” (Müller et al., 2022:2), scholars have recently called for a critical research agenda on hydrogen transitions (Hanusch and Schad, 2021; Kalt and Tunn, 2022). How can an infrastructural lens, as developed in this article, contribute to this call? And what insights into the justice dimensions of this emerging economy can it provide? In what follows, I attempt to answer these questions in a preliminary way,¹ by drawing on brief insights from the hydrogen-producing countries of Colombia and Canada and associated struggles over Indigenous sovereignty.

¹These insights are preliminary in the sense that they are not based on primary empirical data. They have been compiled through a review and content analysis of the gray literature, including online-accessible policy and strategy papers, reports, and written and oral interviews with Indigenous community representatives and members of national governments.

4.1 Infrastructuring hydrogen injustice

As described, the crucial insight of the notion of infrastructuring is that it directs the researchers’ attention to the ways in which infrastructures are being implemented, planned, and maintained and to how these practices intersect with justice and the construction of space. The case of the department of La Guajira in the northeastern part of Colombia is particularly well suited to illustrating these interrelationships. La Guajira is an arid and remote region that is severely affected by climate change and has recently been identified as a promising green-hydrogen production site, primarily due to its potential for wind energy (Ministerio de Minas y Energía, 2021). However, the region is also home to the Wayúu Indigenous people, who suffer disproportionately from water scarcity, access to energy and a general lack of basic services (Ojeda et al., 2017). Given that *Colombia’s hydrogen roadmap* emphasizes the will to “place communities at its heart from the outset, taking into account their current situation, needs, aspirations and capabilities” (Ministerio de Minas y Energía, 2021:24), which means collaborating with Indigenous and peasant communities on equal footing, there seems to be, at least on paper, the political will to implement hydrogen infrastructure in a fair and inclusive way. However, a fair and inclusive participatory process does not currently exist, and existing wind farms, in combination with other extractive industries (especially coal mining), are severely affecting the Wayúu communities in the form of displacement, disrespect for their ways of life, and further restrictions on access to water and land (Rubiano, 2021; Ulloa, 2021).

Therefore, green-hydrogen infrastructuring in La Guajira seems to systematically threaten Indigenous sovereignty and exclude Indigenous knowledges. Moreover, the transition to green hydrogen seems to perpetuate the long and unjust history of colonial land appropriation, leading to conflict, resistance² and increased militarization of the region, which culminated in the deployment of troops at the site of the wind farms in January 2022, justified with the argument of protecting the “strategic assets of the State” (cited in Ramirez et al., 2022:n.p.). Moreover, viewed through the lens of infrastructuring, these developments demonstrate not only how the transition to green hydrogen, mediated by its infrastructure, leads to injustice, conflict and militarization, but also that La Guajira is not a peripheral region per se. Rather, it is being infrastructured as such, first, due to a lack of supply infrastructure for local and Indigenous communities and, second, due to the expansion of hydrogen infrastructure, designed to exploit and export energy to other places but not to address local energy poverty.

²See <https://www.eltiempo.com/colombia/otras-ciudades/la-guajira-protestas-por-parque-eolico-en-cabo-de-la-vela> (last access: 18 July 2023).

4.2 Envisioning contested hydrogen futures

To date, green-hydrogen plans are only being implemented on a very small scale. More than 99% of current global hydrogen production is based on fossil fuels, while only 0.04% is produced by water electrolysis (IEA, 2022:71). Thus, green-hydrogen production is still a dream for the future, albeit with profound consequences for the present. As Hanusch and Schad (2021:82) put it,

Hydrogen futures are in the making right in front of our eyes and will determine socio-ecological path dependencies for decades to come.

A future-oriented focus on the imaginary dimension of this economy is therefore very important, especially since, as Jasanoff argues, these imaginaries and their material expressions are not neutral but highly normative and political.

At first glance, the overarching sociotechnical imaginary of green and blue hydrogen seems to be obvious: it essentially builds on and reproduces a desirable future of ecological modernization, that is, uninterrupted economic growth decoupled from CO₂ emissions through technological solutions. It is therefore a perfect example of an imaginary that ecomodernists call the “good, or even great, Anthropocene” (Asafu-Adjaye et al., 2015:6), that is, a vision that understands planetary crises as a unique opportunity for human flourishing and “a sign of man’s ability to transform and control nature” (Hamilton, 2016:233). However, a closer look reveals that hydrogen imaginaries themselves are heterogeneous and contested. There are, for example, differences over the concrete role that clean hydrogen could play in future economies, i.e., whether it should be reserved only for the so-called hard-to-abate sectors such as certain industrial processes or whether it should also be available for everyday applications such as individual mobility or heating. As Jorgo Chatzimarkakis, Secretary-General of Hydrogen Europe (the European hydrogen industry association) puts it, it is necessary to radically scale up production capacities and “to bring the price of renewable hydrogen from champagne to prosecco, and later table water” (cited in Kurmayer, 2021:5). From the perspective of sociotechnical imaginaries, however, this desirable future of abundant and affordable clean hydrogen for all, which promises to combine economic growth and high living standards with decarbonization goals, glosses over the fact that it must be produced in a technologically complex and expensive way. Moreover, it neglects the negative socio-ecological impacts of green-hydrogen production and its poor energy efficiency, especially compared to the direct use of renewable energy (Nature Editorial, 2022).

In addition to these debates, the contested nature of hydrogen imaginaries becomes particularly evident when they are spatially manifested, i.e., when national governments or other territorial authorities declare certain nations or regions to be hydrogen regions or hotspots. In the case of La Gua-

jira, which was declared by the former Minister of Mines and Energy, Diego Mesa Puyo, the “epicenter of the energy transition” (cited in Ramirez et al., 2022:n.p.) – a vision that has only recently been taken up (at least in terms of content) by the current leftist president Gustavo Petro³ – this becomes particularly apparent. On the one hand, these imaginaries, expressed through metaphorical and political declarations, serve to legitimize top-down infrastructural expansion through which Indigenous sovereignty is being threatened. On the other hand, they collide with counter-imaginaries of a just energy transition based on Indigenous cosmologies and the recognition of Indigenous territorial rights (Ulloa, 2021).

4.3 Decolonizing hydrogen infrastructuring

The case of La Guajira illustrates very well the extent to which hydrogen infrastructuring collides with Indigenous rights and how it might lead to a resurgence of colonial relations and associated injustices. Insights from other hydrogen frontrunner countries in the Global South such as Chile (Cuenca Berger, 2021) or Morocco and Namibia (Müller et al., 2022) show similar (potential) conflicts and confirm this neocolonial tendency. However, there are also attempts to decolonize hydrogen infrastructuring, to build alliances between corporations and Indigenous communities, and to embed green-hydrogen production within relational ontologies and claims for environmental justice and Indigenous sovereignty. In this regard, the Canadian context is particularly interesting. Since 2015, representatives from both Indigenous and non-Indigenous peoples have increasingly viewed renewable energy projects as a potential way to reconcile the historical and ongoing violence against Indigenous peoples perpetrated by energy-related settler colonialism.⁴ As a result, some Indigenous communities (i.e., First Nations, Inuit and Métis) are increasingly taking a prominent role in renewable energy projects across the country, either as equal partners or by taking full leadership, with the goal of breaking free from colonial ties and achieving greater energy autonomy and environmental justice (LaDuke and Cowen, 2020; Stefanelli et al., 2019).

In the case of green hydrogen, there appears to be no difference. More recently, individual First Nations representatives have described renewable hydrogen as a tool for Indigenous self-sufficiency, justice and reconciliation (I. Day, cited in Creamer, 2021), and as an “opportunity for Indigenous peoples across Canada to live up to their reputation as stewards of the land”.⁵ Similarly, the provincial hydrogen

³See interview with Gustavo Petro via *Cambio*, 26 June 2022: <https://www.youtube.com/watch?v=LBbILjrBCP0> (at 01:02:22 in the hh:mm:ss timestamp format, last access: 18 July 2023).

⁴See Preston (2013) for a discussion of Canadian settler colonialism in relation to energy extraction.

⁵See interview with Chief Billy Morin, Vice Chair of the Edmonton Region Hydrogen HUB and Chief of Enoch Cree Nation, via *TheFutureEconomy*, 1 December 2021:

roadmaps for British Columbia and Alberta emphasize the potential of hydrogen for Indigenous communities particularly in remote regions, to become independent of fossil fuels and to regain political and economic power (Government of Alberta, 2021; Government of British Columbia, 2021). And, indeed, as with other renewable energies projects, there are a number of planned green-hydrogen projects that either are entirely Indigenous-led or represent collaborations between hydrogen companies and Indigenous communities. Notwithstanding that respective communities are heterogenous and have very different motivations and positions regarding renewable energy production (Stefanelli et al., 2019), these initiatives thus seem to be in line with Indigenous Principles of Just Transition, based on Indigenous rights and cosmologies and including approaches such as rights of nature and energy sovereignty.⁶ What's more, they also have an experimental character. This is particularly evident in the case of the Fort Nelson First Nation in British Columbia, which, in collaboration with Hydrogen Naturally Inc. (H2N), has developed plans to produce so-called "bright green hydrogen" that would use wood waste as a feedstock in combination with direct atmospheric carbon capture and storage (e.g., through reforestation), resulting in a carbon-negative footprint.⁷

Therefore, these emerging Indigenous-led green-hydrogen projects could serve as examples for what Escobar describes as autonomous design and Szerszynski as planetary infrastructuring, since they represent attempts to infrastructure decolonial worlds, based on an Indigenous and non-Western understandings of nature and in interaction with Mother Earth and planetary forces. Moreover, they also seem to create "practical ontologies" (Jensen and Morita, 2017), namely, by experimentally connecting Western sociotechnical imaginaries with Indigenous knowledges and worldviews, which have historically been treated rather separately.

5 Concluding remarks

The aim of this paper was to show how energy infrastructure and technologies are entangled with issues of environmental justice and struggles over Indigenous sovereignty. Inspired by existing social science research on infrastructure, it aimed to develop an analytical approach that provides deeper insights into its normative, political and spatial implications. This infrastructural lens draws on three distinct but complementary epistemological shifts – from infrastructure to infrastructuring, from social imaginaries to sociotechnical

imaginaries and from human infrastructuring to planetary infrastructuring. In doing so, it allows for the examination of not only how patterns of justice and injustice are practically infrastructured and what kinds of imaginaries they evoke or are entangled with, but also how practices of infrastructuring can themselves become part of a broader political ontology, that is, of struggles over ways of being and ways of relating to planet Earth (Jensen and Morita, 2017). In particular, energy and, more specifically, hydrogen infrastructures demonstrate this very well: on the one hand, despite their claim (and actual potential) to contribute to a more sustainable and just world, they run the risk of reviving neocolonial relations between the Global North and Global South and generating multiple environmental injustices at the water–energy–food nexus (Müller et al., 2022). On the other hand, however, there are attempts to decolonize hydrogen infrastructuring and to experimentally connect Indigenous worldviews and knowledges with a sociotechnical imaginary of ecological modernization. In particular, the emerging partnerships between hydrogen companies and Indigenous communities in Canada, as well as related statements by First Nations representatives, attest to the claim that green hydrogen could indeed become more than just another tool of "infrastructural colonization" (Dunlap, 2021); it could also be a vehicle for decolonization, Indigenous sovereignty and environmental justice.

Of course, these interpretations must be treated with caution. First, it is important to note that this paper is not based on primary empirical data. As such, it does not represent a full-fledged analysis, but rather it provides glimpses into an emerging topic that has only recently become of interest to critical scholars. The insights presented in this article therefore should be seen as starting points for empirical research on infrastructural justice and injustice in relation to hydrogen/energy but not as its endpoints. They are meant to stimulate thought and further research and should not be taken as incontrovertible facts. Moreover, as should be the case generally when studying Indigenous struggles for autonomy, it is important not to fall into the trap of romanticizing Indigenous peoples as modernity's anti-scientific other (Blaser, 2013; Niigaaniin and MacNeill, 2022). Nevertheless, there are ways to valorize Indigenous knowledges without essentializing them and reproducing the modern–premodern binary. One of these might be to demonstrate, as this paper has done, that Indigenous communities are indeed technology-oriented and taking a leading role in renewable energy and hydrogen projects without disregarding their cosmologies and self-given role as "stewards of the land". Similarly, it is important not to derive an ideal path from individual cases. Indigenous communities and worldviews *are* heterogenous, and it would be misguided to take the examples from Canada as models for Indigenous communities elsewhere. At the same time, uncritically endorsing the policy of assigning First Nations a leading role in energy transitions as inherently just should be avoided, as this risks obscuring possible shortcomings (Stefanelli et al., 2019), such as the neoliberal

https://www.youtube.com/watch?v=FZa5d_n8M1s (at 08:00 in the mm:ss timestamp format, last access: 18 July 2023).

⁶The Indigenous Principles of Just Transition were developed and published by the Indigenous Environmental Network; see <https://www.ienearth.org/justtransition/> (last access: 18 July 2023).

⁷See <https://hydrogen-central.com/fort-nelson-first-nation-hydrogen-naturally-inc-h2n-plan> (last access: 18 July 2023) and <https://www.h2naturally.com/> (last access: 18 July 2023).

appropriations of indigeneity. Nevertheless, these initiatives in fact appear to be examples of infrastructure projects that aim not only to produce energy, but also to decolonize energy systems and achieve environmental justice. As such, they might demonstrate that infrastructure projects and related practices of infrastructuring are more than sites of contestation and sources of unrest; they are also potential points of departure for socio-ecological transformation, decolonization and novel forms of cooperation.

Therefore, these examples deserve greater scrutiny and empirical attention, particularly with regard to two areas of research: first, it is necessary to connect and contrast these cases with existing work on renewable energy conflicts and claims for energy democracy (Hughes, 2021; Boyer, 2019; Burke and Stephens, 2018). In this regard, questions of ownership, land tenure, access to energy and energy technologies, as well as questions of the governance of these initiatives, are important. Secondly, the questions of Indigenous sovereignty and Indigenous citizenship under conditions of ongoing settler colonialism need to be critically interrogated in relation to the role of infrastructure and energy technologies. In particular, the seemingly paradoxical situation of creating Indigenous sovereignty that is both detached from and deeply embedded in settler colonial governance, which Simpson (2014:11) describes with her notion of “nested sovereignty”, and the tensions and contradictions that arise from these relationships need to be problematized through empirical analysis. The infrastructural lens developed in this paper is intended to provide conceptual support for these emerging areas of research.

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