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# JLAG *Perspectives*

## Geographical Implications of Brazil's Emerging Green Hydrogen Sector

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CONVERTING RENEWABLE POWER INTO exportable green hydrogen for industrial use and power generation has become a leading technology in decarbonization processes. Electrolyzers powered by hydro, solar, or wind split water into hydrogen and oxygen, providing “energy storage in chemical bonds” (Luna et al., 2019, p. 2). Green hydrogen is powered by renewable or green sources, unlike gray hydrogen, which comes from natural gas, brown hydrogen from coal, and blue hydrogen from natural gas with CO<sub>2</sub> capture and storage. The electrochemical process for splitting water through electrolyzers has been known for several decades, but the industrial scale-up is occurring rapidly. Described as “bottling renewables” (Nature Energy, 2019, p. 721), electrolyzers are critical to net-zero emissions energy systems that would rely on green hydrogen to generate electricity or supply byproducts such as ammonia or methane (Davis et al.,

2018; Saeedmanesh et al., 2018; Ajanovic & Haas, 2019; Griffiths et al., 2021).

Proponents of green hydrogen make three assumptions, apart from economic and technical viability: (1) cheap or excess renewable power supply will exceed demand over extended periods (Glenk & Reichelstein, 2019; Nadaleti et al., 2020; Yan et al., 2020); (2) battery technology—the destination for lithium extracted from the *salares* of Argentina, Bolivia, and Chile (Dorn & Ruiz Peyré, 2020)—will be insufficient to store electricity (Ajanovic & Haas, 2019) and relies on a narrow mineral base (Apostolou & Enevoldsen, 2019); and (3) green hydrogen would not strand fossil fuel assets, but rather would use oil and gas pipelines and storage capacity (Ajanovic & Haas, 2019; Schmidt et al., 2019; Luna et al., 2019), even leading to green electrofuels (Apostolou & Enevoldsen, 2019; Dawood et al., 2020), commodity chemicals (Haegel et al., 2019), and ethylene oxide,

which is heavily used in plastics manufacturing (Leow et al., 2020).

### GREEN HYDROGEN INVESTMENTS IN BRAZIL

In 2021 several investments and state actions in green hydrogen were announced in Brazil, primarily in Ceará state, the country's pioneer in attracting wind farms (Brannstrom et al., 2017). In February 2021, Enegix Energy, an Australian firm, announced a \$5.4 billion green hydrogen facility powered by wind and solar farms and connected to the deepwater Pecém port, an industrial complex and export-processing zone (EPZ) near Fortaleza, the state's capital. The Enegix Base One facility would be fed by approximately 8 GW of distributed wind and solar energy. Enegix emphasized the proximity of Ceará to Europe and the desirability of the Pecém port next to Base One (Ennes, 2021).

Brazilian media emphasized that Base One would create "hundreds of high-paying jobs" and quoted the Enegix CEO as claiming that "we are creating rocket scientists in Ceará" (Quintela, 2021, para. 3-4). Referring to the "export factory" idea, the state's governor, Camilo Santana, noted that the state "is in the vanguard . . . because we have favorable conditions to produce and export green hydrogen" (Ceará, 2021a, para. 3). The Ceará government treats green hydrogen as an economic opportunity rather than an environmental initiative; its environmental agency has been absent from photographs and videos, while the group charged with the state's economy has participated in all public activities relating to green hydrogen.

In quick succession, three other industrial groups announced agreements with Ceará

for future green hydrogen investments. In April 2021 White Martins, a subsidiary of Linde, a multinational industrial gas and engineering firm, and Pecém signed an agreement with the state to support the green hydrogen hub, aiming to prioritize exports to Europe (Ceará, 2021b). In July 2021, the state government signed an agreement with Qair, a French renewable power group, for a green hydrogen plant to be connected by transmission lines and a dedicated substation to an offshore wind farm 200 km west of Pecém (O Povo, 2021). A few days later, Ceará signed an agreement with Fortescue Future Industries, a subsidiary of the Australian mining giant Fortescue Metals Group, to develop a green hydrogen plant that would "train and hire local workers, purchase services, and purchase products locally whenever possible" (Pecém, 2021, para. 3). In October 2021, Ceará signed agreements with four Brazilian firms that will locate in the green hydrogen hub at Pecém (Facundo, 2021), followed shortly by an agreement with TotalEnergies (Chiappini, 2021).

The Ceará state government created a working group (Grupo de Trabalho) comprised of diverse state agencies and industry groups in March 2021 to guide policies for a green hydrogen hub (Ceará, 2021a). The decree creating the Grupo de Trabalho described green hydrogen as a "vector that will permit the import of clean energy from regions favored by nature and with potential exceeding its needs" (Ceará, 2021c, decree no. 34.003), a reference to excess renewable power. Notably, all of Ceará's green hydrogen proposals are sited at the Pecém port and EPZ, which hosts a coal-fired power plant that has

created numerous ongoing land-tenure, water, and environmental pollution conflicts with nearby Indigenous communities (Meireles et al., 2018; Neepes/ENSP/Fiocruz, 2019). The owner of the power plant, the Portuguese energy firm EDP, announced plans in September 2021 to build a pilot green hydrogen plant that would mitigate, and eventually replace, the coal-burning plant at the Pecém port (Herculano, 2021, Serpa, 2021); the state promptly issued an operational license in October 2021, referring to the hydrogen plant as an industrial annex because Ceará only established protocols for licensing green hydrogen facilities in February 2022 (Ceará, 2021d; Ceará, 2022).

Other recent green hydrogen developments in Brazil include the announcement in Pernambuco state by Neoenergia, the Brazilian subsidiary of Iberdrola, for a green hydrogen pilot project at the Suape port, industrial complex, and EPZ (Neoenergia, 2021). In Rio de Janeiro, the Açu port complex signed an agreement with Fortescue Future Industries for a green hydrogen plant (Porto do Açu, 2021). In April 2021, the Centro de Pesquisas de Energia Elétrica (the research branch of Eletrobras, Brazil's state-owned power generator and distributor) and Siemens signed an agreement for a green hydrogen pilot project (Cepel, 2021). Rio Grande do Norte's governor announced an agreement with Enterprize Energy in August 2021 for offshore wind that would power green hydrogen and ammonia production (Globo, 2021).

#### **AN EMERGING GEOGRAPHICAL RESEARCH AGENDA**

What do renewables in a bottle mean for

energy geographies in Brazil? Bridge et al. (2013) developed a framework for understanding energy transitions using geographical concepts. Later work offered specific considerations for the emerging geographical political economy of energy transition, arguing that decarbonization infrastructure may "[reproduce] relations of economic and political power," produce numerous spatial consequences, and demand renewed attention to relations among state, society, and market actors in decision-making (Bridge & Gailing 2020, p. 1041).

Applying these concepts to the case of Brazil's green hydrogen helps identify research questions that could guide future geographical inquiry that might test claims, such as whether green hydrogen will create "opportunities for the reinvigoration of capital accumulation on a global scale and a biophysically significant response to climate change" (McCarthy, 2015, p. 2,495), and question how green hydrogen, as a means of exiting the "subterranean forest" to capture fluxes of wind and solar energy, may require a "massive production of space" (Huber & McCarthy, 2017, p. 9).

The location concept, which emphasizes how decarbonized energy systems necessarily rely on particular locations in absolute space and in relational space, draws attention to the Pecém port as the site for proposed green hydrogen investments because it hosts a contentious coal-fired power plant and because of its proximity to a large cluster of wind farms in coastal Ceará and neighboring Rio Grande do Norte states, which collectively have approximately 7.64 GW of wind power installed capacity supplying the

national electricity grid. Images of the Pecém green hydrogen hub showed wind power next to the port (Ceará, 2021b), where electrons will originate from widely distributed wind farms. Nearby Indigenous communities were erased in these images. Enegix's maps emphasized the proximity of Fortaleza to Rotterdam, Netherlands, which is considered to be a key import facility for green hydrogen.

Landscape encourages us to question how host communities will respond when nearby wind and solar farms become export factories to support the carbon and climate goals of affluent countries. Will host communities respond differently to wind energy when power feeds electrolyzers for export, rather than regional or national electricity grids? Territoriality, which describes the processes by which actors use authority and power to partition and control space, leads us to question how the government of Ceará created the space for potential green hydrogen factories, and more broadly, how promising renewable power sites (onshore and offshore) are made available for the wind and solar investments that would power electrolyzers. Previously, we described fraudulent processes in environmental licensing for terrestrial wind farms, (Gorayeb et al., 2018) and the exaggerated and erroneous claims in licensing documents for wind farms in Ceará (Araújo et al., 2020). Brazil just completed its regulatory framework for licensing offshore wind farms (IBAMA, 2020), which will be critical for generating power for electrolyzers. The licensing successes of future offshore wind farms for green hydrogen may rely on rendering descriptions of traditional coastal fishing communities and their fishing grounds as

archaic or invisible.

We should also consider how the Ceará government created a green hydrogen hub as an innovation site and analyze the ownership of electrolyzer and green hydrogen technologies and intellectual property. We know little about who owns the patents that make electrolyzers economically viable. Nor do we know the human capital requirements to sustain the electrolyzers. As Goldthau et al. (2020) warn, the Global South may be shut out from value chains for decarbonization, while a recent report suggests numerous geopolitical and trade implications from green hydrogen (IRENA, 2022). In terms of scaling the material size and spatial extent of decarbonized energy systems, we should inquire about knowledge and influence links among the Ceará government, federal energy officials, and entrepreneurs. Which Brazilian industrial groups are poised to oppose (or profit from) green hydrogen? Work by Hochstetler (2021) and Soares et al. (2021) on interactions between industrial groups and government officials in shaping wind energy policy may be extended to the emerging institutional framework for green hydrogen production and export.

## CONCLUSION

Turning renewable power into exportable green hydrogen represents a new trend in decarbonization that merits geographical analysis. Brazil is emerging as a potential leading global player in green hydrogen, and green hydrogen plans and investments have also been announced in Argentina, Chile, and Uruguay (ANCAP, 2021; Fundación Chile, 2021; Misculin & Geist, 2021; Total

Eren, 2021). Ceará state's Pecém port facility may soon become the site of green hydrogen export factories powered by offshore and onshore wind and solar farms. Geographical concepts could be deployed in Brazil and other green hydrogen investment sites in South America to create a robust research agenda that contrasts with optimistic and naive claims (Schmidt et al., 2019; Nadaleti et

al., 2020). A critical approach to green hydrogen accepts its importance for decarbonization while questioning the distribution of benefits accrued from turning wind and solar farms into power sources for green hydrogen export factories, emphasizing the territorialization processes that make terrestrial and ocean space available, and interrogating political-economic implications.

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