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Illuminant intersections: Injustice and inequality through electricity and water infrastructures at the Gujarat Solar Park in India

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ABSTRACT

Solar park development in India represents yet another frontier of capital accumulation under the auspices of climate change mitigation and rural electrification, producing new social frictions in the process. The decarbonization of India's electrical grid has put disproportionate burdens on marginalized populations, a trend particularly evident with the Gujarat Solar Park. Aside from solar arrays, it remains unclear how the vast infrastructures that sustain the Gujarat Solar Park will influence social power asymmetries at the local scale. For example, solar parks need periodic cleanings to function properly, requiring vast amounts of water. But dryland farmers from the region lack adequate water resources for irrigation and domestic purposes. Drawing on literature from feminist political ecology and critical infrastructure studies, this study investigates how the socio-material assemblage of water and electrical infrastructures of the Gujarat Solar Park unevenly distributes surreptitious burdens across differently positioned peasants. This study builds upon the conceptual frameworks of infrastructural violence and infrastructural intersectionality to illuminate the pernicious gender and caste politics of India's renewable energy transition. Solar infrastructures, built to ameliorate energy insecurity, may exacerbate water scarcity and pose additional threats to food security by grabbing arable land and denying marginalized smallholders engaged in food production near solar parks the water resources they need to feed themselves and the nation.

1. Introduction

The Gujarat Solar Park (GSP) is a renewable energy infrastructure with roughly 3.2 million solar panels. Sprawling over 5384 acres of land, the GSP has the capacity to generate more than 640 megawatts of electricity (Fig. 1). The Gujarat Power Corporation Limited (GPCL) commissioned the GSP, India's first solar park, on April 19th, 2012 in Charanka village in the Western India state of Gujarat (Fig. 2). At the time, the GSP was the largest solar park in Asia. To ensure local support for the large-scale grid-connected solar project, GPCL promised residents new infrastructure developments, few of which have materialized. Jagubhai recounts the broken promises of infrastructure provision accompanying solar park development with justifiable ire:

> "There was water for farming. Now it is not coming. The canal was not extended to the village because of the solar park. Temperature has increased, so the crops fail or do not grow well. GPCL promised a good road, free electricity, a good hospital, give water, make a high school, make a bank, wage increases beyond 300 rupees per day. Poor people do not get any work at the solar park, women also cannot work there. They give a facility of a bus three times a day but we do not get access to this facility. GPCL said they would make houses for poor people and widows but they have not done any of that." (C023, 9 February 2018)

Jagubhai doesn't work for the solar park. Previously, he was a farmer but sold all 16 acres of his land to GPCL to develop the solar park. Now Jagubhai is a landless wage laborer from the semi-nomadic and historically marginalized Rabari caste, a group officially classified by the government as an Other Backward Caste (OBC). Jagubhai's disappointment in GPCL's broken promises of infrastructure provision emerge from his own material deprivation; he lives alone in an earthen brick house, reliant upon firewood for cooking his meals and fetches water for domestic use from the village lake. Although his house is connected to the electrical grid, he assures me that the solar energy generated at the GSP is unreliable and infrequent. Jagubhai's feelings towards GPCL and the GSP reflect common sentiments among Charanka village residents, many of whom feel that they have given land, labor and resources for this solar park and have received little in return from GPCL.

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Despite hosting a world-class solar park that is well-serviced by various infrastructures and networks to facilitate flows of electricity, water, capital, information and labor, Charanka village paradoxically remains underequipped with vital infrastructures, the lack of which undermines the vitality of residents. To many government officials, Jagubhai's disdain for Charanka's electrical infrastructure may seem perplexing, given recent successes of connecting rural villages to electrical grids. In August 2015, the government of India inaugurated a rural electrification scheme—Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)—seeking to electrify all villages within a span of 1000 days, boasting a successful completion in April 2018. Heralded as "one of the largest electrification success stories in history," DDUGJY has helped more than 500 million rural Indians gain access to electricity [1]. Far from triumphant, the policy defines 'electrification' if a mere 10% of households of a village have access to electricity. Concurrently with DDUGJY in September 2017, the government launched another energy scheme—Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya)—that provided free electricity connections to every household in India, many of which were located in villages newly connected to the grid through DDUGJY. Rural electrification schemes like DDUGJY and Saubhagya have been bolstered by India's rapid development of grid-connected large-scale solar parks like the GSP.

In addition to rural electrification, solar park development concomitantly enables progress towards India's 2015 Paris Climate Agreement commitments to achieve 33–35% below 2005 emissions intensity of GDP and achieve 40% of non-fossil fuel share of cumulative power generation capacity by 2030 [2]. To achieve these goals, India initially pledged 100 GW of solar power by 2022 through the Jawaharlal Nehru National Solar Mission (JNNSM, henceforth *National Solar Mission*)—roughly 60 GW of which will be large-scale grid-connected solar projects—but is now pursuing 450 GW of renewable energy by 2030 [3]. Currently, the National Solar Mission (under management of the public entity Solar Energy Corporation of India, or *SECI*) is developing roughly 36 additional utility-scale solar parks across 21 states with several more having already been established in recent years [4]. Solar parks with a capacity of generating 500 megawatts or more are 'ultra-mega' solar parks, the much lauded and charismatic infrastructures of the National Solar Mission's goal to meet or exceed India's Nationally Determined Contributions to the 2015 Paris Climate Agreement.

Global climate policymakers have established a veritable eco-consensus that prioritize market-based techno-managerial solutions for mitigation [5], including the development of renewable energy projects. India's meteoric rise as global solar leader has been buoyed by discursive formations of ecological modernization and economic development [6]. Prime Minister Narendra Modi—revered as a "champion of the Earth" [7]—voiced this iconic proclamation at COP 21 in Paris: "So, convergence between economy, ecology and energy should define our future" [8]. SECI markets solar parks as unparalleled investment opportunities, echoed in India's Paris Agreement commitments: "The ratio of emission avoided per dollar invested and economic growth attained would be relatively more favourable in case of investments made in India" [2: 3]. Further, SECI promotes solar parks as infrastructures that deliver the 'triple bottom line' of economic development, ecological protection and social equity, ostensibly creating new market opportunities and employment for "people barely living at subsistence level" [2: 3]. Ultra-mega solar parks are modeled after Special Economic Zones (personal communication, 17 July 2018), investment spaces designed to attract foreign direct investment vis-à-vis minimal taxation and liberalized regulations. By 2030, India's ultra-mega solar parks will receive an estimated USD $500–700 billion in financial investments [9]. The GSP has already attracted more than ₹5365 crore (roughly USD $738.4 million) [10]. Yet it remains unclear if the GSP's pro-business institutional structure that redistributes capital flows and risk associated with solar development is coupled with material infrastructures that reproduce social power and marginalization.

This study is motivated by the following research question: *How do the material forms and flows of the Gujarat Solar Park influence local power relations and social differentiation?* This paper engages the literatures of feminist political ecology and critical infrastructure studies to establish a conceptual lens through which I answer the aforementioned research

Fig. 1. The Gujarat Solar Park. (Photo: Ryan Stock).

question in four additional sections. The proceeding section establishes a literature review to examine differentiated deprivation and marginalization resulting from disparate social conditions and material configurations. This section also discusses my methodological approach to fieldwork. Thereafter, I discuss research findings that demonstrate how solar park infrastructures contribute to processes of social differentiation in the adjacent community. I then put these research findings in conversation with global transitions to solar energy. This paper concludes by summarizing this study and a reflection on the broader impacts and stakes of solar park development.

2. The social lives of infrastructure

2.1. Assemblages and flows

Large-scale renewable energy systems like the GSP are built to generate and circulate solar electricity. The built environment facilitates socio-natural processes by unevenly conducting or restricting material flows, functioning as metabolic conduits [11]. Infrastructures like the GSP are relational installations that comprise “a series of interconnecting life-support systems” [12: 28]. More than mere subterranean substrates or subordinate interstices, infrastructures can be thought of as *socio-material assemblages*[1] that are “embedded…into and inside of other structures, social arrangements, and other technologies” [19: 381]. Beyond the bones and bricks of society, infrastructures are “wellsprings of state power” [20]. They enable the exercise of social power, insofar as they mediate social production and reproduction, often the object and terrain of political contestations [21]. The power of infrastructure lies in the politics embedded in its forms and functions, with the ability to “…emerge out of and store within them forms of desire and fantasy and can take on fetish-like aspects that sometimes can be wholly autonomous from their technical function” [22: 329]. Ultra-mega solar parks like the

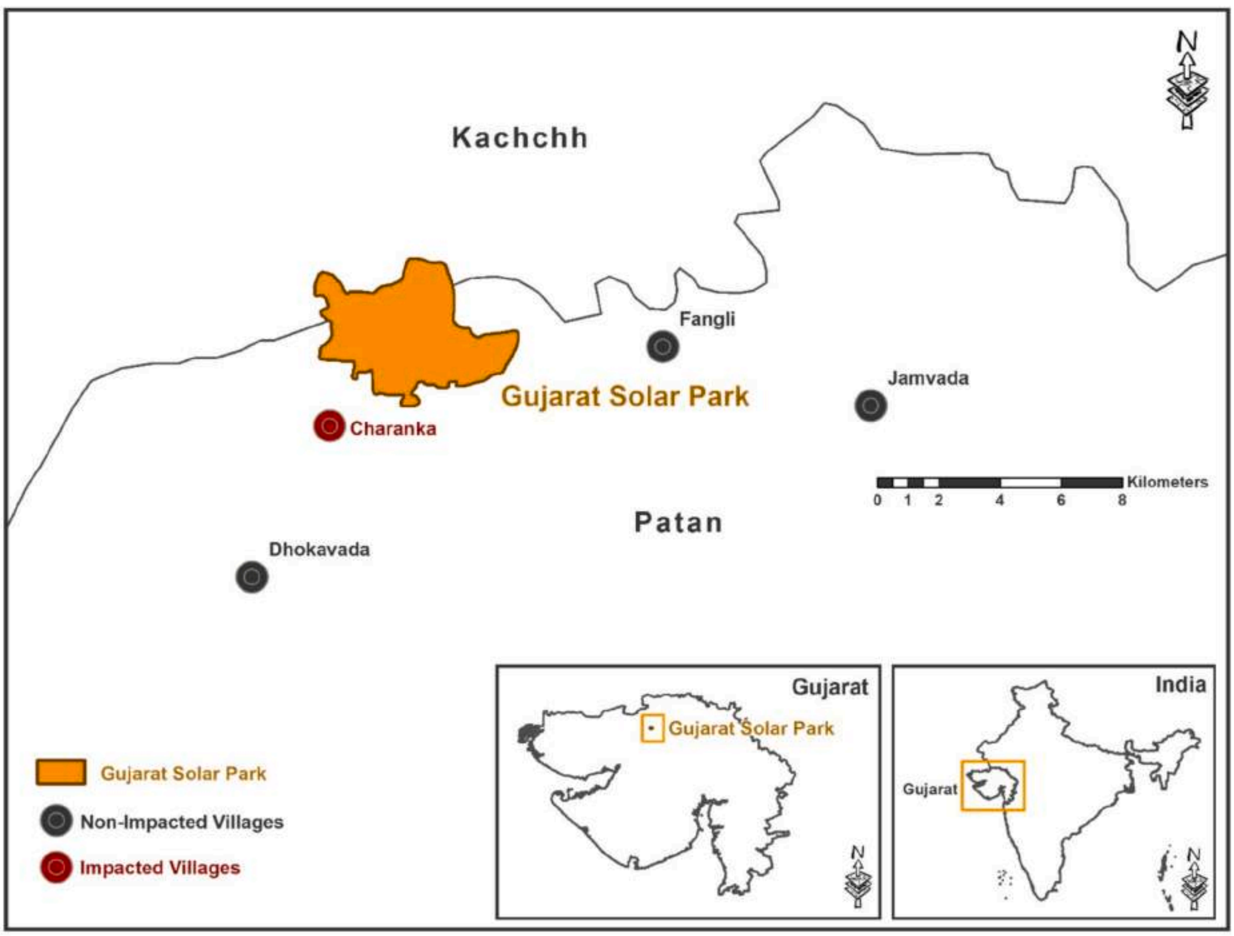

Fig. 2. The Gujarat Solar Park and study villages in Gujarat, India.

[1] Assemblage theory can trace its origin to Deleuze and Guattari’s [13] concept of *agencement*, and has since been prolifically yet heterogeneously employed throughout geographical scholarship to study a vast range of social and material processes and phenomena [14,15]. Tania Li [16] has succinctly described assemblages as “the on-going labour of bringing disparate elements together and forging connections between them.” As such, socio-material assemblages are emergent and unstable configurations of disparate social and material elements “ready to untangle at a moment’s notice” [17: 11]. Solar infrastructures are comprised of heterogeneous forms and materials and can thus be conceptualized as an energy assemblage with implications for social systems [18].

GSP are "admired and marveled at, materially and culturally supporting and enacting an ideology of progress" [23: 122]. Photovoltaic infrastructures are a dazzling phantasmagoria of hypervisible sustainable futures [24], situated within a temporality of promise in the grim context of the climate crisis [25]. The mitigative spectacle of solar parks—sustained through neoliberal discursive formations of progress [6]—enables a fetishization of solar infrastructures that conceal affective and embodied frictions within solar's socioeconomic conditions of production. Ergo, the infrastructural form conceals the material, political, social and economic inequalities that now define large-scale grid-connected solar parks in India.

The promise of renewable energy infrastructures to mitigate the climate crisis often obscures the perils local communities may experience; a techno-optimism that invisibilizes the people whose land, livelihoods and lives are sacrificed for sustainable development. For example, Dunlap and Arce [26] document the green grabbing of indigenous lands in the Isthmus de Tehuantepec in Mexico by Electricité de France to develop the large-scale Gunaa Sicarú 'wind factory, ' abetted by money, hitmen and NGOs to achieve social pacification and engineer social acceptance (see also [27,28,29]). Indigenous populations are dispossessed of land and livelihoods by the numerous wind power projects in the region and engage in sustained and successful resistance movements [30,31]. Throughout the life cycle of solar arrays, locals and laborers are imperiled by the contamination of landscapes, ecosystems and workplaces [32,33,34], often resulting in displacement [35]. Erecting solar infrastructures, generating electricity and circulating solar capital has not always led to rural upliftment or the amelioration of social vulnerability for many people living adjacent [36,37,38]. Solar parks, like other solar infrastructures, may produce new victims of energy-related injustices or exacerbate marginalization for certain groups of people [39,40,41]. As this study will demonstrate, "the workings of infrastructure can be substantially deleterious" [42: 403]. After all, infrastructures are political instruments. I assert that the Gujarat Solar Park is a large-scale infrastructure project that reproduces the marginality of certain community groups, vis-à-vis infrastructurally configured access to resources. Specifically, Charanka's poor and lower-caste households inordinately experience disrupted or denied provisioning of electricity and water, with disproportionate burdens befalling women tasked with household reproduction.

Technological networks and infrastructures that are configured to create, sustain or repair energy systems are heterogeneous across geographies in the global South [43]. India's rural electrification schemes exemplify how energy infrastructures in postcolonial spaces are often configured unevenly and incrementally, with distribution defined by disruption [44]. For example, Silver [45] examines the historical production of disrupted electricity generated by a hydro-electric dam in Accra, Ghana and the neoliberal governance of urbanization that has "resulted in a fragmented, splintered infrastructure that reinforces urban inequalities" (pg. 984). In India, farmers adjacent to solar parks often experience disruptions in electricity provision. Solar electricity generated at the park is routed away from local villages to service urban industrial and financial centers, leaving adjacent residents with an

Fig. 3. Substation transformer at Gujarat Solar Park. (Photo: Ryan Stock).

increased cost for an intermittent supply [46]. India's water infrastructure is similarly fraught, characterized by flow and fixity [47], complexity and leakage [48], fractured and sporadic supply [49], informality and disconnection [50]. When focusing on water infrastructures that service ultra-mega solar parks in semi-arid regions, disconnection becomes dispossession as dryland farmers struggling with water scarcity are deprived of additional surface and groundwater resources procured for and piped to the solar park.

India's ultra-mega solar parks require a vast and heterogeneous circuitry of materials, flows, forms, forces, bodies and capital to generate electricity. Solar parks are networked with other forms of infrastructure, including transmission lines and substation transformers (Fig. 3). Generating solar energy depends upon a bricolage of additional infrastructural forms that sustain human-mediated metabolic flows, including water pipes, drainage canals, street lights, latrines and roads. Yet the services and resources these infrastructures facilitate are not distributed equitably. As attested by Jagubhai, promises of infrastructure exacerbate the burdens caused by a deprivation of infrastructure. Rodgers and O'Neill assert that the "broader processes of marginalization, abjection and disconnection often become operational and sustainable in contemporary cities through infrastructure" [42: 403]. Residents adjacent to the GSP are often differentially included into and excluded from the patchwork provision of material flows. This is especially true for the electrical and water infrastructures networked with the Gujarat Solar Park.

2.2. Infrastructural violence

Despite being built under the auspices of mitigating climate-related impacts and providing energy security in energy poor regions of India, ultra-mega solar parks can paradoxically introduce new risks to these areas [51]. Utility-scale solar energy infrastructures are capital accumulation strategies that, when financialized, allow for a redistribution of financial risk away from investors and toward the community [52,53,54,55,56]. Abetted by financial capital, the rapid expansion of solar infrastructure in India through the National Solar Mission transpires in the policy context of energy federalism, which can reproduce inequitable access to energy [57]. Material risks are also unevenly distributed through infrastructural forms and deprivation is viscerally embodied as acts of violence. In the context of the socio-material assemblage of infrastructures that facilitate energy generation and distribution from solar parks in India, I will argue that the institutional provisioning of incremental, partial, disrupted or inferior infrastructures, along with the intentional withholding of infrastructural provisions promised to residents, represent surreptitious forms of violence upon marginalized peasants like Jagubhai—*infrastructural violence*. Rodgers and O'Neill [42: 404] assert that "…infrastructure is not just a material embodiment of violence (structural or otherwise), but often its instrumental medium, insofar as the material organization and form of a landscape not only reflect but also reinforce social orders, thereby becoming a contributing factor to reoccurring forms of harm." Violence in the form of denied or disrupted access to resources and flows enables an abdication of responsibility by state institutions responsible for provisioning [58], like public water and electricity distribution entities. The surreptitious violence wrought by the heterogeneous configurations of infrastructure supporting the solar park has not placed equal burdens on each differently positioned resident of Charanka village—-specific caste, class and gender groups have been disproportionately affected by solar infrastructural violence.

Without considering the influence of infrastructure, development of the GSP has differentially impacted Charanka residents across axes of social difference. Decision-making processes about the solar park were not inclusive to all caste and class groups and dominated by local elites [59], reflecting global trends in low-carbon energy transitions [60]. The enclosure of public 'wasteland' for solar park development has had a disproportionately negative impact on adjacent resource-dependent populations [46], specifically women and those of lower caste affiliation [61]. Numerous peasants experienced land dispossession and differential remuneration for their land by GPCL [62,63]. Of all households surveyed, 56% of surveyed Charanka residents had land enclosed for the GSP, with an average of 16.7 acres per farmer [46]. A farmer from the dominant Gadhvi caste (OBC) in Charanka expressed his disdain for the GSP: "The solar park is good for India but not for Charanka. It is good as it generates electricity but it has stolen the property of my village. It is not development for Charanka, it is destruction" (CI.009, 12 February 2018). Overall, dominant castes like the Gadhvis have benefitted more from employment and economic opportunities [64], disproportionately burdening members of the marginalized Rabari caste like Jagubhai. The solar park has only provided insecure and low-paying jobs to a handful of villagers—trends consistent with solar's precarious global labor force [65]—most of which are security guards, washing the solar panels and cutting brush under the solar arrays [46]. Even accounting for patriarchal social norms, women are not afforded the same employment opportunities at the GSP as men [66]. Households near the GSP have experienced energy-related disruptions and deprivations in the form of limited electricity and reduced access to firewood. Near the Kurnool Solar Park in Southern India, 76.4% of surveyed residents of adjacent Gani and Sakunala villages decried unreliability of electricity, while 75.5% mentioned limited and erratic supply of electricity [46]. Women tasked with firewood procurement were displaced from previously accessible spaces of woody growth that now host solar arrays in the GSP. Specifically, poor lower-caste women were most affected by the lack of biomass resource access from land enclosures [61]. Adding insult to injury, poor lower-caste women were also excluded from GPCL's corporate social responsibility schemes that boast female empowerment through workshops and market opportunities related to artisanal handicrafts [66]. Evidence from land enclosures and land use, employment opportunities, economic development and social development schemes suggest that the GSP has (re)produced class, caste and gender-based social power relations. Foregrounding the assemblage of infrastructures that sustain and service the GSP will afford unique insights into the distribution of benefits and burdens across residents of Charanka.

2.3. Infrastructural intersectionality

Although infrastructural violence is a gendered relation [67], I argue that the GSP's infrastructural violence must be additionally assessed through the lens of intersectionality. Truelove and O'Reilly [68] conceptually advance discussions on infrastructural violence by introducing the framework of *infrastructural intersectionality*, referring to how a person's multiple social identities (i.e. gender, caste, class) mediate their social vulnerability through multi-scalar power relations manifested through a specific infrastructure or "multiple infrastructures that are inter-connected and co-constituted through each other" (pg. 4). They trace the urban contours of India's Swachh Bharat Abhiyan in Indore to end open defecation in the municipality. In a victorious quest to achieve the 2017 Cleanest City award, the municipal corporation wrought infrastructural violence upon precarious populations dwelling in informal settlements. They withheld latrine infrastructures from residents whose payment for said latrines had already been collected and, for accounting purposes, demolished their homes to erase evidence of unsanitary settlements [68]. Responding to Rodgers and O'Neill's [42: 402] provocative challenge to conceptually determine "when it is that infrastructure becomes violent, for whom, under what conditions, and why," I illuminate how the GSP's socio-material assemblage of infrastructures has intersectional impacts in Charanka, (re)producing caste, class and gender-based social differences that are embodied and affectively experienced by local residents.

3. Methods

Empirical data supporting this argument is drawn from a mixed methods approach to fieldwork that included household surveys, semi-structured interviews and participant observation. Fieldwork was conducted in 2018 at the Gujarat Solar Park and Charanka village in Gujarat, India. A mixed methods approach was chosen to triangulate research findings for additional empirical rigor [69]. Fifty households ($n = 50$) in Charanka were surveyed using a snowball sampling technique, representative of all caste groups in the village (Table 1). General castes (i.e. Sadhu, Joshi, Parmar, Jadeja, Vaghela) of the village tend to be more affluent and have larger plots of land. Dominant OBC castes (i.e. Gadhvi, Ahir) are also more favorably positioned in Charanka. Marginal OBC castes (i.e. Rabari, Koli, Ayar) and Dalits tend to have a lower social positionality and smaller landholdings. This study also surveyed and interviewed Muslims of Charanka, a small minority of residents. Among respondents, 20% were women ($n = 10$) and 80% were men ($n = 40$). Fifteen survey respondents ($n = 15$) were selected for semi-structured interviews, stratified by caste, class and gender. Surveys and interviews were conducted in Gujarati language. The proliferation of COVID-19 throughout India presented a significant limitation to the practice of research (i.e. fieldwork) for this study [70], rendering me unable to collect additional primary data on water withdrawals for cleaning solar arrays at the GSP. I adapted to this limitation by relying more heavily on digital sources and secondary data [71], which (given the context) I hope strengthens the defensibility of my multi-method approach [72]. While conducting fieldwork in Charanka in 2018, I occupied a vastly different positionality than my research subjects. My critical reflexivity, careful and collaborative engagement, language proficiency and intimate family connections in Gujarat fostered a cultural sensitivity and competency that (I hope) helped mitigate reproducing colonial legacies of scientific expropriation, exploitation and knowledge production [73,74,75]. All truth-claims in this paper represent partial perspectives of a privileged Western scholar, truth-claims which are not assumed to be more accurate or authoritative than those held by Charankan research subjects.

4. Results

Solar arrays cannot generate electricity without a configuration of other technical forms which include mounts, wires, cables, substation transformers and transmission lines. The solar park is equipped with the provisioning infrastructure needed to ensure proper functioning of the solar arrays (e.g. water pipes, drainage canals), as well as structures that mediate access to the park (e.g. roads, gates, fences) and facilities for the park's highly stratified labor force (e.g. latrines, street lights, tea stalls). The infrastructural forms that comprise and sustain the GSP are of superior quality than those found in adjacent villages like Charanka.

GPCL initially promised numerous infrastructural improvements for Charanka as part of its 'social commitments' for rural upliftment, which included paved roads, solar street lights, a drinking water facility and a renovation of local schools [76]. However, these infrastructural improvements have not materialized. A chief operations and maintenance officer for the Gujarat Solar Park reflected on infrastructure improvements and rural development: "Since the solar park was built in Charanka, I have seen lifestyle changes in the village. I see vehicles, a new road, electricity, regular water connection to each household, education improvements in the village. GPCL helps with all of this. Before the solar park, they had nothing" (GPCL.CH.002, 23 March 2018). However, most residents of Charanka and adjacent villages have not benefitted from the infrastructures installed to service the solar park (e.g. roads, water pipes, electricity). "Other than roads, there is not much improvement. We have not received electricity or safe drinking water from the solar plant" (SI012, 9 June 2018).

The households of Charanka still generally lack adequate electricity and access to water resources. Of all households surveyed ($n = 50$), 90% had electricity in their homes. However, villages receiving grid-connected solar power from the GSP continue to experience disruptions in access, taking the form of intermittent reliability of supply, variable temporalities of delivery, and an increase of cost per kilowatt hour [46]. Near the Gujarat Solar Park, 59.3% of surveyed residents of Charanka village complained of unreliable current and 56.6% attested to limited and erratic hours of energy received per day. Lower caste groups have been most affected by lack of access to household electricity and also have a more negative perception of reliability and duration of electricity received (Table 2). Considering gender differentiated perceptions of household electricity, women had a more negative perception. Roughly 90% of women claimed that electricity was not more reliable after the GSP and 80% said they had not received additional hours of electricity, indicating no improvement in duration of current. This stands in contrast to men's perceptions of household electricity, with 82.5% indicating a lack of reliability and 75% claiming no improvement in duration of electricity received. In fact, uneven distribution seems to be the intended outcome of how electrical distribution infrastructures were established in the region, as described by a Muslim woman from Charanka: "We get electricity but at a decided rate, not free of charge. Electricity generated at the solar park is re-routed to the substation at Varahi, then to our village. Earlier, they have promised to provide free electricity to Charanka but now the price has doubled" (CI.002, 12 February 2018). Solar electricity generated mere meters away from the nearest Charanka home is directed more than 30 km away to a larger town before returning back to this same home, an irony that many do not find amusing. In spite of DDUGJY and Saubhagya to ensure rural electrification, energy poverty remains a stubborn reality for many households in electrified villages like Charanka. Residents also suffer from acute water insecurity, a deprivation exacerbated by thirsty solar parks in arid lands.

The water resources needed to sustain utility-scale solar infrastructures are an under-examined yet highly consequential factor of renewable energy transitions. India's solar parks are located in water parched arid or semi-arid locations with vast stretches of contiguous land and abundant solar irradiance. Solar arrays must be routinely cleaned of exterior dirt and debris that could prevent photons from knocking electrons free within the electrical current of photovoltaic units, causing generation losses of up to 6% [77]. Washing solar arrays

Table 1
Summary statistics of respondents ($n = 50$) in the project-affected village of Charanka. Average income is self-reported rupees per year, INR ₹71.4 = USD $1. Respondents are differentiated by caste categorization.

Caste Categorization	Percentage of Respondents	Avg. Total Income
General Castes	10%	99,924.49
Dominant OBCs	22%	55,407.74
Marginal OBCs	38%	21,346.15
Scheduled Castes (Dalits)	24%	31,000.00
Muslims	6%	54,221.96

Table 2
Summary statistics of Charankan respondents' ($n = 50$) access and perceptions of electricity after completion of the Gujarat Solar Park. Statistics are differentiated by caste categorization. Household electrification is self-reported. Respondents were asked about the reliability and duration of electricity received.

Caste Categorization	No household electricity	Reliability of electricity has not improved	Hours of electricity have not increased
General Castes	20%	60%	20%
Dominant OBCs	0%	90.9%	90.9%
Marginal OBCs	10.5%	89.5%	73.7%
Scheduled Castes (Dalits)	16.7%	83.3%	91.7%
Muslims	0%	66.7%	66.7%

requires an average of 0.1 cubic meters per megawatt hour (100 L/MWh), a task which occurs every 10–14 days (Fig. 4). The combined labor and water costs of washing solar panels can amount to ₹42,000–105,000 (USD $563-$1,408) per megawatt per year, comprising up to 35% of the total costs of the solar parks' operations and management [77].

India's agrarian spaces are struggling from unprecedented water insecurity, partially caused by the over-extraction of groundwater resources for irrigating crops [78]. Roughly 94% of India's solar parks under development in agrarian spaces will be exposed to medium-to-high levels of water risk in the near future (Fig. 5), further imperiling the future vitality of solar energy and dryland agriculture. Although data is scant and elusive, the Gujarat Solar Park likely requires an estimated 64 m^3 water to clean solar arrays every two weeks [77], a substantial amount of water resources in this parched landscape. This solar park utilizes both surface (~40%) and groundwater (~60%) for the purposes of washing solar panels. The GSP boasts a large artificial pond on-site where rainwater is collected for washing the solar panels. Yet most of its water is derived from surface water delivered 35 km away from the Kachchh Branch Canal of the Sardar Sarovar dam on the Narmada River (henceforth SSNL; Fig. 6), a luxury denied to the region's dryland farmers who are still largely dependent on rainwater for their agricultural production [46]. Put succinctly by a smallholding farmer of the Parmar caste: "Water goes to solar instead of the village" (F040, 7 March 2018). In addition to lacking access to water for irrigation by many farmers who experienced land enclosures and dispossessions for the solar park, the pipeline infrastructure for the SSNL canal was extended through many farmers' lands in Charanka and nearby villages by eminent domain. "The water line for the SSNNL canal passed through our land but did not give any money. The water pipeline passed through farms, under the land. But we did not get any return for it" (F026, 6 March 2018).

Beyond access to irrigation water, numerous households in Charanka lack basic access to water for domestic use. Water infrastructure at the scales of the household and village is uncommon and underdeveloped where present. Roughly 48% of respondents ($n = 24$) fetched their domestic water from the village lake (*talab*), 48% ($n = 24$) purchased water from a truck (*tanker*) that comes through the village to fill large water tanks on site of residence, and 4% of respondents ($n = 2$) sourced water for their domestic use from nearby wells. Caste-based social difference is an indicator of water source in Charanka. As shown in Table 3, respondents from marginal OBC castes (i.e. Rabari, Koli, Ayar) and Dalits sourced most of their water from the village lake. In contrast, more affluent general castes (i.e. Sadhu, Joshi, Parmar, Jadeja, Vaghela), dominant OBC castes (i.e. Gadhvi, Ahir) and the Muslim respondents purchased most of their household water from a tanker. Fetching water is a task of household reproduction undertaken by women of the village. Women are also involved in various tasks of farm labor that require vast amounts of water. When the data from Table 3 is examined through an intersectional lens, solar-related water scarcity disproportionately impacts lower caste and lower class women of Charanka. Water infrastructures for solar—developed for provision or denied for abjection—can constitute a surreptitious form of infrastructural violence in the context of agrarian distress within a grand renewable energy transition.

Charankans are differentially subjected to electricity-related and water-related infrastructural violence from the solar park across axes of social difference, with excessive deprivation befalling marginalized groups. The socio-material assemblage comprising the GSP enables the dispossession of energy and water from adjacent smallholders [80–82]. Putting these results in conversation with Sovacool's [39] novel typology of distinct processes in the political ecology of low-carbon energy transitions, my case shows how differently situated Charankan residents are victims of the enclosure of land and water resources for solar park development, victims of exclusion from the GSP's decision-making and project planning processes, victims of the solar park's encroachment and despoliation of vast amounts of land and excessive water withdrawals that destabilize the semi-arid ecosystem, and victims of how the inequitable material configuration and flows supporting the solar infrastructure entrench social vulnerabilities of marginalized groups. By utilizing an intersectional lens to examine residential access mediated through electricity and water infrastructures, I critically engage the vital questions of infrastructural violence "for whom, under what conditions, and why" [42: 402].

Fig. 4. Laborers washing solar arrays at the Kurnool Solar Park. (Photo: Ryan Stock).

5. Discussion

The commissioning of the GSP in 2012 marked a watershed moment in India's efforts to mitigate climate change through renewable energy generation. The charismatic infrastructure became a global spectacle for techno-optimistic imaginaries of sustainable futures. While inaugurating the project, Modi (Gujarat's Chief Minister at the time) proclaimed: "This achievement is not merely a step in the direction of power conservation, but it provides the world with a vision of how the power needs of future generations can be solved in an environment-friendly manner." The GSP became the blueprint by which all of India's subsequently developed solar parks were elaborated. SECI has since commissioned numerous ultra-mega solar parks and many more are forthcoming [4]. Yet the GSP has also received international notoriety. In the margins of UNFCCC's COP 21, wherein the landmark Paris Climate Agreement was established, India and France announced the initiation of the International Solar Alliance (ISA). Effectively, the ISA strives to be the global OPEC of solar energy [83]. The ISA will develop 1000 megawatts of solar energy capacity throughout 122 'sun-belt countries' between the Tropics of Cancer and Capricorn by 2030 and currently boasts 86 member countries and 94 signatory countries. By 2030, the ISA also seeks USD $1000 billion in direct investments to develop solar infrastructures in the global South [84].

Launching from the ostensible success of the GSP and its successors, the ISA's large-scale solar program is designed to "…promote, assess potential, harmonize demand and pool resources for rapid development of large-scale Solar Projects under Solar Park concept…" in other ISA member countries throughout the global South [84]. Given the urgent need to decarbonize the global electrical sector to help mitigate the

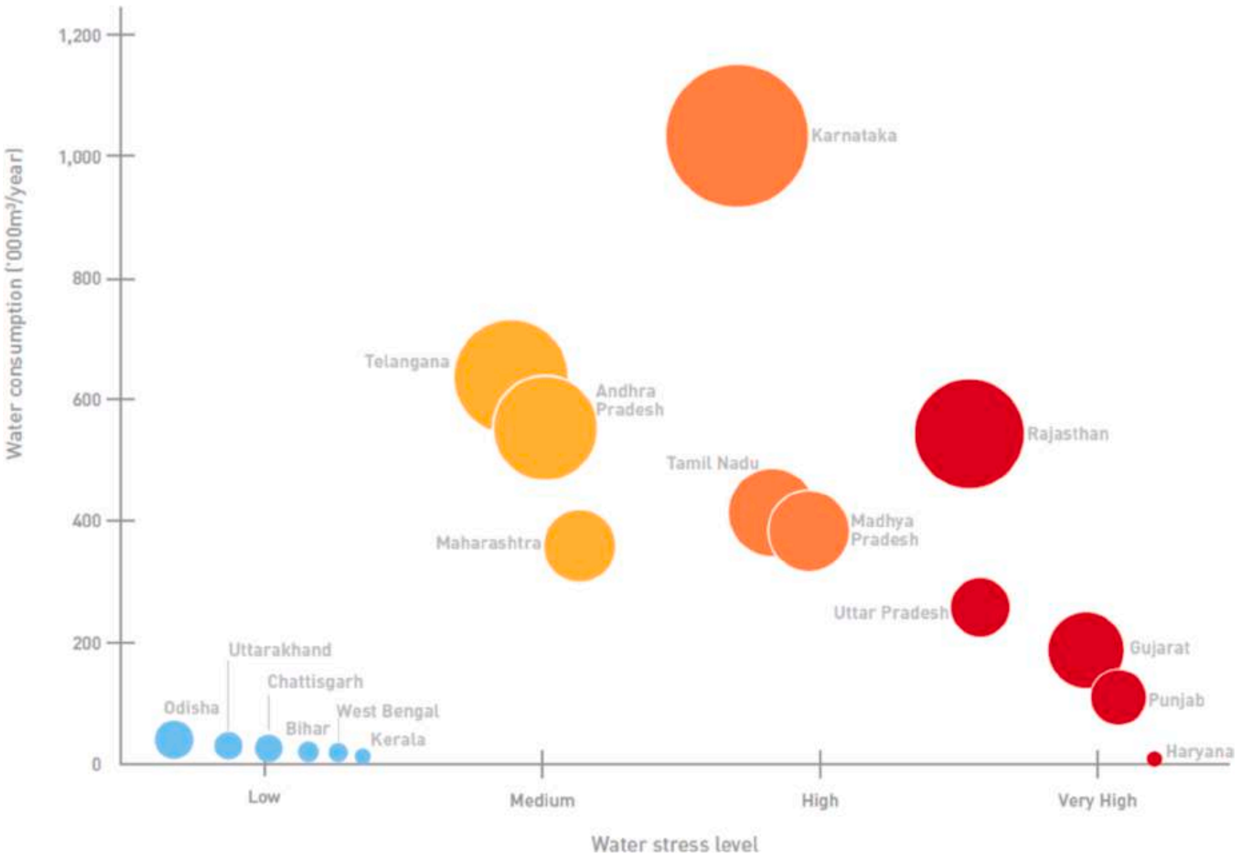

Fig. 5. Estimated water consumption in the solar sector by state, based on installed capacity as of June 30th, 2018 [77].

climate crisis, the rapid expansion of solar energy is imperative. Yet the material configuration of ultra-mega solar parks *in situ* can generate historically specific and contingent social frictions, unevenly mediating resource access and differentially redistributing benefits and burdens in local populations across axes of social difference. According to Colven [24: 326], "…visibility and invisibility are relational: the visibility of one infrastructural network necessarily draws attention and political will away from another." The hypervisibility of solar arrays conveniently obscures the inequitable distribution of electricity and water resources. Semi-arid regions of the global South already struggle with water insecurity, a problem which will intensify with increases in global surface temperature and changes in rainfall patterns. A vast majority of locations with favorable solar irradiation in these poor nations are inhabited by poor and/or marginalized populations, many of whom have been left behind by previous development processes, or producers whose food production systems' integration into an increasingly global neoliberal marketplace has been inequitable. Place-specific asymmetries of social power and systems of social hierarchicalization will mediate the impact of solar park infrastructures on differently situated individuals. As is the case with the GSP in Charanka, heterogeneous populations residing near the solar parks are differently positioned in the political economy and have diverse social identities (e.g. class, race, caste, gender). The ISA's top-down approach to utility-scale solar power infrastructure may exponentially exert infrastructural violence among geographically and culturally distinct vulnerable populations possessing multiple and intersectional social identities, with burdens disproportionately befalling marginalized smallholders like Jagubhai. Although technically effective at mitigating climate change through decarbonizing the dirty electrical grid, solar infrastructures alone cannot fix the sociopolitical causes of climate change nor manifest more equitable outcomes [85,86,87]. Prioritizing mitigative infrastructures that reproduce intersectional social differences suggests that the transnational community of climate and energy policymakers and scientists are essentially staring at the sun, distracted by the promise and potential of ultra-mega solar infrastructures. Squinting past the illusory forms and flows reveals the socio-political frictions wrought by the socio-material assemblage of infrastructures supporting solar energy generation.

6. Conclusion

Solar park development in India represents yet another frontier of capital accumulation under the auspices of climate change mitigation and rural electrification, producing new social frictions in the process. The accumulation of solar capital at the Gujarat Solar Park (GSP) is achieved through the disproportionate dispossession of land, energy and water from marginalized residents of Charanka, made possible through a patchwork of heterogeneous infrastructures. Drawing on literature from feminist political ecology and critical infrastructure studies, this study investigates how the socio-material assemblage of water and electrical infrastructures of the Gujarat Solar Park unevenly distributes surreptitious burdens across differently positioned peasants. This study builds upon the conceptual frameworks of infrastructural violence and infrastructural intersectionality to illuminate the pernicious gender and caste politics of India's renewable energy transition.

India's semi-arid agrarian regions, targeted for solar park development by SECI for their abundant solar irradiance, are parched landscapes. Rapid groundwater decline for irrigation will accelerate as climate change alters precipitation patterns and increases global surface temperatures. The virtually unlimited access and extraction of precious water resources to clean photovoltaic systems at ultra-mega solar parks becomes a threat to regional water security. Further, the GSP case serves as a warning that energy infrastructures built to ostensibly ameliorate energy insecurity may exacerbate water scarcity and pose additional threats to food security by dispossessing arable land and denying

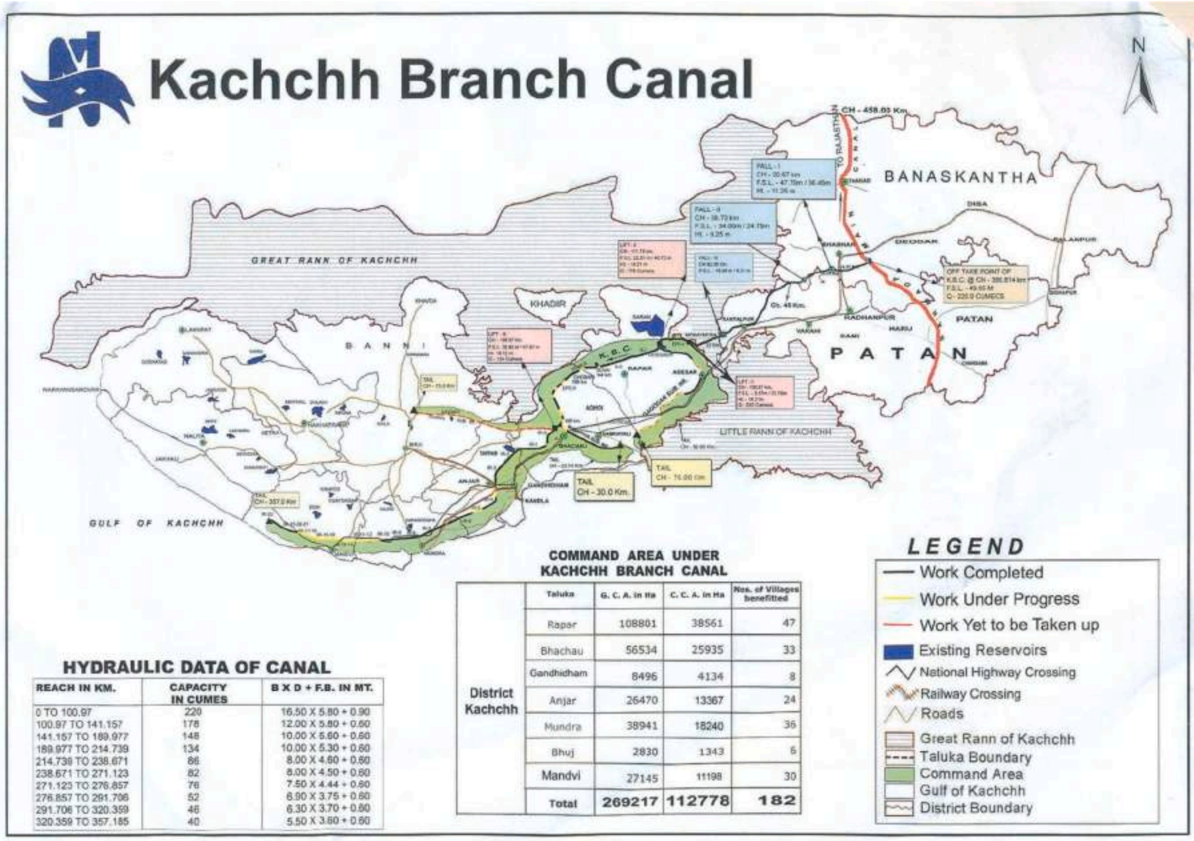

Fig. 6. Kachchh Branch Canal of the Sardar Sarovar Dam on the Narmada River that distributes water to the Gujarat Solar Park [79].

Table 3
Summary statistics of primary water source for domestic use among respondents ($n = 50$) in Charanka. Primary water source is self-reported by respondents and differentiated by caste categorization.

Caste Categorization	Water Source
General Castes	Lake: 16.7%, Tanker: 66.7%, Well: 16.7%
Dominant OBCs	Lake: 33.3%, Tanker: 66.7%, Well: 0%
Marginal OBCs	Lake: 52.9%, Tanker: 41.2%, Well: 5.9%
Scheduled Castes (Dalits)	Lake: 100%, Tanker: 0%, Well: 0%
Muslims	Lake: 0%, Tanker: 100%, Well: 0%

dispossessed peasants like Jagubhai and other marginalized smallholders engaged in food production near solar parks the water resources they need to feed themselves and the nation. Across the ‘sun-belt’ of the global South targeted by the International Solar Alliance (ISA) for large-scale solar development, many of these nations’ agrarian spaces also struggle with water security, energy security and food security. With GSP as a blueprint, the ISA is poised to enact infrastructural violence upon some of the world’s most vulnerable populations, the stakes of which cannot be understated.

Ascending to the existential challenge of combatting climate change necessitates a rapid decarbonization of electricity generation. But efforts must be taken to democratize energy access and management at the local scale which prioritizes the people who are disproportionately burdened by new energy regimes. Moving forward, scholars studying the social dimensions of solar energy should use an intersectional lens to illuminate the role that solar infrastructure plays in social differentiation and material deprivation. With a normative commitment towards fostering an emancipatory politics ‘from below,’ eclipse inequitable infrastructural assemblages and expose those harvesting solar capital who leave the dispossessed to die desiccated in darkness.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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