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Solar energy at the peri-urban frontier: An energy justice study of urban peripheries from Burkina Faso and South Africa

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ABSTRACT

Most of the global population that lack access to electricity services live in sub-Saharan Africa. Peri-urban areas of large African cities, often characterized by the presence of informal settlements, exist in a kind of 'scalar limbo,' unable to benefit from either access to the city grid or from programs aimed at the electrification of rural areas. In addition, in those areas where lack of electricity access is common, energy poverty combined with proximity to the grid leads to a greater likelihood of illegal energy supply arrangements. In this fieldwork-based study, conducted through population surveys and interviews in the peripheries of Ouagadougou, Burkina Faso, and Cape Town, South Africa, we employ a hybrid theoretical framework, based on work in urban political ecology and energy justice, to analyze the situation of electricity access in the two areas. We find that the planned scale, scope, and technological design of solar energy projects in peripheral areas are crucial in determining whether and how a project will be beneficial for local communities. This study provides guidance beyond academia to national and international policymakers and executives of renewable energy companies, as well as tools for a more in-depth assessment of energy justice issues.

1. Introduction

Sub-Saharan Africa is home to around three quarters of the world's population without access to electricity: according to a 2019 report by the International Energy Agency (IEA), 580 million people out of the 770 million globally who were unable to use this vital commodity lived in sub-Saharan Africa [1]. While this number has been decreasing since 2013, mainly thanks to the extension of electricity grids and the spread of decentralized energy infrastructure, the COVID-19 pandemic reversed this trend [2]. Following the 2020 inception of the pandemic, and the consequent redirection of state budgets to tackle it, funding for electricity access projects has decreased. This especially affected non-electrified rural and peri-urban areas. It is not uncommon for peri-urban populations to live close to high-voltage lines but to be unable to connect (a condition known in the literature as being 'under-the-grid') [3].

Peri-urban areas are frequently characterized by a lower socio-economic level than urban areas. Utilities are often reluctant to prioritize or extend services to these areas due to a range of factors: the prospect of payment difficulties on the part of low-income users, high costs of electricity connections discouraging potential customers, and the modest amounts of energy consumed by households, resulting in lower earnings. At the same time, while peri-urban areas may exhibit some characteristics typical of rural areas, they cannot be considered as wholly rural, as their economies and population densities are different. In cases where electricity management is distributed among several agencies depending on geographical scale (e.g., one agency being competent for cities, another for rural areas), conflicts of competence may arise between these. Additionally, peri-urban areas may be treated as marginal areas when compared to more established urban centers on which investments are concentrated.

In peri-urban areas, energy poverty combined with proximity to the grid leads to a greater likelihood of illegal energy supply arrangements, such as energy theft, illicit connections, and tampering with electricity meters [4–6]. The urgency of finding a solution to the twin, linked problems of illegal connections and energy poverty, makes it necessary

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to study peri-urbanity from an energy justice perspective, and to ask how to improve access in these low-income areas. This paper analyzes peri-urban areas in two large African cities (Cape Town, South Africa, and Ouagadougou, Burkina Faso). The paper establishes a dialogue between research on energy justice and literatures from urban geography and urban political ecology (UPE) that have engaged with peri-urbanity and scale. The next section outlines our hybrid theoretical framework.

2. Scale, peri-urbanity, energy justice in African energy studies

2.1. Scale and peri-urbanity

Our focus is on the peri-urban as a key site of production and negotiation of renewable energy landscapes. Much of the energy, urban studies and development literature continues to reproduce a binary distinction between the city and rural areas in terms of the types of projects and approaches in either category. Peri-urban areas escape facile categorizations as wholly urban or rural. In part, this is because they are rapidly changing "transition spaces" [7, p. 1], where a mix of uses and economies blend the urban and the rural. Their fluidity means that they are not easily integrated within urban planning and development frameworks [8]. Finally, peri-urban areas are often the location of urban informality, which is not easily classifiable as formally urban due to infrastructural and socio-economic disconnection and segregation from the formal city.

In focusing on the peri-urban, we base our analysis on a dynamic and relational concept of scale. We argue that considering the nexus between justice and energy in peripheral urban areas necessitates a close engagement with the multiple scalar dimensions and processes that produce the peri-urban as a continuously shifting reality. A relational understanding of scale helps to understand sites of de- and re-territorialization within and outside the city [9]. Additionally, considering the multiple ways in which scale is performed is key to understanding the tensions and power relations that course through energy landscapes. For example, while public authorities and agencies may be seen as hierarchically organized on a spectrum from national to local, when considering energy in sub-Saharan Africa, scale can also be understood to be produced on a matrix between energy centralization and decentralization [10]. In both South Africa and Burkina Faso there remains a key tension between centralization (which is involved in the national, modernist project of energy strategy and electricity planning), and decentralization (including through renewables, independent power producers, and off-grid energy projects).

When considering the broad mix of urban processes and forms of tenure existing in peri-urban areas (from formal to informal urbanization, as well as small-scale agriculture, animal husbandry, and light industry), linked to overlapping formal (the grid as well as formal renewables) and informal energy infrastructures (including off-grid renewables but also other forms of energy), it can be seen that approaching the peri-urban energy landscape from the lens of energy reveals these areas to be what Munro and Bartlett [11, p. 72] describe as a "post-modern energy landscape, one that is neither 'traditional' nor 'modern,' rather the fragmented product of different social and economic processes." It is precisely because of the collage-like nature of the peri-urban that being sensitive to its scalar dimensions is necessary when considering the justice aspects of renewable energy-focused development in urban peripherality.

Drawing on UPE, the emergence of specific energy landscapes in peri-urban areas can be seen as parts and parcel of a metabolic process in which infrastructure is a central component [12], and which is characterized by materialities that are expressed both temporally and spatially, and that flow through institutions, regulations, technical systems and encounters with everyday lives [13]. Analyzing the production of energy landscapes in peri-urban areas also enables us to link the paper's focus on energy justice to the dynamic contexts of Ouagadougou and Cape Town, underlining how heterogeneous infrastructural configurations [14] are part of the process of energy bricolage and fragmentation seen in the peri-urban [15]. Thus, a UPE-informed perspective helps us to understand how scalar power relations are also relational, shifting, and intertwined with solar energy in peri-urban areas [16].

At the same time, they enable a consideration of energy landscapes in a spatial context that is rooted in place: the energy landscapes we consider are the interfaces between energy practices at a variety of scales, and the local communities with which we carried out our research. As Castán Broto and Sanzana Calvet [17, p. 281] show, the lens of landscape "shows that place-based experiences and discourses also shape the political ecology of energy." Additionally, several aspects of the socio-material politics involved in the production of energy landscapes (notably around distribution, policymaking procedures, and the reproduction of inequalities) [18] are linked to their energy justice characteristics, and it is this connection that justifies the use of an energy justice framework, coupled with UPE. It is to these facets that the paper now turns.

2.2. Crossing the peri-urban and energy justice aspects

Over the last two decades, scholars have critically analyzed the tools used by policymakers and energy analysts in assessing energy projects. This strand of research, broadly known as energy justice theory, has typically been formulated in two ways: through tenet- [19] or principle-based approaches [20,21]. The former identified the three tenets of distributive, procedural, and recognition justice, depending on whether the focus was on an energy system's distribution of costs and benefits, the decision-making processes involved, and which actors are recognized as legitimate stakeholders, respectively. The latter is based on the eight principles of availability, affordability, due process, transparency and accountability, sustainability, intergenerational equity, intra-generational equity, and responsibility [21]. Due to the scope and comparative approach of our paper, in our analysis we focus on the three tenets approach.

As well as using an energy justice lens, we root our analysis in the under-studied peri-urban context. While interest in energy justice in renewable energy projects in Africa has been high over the last decade, Africa's peri-urban areas have not been a common and explicit target of research in energy studies. This is probably a result of a 'scalar limbo': that is, the difficulty of attributing purely urban or purely rural characteristics to peri-urban areas, and the consequential geographical and sociological complexity of these areas in terms of energy use patterns and of the choice of the energy system that could most adequately satisfy their needs. This study attempts to partially fill this gap.

Existing studies on renewable energy and social sciences in peri-urban locations in Africa cover a broad range of topics, such as household willingness to pay for green electricity in Tigray, Ethiopia [22]; the potential of solar water heater program in South African townships [23]; energy transitions in urban informal settlements in Kenya, Uganda, South Africa, and Zimbabwe [24,25]; urban energy governance in South Africa's Renewable Energy Procurement Program [26]; investment, service reliability and social sustainability in electricity access in Mozambique [6]; and the rejection of energy technologies by low-income urban dwellers in Cape Town, South Africa [27]. However, only a small subset of these studies includes aspects of energy justice: Samarakoon [28] analyzed energy injustices in Malawi's off-grid solar market; Boamah et al. [4] studied institutionalized corruption in solar PV systems in Ghana and Kenya; and Cantoni et al. [29] examined solar energy in Burkina Faso.

Before explaining our methodology, we need to provide an epistemic warning. This study employs a Western theorization of the energy justice concept: this is a known problematic issue (see [30,31]). Work on the application of non-Western theorizations of justice to energy-related cases has recently been conducted: for example, Sanusi and Spahn [32], and Pellegrini-Masini et al. [33] have both worked on sub-Saharan

Africa's Ubuntu philosophy. This is an area that deserves broader scholarly attention, a full exploration of which falls outside of the scope of this paper. A second limit of this research is that the numerosity of our surveys, and thus their analytical power, differs significantly (100 respondents in the Burkinabe sample versus 223 respondents in the South African one). However, a sample of 100 respondents is considered acceptable in literature for drawing statistically meaningful conclusions [34,35]. Finally, in terms of its applicability, we are aware that the economic conditions of South Africa are rather unique, and that would limit the applicability of this study; however, Burkina Faso's economy has many points in common with the economies of surrounding countries (West African countries in particular). Therefore, we believe that the results of that case study can be applicable to other countries in the subregion with a similar degree of economic development.

In the next section, in order to situate readers, we provide background information on the national energy policies of South Africa and Burkina Faso, and outline the structure of their energy sectors.

3. National energy policies and energy sector structures

3.1. South Africa

South Africa's generation and distribution profile is dominated by Eskom, a state-owned utility which is responsible for producing 96 % of its energy [36] and 90 % of its electricity. Municipalities, redistributors, and private generators supply the remaining 10 % [37]. In turn, Eskom is regulated by the National Energy Regulator of South Africa (NERSA) [36]. Eskom transmits electricity to South Africa's main users (industrial, mining, commercial, agricultural, residential, municipal). In areas that are serviced by Eskom, most often it is the municipalities that redistribute electricity to households and businesses within the municipal area. This, however, is not the case of Qandu Qandu, which is directly supplied by Eskom (as also occurs in some other peri-urban areas).

There have been calls for change in South Africa's energy generation and distribution structure, and of the balance of primary energy sources, spanning at least two decades. The country's initial public electricity strategy, published in 2011, was the Integrated Resource Plan (IRP). This focused on transitioning away from coal, and institutional change, with a 2030 target [38]. The IRP planned for an additional 17.8 GW of renewable power, as well as a smaller increase in coal generation (6.3 GW). Most of the projected increase in renewable energy was based on solar and wind, as well as nuclear and imported hydroelectricity [39]. Updates to the IRP dampened the initially strong focus on renewables. Another attempt to incentivize renewable generation in the country was the Renewable Energy Independent Power Producer Procurement Program (REIPPPP). The initiative resulted in the award of 6327 MW of projects, for a total investment of US$ 20.5 billions. Solar PV accounted for 34 % of this investment [40].

In parallel with the IRP, the country's National Development Plan (NDP) aims for a significant change in South Africa's energy generation profile, with the aims being a reduction of dependency on coal, and more reliance on renewable energies and gas (NPC, 2019). More broadly, the NDP aims for 90 % grid access by 2030 [36], with 95 % of the population having access to electricity (on-grid and off-grid combined) by the same year [37]. Between 1999 and 2005, 3.2 million households were connected to the grid by Eskom, and 1.7 million by local government; in 1996–2011, the percentage of households using electricity for lighting rose from 58.2 to 85 % [41]. To enable the poor to be connected to electricity, since 2003, households are entitled to 50 kWh of Free Basic Electricity (FBE) per month. Notwithstanding these gains, grid access is unequally spread, with 77.4 % of White households electrified, but only 54.4 % of Black African, 47.9 % of Colored, and 59.3 % of Indian/Asian households electrified by 2015 [42], a remnant of the Apartheid system. A significant number of households (3.5 m), remain without access to the grid [43]: this represents c. 15 % of the population, mostly located in rural areas and informal settlements in urban and peri-urban areas [41]. This is key, because lack of grid access is often linked to significant inequalities: c. 47 % of households without electricity suffer from energy poverty countrywide [42], and there are knock-on effects on health, education, socio-economic outcomes and other aspects. Solar electricity has been identified as a potential short- to mid-term solution for electrifying households in rural and informal areas. While South Africa has policies and strategies (such as the NDP) aimed at increasing the number of grid-connected large-scale solar arrays, it also has decentralized, embedded generation schemes aimed at consumption near the site of generation [41].

In South Africa, grid-connected solar generation is mostly aimed at households in formal urban areas. In informal settlements, solar energy technologies are mostly standalone systems (or, in some areas, based around mini-grids). The issue of solar energy provision to informal settlements needs to be seen within a complex web of social, economic, political, and financial interrelations. As Kovacic et al. [44] point out in their critique of energy transitions research in informal contexts, a key obstacle is the definition of 'problems' from outside, and the reduction of these 'problems' to technical energy access issues.

3.2. Burkina Faso

Burkina Faso is a landlocked country with limited access to energy resources. Biomass is the main source of energy consumption for private households (c. 90 % of the total). This is a major national difference with South Africa, with high electrification rates and generation largely based on electricity from cheap coal (the country is reliant on thermal fossil fuels for about 70–80 % of total electricity generation) [45]. In Burkina Faso, 62.3 % of the urban population and 4.7 % of the rural population had access to electricity in 2018. The country's National Plan for Economic and Social Development for the period 2016–2020 set several quantitative targets for access to electricity and renewables by 2020, including: i) an increase in the contribution of renewables to total energy production (from 6.4 % in 2015 to 30 %); ii) an increase in installed national electricity capacity (from 300 MW in 2015 to 1 GW) and electrification rate (from 59.9 % in urban settings, 3.1 % in rural ones in 2015 to 75 % and 19 %, respectively; and iii) the reduction of electricity cost by 25 CFA Fr per kWh ([46]: 64–65; [47]).

For the longer time horizon to 2030, the National Action Plan for Renewable Energy (PANER) also set quantifiable targets for electrification and renewables [48]: i) increase in energy access to 42.4 % of the population; ii) a projected capacity of renewable power plants of 318 MW; iii) increase in the share of renewables as part of total installed capacity to 36 % (excluding grid-linked electricity imports, the target is 27 %); iv) 10 % increase in installed capacity of off-grid renewables systems; and v) increase to 26.9 % of the rural population served by autonomous renewables-based systems. Furthermore, the Burkinabe government recently developed an energy policy consisting of two pillars (transition towards renewables, and energy efficiency) aimed at increasing the energy supply and bridging the urban-rural gap in energy access. This trend has been institutionalized through the creation of the National Agency for Renewable Energy and Energy Efficiency (ANEREE) in late 2016. It is expected that the planned higher reliance on renewable sources will be favored by Burkina Faso's considerable solar potential and solar market development.

Legally, the energy sector in Burkina Faso is regulated through Law n. 014–2017/AN of April 20, 2017, whose main innovations with respect to the existing situation can be summarized as: i) reaffirming the liberalization of the production and distribution segments (once SONABEL's monopoly); ii) taking into account the Economic Community of West African States' regulations, aimed at building a sub-regional electricity market; iii) introducing dispositions to promote renewable energy and energy efficiency. The law gave legally binding value to the National Action Plans 2015–2030 for Renewable Energy (the mentioned PANER) and Energy Efficiency (PANEE), both adopted in 2015. In

particular, with respect to under-the-grid settlements, PANER developed a strategy consisting of: i) optimizing and increasing the use of low-voltage grids; and ii) increasing the coverage rate by extending medium- and low-voltage grids in already-electrified areas, but also by electrifying new rural areas.

4. Methods

We use a concurrent mixed methods approach to analyze two cases in South Africa and Burkina Faso. For each area, we employed a qualitative-quantitative population survey both to extract the main sociodemographic characteristics of the populations and to acquire data on the uses of different forms of energy. In parallel, we conducted interviews with survey respondents as well as with other relevant actors detailed below. Our intention for this study was mainly to collect and analyze opinions from both citizens living in the studied areas and experts from outside: that is why this part of analysis predominates in our Results and discussion section. The South African case was analyzed with a focus on discourses and policies around solar power specifically, and renewables more broadly, at various scales of governance [49]. To engage with governance approaches to solar power on a national, provincial, and municipal scale, interviews were conducted with respondents from a range of government, energy authority, civil society, and academic respondents (more information on this below). In addition, this paper is grounded in analysis of the development and deployment of a solar mini-grid project in Qandu Qandu, an informal settlement of c. 3500 households, founded in 2018 in the partially informal Khayelitsha area of Cape Town (Fig. 1). Qandu Qandu is for the most part not connected to the grid, but there are a range of energy infrastructures present in the settlement, including illegal and generally unstable grid connections (c. 10 % of households), multiple privately-operated solar mini-grids not connected to the grid, and energy supply and distribution networks focused on charcoal, paraffin and diesel used within the confines of the shacks that make up the settlement. Qandu Qandu itself is precariously located in an area prone to regular flooding.

In total, 54 interviews were conducted. The categories of interviewees were: a) governance actors (22 interviews total). These included those working in government departments (5), provincial governments (3), municipal governments (10), and officials from Eskom, the public utility (4); b) energy and development-related civil society organizations (11 interviews); c) scholars (7 interviews); d) residents of Qandu Qandu (14 interviews). These residents were a sample of those contacted for research on a British Academy-funded research project (UWB190088) in the Urban Infrastructures of Well-being portfolio. The interviews with residents were conducted from February 2020 to June 2021, during the timeline of the project. The other interviews (with respondent categories a–c) were carried out in 2017–18, as part of a UK ESRC/Newton Fund-National Research Foundation of South Africa project (ES/N014138/1). In addition, to provide community-level qualitative data on solar power in Qandu Qandu, a survey was used in addition to the above-mentioned interviews. The survey totaled 223 respondents and was conducted between November 2020 and March 2021: it was aimed at constructing a dataset of residents' energy practices. Interviews were analyzed using NVivo, while for the purposes of this article, descriptive and contextual statistics from the survey were used.

The Burkinabe case is based on fieldwork conducted in Zagtouli, an area in the outskirts of Ouagadougou. Zagtouli is administered as a neighborhood of Ouagadougou; in the most recent census (2006) it had around 27,000 inhabitants [50]. Zagtouli is home to West Africa's largest on-grid solar power plant: a 33 MW facility owned and built by the French electricity engineering firm Cegelec. The plant, financed by France's Development Agency and the European Union, has been operational since November 2017. It is scheduled to supply 5 % of the country's total electricity consumption, about 55 GWh per year [51]. Zagtouli is split into a northern and a southern area, separated by the N1 highway and managed separately. Only the latter area, closer to the solar power plant, has been the object of our analysis (Fig. 2).

In the spring of 2019, a survey of 100 households was conducted in the southern part of Zagtouli. Aimed at assessing energy use patterns, it included both quantitative and qualitative questions. Distributional aspects were investigated through socio-demographic and economic information, as well as by collecting information on the energy supply and expenditure of each household. With regard to procedural energy justice and as recognition, respondents were asked whether they had been aware of, or involved in, deliberative or legal procedures resulting from the allocation of land for construction for the plant.

The survey was paralleled by a set of 45 interviews. Of these, 10 were shorter interviews (up to 1 h) conducted with residents of Zagtouli; 35 were longer interviews (1 to 2 h), conducted with entrepreneurs in the field of renewable energy, and solar energy in particular (21), representatives from NGOs (4), utilities and national agencies' executives (5), consulting firms (2), and academics (3). The interviews were mostly conducted in Ouagadougou and its province. The interviewed residents were selected according to their willingness to take part in deeper exchanges following the survey's administration. The 35 participants in the longer interviews were selected principally from a list of energy companies operating in Burkina Faso, retrieved from the directory of companies in Burkina Faso (https://www.goafricaonline.com/bf/annuaire), then expanded through snowball sampling. The purpose of the interviews was: 1) to understand the legislative and institutional framework governing the Burkinabe energy market and the main obstacles to the development of the solar energy market; 2) to collect information about projects operating in the area; and 3) to gain information on the state of the art of ongoing research in the renewable sector. The interviews were analyzed qualitatively using NVivo®. The survey data were analyzed through SPSS Statistics® software.

The energy justice analysis was conducted by distinguishing between the three aspects of distributive, procedural and recognition aspects. Each of these three aspects was evaluated qualitatively from interview and survey responses; distributive and recognition aspects were also assessed quantitatively through specific survey questions (e.g., whether respondents were connected to the electrical grid; whether they could collect/buy energy sources according to their needs; whether they were aware of the nearby solar plant).

In the next section, we report our most significant results and discuss them.

5. Results and discussion

5.1. Case study: Qandu Qandu, Cape Town, South Africa

The historical and geographical specificities that have produced the Qandu Qandu settlement range from the historical trajectories of urbanization processes in and around Cape Town,[1] to tensions between state mandates to provide energy and other infrastructures to citizens, to issues with land tenure and ownership that hamper this mandate. Nonetheless, focusing on the specific context of Qandu Qandu directs attention to two key aspects of UPE as it is expressed in the Southern city, namely everyday practices, and diffuse forms of power [52]. By briefly using the example of energy-related risks and hazards, we aim to show how fragmented access to energy is key to the production of *socionatural hazardscapes of informality*, which are in turn linked to energy justice.

One of the points raised by multiple respondents centers around the issues of energy, safety and risk connected with the use of dangerous sources of energy. As one resident interviewed in March 2021 and one in February 2021 put it:

[1] These are heavily influenced by South Africa's legacy of Apartheid, the system of racial segregation that ended in 1994.

Fig. 1. Map of Qandu Qandu, Cape Town (source: QGIS and Google Maps).

> "Few weeks back I think there were eight *hokies* [shacks] that were burnt because of paraffin and then three guys were found dead in those burnt *hokies* including a small child who was about nine to ten years old."

> "You see these wires [informal grid connections]; many houses have burnt because of these wires. The illegal electricity is not safe."

This shows how the density of the settlement, coupled with the use of flammable materials and energy practices around combustible fuels and informal grid connections, produce a highly relational risk landscape that links energy use by individuals or by a single household to diffuse, real risks that affect the whole community. This is part of a broader hazard landscape affecting informal settlements everywhere: in Cape Town alone, for example, there were over 1195 shack fires that saw emergency response by the city in January–September 2021 [53]. In addition, the lack of reliable energy access means that there is little lighting in the community after dark, which increases the sense of fear and looming danger. This can be understood as part and parcel of the process of "slow infrastructural violence" [54] recurring harms gradually accrue and concentrate along gendered, racialized or other lines.

In contrast, solar mini-grids were perceived as positive developments because of the potential for reducing energy-related risks affecting the whole community. As one resident put it, the electricity delivered through the mini-grid:

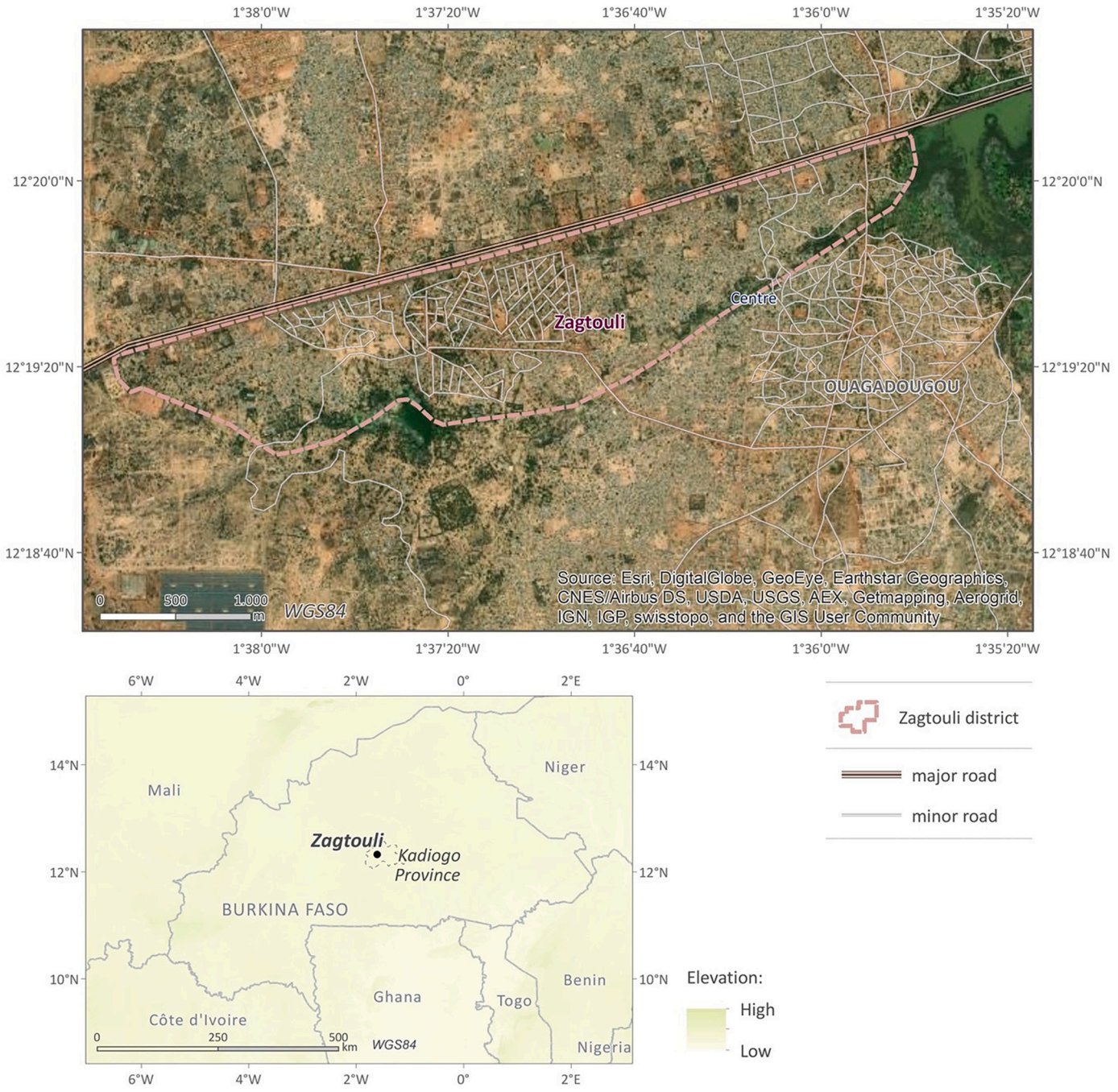

Fig. 2. Map of Zagtouli (source: QGIS and Google Maps).

> "is unlike the electricity that we stole from those lines across above our houses. There will be less people that will get killed by this electricity and kids as well […]. Some of us have to rebuild our houses because of the electricity […] because we just do it yourself. You see it is dangerous."

Thus, the political ecology of energy in Qandu Qandu reveals how energy and community are intertwined in a relational web. These relations, in turn, include and incorporate different scales of governance, as well as specific aspects of the ecology of risk, hazards and fear [55,56].

5.1.1. *Energy justice analysis*

Distributive justice is, in part, about access to energy services as well as the siting of physical energy infrastructure [57]. Qandu Qandu has no formal energy grid connections, but high-tension power lines exist near, and run through, the settlement. Thus, the Qandu Qandu community exists in an under-the-grid space. This is borne out by our survey: out of 223 respondents, 36.3 % thought that lack of access to electricity was the biggest problem faced by the community. Only 6.7 % respondents had access to electricity at all, through means such as grid access (formal or informal), car batteries, generators or solar home systems, and all respondents relied on paraffin/kerosene and/or liquefied petroleum gas (LPG). This is also reflected in lighting in the home: out of all residents, only 5.8 % used electric light bulbs, and 3.6 % used fluorescent strip lights, while the rest used paraffin/kerosene lamps and/or candles; 82.5 % of the surveyed residents reported that lighting was never adequate to meet their needs. Likewise, most (93.7 %) residents reported dissatisfaction with the use of a mix of energy sources (paraffin/kerosene, LPG,

and electric stoves) for cooking. This had knock-on effects on environmental quality and safety: only one respondent had a hood or extractor fan for evacuating exhaust gases and vapor from cooking. Given this general context, 93.3 % of the residents stated a desire to leave the settlement, a clear indication of a large deficit in terms of distributive justice related to energy and other essential services.

The introduction of solar mini-grids to the community had several impacts that can be tied to distributional justice. Firstly, it was seen as a safe, stable and reliable source of energy that enabled not simply the consumption of electricity, but the addressing of multiple needs linked to electricity, as pointed to by a resident interviewed in February 2020:

> "If we can have electricity here in Qandu Qandu, I think our life can be better in many ways [...] we will have something to charge our cell phones. So, we will be in social media. We will know whatever that is happening around us. So, electricity is the best."

At the same time, there are disadvantages associated with gaining access to solar-powered mini-grids. Apart from lesser capacity than that available through grid access, the mini-grids installed in Qandu Qandu deliver direct current (DC), while most appliances available on the market use alternating current (AC). This means that community members either have to purchase and replace specific items of electrical equipment, or rely on the DC-compatible ones supplied by the private sector utility that runs the mini-grids. Thus, there is a distributional justice deficit related to the additional costs accruing to community members who need to adapt to connect to a DC system. This, in turn, is linked to a broader and multi-scalar issue of spatialized justice and equity in service access and delivery: although *some* of the residents of Qandu Qandu can now access electricity by *paying for* services delivered through solar mini-grids, most poor citizens connected to the grid in serviced formal or informal urban areas would otherwise have been eligible to a monthly 50 kWh of FBE. Thus, there remain critical issues around continued lack of access to benefits and entitlements that cannot be realized by residents due to the off-grid nature of informal peri-urban settings.

Injustices associated with recognition include not only misrecognition and inappropriate representation at different levels of politics and decision-making, but also cultural domination and disrespect [19]. All of these are operational in Qandu Qandu and emerge as key themes in community members' interactions with political structures. One of the ways in which misrecognition works in the Qandu Qandu context is the way in which the community's needs only seem to be acknowledged by politicians around the time of elections (in order to stimulate voting), and then swiftly forgotten. This was mentioned frequently by respondents. The pattern that is identified concerns visits by those seeking election or promoting voting for a specific party: access to services is offered as a vague promise in return for appropriate voting behavior. And yet, as one interviewed resident put it in March 2021:

> "We vote, when we are done doing that they don't deliver on our wishes. So it feels like we are not being taken seriously. How to put it, like they don't care about the issues of poor people should I say or the wellbeing of poor people [...]. Their politics [laughing], when it gets to vote they say vote you'll get electricity will get water [...] when the time comes those don't happen."

This underlines the mechanism of what respondents feel are exploitative interactions, aimed at using the community (and the votes they represent) with no positive result, and indeed no acknowledgement between election times, representing non-recognition, as underlined by another resident in February 2020:

> "We have to be like treated like human being, all in all as we are human being. [....]. We feel we have been isolated. In terms of sanitations and all necessities that all the people need. […] We do not belong anywhere."

This highlights the sense of a lack of recognition not only of the respondent as a citizen with rights, but of the respondent as a human being. In this context, the isolation mentioned by the respondent is not simply the isolation of Qandu Qandu as an off-grid, informal community, but isolation as non-recognition of the community's existence and its dignity within the wider Cape Town and South African polity.

The installation of solar mini-grids in Qandu Qandu occurred in a context whereby procedural justice is already sorely lacking, in that residents have little access to decision-makers at different scales of governance, and little to no access to mechanisms whereby their energy needs and rights can be expressed, represented and actioned. Additionally, the introduction of solar mini-grids, and pricing packages associated with these, into an already diverse economic mix around energy stacking practices, introduces informational complexity that is difficult to assess: residents are effectively "being made responsible for provisioning their electricity in the midst of precarity" but at the same time a procedural justice issue is that "the energy poor seldom have the requisite knowledge or support to make decisions that advance their interests" [28, p. 8]. However, this is to some extent offset by the fact that, in Qandu Qandu, the private sector provider opened a shack-based office within the community, providing an anchor point for the services it sells there, and providing a point of information for interested residents. Thus, while residents have little to no access to adequate information at the scale of local government, they can access private sector-related solar mini-grid information with more ease, which is a procedural improvement. As a resident noted:

> "I was happy when I see it [...] two guys they say [...] come and see this, they say you can rent this I said it is fine, I knew I was no longer going to pay 50 Rands or 200 for the guy you know who would come to collect the money for [...] that illegal electricity I knew I was going to last the whole month."

The above quote also underlines one of the key procedural, information-based aspects of solar mini-grid provision: the enhancement of the ability to budget and forecast personal energy (and by consequence, household economic) expenditure. This in turn reduces continuous stress and instability-related aspects of energy precarity.

Many of the aspects of energy justice aspects highlighted in the South African case are also reflected in the Burkinabe case, to which we now turn.

5.2. Case study: Zagtouli, Ouagadougou, Burkina Faso

Three areas were identified within Zagtouli Sud: western, central, and eastern. The central area (35 respondents) is characterized by a higher economic level than the others, as was easily inferred during the population survey by a visual analysis of the size and quality of housing, the presence of family-owned cars, watchdogs, families of servants often living in their landlords' households, better roads, and more modern amenities (TVs, fans, etc.). In the eastern and western areas (65 respondents), the prevailing energy patterns are closer to other rural areas in the region: households are characterized by a general lack of electricity, or in rarer cases, by autonomous electricity production through solar home systems.

While illegal connection to the grid, and the related possibility of fires, were not perceived as much of an issue in Zagtouli as in Qandu Qandu, the main stated risks were those generated by the long-term use of biomass, and the economic constraints linked to gas use. With respect to both firewood and charcoal, by far the most frequently highlighted issue were cooking-related smoke and heat (30 %), and their negative respiratory and visual health effects (23 %), mostly for women, who were the ones in charge of preparing meals in 96 % of all cases. Seasonal scarcity of wood (8 %) and charcoal (11 %), together with wood humidity during the rainy season (7 %) affecting fuel quality, were also frequently mentioned issues. As for gas, problems included seasonal scarcity (28 %), affordability (12 %), possible leaks (9 %), and bottle

filling scams (3 %).

Not unexpectedly, the predominance of each of the problems mentioned depended on the sub-area where residents lived, and as such, on their socio-economic status. Residents of the central area, who mostly make a limited use of firewood, mentioned negative consequences from its use less frequently than residents of the peripheral areas (χ^2 (1, N = 100) = 17.55, $p < 0.001$); on the contrary, they mentioned gas-related issues more frequently (χ^2 (1, N = 100) = 7.03, $p < 0.001$);. Thus, especially for worse-off residents, "socionatural hazardscapes of informality" in Zagtouli materialize in health issues. This status disparity leads us to analyze energy justice aspects in Zagtouli, and the relevance of the solar power plant to those aspects.

5.2.1. Energy justice analysis

As can be inferred by the section above, access to energy is considerably varied within Zagtouli, with the central area's residents enjoying the opportunity to benefit from a wider range of sources than residents of the peripheral areas. An example of the range of possibilities offered to better-off residents, is the following statement by a resident of the central area, head of a family of five and owner of a detached house with a small garden:

> "We built our home here and we bought a large solar panel. We decided not to connect to SONABEL [i.e., the grid] because we don't need it. You see the electricity post there? We could have connected but it was too expensive. And then you have brownouts all the time with the grid".

This evidences both the opportunity to choose which source of energy to use, and a preference for off-grid, a common finding among residents of the central area. It reflects the results of a study on Ghana by Boamah and Rothfuß [58]: the energy security resulting from owning solar PV systems–especially large ones–implies the possibility of enjoying the benefits of lighting even when the rest of the on-grid community cannot: namely, during brownouts and blackouts. PV systems, therefore, act as a proxy for high socioeconomic status.

The situation appears quite different in the two other areas of Zagtouli, where worse-off residents do not benefit from a similar range of possibilities or hold any hope of grid connection in the near future. The structural difference between the central and peripheral areas, and the condition that Cantoni et al. (2021) have referred to as the "unattainable proximity" of electrification [29] for the eastern and western areas, is a reflection of the Zagtouli's peri-urban location. Many residents of the central area have bought land in Zagtouli because it was cheaper than in the capital city. They are typically higher-income professionals (medical doctors, engineers, agents of SONABEL, state officers), working in Ouagadougou and commuting daily between Zagtouli and the capital. They enjoy salaries that are higher than those of the residents living in the western and eastern areas, who work in Zagtouli in lower-paid jobs (farmers, tailors, butchers, sellers, petty traders).

Thus, the very location of Zagtouli, at the border of the urban and the rural, contributes to the maintenance of a status disparity and to generate energy injustices. It also generates problems of territorial jurisdiction. The jurisdiction of the Burkinabe national electrification agencies means that Zagtouli is formally dependent, for its electrification, on SONABEL. However, there are currently no plans to extend the network to electrify the entire territory of Zagtouli Sud. In particular, the lower-income areas would need electrification programs more akin to rural, off-grid projects managed by the Burkinabe Agency for Rural Electrification (ABER). However, because Zagtouli is not classified as a rural community, it does not fall under ABER's competence. Thus, an operational, scalar limbo is generated, which leads to the persistence of an unsatisfying condition of unattainable proximity.

One of the most significant results of the population survey conducted in Zagtouli is that about a third of the respondents (32 %) were not aware of the existence of the solar power plant, while a further 62 % declared the plant had had no impact on their daily energy use patterns and habits. That is telling, especially when we compare it to the case of Qandu Qandu, where the construction of mini-grids actually led to an improvement in access to electricity. While it is true that the power plant was not planned to have a direct impact on the Zagtouli community (but rather to act as a grid stabilizer), it is meaningful that, considering the plant's international resonance (the French and Burkinabe Presidents were present at its inauguration), so many residents did not even know about it. This reflects a lack of authorities' initiative to inform the population about (let alone, involve them in) the development plans envisaged in the area.

When asked about the possibility of grid connection in the future, residents of the peripheral areas showed disillusionment. A young resident from the western area, who lives alone in an adobe and straw hut, stated: "SONABEL doesn't care about us: we are only a few, so it's not economical for them to connect us. And anyway, connection costs would be too big to bear for us". This resident owns a small solar panel, which, he says, is barely sufficient to charge his mobile phone. That is the only electrical appliance he owns in his hut. The feeling of disempowerment and abandonment from the public company that appears from his words is not uncommon among his fellow residents. A young, married housewife, mother of three, living in the eastern area, talked along similar lines: "I know about the solar plant, but it's not for us. It's for the city [Ouagadougou]." When asked if she had a solar panel in her household, she mentioned that they used to have one to charge mobile phones, but it got broken and it was not possible to repair it.

The breakdown of the small solar panel points out a further issue, related to the low quality of solar equipment bought by lower-income residents. This was also emphasized by several local entrepreneurs, and may lead to residents' loss of confidence in renewable energy. There emerges from these accounts not only a lack of recognition [19], but a general resignation to not benefiting from the power plant or, more generally, from the public electricity supply.

Perhaps both a lack of knowledge about the ongoing solar plant-related works and the above-mentioned feeling of disempowerment contributed to the fact that no major protest developed against the construction of the plant in Zagtouli. Of the 100 respondents interviewed for the survey, only one, whose house was in the western area of Zagtouli (some 2.5 km northeast of the plant), complained that part of the lands used for the plant were communal lands on which one of his cousins used to take his goats to pasture, and that he would have liked to receive some compensation. Several other residents–especially those with a higher educational level, and who used to get their information from the press or radio, expressed local pride: "Zagtouli has become a unique location in Africa. We are at the forefront of solar energy in the country. Of course we are proud!", affirmed a high-school teacher and Zagtouli resident.

Nevertheless, focus group discussions with local authorities and household representatives, conducted by a World Bank project team in 2019, revealed minor hostility from the local community towards construction work (related to the transport of machinery during plant construction, which produced dust and intense noise, and led to public nuisance and frustration). In these discussions, residents argued that they should have been compensated for the damage suffered. Moreover, the constructing firms' failure to employ resident labor during construction created some tensions [29].

In the case of Zagtouli, the strategy pursued by the national government involved the local authorities at the borough hall level, whereas, because of the misrecognition mentioned earlier, it is apparent that neither citizens nor NGOs were part of the decision-making process during the planning. While interviewed residents did not mention having participated in public or private consultations, most did not see that as a problem: "No, I was not consulted. Why should I have been? I know nothing about solar energy", a local petty trader stated. "I'm happy that they [the constructors] are using those lands: there's nothing growing there, and if they manage to use them fruitfully, all the better", remarked

a local farmer. These statements reflect, first, a more general belief in top-down decision-making by competent authorities, and second, a view of local lands as a resource to be put to good use, devoid of any other (e.g., symbolic) value. Unlike the Moroccan case studied by Rignall [59], where it was the national authorities that tried to construct land planned for solar installation as marginal to facilitate investment, in Zagtouli it was the residents themselves that supported such a view.

6. Conclusion

In this study, we have hybridized two strands of theory–urban political ecology (UPE) and energy justice–to study the multi-scalar dynamics of renewable energy projects in two African contexts that have one geographical element in common: peri-urbanity. This element is significant not only as peri-urban territories are often considered politically and socially marginal, but also because the phenomenon of diffuse peri-urbanization is an expanding feature, particularly in African metropolises. These show a recent historical trend of demographic growth, acting as magnets of attraction from rural areas. It is therefore urgent to analyze the dynamics of these transitional spaces at a time when international climate policies are leading to an expansion of the renewable energy industry.

Based on considerations from our UPE approach, we chose to analyze energy systems comprised by different governance and technical configurations, power, management modes and purpose, highlighting critical distributional, procedural and recognition aspects in terms of energy justice. Drawing on UPE, our work has underlined how, on the one hand, energy landscapes in peri-urban areas are complex and relational, related to the processes, governance approaches and socio-technical systems through which they emerge, and at the same time are deeply spatial. The spatiality of the solar energy landscapes in the African peri-urban zone is a crucial topic for consideration, since these landscapes are effectively rooted in place and in locality. Place is where the more diffuse and multi-scalar networks that make up energy landscapes are interfaced with everyday lives, where tensions and opportunities around solar energy and its consequences are vocalized and operationalized.

Spatially and technically, as can be seen from the examination of South African and Burkinabe energy policies, a strong expansion of renewable infrastructures is expected: not only in rural areas, where solar home systems are the most widespread technology, but also in the peri-urban areas of large metropolises, where governments' technological preferences and service delivery strategies are more complex and at times unclear. However, as appears from the different choices made by the two national governments, approaches to the electrification of peri-urban areas differed: in the South African case, a largely decentralized approach was developed, with mini-grids as energy production units and operating almost wholly separately from, and in parallel to, existing energy networks and policies. In the Burkinabe case, the preference was to use the peri-urban territory for electricity production to stabilize the national grid, while the territory itself where the power plant was built, being under-the-grid, did not benefit.

We have highlighted how, in the case of Qandu Qandu, even though the installed mini-grids were perceived as a positive novelty compared to the existing reality of disconnection from the grid or illegal connections with fire risk, this did not prevent the simultaneous emergence of energy injustices relating to various aspects: distributional ones (the incompatibility between the types of electricity used by mini-grids and appliances on the market); procedural ones (the limited knowledge that would prevent residents from taking part in decision-making processes); and recognition ones (the perception of being politically manipulated in the run-up to elections, without this leading to effective consideration of their energy needs). Thus, the spatiality and place-based granularity of the energy landscape becomes crucial when considering the facets of energy justice: it is here that approaches rooted in UPE *and* energy justice overlap and can produce useful and constructive analysis.

As far as the Zagtouli case is concerned, we detected recognition injustices similar to those in the South African case, while, from a distributional and procedural point of view, we note significant differences. Regarding the first point, the low local impact of the solar power plant is evident. The neighborhood/village remains, for the most part, in a condition of unattainable proximity, not only for economic but also for structural reasons (lack of a grid connection plan by the public utility), while wealthier households can choose to connect to the grid or use autonomous (solar) systems. As for procedural injustices, the perceived marginality of the area, combined with the lack of a public information/consultation campaign, has led to socio-political invisibility of the power plant itself.

Our work highlights the intertwining of questions of UPE and energy justice: in particular, the uneven and inequitable landscapes UPE studies are often also characterized by inequities in the distribution of energy, as well as by the marginality – better, marginalization – of the communities that inhabits them. This latter aspect is evidence of procedural and recognition injustices regarding who has and ought to have a say in energy decision-making. In our analysis, we have shown how fragmented access to energy is key to the production of *socionatural hazardscapes of informality*, which are in turn linked to both energy justice, and the spatialization and ordinary everyday experiences of energy landscapes, as seen through a UPE lens.

We believe that our work can provide useful information not only to national policymakers to improve the energy justice aspects of future renewables projects, but also, more broadly, to international policymakers operating in countries with economic conditions similar to those studied. Specifically, the analysis of the Burkinabe case can improve knowledge on the outcome of similar projects in other West African countries; the South African case will contribute to a broader understanding of the criticalities of small-scale, decentralized projects. The results of this study will also be of help for renewable energy companies, which often dimension their plants on the basis of demographic and economic considerations of the target areas, but with no prior analysis of issues of distributive, procedural and recognition justice.

We call for further research linking political ecology and energy justice perspectives in the study of renewable energy landscapes in peri-urban settings. Based on our work, we underscore Jenkins et al.'s [57] findings that procedural justice can be improved through promoting three aspects of inclusion, namely, a) mobilizing local knowledge for just outcomes; b) expanded information disclosure, and c) enhanced representation at the level of different institutions and scales of governance. This will enable scholars and policymakers to move past technical 'problem-solving' approaches from 'elsewhere', and towards more contextually specific entry points that engage with peri-urban communities at different scales.

CRediT authorship contribution statement

Roberto Cantoni: Conceptualisation, Methodology, Data curation, Investigation, Resources, Supervision, Writing - Original Draft, Writing - Review & Editing, Revising, Project administration, Funding acquisition.

Federico Caprotti: Conceptualisation, Methodology, Data curation, Investigation, Resources, Supervision, Writing - Original Draft, Writing - Review & Editing, Revising, Funding acquisition.

Jiska de Groot: Resources, Funding acquisition, Review and Editing.

Declaration of competing interest

None of the authors of the submitted article has any conflict of interest to disclose.

Data availability

Data will be made available on request.

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