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International Journal of Urban Sustainable Development

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjue20

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To cite this article: Mélanie Rateau & Sylvy Jaglin (2022) Co-production of access and hybridisation of configurations: a socio-technical approach to urban electricity in Cotonou and Ibadan, International Journal of Urban Sustainable Development, 14:1, 180-195, DOI: 10.1080/19463138.2020.1780241

To link to this article: https://doi.org/10.1080/19463138.2020.1780241

Published online: 17 Jun 2020.

INTERNATIONAL JOURNAL OF URBAN SUSTAINABLE DEVELOPMENT
2022, VOL. 14, NO. 1, 180–195
https://doi.org/10.1080/19463138.2020.1780241

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ARTICLE

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Co-production of access and hybridisation of configurations: a socio-technical approach to urban electricity in Cotonou and Ibadan

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ABSTRACT

The article examines the dynamics of access to electricity in two West African cities: Cotonou (Benin) and Ibadan (Nigeria). Due to poor supply from the grid, households are developing varied ways of accessing electricity, based on different socio-technical *dispositifs*. In this paper we first demonstrate that access to electricity is based on co-production processes that must be approached from a multi-scale perspective (from the household to the urban scale). We then argue that particular attention to the socio-technical and spatial dimension of co-production arrangements makes it possible to interpret urban electrical configurations and their evolution. We thus show that co-production processes, relying on many actors and technologies to meet a growing and diversified demand for electricity in cities, support an ongoing movement of extension-hybridisation of electricity configurations on an urban scale, thus offering an interesting perspective on power changes in sub-Saharan Africa.

ARTICLE HISTORY
Received 9 July 2019
Accepted 4 June 2020

KEYWORDS
Co-production; access to electricity; urban electricity configuration; hybridisation; Cotonou; Ibadan; sub-Saharan Africa

1. Introduction

Access to electricity was one of the big oversights in the UN's Millennium Development Goals in 2000, but this was rectified with the adoption of the Sustainable Development Goals in 2015. Among the 17 new goals, the seventh was to 'Ensure access to affordable, reliable, sustainable and modern energy for all' by 2030 (United Nations 2015). With more than 600 million people without access to electricity out of a population of a billion, sub-Saharan Africa is the region of the world with the worst indicators: generation and distribution capacities are insufficient and average per capita consumption is among the lowest in the world (UNEP 2017). To meet the challenge of electrification, off-grid and mini-grid technologies are promoted as a pragmatic solution for rural areas, whereas networked extensions remain the preferred option for urban areas (Desarnaud 2016; Jaglin 2019). Although there is a growing literature characterising the limited capacity and contested socio-technical hegemony of conventional electricity systems in sub-Saharan cities (Silver 2015; Baptista 2016; Monstadt and Schramm 2017; de Bercegol and Monstadt 2018; Smith 2018), co-production has not been discussed as an alternative viable option for electricity services delivery. Drawing on studies on the co-production of water and sanitation services in the Global South (Nastiti et al. 2017; Adams and Boateng 2018; Moretto et al. 2018), we show that the dynamic arrangements for accessing electricity in two West African cities, Cotonou (Benin) and Ibadan (Nigeria), can be critically analysed through the concept of co-production. Combined with a socio-technical approach to electricity configurations, this concept provides a useful perspective on urban energy changes.

The development and electrification indicators for the two adjacent countries are very different. While the population of Benin hovers around 11 million, with a per capita GDP of US$806, Nigeria is a giant with 191 million inhabitants and a per capita GDP of US$1,962 (AfDB 2018). There are also marked differences in the rates of access to urban electricity (70% in

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Benin and 86% in Nigeria (ESMAP 2016)) and in the characteristics of the conventional grid. Whereas Nigerians experience uncertainties associated with repeated failures of the national electricity sector, reflected in power cuts in the cities (Té-Léssia Assoko 2018) and poor quality of network supply, the people of Benin in many cases remain without conventional access to the grid. Under these circumstances, regardless of the neighbourhood studied, the residents of these two cities develop different practices to access electricity that rely on various socio-technical devices, actors, and governance arrangements.

The argument developed in the paper is twofold: first, these practices give rise to specific co-production processes that must be seen from a multi-scale perspective (from the household to the urban scale); and second, close attention to the socio-technological and spatial dimension of co-production arrangements is an essential key to interpreting urban electricity configurations and the way they evolve. The analysis relates to arrangements in which various actors and resources from different worlds (utilities, households, private suppliers and installers) are brought together to allow uses requiring electricity by both middle class and poor households. We suggest that thinking about these processes in terms of co-production makes it possible to reassess its scope in a critical perspective, based on situated African experiences. Following Watson and her call to clarify the different meanings of the term co-production and how they are informed by interpretations reflecting particular social contexts (Watson 2014), we therefore argue that, in many sub-Saharan cities, actual co-production processes of access to electricity involve various forms of state-residents-market player engagements, and that they are demand-driven and based on individual rather than community initiatives.

These co-production processes are not just about social relationships, however. Their spatial and material characteristics also matter. A distinctive feature of the situations observed is the technological pluralism that affects the local chains of electricity technology (production, distribution, storage, uses) and gives rise to a variety of combinations, whether at household, neighbourhood or city scale. Analysing these diverse and situated socio-technical practices along with the way in which they combine is thus essential to an understanding of how urban electricity configurations are changing. Derived from the sociology of Norbert Elias and its conceptualisation by Olivier de Sardan (2011), the notion of urban electricity configuration provides a useful framework both to encompass the heterogeneous socio-technical arrangements for accessing electricity and to describe their interactions.

The paper draws on data that were collected from field surveys in the two cities.[1] The methodology combined a survey of households' socio-technical practices to access electricity in a selection of neighbourhoods with different socio-spatial characteristics, and semi-structured interviews with various public and private actors involved in electricity co-production processes at the urban scale. Our aim was not to compare cities, but rather to compare electrification processes in two geographically close cities with distinct electrical contexts, using the 'comparative monograph' method (Pinson 2019). The second section discusses the heuristic benefit of a co-production analytical framework to reflect on electricity access, and explains how it can be combined with a socio-technical approach to contribute to an understanding of how urban electricity configurations are changing. The third section presents the data collection methodology based on a ground study in the two cities of Cotonou and Ibadan. The fourth section presents some of the empirical material arising from this approach, which documents the heterogeneity of household practices grounded in a diversity of material arrangements and systems of actors. The fifth section discusses the socio-technical and spatial dynamics of co-production in the two urban configurations and their processes of evolution through hybridisation. This leads us, in the concluding section, to show the contributions of an analysis of co-production based on the spatialised technological practices of households.

2. Deciphering electricity configurations through co-production and households' practices in Cotonou and Ibadan

2.1. Defining co-production of access to electricity

Co-production is not a new concept and its analytical and normative thinking in service delivery has primarily been informed by the particular social conditions of cities in the North. Building on ideas developed in the public administration field in the 1970s, it was first conceived to designate situations in the UK and USA where state and community engagement could improve service provision. In the 1990s, linking social

capital thinking and urban governance theories, with a position advocating decentralisation and a closer relationship between communities and officials, Ostrom defined co-production as 'a process through which inputs from individuals who are not "in" the same organisation are transformed into goods and services' (Ostrom 1996, p. 1073). Since then, the development of the concept has followed several paths, either to account for the role of 'intermediaries' in the relationship between professional service providers and beneficiaries (Bovaird 2007) or to qualify 'institutionalised co-production' in weak state environments (Joshi and Moore 2004). All these definitions insist on long-term arrangements in which individual citizens and groups are regularly involved, while discussing both the conditions and effects of co-production in various environments (Verschuere et al. 2012).

With reference to the South more specifically, co-production has been recognised either as a means to support more efficient service delivery in the context of failing utilities (Moretto et al. 2018) or as a means to strengthen community capacities and enhance citizenship (Mitlin 2008; Mitlin and Bartlett 2018). At first sight, urban practices to access electricity do not seem to fit the standard definition of co-production. The first question is therefore whether they are clearly outside the scope of its conceptualisation or if they have been neglected because of the contexts and situations initially considered. In discussing this point below, we highlight some of the discrepancies related to 'underlying informants' (Watson 2014, p. 62), either because they hold only partially or because they point to gaps in the contextual knowledge embedded in the concept. In fact, the different ways of grasping and interpreting this concept in urban studies in the South are still a matter of debate and have been critically examined by recent studies, particularly in relation to planning issues (Watson 2014) and delivery of water and sanitation services (Ahlers et al. 2014; Moretto et al. 2018). In a case study focused on a commercialised spring water value chain in Bandung (Indonesia), Nastiti et al. (2017) view co-production processes as being open to private local entrepreneurs. Rather than the distinction between state and market, they found that the presence of effective community members and their capacity to nurture institutional innovations are crucial for co-production arrangements to yield a safe and affordable water supply service. While examining whether co-production can improve water delivery in the urban informal settlements of Lilongwe (Malawi), another study discusses the potential pitfalls that undermine participatory governance in many sub-Saharan African countries. It considers environments where the underlying assumptions on the real objectives pursued by the state, the capacity of local elite to regulate conflicting interests, the genuine will of utilities/public agencies to establish more equal power relations with urban communities, and so on can be problematic (Adams and Boateng 2018). Considering these ongoing discussions, we test the concept with regard to real practices of access to electricity in different types of neighbourhoods in two West-African cities.

First, it is worth emphasising that electricity has particularities which must be taken into account when considering the co-production of services. Electricity supply and access are mediated by technological developments that are undergoing significant and rapid changes. While the conventional service is based on a centralised networked infrastructure that connects households individually through a metre, other informal wiring to the grid also exists and off-grid technologies (old ones like generators and new ones like solar panel) are proliferating in urban neighbourhoods with poor or no electricity supply (Munro 2019). Another characteristic is that electricity is not a final good but a means for uses such as lighting, charging (for appliances including mobile phones), food preservation (fridge), housing ventilation or even air conditioning. When the power grid is absent or inefficient, needs can be met in two different ways: either by generating electricity with decentralised devices (generators, solar panels, batteries), or by buying the desired final service (of mobile charging or cold storage for example). Through devices and skills, technology acts as a mediator connecting all the elements of electricity delivery channels (Akrich 2010). In our case, it circulates through market actors and mechanisms which are an essential part of the processes of co-production. The definition of the concept of co-production can therefore be broadened to encompass centralised and decentralised socio-technical practices of electricity generation, as well as a set of services that use electricity and are provided by market intermediaries. In this paper, we use the notion of access to electricity to describe this diversity of practices.

Secondly, as co-production is based on state-society interactions, it raises questions on the nature and conception of the state when it does not correspond to the Weberian model. Most authors writing on politics and the state in sub-Saharan countries

assume a plurality of power centres and of actors involved in the delivery of public services: state administrations, international actors such as NGOs, international donor organisations, community-based organisations, and private companies (Blundo and Meur 2009; Bierschenk and Olivier de Sardan 2014). Olivier de Sardan has analysed the resulting situations in West Africa in terms of different 'modes of governance' (Olivier de Sardan 2011). Under such circumstances, the common situation is therefore 'the involvement of individual citizens and groups in public service delivery' (Verschuere et al. 2012, p. 1086) rather than a public monopoly. However, whether these forms of supply can be analysed in terms of co-production or not is an issue complicated by informality, which permeates the whole urban fabric and blurs the public/private, merchant/non-merchant, legal/illegal categories: 'from elite to low-income urban areas, [informality] is not spatially or socially detached from the rest of the city' (Ahlers et al. 2014, p. 5). Analysing water provision in such circumstances, Ahlers et al. suggest that 'co-production describes a process where hybrid service provision modalities are produced as a result of the articulation of socio-political, economic, biophysical and infrastructural drivers whose interaction constitutes new practices, thereby producing new meaning' (Ahlers et al. 2014, p. 2). It 'allows us to analyse the different dynamics that shape such a hybrid service configuration, without falling into dichotomous traps' (ibid.: 6). Any analysis of the co-production of electricity access also needs to adapt to dynamic boundaries between formal and informal processes. Despite the legal monopoly of utilities in charge of the network, alternative practices of a wide range of households concern electricity generation, consumption and end-uses, depending on the state of the grid and its (un) reliability. We therefore suggest that, in situations where the legal norms of the state are challenged or violated, and where services supply depends on the agency of many other urban actors, the understanding of co-production processes must take informality into account both as a feature of and as a potential resource for the resulting arrangements.

Thirdly, in state-of-the-art discussions, the involvement of urban dwellers is envisaged at different stages of service co-production (Verschuere et al. 2012). In circumstances such as the implementation of an electrification project, this analytical framework could be used to account for different phases of co-production processes. However, in the locations surveyed, where urban planning is the exception rather than the norm, infrastructure extension and service delivery mainly result from dispersed and incremental initiatives driven by populations' immediate needs, and are poorly coordinated over time. This is the case in many sub-Saharan cities (Clerc et al. 2017). It follows that co-producers' efforts focus on designing practical solutions for end-users – providing first access to electricity or securing individual supplies – which, due to the shortcomings of the state and its utilities, are likely to be initiated mostly by ordinary city-dwellers. Therefore, in this paper, the focus is on the practices of citizens who, faced with the difficulties of meeting their electricity needs through the grid, are turning to other technical solutions. We look at how they put them into practice, routinise their use, and negotiate innovations and contents through experimentation and environmental circumstances (Akrich 1989). As such, users are central to our investigation of the socio-technical dimensions of co-production.

In short, in both cities, access to electricity and the services that depend on it are not provided only by the state, nor are they dependent only on market mechanisms. They rely on arrangements based on various forms of state-society engagement mediated by market actors and mechanisms. Unlike the more familiar definition of co-production by Joshi and Moore – 'the provision of public services (broadly defined, to include regulation) through a regular long-term relationship between state agencies and organised groups of citizens where both make substantial resource contributions' (Joshi and Moore 2004, p. 31) –, our field surveys emphasise the complex and multi-dimensional interactions (technical, economic, legal, political) necessary to provide electricity access in Cotonou and Ibadan. They illustrate situations in which, rather than smooth cooperation between state and non-state actors (Joshi and Moore 2004), co-production processes are 'tense and riddled with power asymmetries and political aspirations, thereby producing uneven and highly contested [...] service provisioning' (Ahlers et al. 2014, p. 2). Finally, we argue that the conceptualisation of co-production processes should also include an understanding of

how space and technologies influence the conditions of access to electricity and how the various arrangements fit into urban scales.

2.2. From co-production processes to electricity configurations: analysing electricity access in its urban and technological plurality

Field evidence reveals that electricity supply and access in sub-Saharan African cities are experiencing a diversification of socio-technical arrangements (both on- and off-grid), the material, spatial and socio-political dimensions of which remain poorly understood (Jaglin 2019). It is therefore now necessary to examine how processes of co-production and socio-technical plurality shape and are shaped by local demands for electricity uses. As they combine differently across urban space, we have designed a multi-scale approach that extends from the individual land plot to the urban macro-structure.

We consider each mode of access, whether through grid (conventional or non-conventional), power generator or solar panel, as a socio-technical *dispositif* that involves a specific set of actors, resources, material artefacts, technical knowledge, and formal and informal institutions. Our conceptualisation of a *dispositif* is inspired by the socio-anthropological analysis of technology and the concept of technical mediation, which aims to explain how technologies and their socio-natural environment are jointly constituted (Akrich 1989). By defining technical devices as a mix of human and non-human, social and artefact, it restores them to their full consistency, thus making them mediators rather than mere instruments (Akrich 1993). At the household and neighbourhood levels, socio-technical *dispositifs* are selected and assembled through practices in various combinations that vary across the urban space. At city scale, this results in an urban electricity configuration. With this concept, we seek to express the embeddedness of socio-technical arrangements in their urban environment, of which they reflect the informality and the legal pluralism, as well as the heterogeneous practices and lifestyles.

As Jean-Pierre Olivier de Sardan shows in his analysis of the governance and delivery of public goods in Niger (Olivier de Sardan 2011), the concept of configuration is useful to grasp this complexity and its multi-level dimension. It refers to the process of heterogeneous elements being grouped into a systemic and dynamic whole, itself perpetually remodelled by the interactions of its constituent parts. Analysing urban services through the concept of configuration makes it possible to take into account not only the diversity and heterogeneity of the socio-technical *dispositifs* underlying co-production processes, but also their interdependencies within relatively *open* and *dynamic* assemblages (Jaglin 2014). As suggested by Lawhon et al.: 'A configuration might be thought of as the range of infrastructural options potentially available to a person for everyday use, a point which shifts us from focusing on the system-developed-from-outside towards situated users. They shift over time; some might be unavailable at any given moment for various reasons (functionality, finances, social relationships)' (Lawhon et al. 2017, p. 7). The range of co-production processes and of technologies displayed is not contingent however: configurations express complex articulations of social and material components in symbiosis with the urban environment and they translate situated arrangements.

Figure 1 draws attention to another feature of urban electricity configurations: their socio-technical *dispositifs* are not only diverse, they are also functionally interdependent. Thus, the practices of suppliers and users in poor areas are influenced by those of the middle classes, and extension of the network influences and is influenced by that of other solutions. Looking at the various processes of co-production through the dynamics and spatial patterns of their various socio-technical aggregates at the scale of a configuration thus provides an interesting perspective on electrical changes in Sub-Saharan Africa.

Broadly speaking, as shown in Figure 2, electricity configurations in different sub-Saharan cities evolve along two main pathways of change (Jaglin 2014, 2016). The first one, at the initiative of public authorities and utilities, follows the spatial deployment and the functional strengthening of large networked infrastructures. This process of infrastructuralization (Chatzis 2017) involves technical plurality at various stages but a convergence towards more homogeneity in the long run. The second path leads, on the contrary, to increasing heterogeneity. As electricity shortages have a rising political cost, governments endorse *de facto* liberalisation, driven inter alia by co-production processes and market mechanisms. Together, both old technologies (like generators) and new ones (like solar panels and batteries) add up in a complex socio-technical mix in urban areas, where they combine with the grid (Jaglin 2019). The outcome of these two dynamics is a tense and contested process of hybridisation of electricity

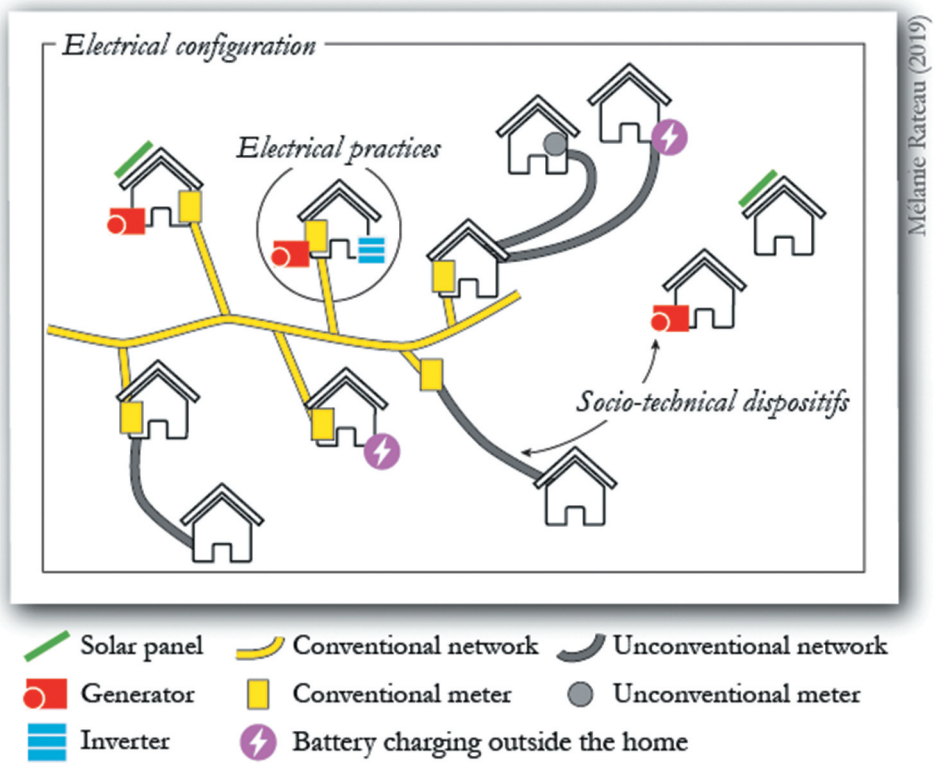

Figure 1. An electricity configuration and its socio-technical dispositifs.

configurations, fuelled by rapid urbanisation and socio-economic differentiation of urban societies.

Our field work therefore had two main objectives: first, to document the aggregation of varied socio-technical solutions at the household level (for generation, distribution, storage or use), in different neighbourhoods and for different social groups; and second, to analyse how co-production arrangements, bringing together numerous actors and technologies to meet a growing and diversified demand for electricity in cities, support a constant movement of extension-hybridisation of electricity configurations at the urban scale.

3. Methods: grounded study in Cotonou and in Ibadan

The city of Cotonou, located on the coastal bar between Lake Nokoué and the Atlantic Ocean, was originally a fishing village and then a slave market (Sotindjo 2010), before it was ceded to France by the Kingdom of Dahomey in 1868, almost 30 years before Dahomey became part of French West Africa (Bonnichon et al. 2012). The first electricity infrastructures were installed there by the colonial administration to serve the European quarters (Sotindjo 2010). The other city in our study, Ibadan, the capital of the Oyo State in south-western Nigeria, is often described as the biggest pre-colonial sub-Saharan city (Chokor 1986; Falola 2012). Its foundation dates back to the 1820s, when the military camp became a place of settlement for refugees fleeing the Yoruba wars (ibid.). The British colonial administration, which settled there in 1893, encouraged the emergence of a socially and spatially segregated city. A modern and British-planned city extended to the west (Chokor 1986), whereas the historical centre remained under the control of the traditional authorities.

To understand the co-production of electricity access, we collected field data in 2017 and 2018 during sixteen field visits and field observations. The data were obtained while the researchers wandered around as pedestrians and motorcyclists (neighbourhoods, marketplaces, etc.), and from interviews with twenty-one

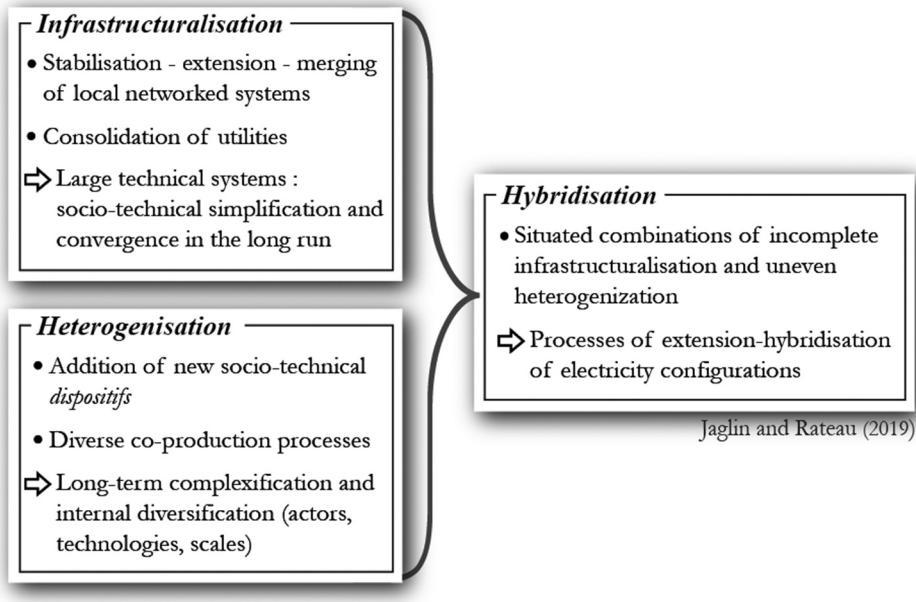

Figure 2. Hybridisation of an electricity configuration in sub-Saharan cities.

Interviewees	Interview topics
Institutional actors in the electricity sector	Functioning of the sector - Institutional and regulatory framework - Guidelines and objectives - Development of the sector - Relations with other actors - Formal/informal
Institutional actors and academics in the urban planning sector	Functioning of the sector - Institutional and regulatory framework - Guidelines and objectives - Formal/informal - Geography - Relations with other actors
Formal and informal market actors	Products sold (origin, guarantee, new products, etc.) - Maintenance and lifetime - Uses and practices - Sectoral policy - Sector and competition
Community/Consumer representatives and local authorities	Their organization - Importance of the electricity subject for their organization - Problems, conflicts around electricity - Relations with other actors
Urban households	Energy and electricity use - Level of equipment - Cost, networks of actors and knowledge involved in electricity use - Land status and economic level of the household

Mélanie Rateau (2019)

Figure 3. Interviewees and topics of the interview questions.

institutional actors in the electricity and urban planning sectors, sixteen formal or informal market actors, ten community representatives, local authorities and academics (Figure 3). As a result, in 2018 we were able to target certain districts with varied social and infrastructural characteristics. In all these neighbourhoods, we chose to target households according to two criteria: their spatial proximity to the electricity network, and the external appearance of the dwelling, which gives clues about the socio-economic environment. The objective was to interview 25 households in each district in order to identify as many electrical practices and socio-technical *dispositifs* as possible, but access to households in the wealthier districts was more difficult and we were able to interview a total of 160 households. Different modes of access were subsequently grouped into four categories: conventional network, spider webs, off-grid market solutions (generator set and solar panels), and electricity storage technologies. The results obtained from the households were made more reliable by cross-referencing the interviews conducted with actors in the electricity sector and field observations of infrastructural forms.

The research in Benin focused on four districts: Haie Vive, an urbanised area in the city centre with a long history of urbanisation and an upper middle-class population; Ladji, a lagoon and lakeside peripheral[2] district of Cotonou (though centrally situated on the map); Fiyégnon, a neighbourhood located partly on the beach, undergoing residential urbanisation; and Ouédo Adjagbo, a village on the outskirts which is the location of the government's social housing projects. In Ibadan, three districts drew our attention: Ojé, located in the historical centre, is the city's largest and oldest slum (Fourchard 2003); Mokola, a lower-middle-class area of dilapidated housing within a well-maintained urban environment (Fabiyi 2004); and New-Bodija, a district planned by the central government in the 1970s to provide homes for the well-to-do (ibid.).

The data has been mapped (see Figure 6). A specific positioning method has been used to allow the comparison of the districts of Cotonou and Ibadan on the same map (see Figure 4). The aim is to show the homogeneities/heterogeneities in the socio-technical arrangements that form the urban electrical configurations. The number of districts studied in Cotonou is greater than in Ibadan because the practices encountered there are more varied. We do not claim that data collected are statistically representative, as we did not take into account the demographic weight of each district.

4. Heterogeneity of households' practices to access electricity

4.1. An erratic grid supply

The electricity supply system is a large system with standardised socio-technical and spatial characteristics. The conventional system consists of 'a set of interconnected infrastructures, centrally planned and operated, sometimes at local, sometimes at larger scale, which offers a more or less uniform service over a given area, which it helps to unify' (Coutard and Rutherford 2009, p. 6). The socio-technical device that mediates the supply of this conventional service to households is the electricity metre. Many kinds of domestic connection practices are available in this system. Customers of power companies usually have the choice between a post-payment or a prepay metre. They either receive a bill for their previous month's electricity consumption, or they buy electricity in advance by feeding the metre and maintaining an electricity supply until this money runs out. Most of the households we spoke to prefer these prepay metres. They feel that it protects them from billing errors and enables them to adjust their consumption to their varying capacity to pay. If a household lacks money to feed the metre, it is not exposed to the threat of having the prepay metre removed.

In Ibadan, however, people can obtain an electricity supply without a metre. In fact, estimation is the most widespread method of billing in the households that we met; it is used in households that have no metre or where the metre is too old to be read. This is not an informal practice, since billing is overseen by the electricity sector regulator, which provides a method of calculation. Nonetheless, there are conflicts between the electricity distribution company and its customers because of the lack of transparency. A large majority of the households we met pay only the amount that they consider appropriate in relation to their consumption, the quality of the service and the number of power cuts. This results in loss of revenue for the company. The regulatory authority is therefore running *meterization* campaigns to resolve this problem.

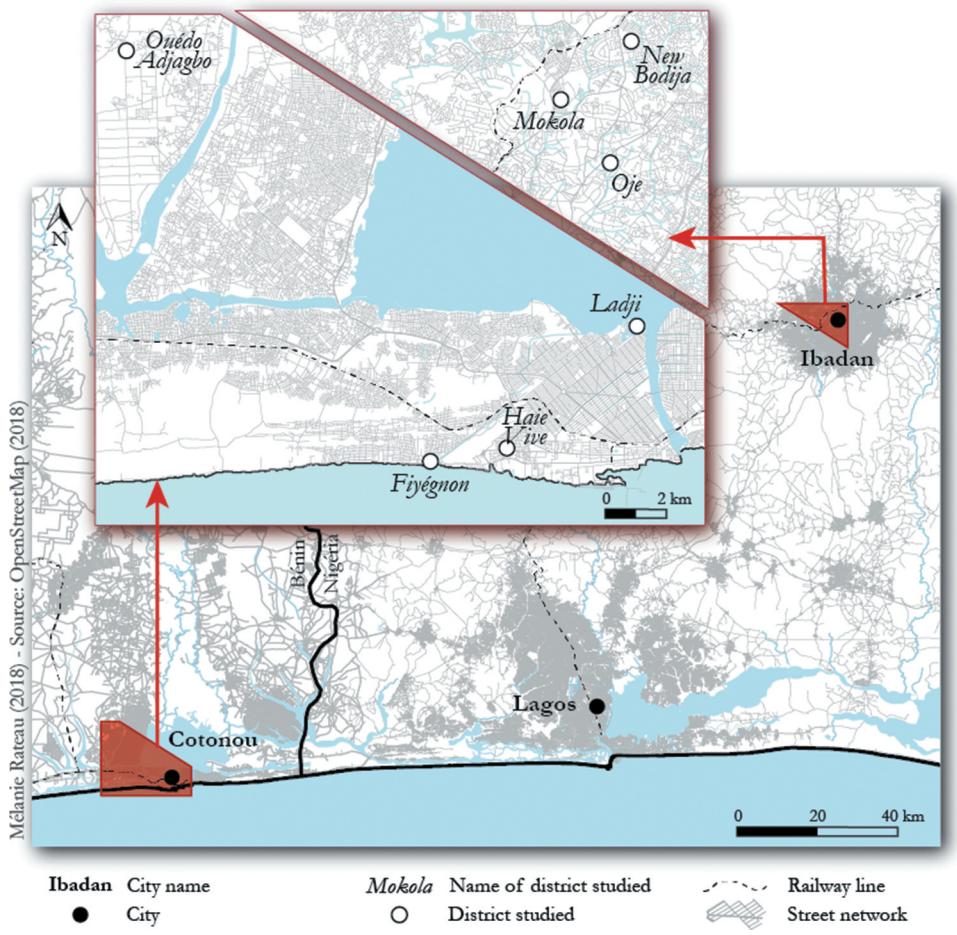

Figure 4. Cotonou and Ibadan, face to face to visualise the extent of the territory studied.

Being connected does not guarantee an electricity supply. Power outages are common. The lack of electricity and the mismatch between infrastructure capacity and demand (Oladejo 2017) force the Ibadan company to prioritise certain lines. Priority is given to health institutions, but also to economically profitable areas. One local electricity company executive explained[3]: 'Why do we prefer to supply Bodija rather than Oje? Okay, we have customers on both sides. But, as the owner of the company, I would prefer to supply Bodija, because they pay me every month.' On average, the local company is hard put to supply seven hours of electricity per day over its area as a whole.[4]

4.2. Spiderwebs on the margins of the grid

Beyond the conventional network's supply area, some households cobble together makeshift electrical extensions with whatever materials they can find. The interwoven wires resemble a spider web that some managers in the sector describe as *réseaux d'infortune* (networks of misfortune).[5] The people that set up these electrical spider webs in the many areas not covered by the conventional grid can suffer serious harm from fires or electrocution, for example, because of the failure to comply with electrical safety standards.

Following the official procedure for connection to the conventional system in Cotonou is expensive and depends on being close to the grid. The contract between the distribution company and the subscriber stipulates that electricity must only be used in the dwelling where the metre is installed. Whilst in urban areas, people must have a property title to apply for connection, in the countryside the rules are

Figure 5. Metres installed in the neighbour's house and DIY connection.

relaxed, to take account of the lack of an official land registry. Rural consumers can apply for the metre to be installed off their land, on the main road or with a neighbour. They thus have a metre and a contract in their own name, but must make their own arrangements for the connection between the metre and their home (Figure 5). This kind of DIY connection in the countryside is tolerated for urban areas exclusively in places not covered by the grid.

DIY connection is not the same as reselling. Some customers with a mains connection are prepared to sell their electricity to their neighbours, either as a favour or for profit. Neighbours agree on a price for this service: they may pay by the kWh if the buyer has an unconventional metre, or a flat fee based on the number and type of domestic appliances, or a fixed subscription. The unconventional metre is an electricity consumption measuring device that is not recognised by the electricity distribution company. It is a way to avoid conflicts between neighbours. However, it is the reseller who chooses whether or not this device is used. In all these arrangements, the price per kWh exceeds the regulated price for the base level of consumption. A reseller's consumption level therefore exceeds the base price rate, and the additional cost is passed on to the purchaser, sometimes with an additional profit margin.

4.3. A diverse range of off-grid technologies

The devices available for individual electrification, historically based on fossil fuels, are diversifying by incorporating technologies using renewable energy sources. It is possible to buy a generator, a solar lamp, a solar mini kit,[6] a domestic solar system, a domestic wind turbine, and so on. Households vary in their use of these different technologies. The generator is the most widespread off-grid device. Generators come with different power outputs and different price tags. This means that they can be adapted to different socio-economic levels of urban demand. The most well-to-do households have high capacity generators with automatic self-start, whereas poorer households make do with small, sometimes second-hand generators, which they repair and refuel according to their financial capacities.

The technologies available in the city also reflect the diversity of urban demand. The wealthiest residents are able to purchase domestic solar systems in specialist shops offering multifunctional solar lamps with special payment facilities for their poorer customers. With this pay-as-you-go type service, households with limited means can stage their payments to acquire equipment of certified quality. Yet these payment terms, often described as pro-poor, are still beyond the reach of the most vulnerable households. As a seller explains[7]: '*Although people have to pay a little every month, the initial payment is high, to screen customers with the capacity to pay*.' The poorest households therefore go to the market or to street sellers to buy in the less formal sector. Informal sellers do not provide personalised advice, or payment facilities, but charge much more

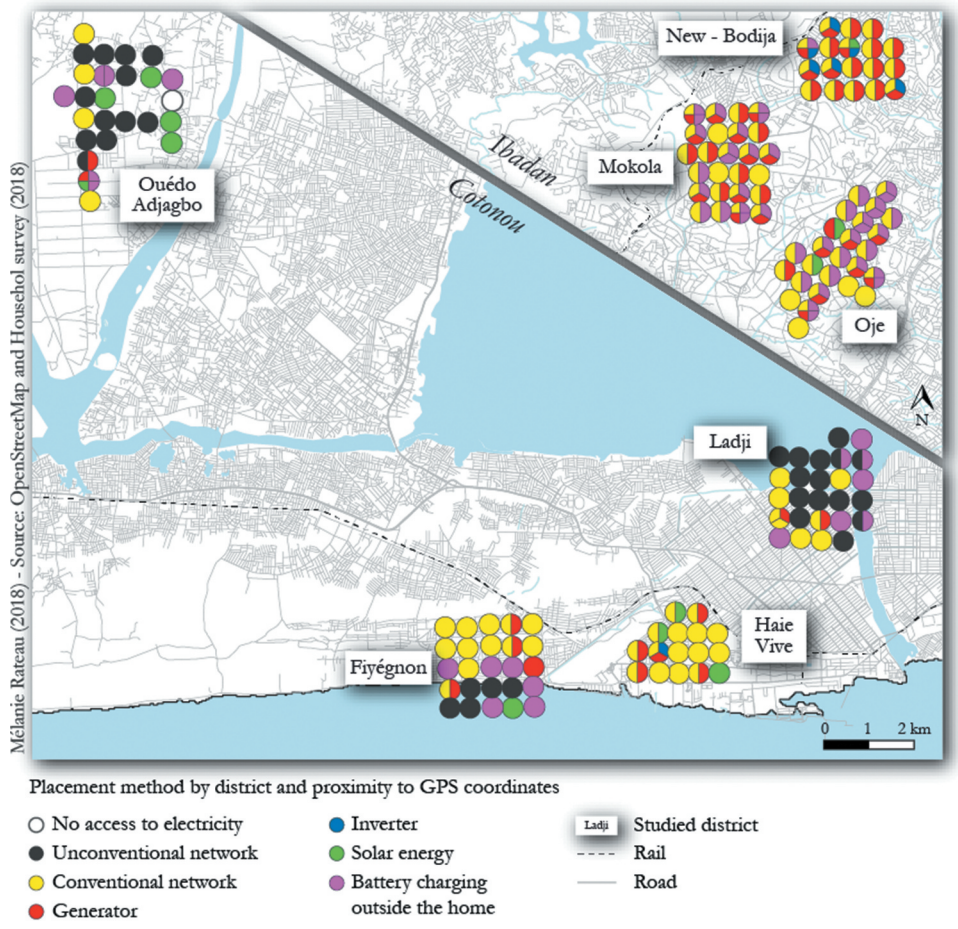

Figure 6. Households' practices for access to electricity in Cotonou and in Ibadan.

affordable prices for uncertified products imported directly from China.

4.4. Emerging electricity storage technologies

The households we met frequently charge their portable devices outside the home: in the workplace, at friends and family, in their place of worship or at charging point shops. The latter are rudimentary outlets that provide a mobile device charging service, which costs 100 Fcfa (US$0.17) in Cotonou, but varies in Ibadan depending on the power source, between 40 Nairas (US$0.11) for charging from the main grid and 50 Nairas (US$0.14) from a generator during power outages. These businesses have been able to develop because of the growth in increasingly portable, battery-powered devices: mobile phones, tablets, radios, torches, and more recently fans. These services compete directly with sales of throw-away batteries.

Improvements in the technological performance of batteries and falling prices mean that they can now be used to do more than simply powering a portable device. The electrical needs of an entire dwelling can now be met with batteries. Households are equipping themselves with backup battery systems. These systems, mainly imported from India, have emancipated batteries from the photovoltaic panel. They are recharged by means of an inverter connected to the standard power grid. When electricity is available, the system stores it. When there is a power outage, it automatically takes over domestic supply. The switchover is fast enough for

domestic appliances to continue working without disruption. Nonetheless, the initial investment cost is high, and the batteries need replacing every five years.

5. Situated co-production arrangements in response to distinct rationales

5.1. In Cotonou: the grid at the heart of the co-production of electricity access

In Cotonou, the households we met mostly use a single system – the circles in Figure 6 are monochrome. Fewer than half are connected to the conventional grid, closely followed by the spider web, and almost a quarter are off-grid. It is in the Ladji district that the most spider web practices are concentrated because of its unplanned urbanisation. The head of a consumer organisation explained that '*moving the network costs more than installing it*'.[8] However, much of Ladji does not meet the necessary criteria for inclusion in the official land registry, in particular because it is located in a lakeside and slum area. The spider web network follows temporary routes and supplies electricity even to the houses on stilts on the lake itself.

In the suburban Ouédo Adjagbo district, off-grid solar installations typify the electricity landscape. In fact, the spider webs remain close to the conventional network. The longer the wires, the greater the technical losses and the poorer the quality of service. The households furthest from the conventional grid are therefore equipped with small, low-power and low-quality solar kits. Their lifespan is limited, but sufficient until the arrival of the grid, with its promise of unlimited consumption.

In the Fiyégnon district, many households located on the beach with its ongoing residential development depend on charging point kiosks. Here, it is not distance from the network that keeps households in the dark, but disconnection by resellers on the spider web network. Despite this, the disconnected households we met do not want to invest in off-grid systems, because the state of disconnection is temporary, attributable to conflicts with a reseller or removal from the grid because of non-payment. These households wait for more funds to pay for reconnection or to negotiate service access from another neighbour. The common feature of the co-production of electricity access in Cotonou is the local residents' perception of the grid as an ideal. The aim is to connect to the conventional power grid when it is close enough, and to use a range of temporary electrification arrangements while waiting for the grid to be extended.

5.2. In Ibadan: practices of securing electricity supply restricted by purchasing power

In Ibadan, the grid supplies all urban households, in well-to-do and working-class neighbourhoods as well as in the slums of the old centre. Although infrastructure coverage is universal, the service is not continuous but limited to a few hours a day. All the electricity company's customers therefore experience poor connections. Households are accustomed to these outages, which they see as a method of sharing electricity. A customer explains: '*When it's like 5:30 or 6, they will bring light*.[9] *It will stay till 5:30 in the morning. They take it. That's the way they are sharing it*.' During the long power cuts, households get their electricity elsewhere: generators, charging kiosks, backup batteries and solar panels.

Generators are part of the electricity landscape everywhere in Ibadan. They differ in number and power output from one district to another. In the New-Bodija neighbourhood, all the households we met owned at least one generator, some of them several. In Mokola, generators are both less numerous and, more importantly, less powerful than in New-Bodija. They are even less numerous in the Ojé district, where households buy fuel only occasionally. The households with the least purchasing power are equipped with small generators colloquially called 'I better pass my neighbour' ['I'm better than my neighbour']. Nowadays, the importation of these small generators is forbidden, but they are still being sold.

When the generators run out of fuel, households recharge their mobile devices outside the home. In the Mokola neighbourhood, they often go to one of the area's many print shops, which require large generators to deal with outages. Households can get their devices charged for free or at the same price as at a charging point. In Ojé, this service is provided free of charge by mosques during prayer times, but people usually go to the charging kiosk. According to its manager, it handles an average of 50 customers a day.[10] In an electricity landscape marked by a universal network with an erratic service, the purpose of the co-production of electricity access in Ibadan is to secure the supply and maintain continuity. The systems purchased and used for this purpose depend on households' financial capacities . When purchasing power increases, the methods

used by households to maintain a continuous supply and so to get the best service from the grid become more diverse.

5.3. *In the well-to-do districts of both cities: aggregation of alternative solutions to the grid*

Wealthy neighbourhoods employ socio-technical arrangements that differ from other neighbourhoods, but nevertheless reflect their urban environments. They are distinctive in their ways of combining socio-technical arrangements to extract the best possible service from the network. Being connected to the conventional grid in Cotonou is a guarantee of receiving electricity with few outages. In this urban electricity context, some well-to-do households equip themselves with an off-grid solution as a backup to mains electricity. Generators are not used on a daily basis; they are standbys in the event of a power outage. A young man explained[11]: '*We haven't used our generator for more than a year, but we still maintain it. We're not selling it. We're still waiting, to see how things go*.' Other households have chosen to instal solar panels for the same reason, but also as a way to reduce their conventional electricity bills.

Power outages in Ibadan are frequent and the voltage is too low. The New-Bodija district is mainly distinctive for the high concentration of prepay metres. Almost all the households we met had these metres, because the local electricity company was running a *meterization* campaign. The installation costs for this new device are borne by the customers. This district also stands out as the only one where the households use the backup battery system. This quiet and discreet technology protects them from the intermittency of the grid, but the electrical current it supplies is low, with the result that not all domestic appliances work properly. At best, the electricity supplied by the grid powers light bulbs, fans, refrigerators and audio-visual equipment, but it is not reliable for more energy-intensive appliances and a generator is needed to run the air-conditioning and water pump effectively.

Co-production arrangements to access electricity are thus also common in wealthy neighbourhoods, but households can afford more diverse and more effective socio-technical devices sold on local markets to improve their level of service.

6. Conclusion

Like many cities in sub-Saharan Africa, Ibadan and Cotonou have been experiencing electricity problems as a result of inadequate coverage by the grid or supply shortages. As solutions focused on the conventional network are insufficient to meet urban demands, households rely on various alternative solutions to access electricity, based on both grid and off-grid technologies. These solutions involve forms of cooperation between actors that are not bound by formal agreements or contracts. The resulting assemblages are socio-technically heterogeneous and spatially situated. At the urban scale, they give rise to electricity configurations that evolve along hybridisation processes.

At first sight, these arrangements for accessing electricity do not fit the classical interpretation of co-production (Verschuere et al. 2012). Drawing on Watson's recommendation to unpack the 'underlying informants' (Watson 2014) and on Adams and Boateng's finding that partnerships are contingent on local conditions (2018), the discussion about the dissimilarities prompted us to contextualise the notion of co-production.

We first argue that not only the outcomes but also the design of co-production processes are context-specific and must be assessed accordingly. The study of Ibadan and Cotonou thus highlights that this design must take into account all modes of access – centralised and decentralised – to electricity, the agency of many actors from three distinct spheres – urban society, state and public utilities, and market players providing materials and skills -, and a great diversity of socio-technical *dispositifs* and spatial features of households' practices that reflect the heterogeneity of their urban environment.

We then suggest that the resulting arrangements are better understood under the umbrella of co-production, which allows us to group together in the same analytical framework many heterogeneous arrangements organising access to electricity for different types of households in different neighbourhoods, thus emphasising the structurally multi-actor and multi-technology nature of urban electricity systems. It also helps to conceptualise the role of the state other than in terms of absence or failure, and to see the relationships between the many actors of electricity configurations without framing them dualistically in terms of state/society, formal/informal, and conventional/alternative.

These categories are unhelpful to an analysis of the hybrid arrangements governing electricity provision and access. Finally, once contextualised and considered from a multi-scale perspective, the concept of co-production has proved fruitful to explore how households' practices of accessing electricity, on the one hand, and the urban electricity configuration, on the other, mutually shape each other. We have explained how co-production processes support a constant movement of extension-hybridisation of electricity configurations in order to meet a growing and diversified urban demand for electricity.

The paper argues that these characteristics, defined from field surveys, contribute to a better understanding of the actual and widespread processes of an 'ordinary' co-production in sub-Saharan African cities. It suggests two additional reflections. While scholars of urban electricity in sub-Saharan cities tend to give prominence to practices shaped by poverty and informality (Silver 2015; Baptista 2016; de Bercegol and Monstadt 2018; Smith 2018), our case studies highlight the overall and persistent diversity that shapes electricity markets and practices. Analysing unconventional electricity arrangements in terms of co-production thus rightly emphasises various processes of consolidation (if not institutionalisation) – processes that are frequently overlooked because assumed to be temporary and fluid.

The nature of user/citizen involvement is also at the centre of many studies on co-production, with the empowerment of poor communities and more democratic decision-making processes often being outlined as expected outcomes (Mitlin 2008). In the neighbourhoods surveyed, co-production is neither claimed by dwellers nor sought by utilities, it does not appear to be part of a 'social movement' seeking 'to change the way in which institutions of the state govern' (Watson 2014, p. 66). Individual initiatives and everyday practices focused on basic needs are more usual and may be partly explained by citizens' lack of confidence in the capacity of state actors to engage in reliable partnerships. As a result, coproduction arrangements provide electricity access for a large part of the population without providing mechanisms to redress city-scale inequalities. Mainly based on individual and market dynamics, in an ambiguous relationship to state bureaucracies, they open up space for demand-driven arrangements within electricity configurations that lack proper institutions and tools for their governance and regulation.

This raises the crucial question of the consequences of ordinary co-production processes on inequality of access to electricity. More research is needed and only a few thoughts are outlined here in conclusion. In Cotonou and Ibadan, co-production arrangements are first and foremost a household response to network failures. As such, they reflect urban heterogeneity by specialising on the basis of the purchasing power of different customer segments. In socially and spatially very unequal urban spaces, they do not lead to an improved level of service for all households at the urban scale of the electricity configuration. The gaps in the financial, social, health and environmental costs of access to electricity cost are widening between the wealthiest and most vulnerable households. As urban electricity policies have been unable to think beyond the conventional standpoint of a monopolistic service network, hybridisation processes and their effects in terms of inequalities of access have been left to market mechanisms and individual-scale arrangements. These issues raise political questions: what would the adequate mechanisms and policies be to address social inequalities and to steer co-production processes towards a more sustainable and equitable way of addressing urban heterogeneity?

Notes

1. This article is based on the doctoral research undertaken by Mélanie Rateau (Latts – Université Paris Est), under the joint supervision of Sylvy Jaglin (Latts – UPEM) and Armelle Choplin (University of Geneva). The fieldwork in 2017 and 2018 was made possible by the financial support of ANR Hybridelec and institutional support by the IRD in Benin and the IFRA in Nigeria.
2. The District Head in Ladji describes his neighbourhood as being on 'the periphery of Cotonou'. Based on an interview conducted on 19/07/2018 by Mélanie Rateau.
3. Interview with an IBEDC executive conducted on 12/07/2018 by Mélanie Rateau.
4. Source: https://iwin.org.ng/daily-hours-of-supply-availability (page accessed on 22/04/19).
5. Interviews with different SBEE managers conducted on 4 and 10/07/2017 by Mélanie Rateau.
6. Solar mini-kits usually have the capacity to power three light bulbs and an electric socket.
7. Interview with a sales manager for a solar kit brand conducted on 28/07/2019 by Mélanie Rateau.
8. Interview with the chairman of the Benin Water and Electricity Association conducted on 04/04/2018 by Mélanie Rateau.
9. Interview with an IBEDC customer conducted on 21/07/2018 by Mélanie Rateau.

10. Interview with the manager of the Oje charging kiosk conducted on 02/06/2018 by Mélanie Rateau, translated from Yoruba by Adejoke Iyabadan.
11. Interview with a Fiyégnon household conducted on 14/06/2018 by Mélanie Rateau.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The project was supported by the Agence Nationale de la Recherche - France, project "Electric Hybrids: emerging forms of energy transition in southern cities – HYBRIDELEC" https://anr.fr/Projet-ANR-17-CE05-0002 https://hybridelec.hypotheses.org/

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