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The hybrid domain for energy in India: exploring the early diffusion of off-grid urban solar power

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Abstract

Purpose – The purpose of this study is to reveal how the urban market for off-grid energy production in the hybrid domain developed in the Indian context and to critically reflect on this phenomenon.

Design/methodology/approach – The authors explore hybrid infrastructure for electricity supply in the Global South, with a focus on Bangalore, India. The authors conduct a case study to reveal how diffusion of off-grid solutions offered by a social enterprise – which was originally set up to provide off-grid solutions to poor rural communities – went from rural into more affluent urban users.

Findings – The hybrid domain develops through the engagement of proactive and savvy urban users interacting with socially minded corporate entrepreneurs to deliver customised off-grid technological solutions. Unlike rural users, urban users have broader societal interests and missions. These interactions allow the social enterprise to develop new capabilities and design off-grid solutions that meet technical, ethical, pedagogical and financial requirements in urban niches that may eventually spill-over back into rural areas.

Research limitations/implications – The work is based on one case, which limits the generalisability of findings. It provides off-grid energy and infrastructure researchers with new themes and directions for research on the hybrid domain for energy provision where both the modern infrastructure ideal and the making-do improvisation model no longer fit.

Practical implications – The study provides insights into how social enterprises offering off-grid solutions can expand into new market niches, the factors that encourage this and the capabilities required. It also highlights potential downsides to the non-state model that should be addressed in policy.

Social implications – Urban users struggling with unreliable centralised energy provision can draw help from social enterprises by communicating mission-oriented motivations for adopting off-grid technology on top of the core need. This may translate into improved capabilities in social enterprises that are also offering services to poor rural communities.

Originality/value – Uncovers overlooked mechanisms by which off-grid technology originally intended for poorer rural areas can be diffused into richer urban areas.

Keywords Hybrid domain, Off-grid technology, Solar photovoltaic cells, India

Paper type Research paper

1. Introduction

The diffusion of off-grid photovoltaic (PV) systems in the Global South began more than four decades ago. The initial installations were primarily in remote areas targeting underserved

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communities, with the support of international donors and agencies and within socio-technical niche [1] contexts such as poor rural villages (Byrne *et al.*, 2018). High profile international initiatives to facilitate access to basic services for all, such as the United Nations Sustainable Development Goal #7 (affordable and clean energy) have been established. Yet, challenges for provision of affordable and clean energy remain, and these are not just in rural areas, but also in growing urban areas too where populations have increased. The disruption of basic service supplies such as water and electricity has been commonplace and has impacted all sections of society, not only the poorest but also the growing middle class. In this context, a hybrid infrastructure configuration in both urban and rural areas has become the norm rather than the exception (Graham and Marvin, 2002; Furlong, 2014). Off-grid alternatives to the official electricity grid system have developed in various forms, including using solar PV technology.

The Indian context has experienced a continuous penetration of PV systems, helping to make India the third-largest PV market after the USA and China, with a yearly installed capacity of 9 GW in 2017 (IEA, 2018). The State's failure to provide stable access to electricity presented an opportunity for various organisations (including NGOs and social enterprises) to develop the market for off-grid solar home systems for underserved populations, first in remote areas, and then in second tier and third tier cities [2] and wealthier sections of the society. This diffusion of off-grid PV technology from rural areas back to urban areas may be counter-intuitive. The economic and institutional barriers to solar technology diffusion (Philibert, 2006) would suggest that this technology might diffuse in the opposite direction. One reason that poor rural areas were targeted first was because actors emerged to minimise the burden of risk for lenders in rural markets. Financial incentive schemes were put in place to encourage off-grid deployment in rural areas before urban areas. Little has been documented, however, on how such off-grid technology can then diffuse across society from rural and poor, where it was originally targeted, to middle-class urban areas, where financial incentives may not be the primary issue. Various scholars have called for more fine-grained analysis of this topic, noting how it is under-researched (Seyfang and Smith, 2007; Grin *et al.*, 2010; Hargreaves *et al.*, 2013). We contribute towards addressing this gap and explore the following research question: How does the urban market for off-grid energy production in the hybrid domain develop in the Indian context?

We chose Bangalore in 2014 as the context for our explorative study, examining the role of a local social enterprise collaborating with new urban users as they co-created a new market for off-grid solutions before it was officially legalised by the State in the form of net-metering. Bangalore in 2014 was an ideal setting to examine this due to its dramatic economic and demographic growth that had occurred because of high-tech industrial development. This led to the emergence of new urban consumption patterns associated with waves of migrants and impacted the way public authorities and private organisations coped with meeting the demand for essential services such as electricity and energy. Indeed, the population of the city had mushroomed from c. 6 million to c. 10 million inhabitants between 2000 and 2014. We position the current analysis in 2014, in advance of the regulated introduction of net-metering which allowed users to sell electricity back to the grid. This was an important juncture in the evolution of off-grid systems because it allowed stakeholders to gain knowledge through proof-of-concept systems and for key actors to learn about how to improvise and adapt systems in a new context.

The analysis reveals how urban users' interactions with social entrepreneurs within a larger corporate organisation spearheaded rural-to-urban diffusion of off-grid technology. It contributes to the emerging literature on user-led technology diffusion (Dupont *et al.*, 2023; Sopjani *et al.*, 2019) in the Global South and reveals a particular kind of agency developed by these actors with some similarity to "grassroots" action to enact urban energy transition

(Silver and Marvin, 2017). It goes beyond being simply a "making-do" solution in the context of a failed modern infrastructure ideal. Instead, it involves an evolution of capabilities within a social enterprise established originally to serve poorer rural communities to develop off-grid alternative markets in urban areas, i.e. away from a traditional mission-oriented market to a more commercial market. Policy needs to be able to address the potential downsides of this phenomenon, which include:

- increasing dependence on private, non-State actors;
- a foregoing of early market knowledge by State actors; and
- the potential for longer-term equity issues in rural-urban diffusion.

2. Literature review

Two contrasting streams feature in the literature on infrastructure and world development. The first is the diffusion across the globe of the "modern infrastructure ideal" (Graham and Marvin, 2002, p. 40). The second is the improvisation and "making-do" spirit that actors adopt when this ideal is not met. These two streams of literature help to characterise the situation of access to energy in Bangalore. Table 1 provides a summary of the key concepts discussed below, and their relevance to the context of Bangalore.

2.1 From the "modern infrastructure ideal" to improvisation

The modern infrastructure ideal refers to a process observed across the metropolises of industrialised countries, where "small, fragmented islands of infrastructure were joined up, integrated and consolidated towards standardised, regulated networks designed to deliver predictable, dependable services" (Graham and Marvin, 2002, p. 40 in Bocquet *et al.*, 2008, p. 1). This evolution took over a century (1850–1960). However, a splintering phenomenon occurred in developing countries, a sustained fragmentation in the provision of, and access to, reliable services (Graham and Marvin, 2002). The modern infrastructural ideal became out of reach in these contexts due to poor management, an increase of population and resource depletion. This splintering stimulated comprehensive reform processes in the public authorities responsible for the provision of public services. Such processes often developed under the aegis of multilateral institutions or national development agencies, sometimes through performance contract projects.

Secondly, the "improvisation [3]" or "making-do" spirit in infrastructure service emerged because of the need for alternative forms of supply under challenging and constrained circumstances. This is often based on practical local knowledge and experience (Kumar, 2021, p. 4). Offenhuber (2019) offers an insightful perspective on improvisation and bricolage: the latter is a concept closely related to improvisation which was defined by Lévi-Strauss (1966) as "make do with whatever is at hand". This characteristic, along with the recombination of resources for new purposes and making-do with whichever job needs to be done constitute the three components of bricolage harnessed by entrepreneurs to provide solutions within resource-scarce contexts (Baker and Nelson, 2005). In many instances, improvisation or make-do initiatives are accepted by the State in relation to basic infrastructure services. Insufficient support from local governments causes individuals and other actors to initiate pragmatic actions when their needs for basic services are at stake.

2.2 The reality of improvisation

Scholars underline the role of individual and collective initiatives in improvising to provide essential services under challenging conditions. These initiatives relate to actions taken by

Table 1. Summary of key concepts and relevance to Bangalore

Concept	Definition	Selected literature	Relevance to Bangalore
Failure of the modern infrastructure ideal	A failure to achieve the ideal of modern, integrated infrastructure, typically driven by state-led or planned economic logics. The evolution of infrastructure in industrialised countries from fragmented, localised systems into standardised, regulated networks delivering predictable and dependable services. This process occurred mainly between 1850–1960 and was characterised by centralisation, universality and stability	Graham and Marvin (2002) Bocquet *et al*. (2008)	Bangalore experienced chronic power outages; BESCOM (public electricity provider) received 360 complaints per day about power failures (63.5% of all complaints) (2021) Energy governance in Bangalore included forced blackouts
Hybridisation (caused by the failure of the modern infrastructure ideal)	The phenomenon of combining multiple systems—formal and informal, public and private, on-grid and off-grid. A condition where centrally planned infrastructures coexist with informal or alternative systems, such as those created by grassroots initiatives or private actors. It reflects the socio-technical heterogeneity and non-uniformity of service provision in many global South cities	Furlong (2014) Verdeil and Jaglin (2023)	Bangalore state actors had an explicit policy to hybridise infrastructure to actors in the commercial domain as well as civil society actors (van Gils and Bailey, 2023)
Improvisation (a consequence of hybridisation in localised situations, buildings, houses etc.)	Strategies by local actors and users to respond improvisationally within constraints of resources and institutional limitations. Pragmatic, creative responses by individuals or organisations under constrained or failing conditions, especially where state infrastructure is absent or inadequate. It includes the recombination of available resources and the development of context-specific, provisional solutions	Baker and Nelson (2005) Offenhuber (2019)	Bangalore had been noted as a place where improvised solutions for public services and civil society were utilised, including in traffic decongestion (Gopakumar, 2015) – this was a cultural norm
Co-creation of service (required for improvisation)	A collaborative relationship in which service providers and users mutually shape the content and form of services. The iterative and collaborative process in which technology providers and users jointly develop solutions. It emphasises mutual learning, local adaptation and shared problem-solving in contexts where services cannot be simply transferred from one place to another	Aoyama and Parthasarathy (2016) Seyfang and Smith (2007)	Co-creation of public services in the Indian context were common, including in Bangalore in sectors such as construction

Source(s): Authors' own work

different sections of society (from the weakest to the wealthiest) often with the support of the State's representatives (Williams *et al.*, 2022). They highlight the role of street-level bureaucrats (Lipsky, 1980) in facilitating people's provisional access to basic services, sometimes in a manner that goes beyond their reach and official prerogatives, to make a city "more or less work". In the Indian context, the hybrid status of former civil servants helped the building of these improvisational infrastructures (Ghertner, 2017, p. 740). In his description of the development of an off-grid solar market in Uttar Pradesh, Balls (2016) notes how improvisation is "forced upon many people in contexts of state welfare abandonment" (Balls, 2016, p. 367). In her description of the urban energy landscape of Bangalore, Broto (2019) stresses the improvised actions taken by households in favouring autonomous approaches to energy provision, irrespective of social class and income groups. From the use of fuel to solar water heaters, "fragmentation and autonomy shape the daily choreographies of energy use" (Broto, 2019, p. 106).

This phenomenon of fragmentation of infrastructure has been discussed in the literature in different ways. Some have referred to it in terms of post-networked infrastructure (Coutard and Rutherford, 2016; Monstadt and Schramm, 2017). Others have called it hybrid infrastructure (Furlong, 2014; Larkin, 2008), incremental infrastructure (Silver, 2014) or people as infrastructure (Simone, 2004). Some proposed a "modest imaginary" in contrast to the modern infrastructure ideal, to qualify and interpret less grand alternatives (Lawhon *et al.*, 2023a, 2023b, pp. 149–150). The limits of the modern infrastructure ideal have been pointed out by the fact that in the Global South, urbanism is already splintered and not splintering (Coutard, 2018, p. 1816).

In most infrastructure in cities of the Global South, the failure of the modern infrastructure ideal has led to hybridisation of solutions: "the interplay of two infrastructural trends, the patchy and limited extension of the grid and the widespread socio-technical heterogeneity" (Verdeil and Jaglin, 2023, p. 2). This legacy of non-uniform modes of service provision is visible in urban contexts where centrally planned infrastructures coexist with solutions developed by local entrepreneurs and grassroots led initiatives (Lawhon *et al.*, 2018). These configurations are "[…]fluid, constantly being reworked, and more easy to rework in response to uncertainty and change" (Lawhon *et al.*, 2023a, 2023b, p. 3–6). They end up being longstanding configurations that satisfy a demand (ibid., p. 12).

The resulting scattered energy landscape provides opportunities for actors in off-grid low carbon innovations. In Bangalore, for instance, it brings an unexpected dynamism in terms of innovation (Broto, 2017, p. 760). A project known as T-Zed involved reducing the dependence from grid based municipal services in a holistic manner by exploiting locally available natural resources, from rainwater harvesting to solar energy (Sawamura and Amiraly, 2015). This also highlights how improvisation in off-grid solutions involved residents "[…]spread[ing] the message about the potential of 'green' living virally" (Bulkeley and Castán Broto, 2014, p. 411). While heterogeneous solutions are used by the poor in contexts of economic constraints and forced frugality, in contrast, urban middle and upper classes harness their potential in ways that are not necessarily frugal (Verdeil and Jaglin, 2023, p. 8), becoming advocates for their use.

2.3 Enabling the co-creation of services in the hybrid domain

In a context of the State failing to deliver essential services, scalable solutions can be co-created by different types of actors. Aoyama and Parthasarathy (2016) define the hybrid domain as not only involving conventionally hierarchical actors of governance but also grassroots actors producing and consuming goods. This combination of actors engages in a process of coordination around a common agenda for problem-solving. Off-grid technology

providers offer technological and managerial expertise while users/consumers become involved to articulate evolving needs (Aoyama and Parthasarathy, 2016, p. 29). Solutions cannot be generated solely through market research; they arise through learning by doing in local settings, iterations and many repeated interactions between the technology providers and users (Dupont *et al.*, 2023). Aoyama and Parthasarathy (2016) stress the necessity of learning through these interactions. This requires proximity to markets and face-to-face interactions in problem settings. Seyfang and Longhurst (2013) underline the lack of work on how niche market formation occurs through grassroots innovations; the literature mostly stresses the supply-side of technological innovations, in contrast to the consumption-side of social innovations in challenging settings (Seyfang and Longhurst, 2013).

Off-grid grassroots innovations are differentiated from market-based innovations in the literature. The former consist of informal community groups and "[…]networks of activists and organisations that lead bottom-up off-grid solutions for sustainable development" (Seyfang and Smith, 2007, p. 585). Scholars have examined the co-production phenomena from the perspectives of a pair of actors, i.e. a public agency and citizens (e.g. Joshi and Moore, 2004; Bovaird and Loeffler, 2016) and have also highlighted how technology providers and producers can adopt a mission-oriented logic as well as an economic logic (Dacin *et al.*, 2011). In contrast to this well-established co-production perspective, the grassroots approach seeks to address a far less explored topic, namely the concomitant and iterative actions of diverse stakeholders engaging in off-grid technology diffusion for households and institutions.

3. Bangalore as a context for understanding off-grid diffusion

3.1 Electricity supply and the increased adoption of off-grid solutions

By 2010, Bangalore had the second fastest-growing population among Indian metropolitan cities, after Delhi. Users suffered from daily electricity outages of the central grid. It had been more than a decade without improvement [4]. The Bangalore Electricity Supply Company (BESCOM), the public electricity supply company in the city, received a daily average of 360 complaints on power supply failure, 63.5% of its total complaints. Blackouts were routinely used to manage shortages at peak demands and constituted a tool for energy governance (Broto, 2017). Off-grid energy systems (including battery, diesel generators or solar PV) were an intermediate solution to deal with the discontinuity of electricity supply in Bangalore [5]. These decentralised energy sources provided back-up supply when the central grid failed [6]. This was also observed in other cities such as Nagpur where nearly 90% of the middle-upper-class had used a backup system (Werulkar and Kulkarni, 2015). A key driver for the expansion of off-grid solutions was the cost reduction of renewable energy technology (especially solar PV) and of the equipment attached to them (Bhandari and Stadler, 2009; Hostettler, 2015). There were also grassroots innovations in payment, selling and marketing models (Singh, 2016). For example, street market sellers using portable PV apparatus at night (Yaqoot *et al.*, 2014) – such as solar lanterns – was already a widespread phenomenon in the early 21st century (Velayudhan, 2003).

Public policies at national and state level also encouraged the expansion of the off-grid PV market. In 2010, the Indian government launched the Jawaharlal Nehru National Solar Mission that aimed at achieving 100 GW solar capacity by 2022 (Government of India, 2010). At state level, Karnataka launched the Karnataka Solar Policy 2014–2021 aiming for 2,000 MW of solar power generation capacity by 2021 (The Government of Karnataka, 2014). Overall, the adoption of off-grid solar PV technologies had constituted an important part of rural electrification and social upliftment in India (Mukhopadhyay and Mukhopadhyay, 2018; Joshi *et al.*, 2019).

3.2 Solar Energy Light Company: a social enterprise developing an urban niche for photovoltaic systems

Founded in 1995 in Bangalore, the Solar Energy Light Company (SELCO) [7] initially provided affordable PV lighting systems for low-income customers in rural underserved communities. SELCO considered access to energy as a source of socio-economic development, i.e. an "underlying condition to catalyze progress related to health, education, livelihoods, financial inclusion[…]leading to overall improvement in quality of life" (SELCO India, 2024). The initial conviction of the founders was that solar energy is cheap for the poor but expensive for the rich. The thinking was that, in contrast to the former, the latter already had access to electricity from the grid. Setting up off-grid systems for poor, rural users required financial capital. The company had installed systems for more than 1,500,000 households by 2014 (SELCO India, 2014). It claimed that it had "installed over 450,000 so-called 'expensive' solar solutions for the poor using various financing methods designed internally in cooperation with financial partners that match their cash flows" (SELCO India, 2020). As a financial loan to low-income borrowers was relatively risky, banks did not want to take 100% of the loan for the installation of the system. SELCO facilitated the access to loans for low-income users by participating up-to 20% of the total amount of the loan.

The company's strategy involved adaptation and localisation through long-term relationships with rural communities. It aimed to improve the livelihood of low-income groups who still had some capability to pay for the system by supplying lighting, water pumping systems and a range of services with solar powered machines for multiple purposes (roti rolling, milking, sewing, printing, refrigerating, chilli pounding) enabling the launch of small businesses:

> SELCO views energy access as an underlying precondition to catalyse progress related to health, education, livelihoods, financial inclusion and so on leading to overall improvement in quality of life. It understands the root of the problem within context and then assesses how energy can resolve it (SELCO, 2020).

Indeed, the social mission was a core principle of the organisation:

> SELCO has carefully structured its investment journey to achieve financial sustainability and retain its social mission by (i) partnering with non-profit, impact first investors, (ii) not focusing on quarterly assessments of performance rather, opting for long term investments in its people and operations (SELCO, 2020).

It put effort into providing an affordable and financially inclusive service for underserved populations that were not only considered as customers:

> The poor are looked at as partners, innovators, inventors, enterprise owners in order to develop solutions that are truly inclusive and not designed based on assumptions of what the poor need (SELCO, 2020).

4. Field work

We adopted a case-based explorative approach (Hartley, 2004; Yin, 2011) to address the research question in the context of Bangalore and SELCO. Case-based research has been a common research strategy in contexts of energy poverty in the Global South (e.g. Joshi and Yenneti, 2020; Pereira *et al.*, 2011) and is particularly useful in situations where there are no *a priori* assumptions concerning outcomes and where sensitivity to context of the phenomenon is important (Hartley, 2004; Yin, 2011). This was vital in the SELCO case as the company had previously mainly focused on rural clients, and our research question

focused on the emerging urban market. The research strategy involved the principal investigator obtaining direct access to off-grid urban solar PV projects in the urban context of Bangalore during their initial implementation by SELCO. This approach aimed to uncover the lived experiences of individuals close to the phenomenon of energy poverty and entrepreneurial solutions in a Global South setting (Heredia *et al.*, 2024; Williams *et al.*, 2022). It explicitly considers the viewpoints and interactions of multiple actors involved in the adaptation and provision of new technology and services. Such a qualitative research approach is relevant when researchers gain direct access to social entrepreneurs involved in working to resolve the issues of energy poverty (Williams *et al.*, 2022).

While face to face interviews with the SELCO management team were made from 2013 to 2019, the current analysis is based on the situation in July 2014, before net metering was permitted by the State. An interview guide with open-ended questions served to lead the data collection. The first interaction with the company began in March 2013 with SELCO's co-founder, with the initial purpose of understanding its business model and market. Field visits were conducted with a regional manager in second tier cities of Karnataka (Hubli-Dharwad), giving us an understanding of urban customers and the way the company approached them. In 2014, we obtained approval from SELCO management to analyse the way it explored and cultivated the urban niche market for off-grid solutions. There were 10 such solar PV projects in Bangalore at the time, and the company allowed access to two of them, a private school (referred to as Client #1) and a vegetarian restaurant (referred to as Client #2).

Our interviews with project managers in charge of implementing the projects allowed us to understand SELCO's interactions with customers and how these relationships formed and evolved. Follow-up interviews were conducted: with a senior program manager and with the assistant general manager. We also collected photographic evidence that documented the progress of implementation of the two systems at Client #1 and Client #2 (not reported here) and had many informal (unrecorded) interactions with members of the communities at Client #1 and Client #2 as we gained access to inspect the installations of the off-grid systems.

In line with the phenomenological approach, interviewees were invited to explain how they gained knowledge of the needs of urban customers and how they developed and adapted the offering accordingly. Field visits were conducted with the project managers and whenever possible, customers were also interviewed to understand their motives and involvement. This allowed us to obtain first-hand information on the nature of the off-grid PV diffusion in this context, something quantitative secondary data could not have done.

4.1 SELCO's initial foray into the urban market

In 2013, the company started exploring urban collective customers that were larger than households and smaller than factories: such as hospitals, schools and banks. Several competitors were in this market: Tata Power solar, Anu Solar and Bunt Solar. In 2014, up to 10 such projects were initiated by SELCO in Bangalore. One example was the National College in Jayanagar, Bangalore where a 5kWp solar system with batteries and inverters was installed. This provided the basic loads for the principal's room, board room, office room and a classroom. According to SELCO, the institution wanted to promote environmental consciousness, innovation and best practice by using renewable energy. The company considered that the project created awareness for students on solar technology, while reducing grid electricity consumption and related expenses.

In another example, the arrival of rural migrant wageworkers in the construction industry at the city's periphery spurred private organisations to propose tailored energy services for their workforce in the immediate vicinity of construction sites. In the outskirts of Bangalore, these temporary sites constituted urban slums, and SELCO started providing energy services

in the form of solar containers designed for basic electricity needs such as charging mobile phones and refrigerators for construction workers. A group of employees [8] from the institutional project team (a dedicated business development unit in SELCO) developed these urban projects. This unit was then formalised to explore and exploit new urban niche opportunities.

The early exploration of these urban niches addressed two market goals. The first was the need to create awareness among potential customers of environmentally friendly off-grid systems. The second was to present these projects as a showcase for organisations with headquarters in Bangalore that could be potential future customers of off-grid systems. SELCO anticipated some of these organisations working in the rural context and considered that it could eventually diffuse this off-grid system in their field offices. In this way, these early customers became indirect marketing channels for spreading the idea that off-grid PV was an alternative or a complement to the grid and provided reliable and sustainable power.

One respondent explained how the company used this early experience to classify the emerging urban niche into four – non-mutually exclusive – categories. The first category concerned customers exposed to acute problems with grid electricity supply and seeking an alternative source of energy for practical reasons. The second category dealt with high-income customers wanting to use eco-friendly energy systems. The third category related to savings-minded customers willing to save energy for economic reasons (financial payback). The fourth category was for environmentally conscious customers willing to sell back the energy they generated to the grid system; this category captured the customers' desire, but at that point not the reality, since the State's regulation did not yet allow net-metering systems at the time of data collection.

4.2 Two case studies of urban clients

The two cases we gained access to were:

(1) an educational institution; and

(2) a restaurant for vegetarians.

In both cases, the supply capacity of PV systems was adapted depending on the requirements based on the daily usage of electricity. Since the two case organisations both had their own end-users, the required capacity was larger than that of individual users: multiple PV panels and batteries were installed.

Productivity increase by the introduction of the PV systems was not a motivation for the urban customers, in contrast to low-income groups of peri-urban and rural customers who engaged in multiple income-generating activities. The conventional wisdom was that productivity increase impact is important when implementing off-grid PVs (Bhalla and James, 1991; Schäfer *et al.*, 2011). However, we observed the increase of educational productivity to be a motivation in the case of the Client #1, while for Client #2 it was based on a social-orientation and a desire for self-sufficiency.

4.2.1 Client #1: Educational institution. The first case was a private school in Bangalore. It was a hundred-year-old academic institution, originally set up to help destitute women. An off-grid PV system from SELCO was installed to power a computer room in a new three-story building dedicated to children's education, planned to coincide with the centenary anniversary of the institution [9].

The first encounter between the client and SELCO was initiated through one email sent by a SELCO project manager. He was looking for a new kind of customer for its off-grid solar power generating system. Before joining SELCO, he worked for an organisation addressing environmental issues. That organisation had been using an online social

networking service as a communication tool to discuss environmental issues in Bangalore. To find a suitable candidate customer, he sent out an email on the platform mentioning his wish to get in touch with people interested in implementing a solar power generating system. Shortly after, he received a response from a science teacher at the school. She received the forwarded email from a member of the environmental organisation and then contacted the company directly because of her interest in the opportunity provided by the system. Her awareness of green services came from relatives having an eco-friendly house equipped with solar panels and composting for their organic garbage.

The initiation and development of the opportunity happened through such social networking as opposed to the traditional marketing approaches and visits made by SELCO in rural areas. Urban customers already had a pre-awareness of the type of technology and its potential suitability. And they were active on Internet-enabled social networking platforms, unlike users in rural areas. SELCO created a proposal specific for the installation to finalise the sale, a narrower and later stage activity compared to sales in rural areas. The importance of identifying the right contact person within an urban institution was also emphasised:

> Within the institution, you have to figure out who the contact point is. Whereas for [rural] individuals you know that it is one person. And sometimes they could be multiple people as contact points […] and then, if that person is not available then there's a backup person. […] (Project Manager).

Interestingly, the science teacher that we interviewed was a key individual who actively took on the initiative on behalf of institutional client she represented. The process was driven by her own growing understanding and appreciation for off-grid technology:

> The work to be done with institutions is a lot more complex because the systems are bigger but we are capable of doing that sort of project. […] The client kept changing their requirements. Every time they change the requirement we get them a new design. […] We gave four or five proposals (Project Manager).

In this case, the PV installation project was co-designed with the client, based on a continuous exchange of ideas. During the construction of the building, the project manager kept advising the client on technical issues relating to the appropriate installation of the system:

> We had to educate clients on how to provide a separate wiring scheme for connecting the solar system to the computers. We talk to the architects and make them understand the kind of wiring that is required (Project Manager)

Eventually, the solar panels were installed on the rooftop and the batteries were installed in a room beside that equipment. The teacher interviewed started considering the option for the school to sell its surplus energy back to the public electricity grid, even though this was not permitted at the time. The system did not have a metering-enabled device in it. To anticipate that option, the client wanted to know its feasibility:

> Is it possible to sell electricity? For example, we are not using energy during the weekend (Science Teacher).

During one site visit, the teacher asked SELCO to add an energy use record device of the consumption to their system. According to her, three motivations incited the school to install the system. The first motivation was securing the supply of energy: a stable energy source since the intermittent power outages hindered the usage of the computers. The client required 20 desktop personal computers at a wattage of 100 W to be powered for an average of 6 h a day. They also required 3 new compact fluorescent lamps lights for a usage of 3 h per day.

The second motivation was self-sufficiency of the system: an autonomous solar power generating system, to power the room rather than charging the backup batteries with the public grid electricity. The third motivation was a pedagogical purpose: a project to sensitise students to the PV system and other environmentally friendly technologies beneficial to society.

On SELCO's side, the motivation was to execute the project in a non-rural context – an important strategic step for the company. Based on this, SELCO became more willing to develop off-grid projects in the urban context. They were also aware that by installing their system within the premises of an educational institution, they could spread awareness of PV technology to different generations of students.

4.2.2 Client #2: Vegetarian restaurant and activists' centre. The second case was a restaurant offering sustainable plant-based food products. It included an activist centre and was in a popular area of Bangalore; a cradle for start-ups. The restaurant attracted a young community of citizens on a regular basis to debate events on challenges faced by the society on environmental issues (e.g. the 3R concept: Recycle-Reuse-Reduce) and on social issues (e.g. women upliftment, women self-defence workshop, gender equality) with a practical orientation. Sensitive to environmental issues, the restaurant owner decided to install an off-grid solar power generating system as an alternative energy source for lighting and fan ventilation. She came to know about the activity of SELCO through a friend having a classmate in the company.

According to the project manager, the client had three reasons to install the PV system. The first reason was self-sufficiency: the client was convinced of the reliability of the PV system given the R&D effort spent by SELCO in rural areas. The second reason was the social orientation of the company: the client believed that paying for SELCO's service in an urban context indirectly helped underserved rural communities to have access to electricity. The third reason was financial benefit: by installing the PV system, the client saved on electricity costs and recovered the initial cost through the savings realised on the grid supply, within a few years. Two motivations induced SELCO to fulfil this project. The first was that the PV installation in that specific urban area was likely to become newsworthy and spread to many more people in the vicinity. The second reason related to the restaurant's identity which helped the work of SELCO to be spread to a wider range of people interested in social and environmental issues in Bangalore.

Table 2 provides a summary of the case insights and emerging themes for each of the main concepts discussed above.

5. Discussion

The point of departure for the present study was the observation that addressing the failure of the modern infrastructure ideal in the Global South (Graham and Marvin, 2002), requires attention to the role of users in shaping the acceptance and configuration of infrastructure such as off-grid technology. These requirements are not always anticipated in advance by developers and technology producers. Indeed, Graham and Marvin (2022) emphasise this as a central concern in their retrospective of splintering urbanism. While it has been recognised that practical local knowledge and experience matters in this process (Kumar, 2021), the fact that improvisation is forced on individuals in the context of welfare abandonment (Balls, 2016) puts the interactions between users and social enterprises under the spotlight. The emergence of various forms of hybridised solutions is well-documented by scholars (Coutard and Rutherford, 2016; Monstadt and Schramm, 2017; Furlong, 2014; Larkin, 2008). However, the motivations and micro-dynamics for co-creation of legitimate off-grid solutions in new market niches is less well understood, especially niches that are different to those originally served by a social enterprise.

Table 2. Summary of case insights and emerging themes

Concept	Case insights	Emerging themes
Failure of the modern infrastructure ideal	Widespread acknowledgement of grid unreliability: Urban users, including migrant workers and the school and restaurant cases (Client #1 and #2), proactively sought alternative solutions due to grid unreliability	Market niche emergence: New types of clients in the form of environmentally savvy urban users
Hybridisation	Educated urban clients wanted to use solar PV systems as backups to the main grid — not replacements, but coexisting systems • Client #1's solution involved both grid supply and a SELCO-provided PV system for the school's computer room • Client #2 used solar PV for lighting and ventilation, while remaining partially connected to the grid SELCO's shift to urban projects developed their capabilities in integration of off-grid systems with grid-based supply	New entrants: Strategic shift of a social enterprise from rural to urban markets Developing capabilities: New technical capabilities within the social enterprise in needs analysis and system integration
Improvisation	SELCO project managers discovered clients via posts on emerging digital channels (e.g. email lists, social media) SELCO adjusted and re-worked designs multiple times based on changing client specific needs (e.g. roof layout, temperature and cooling considerations in rooms)	Iterative development of solutions: responsiveness to needs of digitally connected clients Incrementalism: Solving localised problems one by one with available resources
Co-creation of service	Project managers interacted with lead client and other professionals (e.g. architects) during construction • Client #1: The project was co-designed: multiple exchanges and revised proposals. The teacher requested an energy usage display (information purpose) and inquired about net-metering options • Client #2: The restaurant's owner chose SELCO for its social values. The client believed that using SELCO's urban service would support rural electrification (alignment of its social missions/values) SELCO adjusted its offering based on clients' differing motivations and created a new "urban institutional client" category. SELCO's staff exercised autonomy in identifying niche clients, reflecting entrepreneurial freedom	Enhanced client involvement: defining a new client category Autonomy: exercised by entrepreneurial social enterprise employees Expanded social mission: new emphasis on urban as well as traditional rural communities

Source(s): Authors' own work

5.1 Co-creation of the hybrid domain

The SELCO case highlights the concomitance of actions taken by two kinds of actors to co-create an emerging market for off-grid PV systems:

(1) socially minded corporate entrepreneurs with considerable autonomy operating within a social enterprise known for its societal commitments; and

(2) environmentally savvy urban customers with a range of purpose-oriented interests beyond basic power needs.

The cases represent collaborations that support the diffusion of what was perceived to be environmentally efficient off-grid technology addressing United Nations sustainable development goal (UN SDG) #7 at a local level. They show how these collaborations unfolded through urban users' purchasing power and willingness to explore alternative solutions to satisfy their own purpose and missions. Our work is supportive of research on how different actors engage in communities based on "green" technologies (Lange and Meier, 2009) while offering an alternative to the distinction seen in much of the literature on co-production between public agencies and users (Joshi and Moore, 2004; Bovaird and Loeffler, 2016).

On the one hand, what we see in our study is the involvement of end-users who already have knowledge and appreciation for environmental problems, their causes and potential remedies. We refer to these as environmentally savvy users and note how prior literature refers to them slightly differently, such as in terms of contribution by households to improvisation (Broto, 2019). It also complements the literature that highlights the role of street-level bureaucrats (Lipksy, 1980) and former civil servants (Ghertner, 2017) contributing to improvisation in facilitating people's access to basic services. On the other hand, the case provides insight into the role of a social enterprise in identifying opportunities for impact by understanding evolving aspirations of customers in the off-grid market that were not originally served by the strategic mission-oriented mandate of the enterprise. This contributes to the literature on sustainability transitions at a grassroots level (Hargreaves *et al.*, 2013; Grin *et al.*, 2010; Seyfang and Smith, 2007) by putting co-creation and aspirations of the middle-classes at the forefront, in contrast to literature that emphasises the technology-push and basic need in rural areas. A socially minded corporate entrepreneur within the social enterprise with a considerable degree of autonomy is seen as a key agent that utilises network connections to facilitate and initiate actions to implement an off-grid based technology in these new market spaces. These corporate entrepreneurs are seen to assume autonomy to identify new customers and continually adjust the offering based on emerging client-specific requirements. This emphasises the freedom of action left to the individuals within an established social enterprise and the spirit to develop new projects in new market niches (Sopjani *et al.*, 2019). It emphasises the organisation's culture that encouraged localised action to improvise with a client and design co-adapted, co-constructed solutions.

The case reveals how an organisational culture within a social enterprise can resonate with customers' needs and aspirations related to energy use and environmental awareness. In one case, a teacher was involved in defining a previously unexpressed demand for having an alternative access to energy in a computer room. This was not only about mitigating electricity grid failure, but it also had a pedagogical purpose. From such collaborative actions between socially minded corporate entrepreneurs and new types of customers an off-grid solution is co-created. This improvisation in the urban hybrid domain at the grassroots level is likely to resonate in other urban energy transitions across the Global South (Silver and Marvin, 2017).

5.2 Customer motivations in urban versus rural areas

Scholars have debated the motivations behind the rise of off-grid PV systems (Jaglin, 2012). The SELCO case indicates that in both rural and urban contexts, the problems of the grid electricity supply legitimise the emergence of a hybrid domain of action with participants coming from different spheres of the society. A first factor is access to an autonomous energy supply system that satisfies needs and reduces their dependency to the grid. A second factor is access to an additional and sustainable source of energy. However, in urban areas, additional factors drive customers to seek off-grid solutions. A third factor, then, is the deployment of a capability that contributes to spreading environmental awareness and supports the interests of a specific community (e.g. educational or activist). In rural underserved areas, adopting solar PV systems fosters citizenship through equitable access to services and is economically beneficial (Ahlers *et al.*, 2014; Moretto *et al.*, 2018). In contrast, our study shows that urban users can have different aspirations and motivations, and these are arguably more nuanced and complex than previously acknowledged, being rooted in their educational level, professional status and worldviews.

The case of Client #1 shows a performative action by which a user (a schoolteacher) initiated a first step based on her prior awareness and knowledge. She engaged in a learning by doing process and acted as a trailblazer for the institution she represented. She was a proactive user and added value to the social enterprise by providing SELCO with insights on potential modifications and additional features for their urban off-grid service, something that did not happen in rural areas. Customers' pre-existing levels of knowledge are linked to their motivations and proactivity. They are therefore an important component of the social enterprise innovation process and subsequent diffusion of off-grid technology. What stands out in our analysis is how motivations for off-grid solutions are differentiated across economic strata of society in the South (e.g. rural vs urban and even between different types of customers within urban areas).

5.3 Shifts in niche development for off-grid photovoltaic technology

The present analysis points to three underlying shifts that characterise the hybrid domain of off-grid solutions. The first shift concerns the rise of an urban niche market for solar PV in a context of heterogeneous infrastructure configuration. The company brought PV technology initially conceived for the rural market into an urban context. While centralised energy supply prevailed in cities, decentralised systems gained value because the grid was not able to cater to the growing needs of an increasing urban population. In such a context, a range of alternative solutions to the centralised supply of electricity is considered by society at large. The contribution of different types of actors working together to solve acute energy issues illustrates the growth in the hybrid domain of action in the field of basic service provision. The second shift concerns the evolution of the strategy and capabilities of the social enterprise: a service initially designed for poor customers is brought to middle class customers, from rural low-income to urban upper-middle income groups. For these new customers, the alternative off-grid energy source is an option but not an immediate need. New capabilities in market segmentation, technology adaptation and public relations were required. The third shift concerns the rising knowledge and awareness of urban customers on environmental issues. This shift encapsulates environmental awareness, protection of the world's finite resources and a desire for technology that is aligned with UN SDG goals. These emerging aspirations of middle-class customers in a metropolitan Global South city is different from that of the population of the rural areas.

5.4 Critical reflection and implications for policy

There are potential downsides related to the phenomenon revealed in this case. Firstly, there is an increasing dependence on private, non-State actors, both on the emerging market "pull" side of the equation, as well as on the technological "push" side. By letting private organisations form and manage the market for the provision of a basic service, public utilities are abandoning a share of their responsibility as market participants. By doing so, they may further undermine the reliability of grid-based options in the future. Improvisation in the cases was necessary; and the mind-sets and capabilities of non-State actors in working and re-working solutions as their learning unfolded appears to have been important to outcomes. It may be the case that State employees will not be as effective in this improvisational and problem-solving process as the types of non-State actors revealed in the cases. Nevertheless, the formation of a nascent market for off-grid solutions exclusively involving non-State actors may tie the market to private modes of governance and control for many years after its formation. Secondly, related to this is the notion that State actors were not a part of the projects at a grassroots level, preventing them from gaining early first-hand knowledge of client needs, motivations and site-specific workarounds. Such tacit knowledge can be useful for subsequent projects and market expansion. **Foregoing this early knowledge may put State agencies at a disadvantage and make it difficult for them to catch up in the future**. Thirdly, the phenomenon may lead to longer-term equity issues in rural-urban diffusion that need to be understood and managed. Inequality may come about as the type of systems and solutions developed for urban needs surpass those for rural needs in terms of sophistication and quality. If this became entrenched, a two-tier situation could arise in which the rural market is treated in a fundamentally different way to the urban market. In other words, newer technologies that may be more efficient in terms of energy capture and storage may start to be offered first to more affluent urban clients before the rural market. In this scenario, rural clients may even end up receiving the cast-off or previously used technology from urban clients, exacerbating inequality.

The State should be aware of these issues and can seek to play a role as a market maker in enabling off-grid solutions in new market niches, especially given its failure in providing a continuous electricity grid service (Aoyama and Parthasarathy, 2016). Our study suggests several ways this can be implemented. These include growing solar PV capacity, making the off-grid system more financially attractive and legislative conditions (e.g. safety guidelines, certifying service operators). Support for net-metering would also enable the State to contribute to the hybrid domain of action, and to compensate for its failures in running the centralised system. Furthermore, while urban markets are profitable, ways in which they benefit the rural market should be identified and encouraged. Social enterprises can reach new customer bases with the aim of democratising their service to include a wider range of actors in society. They can support the growth of an emerging niche by making their service affordable and adoptable assuming a conducive institutional landscape. Through this shift, social enterprises may then be able to cross-subsidise some of their activities in rural areas from the profit generated in urban projects. If this happens, these private entities will develop a similar role to the one played by the State that cross-subsidises the electricity tariff in rural areas by the profit generated in urban areas.

5.5 Limitations and conclusion

Limitations of the present study include the lack of generalisability to other countries, and to other cities within India. The main part of our interview data came from SELCO managers and employees at the time of specific projects and does not inform us of longer-term perceptions from a wider body of users and changes in hybridisation that ensued. We also did not capture quantitative indicators of financial performance for clients or SELCO. We did not investigate

how SELCO's experiences in urban markets influenced its continued approach to users in poorer, rural communities. Expansion of information technology based industries in cities such as Bangalore result in migrant construction workers from rural areas staying in temporary shelters that require access to electricity (this became known as the "rurban" segment). How private organisations engage with this market to deliver services, given that State actors can ignore this segment, is not something we examined. Future research can address these limitations and delve more deeply into the micro-dynamics of relationships between key actors in niche markets for off-grid technologies as they form part of the solution to the failed modern infrastructure ideal.

The dynamics between socially minded corporate entrepreneurs in a social enterprise and environmentally savvy users sheds light on how the urban market for off-grid energy production in the hybrid domain develops. Proactivity amongst corporate social entrepreneurs as well as educated users allows diffusion and an opening of new market niches for off-grid solutions. Motivations for shifting focus from rural to urban areas are different from those needed to continue penetration in rural areas. They highlight how an urban user base is an important force for promoting environmental improvements that align with UN SDGs and how socially minded corporate entrepreneurs with prior experience in rural areas are pivotal in fulfilling these motivations.

Notes

[1.] A micro level of technological and social change where actors try out new ideas in dedicated experimental projects (Hermans *et al*., 2013).

[2.] This refers to classification of city population: first-tier city (5 million inhabitants and above); second-tier city (500,000 to 5 million inhabitants); third-tier city (less than 500,000 inhabitants).

[3.] Organisational improvisation is "the conception of action as it unfolds, by an organisation and/or its members, drawing on available material, cognitive, affective and social resources" (Cunha, and Kamoche, 1999, p. 302).

[4.] In 2010, "the outage faced by a customer on an average was 86 hours per year with large interims per outage" (Balijepalli *et al*., 2010). In 2018, an average of 115 hours of outage per year was recorded in urban Bangalore.

[5.] The demand for solar PV lighting systems was not recent in the Indian context: In 1993, a market survey in Madurai (Tamil Nadu) indicated that solar PV technology attracted commercial users as a cost-effective and viable alternative to conventional engine generator portable sets.

[6.] The back-up off-grid systems were rather a collection of independent, individual devices adopted in response to the failure of the public grid electricity supply system.

[7.] SELCO as of July 2020 had over 500 people working in more than 50 branches in Andhra Pradesh, Bihar, Karnataka, Kerala, Maharashtra, and Tamil Nadu (SELCO India, 2020).

[8.] A project manager, a design engineer and a service engineer.

[9.] With ten PV panels (3000 Wp in total) and ten batteries (180 Ah), the system supplies power to computers and ceiling lights. The total investment cost was 600 000 Rs.

References

Ahlers, R., Cleaver, F., Rusca, M. and Schwartz, K. (2014), "Informal space in the urban waterscape: disaggregation and co-production of water services", *Water Alternatives*, Vol. 7 No. 1, pp. 1-14.

Aoyama, Y. and Parthasarathy, B. (2016), *The Rise of the Hybrid Domain: Collaborative Governance for Social Innovation*, Edward Elgar Publishing.

Baker, T. and Nelson, R.E. (2005), "Creating something from nothing: resource construction through entrepreneurial bricolage", *Administrative Science Quarterly*, Vol. 50 No. 3, pp. 329-366.

Balijepalli, V.M., Khaparde, S.A., Gupta, R.P. and Pradeep, Y. (2010), "SmartGrid initiatives and power market in India", *IEEE PES General Meeting*, IEEE, pp. 1-7.

Balls, J. (2016), "Fluid capitalism at the bottom of the pyramid: a study of the off-grid solar power market in Uttar Pradesh, India", Doctoral dissertation, University of Oxford.

Bhalla, A.S. and James, D.D. (1991), "Integrating new technologies with traditional economic activities in developing countries: an evaluative look at 'technology blending'", *The Journal of Developing Areas*, Vol. 25 No. 4, pp. 477-496.

Bhandari, R. and Stadler, I. (2009), "Grid parity analysis of solar photovoltaic systems in Germany using experience curves", *Solar Energy*, Vol. 83 No. 9, pp. 1634-1644.

Bocquet, D., Chatzis, K. and Sander, A. (2008), "From free good to commodity: Universalizing the provision of water in Paris (1830–1930)", *Geoforum*, Vol. 39 No. 6, pp. 1821-1832.

Bovaird, T. and Loeffler, E. (2016), "What has co-production ever done for interactive governance", *Critical Reflections on Interactive Governance: Self-Organization and Participation in Public Governance*, Vol. 12, p. 254.

Broto, V.C. (2017), "Energy landscapes and urban trajectories towards sustainability", *Energy Policy*, Vol. 108, pp. 755-764.

Broto, V.C. (2019), *Urban Energy Landscapes*, Cambridge University Press.

Bulkeley, H. and Castán Broto, V. (2014), "Urban experiments and climate change: securing zero carbon development in Bangalore", *Contemporary Social Science*, Vol. 9 No. 4, pp. 393-414.

Byrne, R., Mbeva, K. and Ockwell, D. (2018), "A political economy of niche-building: neoliberal-developmental encounters in photovoltaic electrification in Kenya", *Energy Research and Social Science*, Vol. 44, pp. 6-16.

Coutard, O. (2018), "Placing urbanism: Introduction", *Geoforum*, Vol. 39 No. 6, pp. 1815-1820.

Coutard, O. and Rutherford, J. (Eds) (2016), *Beyond the Networked City: Infrastructure Reconfigurations and Urban Change in the North and South*, Routledge.

Dacin, M.T., Dacin, P.A. and Tracey, P. (2011), "Social entrepreneurship: a critique and future directions", *Organization Science*, Vol. 22 No. 5, pp. 1203-1213.

Dupont, L., Kasmi, F., Pearce, J.M. and Ortt, R.J. (2023), "'Do-It-Together' and innovation: transforming European industry", *Journal of Innovation Economics and Management*, Vol. 40 No. 1, pp. 1-11.

Furlong, K. (2014), "STS beyond the 'modern infrastructure ideal': extending theory by engaging with infrastructure challenges in the South", *Technology in Society*, Vol. 38, pp. 139-147.

Ghertner, D.A. (2017), "When is the state? Topology, temporality, and the navigation of everyday state space in Delhi", *Annals of the American Association of Geographers*, Vol. 107 No. 3, pp. 731-750.

Gopakumar, G. (2015), "Who will decongest Bengaluru? Politics, infrastructures and scapes", *Mobilities*, Vol. 10 No. 2, pp. 304-325.

Graham, S. and Marvin, S. (2002), *Splintering Urbanism: networked Infrastructures, Technological Mobilities and the Urban Condition*, Routledge.

Graham, S. and Marvin, S. (2022), "Splintering urbanism at 20 and the 'infrastructural turn'", *Journal of Urban Technology*, Vol. 29 No. 1, pp. 169-175.

Grin, J., Rotmans, J. and Schot, J. (2010), *Transitions to Sustainable Development: new Directions in the Study of Long Term Transformative Change*, Routledge.

Hargreaves, T., Hielscher, S., Seyfang, G. and Smith, A. (2013), "Grassroots innovations in community energy: the role of intermediaries in niche development", *Global Environmental Change*, Vol. 23 No. 5, pp. 868-880.

Hartley, J. (2004), "Case study research", in Cassell, C. and Symon, G. (Eds.), *Essential Guide to Qualitative Methods in Organizational Research*, Sage, London, pp. 323-333.

Heredia, M.G., Sánchez, C.S.G. and González, F.J.N. (2024), "Integrating lived experience: qualitative methods for addressing energy poverty", *Renewable and Sustainable Energy Reviews*, Vol. 189, p. 113917.

Hermans, F., Van Apeldoorn, D., Stuiver, M. and Kok, K. (2013), "Niches and networks: explaining network evolution through niche formation processes", *Research Policy*, Vol. 42 No. 3, pp. 613-623.

Hostettler, S. (2015), "Energy challenges in the global South", *Sustainable Access to Energy in the Global South: Essential Technologies and Implementation Approaches*, Springer International Publishing, Cham, pp. 3-9.

Jaglin, S. (2012), "Networked services and features of African urbanization: other path toward globalization", *L'Espace Géographique (English Edition)*, Vol. 41 No. 1, pp. 51-67.

Joshi, A. and Moore, M. (2004), "Institutionalised co-production: unorthodox public service delivery in challenging environments", *Journal of Development Studies*, Vol. 40 No. 4, pp. 31-49.

Joshi, G. and Yenneti, K. (2020), "Community solar energy initiatives in India: a pathway for addressing energy poverty and sustainability?", *Energy and Buildings*, Vol. 210, p. 109736.

Joshi, L., Choudhary, D., Kumar, P., Venkateswaran, J. and Solanki, C.S. (2019), "Does involvement of local community ensure sustained energy access? A critical review of a solar PV technology intervention in rural India", *World Development*, Vol. 122, pp. 272-281.

Kumar, A. (2021), "Between Metis and Techne: politics, possibilities and limits of improvisation", *Social and Cultural Geography*, Vol. 22 No. 6, pp. 783-806.

Lange, H. and Meier, L. (Eds.) (2009), *The New Middle Classes: globalizing Lifestyles, Consumerism and Environmental Concern*, Springer Science and Business Media.

Larkin, B. (2008), *Signal and Noise: Media, Infrastructure, and Urban Culture in Nigeria*, Duke University Press, Durham, NC.

Lawhon, M., Nilsson, D., Silver, J., Ernston, H. and Lwasa, S. (2018), "Thinking through heterogeneous infrastructure configurations", *Urban Studies*, Vol. 55 No. 4, pp. 720-732.

Lawhon, M., Nsangi Nakyagaba, G. and Karpouzoglou, T. (2023a), "Towards a modest imaginary? Sanitation in Kampala beyond the modern infrastructure ideal", *Urban Studies*, Vol. 60 No. 1, pp. 146-165.

Lawhon, M., Follmann, A., Braun, B., Cornea, N., Greiner, C., Guma, P., Karpouzoglou, T., Revilla Diez, J., Schindler, S., Schramm, S., Sielker, F., Tups, G., Vij, S. and Dannenberg, P. (2023b), "Making heterogeneous infrastructure futures in and beyond the global South", *Futures*, Vol. 154, pp. 1-15.

Lévi-Strauss, C. (1966), *The Savage Mind, Chicago*, The University of Chicago Press.

Lipsky, M. (1980), *Dilemmas of the Individual in Public Services*, Russell Sage, New York, NY.

Monstadt, J. and Schramm, S. (2017), "Toward the networked city? Translating technological ideals and planning models in water and sanitation systems in Dar Es Salaam", *International Journal of Urban and Regional Research*, Vol. 41 No. 1, pp. 104-125.

Moretto, L., Faldi, G., Ranzato, M., Rosati, F.N., Ilito Boozi, J.P. and Teller, J. (2018), "Challenges of water and sanitation service co-production in the global South", *Environment and Urbanization*, Vol. 30 No. 2, pp. 425-443.

Mukhopadhyay, B.R. and Mukhopadhyay, B.K. (2018), "The instrumentality of solar energy entrepreneurs in transforming rural lives in India", *Indian Journal of Regional Science*, pp. 109-120.

Offenhuber, D. (2019), "The platform and the Bricoleur—improvisation and smart city initiatives in Indonesia", *Environment and Planning B: Urban Analytics and City Science*, Vol. 46 No. 8, pp. 1565-1580.

Pereira, M.G., Freitas, M.A.V. and da Silva, N.F. (2011), "The challenge of energy poverty: Brazilian case study", *Energy Policy*, Vol. 39 No. 1, pp. 167-175.

Philibert, C. (2006), "Barriers to technology diffusion: the case of solar thermal technologies".

Sawamura, H. and Amiraly, A. (2015), "Diffusion of alternative electricity supply solution in Bangalore: the emergence of a market for Middle-income customers with new aspirations, case studies of SELCO and BCIL promoting photovoltaic systems", *Proceedings, MES, 2015*, pp. 85-89.

Schäfer, M., Kebir, N. and Neumann, K. (2011), "Research needs for meeting the challenge of decentralized energy supply in developing countries", *Energy for Sustainable Development*, Vol. 15 No. 3, pp. 324-329.

SELCO India (2014), "SELCO solar light private limited", available at: www.selco-india.com (accessed 14 June 2021).

SELCO India (2020), "SELCO solar light private limited: who we are", available at: www.selco-india.com/who-we-are (accessed 1 October 2020).

SELCO India (2024), "SELCO solar light private limited: Our philosophy", available at: https://selco-india.com/who-we-are (accessed 10 July 2024).

Seyfang, G. and Longhurst, N. (2013), "Desperately seeking niches: Grassroots innovations and niche development in the community currency field", *Global Environmental Change*, Vol. 23 No. 5, pp. 881-891.

Seyfang, G. and Smith, A. (2007), "Grassroots innovations for sustainable development: towards a new research and policy agenda", *Environmental Politics*, Vol. 16 No. 4, pp. 584-603.

Silver, J. (2014), "Incremental infrastructures: Material improvisation and social collaboration across post-colonial accra", *Urban Geography*, Vol. 35 No. 6, pp. 788-804.

Silver, J. and Marvin, S. (2017), "Powering Sub-Saharan Africa's urban revolution: an energy transitions approach", *Urban Studies*, Vol. 54 No. 4, pp. 847-861.

Simone, A. (2004), "People as infrastructure: intersecting fragments in Johannesburg", *Public Culture*, Vol. 16 No. 3, pp. 407-429.

Singh, K. (2016), "Business innovation and diffusion of off-grid solar technologies in India", *Energy for Sustainable Development*, Vol. 30, pp. 1-13.

Sopjani, L., Stier, J.J., Ritzén, S., Hesselgren, M. and Georén, P. (2019), "Involving users and user roles in the transition to sustainable mobility systems: the case of light electric vehicle sharing in Sweden", *Transportation Research Part D: Transport and Environment*, Vol. 71, pp. 207-221.

The government of India (2010), "Jawaharlal Nehru national solar mission—towards building solar India", Ministry of new and renewable energy, available at: www.indiaenvironmentportal.org.in/files/mission-document-JNNSM.pdf (accessed 15 December 2021).

The government of Karnataka (2014), "Solar policy 2014-2021", Karnataka Renewable Energy Development Limited, available at: www.cbip.org/policies2019/PD_07_Dec_2018_Policies/Karnataka/1-Solar/Kranataka%20SP%20Summary%20.pdf (accessed 22 May 2014).

van Gils, B.A. and Bailey, A. (2023), "Revisiting inclusion in smart cities: infrastructural hybridization and the institutionalization of citizen participation in Bengaluru's peripheries", *International Journal of Urban Sciences*, Vol. 27 No. sup1, pp. 29-49.

Velayudhan, S.K. (2003), "Dissemination of solar photovoltaics: a study on the government programme to promote solar lantern in India", *Energy Policy*, Vol. 31 No. 14, pp. 1509-1518.

Verdeil, E. and Jaglin, S. (2023), "Electrical hybridizations in cities of the South: from heterogeneity to new conceptualizations of energy transition", *Journal of Urban Technology*, Vol. 30 No. 2, pp. 1-10.

Werulkar, A.S. and Kulkarni, P.S. (2015), "A case study of residential solar photovoltaic system with utility backup in Nagpur, India", *Renewable and Sustainable Energy Reviews*, Vol. 52, pp. 1809-1822.

Williams, C., Hailemariam, A.T. and Allard, G. (2022), "Exploring entrepreneurial innovation in Ethiopia", *Research Policy*, Vol. 51 No. 10, p. 104599.

Yaqoot, M., Diwan, P. and Kandpal, T.C. (2014), "Solar lighting for street vendors in the city of Dehradun (India): a feasibility assessment with inputs from a survey", *Energy for Sustainable Development*, Vol. 21, pp. 7-12.

Yin, R.K. (2011), *Applications of Case Study Research*, Sage publications.

Further reading

International Energy Agency Photovoltaic Power System Programme (2018), "Snapshot of global photovoltaic market", Paris: International Energy Agency. Report No.: IEA PVPS T1-33, available at: www.iea-pvps.org/fileadmin/dam/public/report/statistics/IEA-PVPS_-_A_Snapshot_of_Global_PV_-_1992-2017.pdf (accessed 15 December 2020).

Karnataka Renewable Energy Development Limited (2021), "Details of year wise commissioned projects of renewable category in MW as on November-2021".

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