Limits of the corporate-led market approach to off-grid energy access: A review

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ABSTRACT

Markets not only enable wide technology diffusion but also shape sustainability transitions. From this perspective, it is critical to investigate the shaping effects of markets and market formation processes for human wellbeing and the environment. Through a systematic literature review, this study explores the limitations of the dominant corporate-led market development model. This constitutes the global compass for present-day energy access programs and international development policy, framed around the potential of foreign-affiliated corporate enterprises for the market-based diffusion of solar products in the Global South. Findings suggest that due to tradeoffs between people, planet, and profit-directed goals, the companies cannot enable sustainability transitions and equal and sustainable access to the energy poor. Instead, the corporate-led market development route reproduces structural injustices. A more pluralistic route with greater roles for local, non-affiliated entrepreneurs, non-profits, and the public sector is proposed for negotiating the tradeoffs to the extent possible.

1. Introduction

Markets are critical for large-scale diffusion of new technologies, as well as crucial enablers of sustainability transitions (Boon et al., 2020; Geels, 2004; Santos and Eisenhardt, 2017). At the same time, how markets are shaped matters a great deal for the outcomes they give rise to (Feola, 2020). Markets can act as the primary vehicles that facilitate the provision and uptake of life-supporting technologies that meet basic human needs. Yet they may also provide incentives that put sustainability at stake, and can reproduce structural forms of injustice by determining who can avail of particular solutions and on which conditions, and who is bypassed (Baurzhan and Jenkins, 2016; Bombaerts et al., 2020). Especially in contexts characterized by extreme poverty, there are rising concerns about unanticipated excesses of markets as vehicles for technology dissemination and development (Arora and Romijn, 2012; Davies, 2018). Adverse effects are more likely when private firms act in situations characterized by pervasive market imperfections: where important resources are not readily available, critical infrastructure exhibits constraints, institutions for regulation and oversight are weak, and clientalism and patriarchal relations are common (Ramos-Mejía and Balanzo, 2018). There is a growing recognition that due to reasons of context, market formation in the Global South and North may unfold differently (Cross and Neumark, 2021; Groenewoudt et al., 2020), just like there are substantial variations in the way overall sustainability transitions take shape in these different environments (Cherunya et al., 2020; van Welie, Cherunya, Truffer, and Murphy, 2018; Wiczorek, 2017).

In the Global South, private market actors play an especially crucial role in the diffusion of new technologies because governments...
fail to develop adequate public systems for the provision of basic services while donor-driven programs alone don’t succeed in creating sufficient large scale durable impact (Hansen et al., 2015; Sesan, 2014). Based on the argument that otherwise people in the Global South won’t get equal and sustainable access to basic services, international policy and development programs support a ‘corporate-led market development’ route (Bensch et al., 2018; Ockwell et al., 2017). The supported companies are typically medium or large foreign enterprises and affiliated to donors and investors from abroad (Sesan, 2014; Serraj et al., 2015). They attempt to create markets by means of developing business models especially designed to serve the ‘Base of the Pyramid’ (BoP). This way, they aspire to unlock commercial opportunities and guarantee financial sustainability while providing affordable access to the world’s poorest populations and addressing wider societal and environmental challenges (e.g. Dembek et al., 2020; Zerriffi, 2011). The firms pursue a win-win for people, profit and planet that is pivotal to foster sustainability transitions. Once established, companies use their business models to increase scale and expand markets (Bocken et al., 2016; Jolly et al., 2012).

Increasingly, however evidence is becoming available that shows that there are limits to this corporate-led market development model, especially in the off-grid solar energy access domain (Cross and Neumark, 2021; Samarakoon, 2020). Corporate market-based development as a primary mechanism for poverty alleviation and welfare might be inadequate to serve the very poor and reproduce structural forms of injustice (Kumar et al., 2019; Sovacool et al., 2020). Schot and Steinmüller (2018) suggest that it could contribute directly to inequality because the internationally supported foreign firms favor high tech ‘high quality’ solutions, producing innovations that are only accessible for customers with substantial purchasing power. Recent literature and discourse appear to suggest that the contemporary model as such may not enable a sustainability transition along all its essential dimensions and may offer a partial solution at best (Bensch et al., 2018; Conway et al., 2019; Sesan, 2012; Radley, 2021).

This paper acknowledges the necessity of markets for sustainability transitions; however, it critically examines how the current dominant corporate-led market development trajectory shapes the economic, social, and environmental outcomes in the Global South, and offers a response to calls to identify sustainability pathways for socially and environmentally inclusive transitions (e.g. Antal et al., 2020; Köhler et al., 2019; Leach et al., 2012; Nilsson et al., 2013). More specifically, this study assesses the potentials and limitations of the current market-development model by studying the latest developments in the off-grid solar markets. Sub-Saharan Africa’s and Southern Asia’s solar markets are considered frontrunners in corporate-driven BoP innovation. With an estimated annual sales volume of around 8 million solar devices in 2019, realized by international solar companies that are supported by global energy initiatives such as the World Bank’s energy program Lighting Global and the Global Off-Grid Lighting Association (GOGLA) (hereafter denoted as ‘affiliate’ companies), the sector counts as one the first sustainable technology sectors of substantial size in the international development domain (Lighting Global, 2020). In areas unreached by the grid, solar products like solar home systems and solar lanterns can help close the gap in the electricity system for poor and rural households (UN Energy, 2021; Ojong, 2021). Global off-grid solar capacity increased 10-fold in the last decade. US$ 1700 million was invested in private sector projects in 2020. The World Bank’s Lighting Global program claimed to have outfitted 470 million Africans with off-grid solar products (Lighting Global, 2020).

The review presents a systematic analysis of solar business literature, a growing body of literature that offers insights in the sustainability issues that arise in the sector and how companies deal with them, and sheds light on what solar enterprises can, and cannot, achieve in BoP settings. The discourse in this literature is becoming increasingly critical about the impact of international companies (Cross and Neumark, 2021; Ockwell et al., 2017). By identifying so-called sustainability tradeoffs that the firms run into, we synthesize and gain systematic insights from the scientific literature and use this to draw lessons about the limits of the dominant market-based development model for the diffusion of solar technology. We find tradeoffs between different sustainability dimensions that cannot always be mitigated, making it impossible to achieve one goal without hampering progress towards another goal and force companies to choose between, for instance, pursuing profit and serving the most impoverished and remotely located populations. These trade-offs prevent companies from realizing a win-win for people, profit and planet and appear to be responsible for undesirable outcomes arising from the fast growth of the solar market that are generated when businesses scale up without succeeding in mitigating them.

This study discusses the implications of the tradeoffs and concludes that expectations about the dominant market creation approach led by foreign companies, in its current form, are too high, and that alternative and complementary solutions need to be explored if we are to achieve universal energy access and sustainability transitions. The study seeks to advance the debate around corporate-led market-based development by pinpointing the gaps and possibilities to create realistic expectations. In this regard the study also responds to recent requests for a re-assessment of the dominant support for Global North-initiated entrepreneurship models based on the argument that alternative market formation models with a central role for local, nonaffiliated enterprises has sustainability potential as well (Groenewoudt et al., 2020; Meagher, 2018; Samarakoon et al., 2021; Sanyal et al., 2020).

The paper starts, in Section 2, with a discussion of the dominant contemporary corporate-driven development paradigm for the market-led diffusion of new technologies to improve lives. Section 3 sets out the method of the systematic literature analysis and Section 4 presents the findings from the review of BoP solar business literature. The study concludes with a discussion on the limitations of the current corporate market development model in the off-grid solar sector in the Global South for sustainability transitions and offers alternative perspectives (Section 5).

2. The contemporary market development paradigm

In low-income countries technology dissemination is not only key in a transition to lower carbon energy sources but also in the provision of services for basic human needs. Reaching universal access to essential services is high on the international policy agenda with goals for access to basic life-supporting services and financial services (SDG 1), food and agriculture solutions (SDG 2), healthcare services (SDG 3), education (SDG 4), safe water and sanitation (SDG 6), clean energy (SDG 7), internet, information and communication and financial services (SDG 9), and sustainable housing (SDG 11). Markets are put forward as the main instrument to facilitate
the large-scale uptake of SDG-promoting technologies in all these sectors (Ramani et al., 2012; Sesan et al., 2013). In large parts of (rural) Africa, the Indian subcontinent and South-East Asia, and particularly among the poor, the provision of basic energy (and other) services access is no longer seen as the typical role of state-owned power utilities and rural energy agencies (Bardouille, 2012). This role has primarily been taken over by private sector actors functioning as new ‘development agents’ (Blowfield and Dolan, 2014) who are expected to cover the gaps in inefficient public systems (Dumalanedee et al., 2020).

This is a consequence of the fact that the dominant approach to development of poor countries pursued by the world’s big aid donors since the early 1980s has been based on neoliberal principles in line with the “Washington Consensus”, which advocates free markets as the most efficient means of distributing resources. In broad terms, the approach stands for government policy reform, in particular the pursuit of macroeconomic stability through control of inflation and fiscal deficits; unimpeded trade and investment flows with the rest of the world, and liberalized domestic product and factor markets through privatization and deregulation (e.g., Gore, 2000; Hurt, 2020; Rapley, 2007). In this approach, markets are seen as the main vehicle through which development benefits can - and should be - delivered. In the words of Mendoza and Thelen (2008): “Markets provide myriad benefits to those able to gain access and participate successfully in them. … markets can be an engine not just of overall economic growth but also of individual human development and economic empowerment” (p. 427). Business is seen as the main protagonist in this strategy, rather than governments or NGOs, whose impacts on development in the post-WWII period had come to be viewed with widespread disappointment and disillusion (McKague et al., 2011; Esman et al., 1997; Hunt, 1989). While it is acknowledged that barriers to the full participation in markets by certain groups and individuals can occur, and issues emanating from incomplete markets do exist, this is no longer primarily seen as constituting an agenda with non-commercial actors in the lead. In any case, the importance of areas like institution-building and targeted efforts to improve opportunities for the weakest in society, which are arguably very important in many Global South contexts and which do not lend themselves well to commercial approaches according to leading critics of the approach, became de-emphasized (Stiglitz and Narcís, 2008).

An important consequence of the paradigm shift towards market-based development has been that, especially since the formulation of the Millennium Development Goals (MDGs) in 2000 and the UN Johannesburg World Summit on Sustainable Development in 2002, the clear boundary that previously existed between for-profit businesses and non-profit non-governmental organizations (NGOs) has blurred. These two traditional organizational forms have become the two extremes on a complex continuum with a variety of “hybrid” organizations in between (Bocken et al., 2016). Along the continuum lie different shades of “social”, “inclusive”, “sustainable”, and “green” enterprises for whom profit is a way to sustain their activities, rather than a goal in itself. The development aid landscape, traditionally revolving around funding of governments and NGOs, underwent a sea change in the early 21st century as donors became specifically focused on reaching the MDGs by stimulating firms and NGOs alike to go hybrid, in the direction of “doing business with the poor”. Development programs such as those administered by the UNDP (2008) became focused on encouraging business to pursue combined financial viability and anti-poverty impact in the belief that such a win-win strategy is indeed possible (Chesbrough et al., 2006; Martinot et al., 2001). Non-traditional funders such as impact investors have also been fast increasing in importance in developing countries. Many NGOs converted themselves into social enterprises to avoid being annihilated by the shrinking development funding for non-profits in donor countries, while taking advantage of the newly emerging financing opportunities for-profits with a societal mission. Conversely, the for-profit business sector came to embrace stronger societal goals to greater or lesser degree, beyond traditional Corporate Social Responsibility sideline activities (Newell and Frynas, 2007).

The business-cum-development paradigm is centered around the idea of Prahalad and Hart (1999) that the world’s poorest populations at the Base of the Pyramid form a large potential customer market full of unfulfilled needs and opportunities for entrepreneurs (Dolan and Roll, 2013). Tapping into these potential markets requires viable business models that can service low income households and deal with context-specific deficits like underdeveloped infrastructure, last-mile distribution problems, and weak formal institutions (Barrie and Crucshank, 2017; Scott, 2017; Seelos and Mair, 2005; Simanis, 2011; Tigabu et al., 2015; Yunus et al., 2010). These are expected to be developed by, or in partnership with the private sector, more specifically with western corporations or firms with western origins or linkages in a leading role (London and Hart, 2010).

Initially, the BoP argument was introduced as a possibility of combining profit making with serving the poor (known as BoP 1.0) but soon became contested (Blowfield and Dolan, 2014; Karnani, 2006; Simanis, 2012). Especially after ethical criticism, attention shifted to so-called BoP 2.0 approaches aiming for more local embeddedness, emphasizing business co-venturing or partnering between western companies and local parties and moving to models with job opportunities for the BoP population in functions like sales, distribution and even co-invention (Hart and London, 2005; Hart and Sharma, 2004). Most recently, scholarly BoP literature has steered towards a third generation of BoP strategies (BoP 3.0) which extends the scope to environmental sustainability concerns, moving towards a genuine triple bottom line perspective. This indicates that the BoP scholarly community itself has begun to perceive crucial shortcomings in extant BoP strategies and sees the need for a shift towards truly holistic solutions and engagement through wider innovation ecosystems approaches (Cateque and Hart, 2017; Bradley et al., 2020; Madsen, 2020; Mason and Chakrabarti, 2017; Nosratabadi et al., 2019), thus setting a more ambitious agenda that aligns with the aim of this paper.

Still, especially in the energy sector, the evolution from the initial BoP 1.0 to its later versions appears incremental in the sense that the international policy and aid strategy has remained fixated on market-driven development framed around large international companies affiliated to donors and investors from the Global North (Serraj et al., 2015; Sesan et al., 2013; Ockwell et al., 2017), with local, often small-scale and informal parties without foreign affiliations at best seen in dependent subsidiary roles. This is the case notwithstanding a resurfacing emphasis over the past two decades in the international development discourse on pro-poor and inclusive development, in the face of pervasive human fallouts from the push for strong neoliberal reformism in poor countries in the 1980s and 1990s. Based on the premise that foreign-affiliated companies can deliver high quality products and services to the poor at affordable prices, the corporate BoP players are expected to pull the cart that will ultimately result in widespread development “trickle down”
effects. They are the ones that continue to receive support from donors, the World Bank, international development programs and institutions like Lighting Global, UN Development Program (UNDP), Global Off-Grid Lighting Association (GOGLA), International Renewable Energy Agency (IRENA), and impact investors like the Royal Dutch Shell Foundation and Japan’s Mitsubishi Corp (Ojong, 2021; Lighting Global, 2020). Energy and development programs call on them for holistic development solutions framed around the integral implementation of the Sustainable Development Goals (SDGs) (Fly and Bell, 2009; Rizza, 2019) and stimulate them to address sustainability problems e.g. by integrating responsible production methods and waste recycling (GOGLA, n.d.; SDG Compass, n.d.).

While the corporate-led market-based development model envisions a triple-bottom-line (people, planet, profit), scholars have begun to raise concerns that these companies cannot live up to the paradigm’s high expectations (e.g. Cross and Neumark, 2021). Ockwell et al. (2017) and Bensch et al. (2018) argue, for instance, that the kind of private sector approach that funders and development agents currently prioritize does not function financially sustainably in absence of promotion programs or at least supportive regulatory interventions such as import tariff waivers on product components. Despite upbeat stories of business bringing ‘solutions’ in the off-grid solar sector, few if any companies appear to have reached their break-even point and financial independence yet (Ockwell and Byrne, 2016). The bankruptcy in 2019 of a big solar home systems provider operating in East Africa, the German-backed MobiSol, was a big wake up call to the industry as a whole (Shambhani, 2019). Even with the solar market reaching a substantial size with a sales volume of 30 million in 2018 and 2019 and international companies like BBOXX, SolarNow, and Azuri Technologies scaling up their business activities there is still need for US$ 6.6–11 billion in additional financing to reach the remaining 617 million people with off-grid energy products (Lighting Global, 2020; Kizilcec and Parikh, 2020; Ojong, 2021).

Furthermore, there are signs that companies fall short in delivering on the other central dimensions of the much-anticipated people-planet-profit benefits, suggesting that they cannot create the win-win that is needed for a sustainability transition. Pressurized by the need to pursue their commercial break-even point through fast upscaling strategies, firms appear to target the better-off sections of the BoP and exclude the most impoverished communities, whereas especially for those populations improved energy access is a critical component in the fight against poverty and realization of improved living standards (Grimm, 2020; Szabó et al., 2016). Moreover, there are concerns about companies’ production of e-waste in the African solar market (Hansen et al., 2021), and an increasing number of studies highlights such issues in various sustainability domains, especially in the off-grid energy sector. Despite growing concerns, we lack an integral overview of such issues as a response to the sector’s possibly too high expectations.

BoP literature points towards the issue of ‘tradeoffs’ as an underlying problem that hinders companies from designing sustainable and holistic business models that are essential to addressing all three social, economic, and environmental pillars of sustainable development (Kolk et al., 2014). As a result, BoP ventures are co-producing negative along with positive effects for the BoP (Arnold and Williams, 2012; Hall et al., 2012; Likoko and Kini, 2017), for instance, when businesses fail to succeed in their aim to serve deeply impoverished populations because of the slim profit margins and high costs of bridging the ‘last mile’ in remote locations, factors that interfere with meeting the need for financial viability. Empirical case-based evidence suggests that in the energy sector too, such tradeoffs form a structural problem for the realization of sustainability transitions and that, despite best intentions, such contradictions prevent solar companies from achieving the best outcomes for society and the environment (Balls, 2020; M. Grimm and Peters, 2016; Groenewoudt et al., 2020). This study reviews the solar business literature through the lens of such tradeoffs. To this end we adopt the definition from sustainability and SDG-focused literature that describes tradeoffs as situations (not in business context per se) where the achievement of one goal constrains, counteracts or cancels progress towards other sustainability goals, and that discusses the issue of tradeoffs in relation to consistent implementation of the UN’s agenda for sustainable development (e.g. McCollum et al., 2018; Nilsson et al., 2016; Weitz et al., 2018). The next section sets out the method for the literature review and analysis.

3. Method

3.1. Literature selection and analysis

To identify and analyze the tradeoffs that hamper the unfolding of sustainability transitions the study started with collecting a primary sample of scientific, peer-reviewed solar business literature for the review. More specifically, we selected literature discussing

**Table 1**

| Database          | Search criteria                                                                 | Selection criteria                                                                 |
|-------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Scopus            | (“solar home system”*) - (“off-grid”*) - (“pico product”*) - (“solar product”*) - (“solar lantern”*) | •Studies discussing companies active in the off-grid solar market (solar home systems, solar lanterns and solar pico products sold to households), and more specifically; |
|                   | AND Title-Abs-Key (“business”*) - (“corporate”*) - (“corporation”*) - (“initiative”*) - (“venture”*) - (“multinational”*) - (“partnership”*) - (“enterprise”*) - (“entrepreneur”*) - (“company”*) - (“companies”*) - (“shop”*) - (“dealer”*) - (“supplier”*) - (“vendor”*) - (“firm”*) - (“market”*) - (“organization”*) - (“for-profit”*) | •Including only studies focusing on enterprises, firms, businesses, and other market-based initiatives that commit to pursuing financial viability. Both fully commercial and “hybrid” enterprise forms qualified for they share the common requirement to pursue a break-even point; |
|                   | AND limit to document type “ar” and “re” AND limit to subject area “SOC” or “ENER” or “ENV” or “BUS” AND limit to language “English” AND limit to year “2016” or “2017” or “2018” or “2019” or “2020” or “2021” search result: 348 publications | •non-profits are excluded. |
|                   | criterion applied: “6.6–11 billion in additional financing to reach the remaining 617 million people with off-grid energy products” |

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- criterion applied: "6.6–11 billion in additional financing to reach the remaining 617 million people with off-grid energy products"
solar enterprises that deliver solar home systems, solar lanterns and solar ‘pico’ products to households in sub-Saharan Africa and southern Asia; the areas where the solar household solutions are most popular. The review includes publications from 2016 onwards, as we expect this selection to cover the main period of research for that describes the impact of established, internationally supported solar companies, most of which were founded between 2011 and 2013 (Lighting Global, 2020). Relevant publications were identified through application of the search and selection criteria set out in Table 1. This led to the selection of 36 articles published between January 2016 and August 2021. We selected publications about solar companies that are fully commercial or pursue a financial breakeven point (at least on paper; the term social ‘enterprise’ is sometimes also used as label to attract financial support from donors) (see for an in-depth discussion: Cross and Neumark, 2021; Ockwell et al., 2017).

The analysis follows the procedure set out in Table 2 and consists of a three-step procedure that is based on the protocol by Nilsson and colleagues (2018) for a systematic review of so-called interaction effects between Sustainable Development Goals and that was specifically designed to collect and collate lessons of tradeoff cases. Our steps follow the part of their framework that is focused on the appraisal of trade-offs; negative interactions that hinder progress towards sustainability goals.

In the first step of our literature analysis, we surveyed general article details and the context of knowledge claims of all studies in the sample (e.g., country; business characteristics). In the second step, we closely examined the articles where we came across accounts of tradeoffs. We considered firms’ goal incompatibilities and conflicts between social, environmental and economic goals as a representation of tradeoffs. In some cases, researchers are very explicit about tensions and the consequences thereof and linking this to drawbacks of the market-based development paradigm, while in other cases we found tradeoffs yielding from circumstantial evidence (for instance: Kolk & van Buuse observe that cheaper solar products have less productive use for users). Fig. 1 shows that out of the 36 selected articles we identified tradeoffs in 20 of them.

To systematically disentangle tradeoffs and review the effects on the envisioned triple-bottom-line benefits of international companies, we structured tradeoff accounts along their impact on the social, economic and environmental dimensions of sustainability using the Sustainable Development Goals. Conforming to Nilsson et al. ’s protocol we used the tool by the Stockholm Environment InstituteOF, a tested method to evaluate tradeoffs (see also Weitz et al., 2017; Fuso Nerini et al., 2018), and mapped them against the 17 Sustainable Development Goals. Doing this, and thus assessing for each of the tradeoffs we came across which SDGs they affected, we developed the heatmap presented in Fig. 2. This helped to order our findings and in the results, we discuss the four most fundamental tradeoffs that are the outcome of an in-depth analysis and synthesis of the literature findings.

In the third step, we reviewed the studies to see to what extent companies tried to mitigate (the consequences of) tradeoffs and how they did this, and how this worked out in the given context.

3.2. Sample

The majority of reviewed studies discusses affiliate high-profile solar companies such as Bboxx, SELCO, Dlight, Greenlight Planet, Azuri Technologies, and M-Kopa, and also described as pay-as-you-go companies (Lighting Africa, 2020). A small portion discusses also a second type of solar enterprises: non-affiliates. Non-affiliates are described as local low-profile businesses operating in an informal setting and that are unsupported by the international market promotion programs. The reviewed studies show that they sell what the World Bank’s Lighting Global platform calls ‘unaffiliated’ products, also referred to as ‘nonbranded’ and ‘uncertified’ products (Balls, 2020; Bensch et al., 2018; Groenewoudt et al., 2020; Samarakoon et al., 2021; Samarakoon, 2020). Given the scope of this study our primary interest is the first category of enterprises, yet we will reflect on insights gained with regard to the second group as well. Table 3 presents descriptions of all solar companies in the sample and distinguishes between ‘affiliate’ and ‘non-affiliate’ solar suppliers.

The sample includes 29 original research papers and 7 reviews. Literature in the sample appears to become increasingly critical about the industry’s performance over time, as scholars more frequently question the feasibility and sustainability of corporate-led market development. Yet, none of them systematically assesses the impact of solar enterprises on the social, environmental and economic dimensions of sustainability, and this underlines the relevance of a systematic review to collect and combine lessons about the solar industry from dispersed publications.

4. Results

Central in the pro-market development argument is the expectation that Global North-affiliated companies should be supported as they can commercialize the uptake of SDG-relevant technologies by the BoP and do so in a socially inclusive and environmentally responsible manner. This section outlines four core tradeoffs (Fig. 3) that are in the way of a sustainable transition to clean off-grid energy access.

4.1. Tradeoff 1: Profit versus energy access ‘for all’

Despite hopes of a commercial solar market to realize “clean and affordable energy for all”, profit generation appears incompatible with the goal of diffusing solar home systems and lanterns among poorest populations and those living in rural areas. A tradeoff arises

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1 https://www.sei.org/projects-and-tools/projects/disentangling-interactions-sustainable-development-goals/
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between profitability and provision of clean energy access ‘for all’ because companies cannot sufficiently earn from the minor profit margins on small-sized solar products when sold to a clientele with extremely low purchasing power. In addition, many of the world’s poorest populations live in sparsely populated places and due to high last-mile distribution costs and relatively dispersed sales, those areas are particularly unattractive to serve. High unit margins are infeasible to attain in BoP markets (Bocken et al., 2016; Jolly et al., 2012) and unit sales volumes must be high and combined with at least reasonable margins in order to recover business costs and attain financial viability (Wigboldus et al., 2016). Only a few solar firms like D.Light, Greenlight Planet and M-Kopa have achieved a large scale (Lighting Global, 2020), and sometimes only because they were subsidized (Balls, 2020). Many studies conclude that solar enterprises thus far have failed to reach breakeven points with pure for-profit models (Ahmed et al., 2020; Conway et al., 2019). Others are more optimistic and suggest that - at least for some parts of the market, companies can be profitable, like Pai and Hiremath (2016) who argue that Selco, after a financial crises, pressure from investors and help from socially-oriented foreign investors, ‘returned to profitable ways’ (p.154). On its company website, Selco underlines this by stating it has maintained modest profits in the last 8 years with annual average growth rates of 20% (Selco, n.d.).

Accumulating evidence has shown, however, that mainstream solar companies are unlikely to reach the very poor (Grimm et al., 2020; Kumar et al., 2019; Groenewoudt et al., 2020; Bocks, 2020). A recent study by Thomas and colleagues shows that market leading firm Bboxx, one of the leading solar company in Africa, and BELECOM (a newer market entrant) sold products to only ~32% of the households in Rwandan refugee camps. Not only academics cast doubt on the BoP premise; also actors from within the industry no longer believe that the extreme poor can be part of the addressable market (Cross and Neumark, 2021). A large group of international solar companies represented by the Global Off-Grid Lighting Association point out that end-user subsidies will be necessary, a form of subsidy to reduce the purchasing cost for end-users, to allow companies to reach the poorest African and Asian households (GOGLA, 2021).

The call from the industry suggests that other solutions such as Pay-As-You-Go, ‘downscaling’ off-grid products (offering smaller, cheaper products) and creating economies of scale are not enough for the private sector to address this segment of the market (GOGLA, 2021). Where Pay-As-You-Go models were hyped a couple of years ago (Barrie and Cruickshank, 2017; Muchunku et al., 2018; Rolffs et al., 2015), the literature has become more critical towards this financing mechanism that allows customers to make periodic

### Table 2

| Step | In review | Detailed features |
|------|-----------|------------------|
| (1) Article details and context of knowledge claims | Initial sample: 36 | Title, authors, year; Type of study, e.g., empirical, review Description of context: technology scope; geographical place; Business-specific context details, e.g., type of organization, actors involved, company names, profitability and/or dependence on donors. |
| (2) Identification and assessment of trade-offs | Sample surveyed: 36 | Accounts of incompatibilities and conflicts between social, environmental, and economic goals Assessment of how trade-offs play out in the given context Identification of affected goals, and translated to the Sustainable Development Goals to aid the disentanglement of tradeoffs (Fig. 2) Evidence for trade-offs offered in publication, e.g., first-hand empirical data, based on literature review |
| (3) Mitigation experiences | Sample surveyed: 20 | Descriptions of measures taken to mitigate trade-offs Outcomes and experiences of such actions (quantified if possible), the conditions enabling positive or negative results for aspired objectives |

**Fig. 1.** Tradeoffs in reviewed literature.
installments (monthly, weekly, or on occasion, depending on the supplier) through a mobile payment platform for the repayment of solar systems over time. PAYG allows companies to increase their customer base and it offers an affordability solution for people with regular incomes and living in areas covered by telecom networks (Rastogi, 2018). Yet, there is a risk that these credit arrangements can place a financial burden on the energy poor that they cannot sustain (Samarakoon, 2020) while instead of just benefiting from eco-

"they are making a killing out of them" (quote from Cross & Neumark, p.13). In other words, PAYG reduces existing inequalities but creates new ones. This becomes also visible in cases where systems of indebted PAYG customers were disabled by the supplier because the customers did not keep up repayment, the increase in repossessions of systems, the high prices of systems sold under PAYG because of interest rates charged to buyers, and ethical issues associated with the storage, collection and sharing of user data (Bisaga et al., 2017; Cross and Murray, 2018; Grimm, 2020). Solar firms and financiers also take a credit risk and can only offer PAYG when they have access to sufficient working capital (Adwek et al., 2020; Urpelainen and Yoon, 2016).

In other words, a limitation of the neoliberal development model is that it provides little incentives to deliver electricity to contexts and customers where risks are high and where there is no or little return on investment (Ferrall et al., 2021; Sergi et al., 2018; Thomas et al., 2021). Neglect of unprofitable segments appears inevitable in the market-based development strategy, and in attempts to include them, new ethical challenges and new forms of injustice tend to emerge. Singh’s (2016) study points out that off-grid solar technology enterprises can achieve higher unit scale by focusing on fewer product categories and this suggests that those who need electricity access the most may also be the ones with the most limited options.

Cross and Neumark (2021) describe how over the past decade companies became less interested in achieving universal electricity access and instead primarily concerned with sales numbers and financial returns on investments, arguing that ‘underpinning this restructuring of goals was an ambitious commitment to growth’ (p.10) by off-grid energy companies like Mobisol and pressure from investors. Venture capitalist investment funds and private equity and were attracted by the sector, but seeking for short-term returns on investments, some allowed (or induced) companies to scale their business operations beyond the poor. The shift away from the sector’s primary off-grid energy access goal is argued to be a growing concern in the industry.

In attractive areas, on the other hand, the market approach leads to competition between energy providers, like between Mobisol and M-Kopa in some parts of Tanzania (Rastogi, 2018). Competition increases product choice for customers, who then become aware of the relative advantages and disadvantages of the products, and puts pressure on firms to lower system prices, but can also be interpreted as inefficient use of funding resources (Steel et al., 2016; Thomas et al., 2021).

Another aspect of the afore mentioned tradeoff is that in areas with low diffusion levels, the costs of maintaining a store permanently is often too high, and companies fail to secure an adequate ecosystem for maintenance or repair of solar products in those areas (Kumar et al., 2019; Thomas et al., 2021). Thomas and colleagues (2021) write for instance that ‘Bboxx did not maintain a permanent presence in the Rwandan refugee camps, preferring to use a customer service hotline, and that the Bboxx sales agents were paid on a commission-only basis and were not trained or paid to deal with technical issues’ (p.129). In such situations, customers deal with more unrepaired system deficits and breakdowns, or pay higher prices for repairs. Local repair by independent technicians for simple technical issues exists, but such repair invalidates warranties of Bboxx and other international suppliers, many of which work with similar warranties (Groenewoudt et al., 2020; Thomas et al., 2021). This issue was particularly pressing in the Rwandan camps in times of Covid-19 when supply chains and technicians could not access the areas.

The profitability challenges and failing attempts to include the lower strata of the BoP is further exacerbated by a second tradeoff:

| Heatmap explained in four cross-sectional patterns: | conflict between: |
|---|---|
| one | SDG 8 - economic viability and business profits |
| two | SDG 7 - modern and reliable energy access |
| three | SDG 7 - distribution of clean off-grid solar technologies |
| four | short-term goals such as: SDG 7 – target for number of people with energy access; SDG 8 – economic prosperity, returns on investment |
| | long(er)-term sustainability impact; integral part of the sustainable development and linked to goals such as: SDG 1, 10, 16 – no poverty, justice, inclusive societies; SDG 12 – no waste |

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Fig. 2. Heatmap of tradeoffs translated to conflicts between Sustainable Development Goals.
Table 3
Affiliated and non-affiliated companies operating in solar markets.

**Table 3**

Affiliated companies, associated to international organizations, donors, and investors from the Global North

| Description | Location | Publication |
|-------------|----------|-------------|
| Companies with market-based delivery models | Rwanda | Thomas et al. (2021) |
| Private market approaches | Tanzania | Ferrall et al. (2021) |
| North American and European solar energy companies | East Africa | Cross & Neumark (2021) |
| Venture capital backed solar enterprises | Malawi | Samarakanon et al. (2021) |
| Renewable energy enterprises | South Africa | Diale et al. (2021) |
| Off-grid solar suppliers, GOGLA affiliates | Global South | Hansen et al. (2021) |
| High-profile solar businesses | India | Balls (2020) |
| SHS companies, Boond and Selco | India | Bandi et al. (2020) |
| Suppliers of certified, ‘affiliated’ products | Malawi | Samarakanon (2020) |
| Full-service and plug-and-play systems suppliers, proclaimed ‘high quality’ | Uganda | Groenewoudt et al. (2020) |
| Solar home system business models | Sub-Saharan Africa | Kizilec & Parikh (2020) |
| Pay-as-you-go solar firms | Sub-Saharan Africa | Adwek et al. (2020) |
| Market-based dissemination of off-grid technologies of DLight, Greenlight Planet, and ASE | Rwanda | Grimm et al. (2020) |
| SHS business model, Infra. Development Company Ltd | Bangladesh | Ahmed et al. (2020) |
| London-based solar power company, BBOXX | Rwanda and Kenya | Kennedy et al. (2019) |
| Social enterprises | South Africa and Zimbabwe | Conway et al. (2019) |
| Off-grid solar PV intervention | India | Joshi et al. (2019) |
| Solar lighting social enterprise, Solar Sister | Tanzania | Gray et al. (2019) |
| Pay-as-you-go business model | Kenya | Carr-Wilson and Pai (2018) |
| Market-based renewable energy services provision model | Sri Lanka and Indonesia | Sovacool (2018) |
| Social enterprises, SEWA Bharat and SELCO | India | Ali and Yasmin (2018) |
| Off-grid companies | Kenya and Tanzania | Sergi et al. (2018) |
| Donor-backed companies offering ‘branded’ products | Burkina Faso | Bensch et al. (2018) |
| Pay-as-you-go provider, M-Kopa Solar | East Africa | Rastogi (2018) |
| Solar PV businesses | East Africa | Muchunku et al. (2018) |
| Private-led market development | Kenya | Nygaard et al. (2017) |
| Solar business | Bangladesh | Hossain et al. (2017) |
| Solar home systems provider BBOXX | Kenya and Rwanda | Bisaga et al. (2017) |
| Solar Electric Lighting Company (SELCO) | Central East Africa | Barrie & Cruickshank (2017) |
| Ashden Award-winning for-profit enterprises | India | Pai & Hiremath (2016) |
| USAID supported SHS provider Azuri Technologies | Developing countries | Weldon, Sharma & Dobbs (2016) |
| Solar-LED lighting companies | Rwanda | Collings & Munyehiriwe (2016) |
| Local social enterprise, Boond | Developing countries | Mills (2016) |
| Off-grid solar energy providers | India | Urpelainen & Yoon (2016) |
| | India | Singh (2016) |

**Table 3 (continued)**

Non-affiliated enterprises

| Description | Location | Publication |
|-------------|----------|-------------|
| Distributors of ‘somewhat original’ products | Malawi | Samarakanon et al. (2021) |
| Informal shops | India | Balls (2020) |
| Suppliers of uncertified and ‘unaffiliated’ products | Malawi | Samarakanon (2020) |
| Local vendors and wholesalers selling mix-and-match systems, proclaimed ‘low quality’ | Uganda | Groenewoudt et al. (2020) |
| Suppliers of local market-offered non-branded products | Burkina Faso | Bensch et al. (2018) |

**Table 3 (continued)**

Description – uncategorized

| Description | Location | Publication |
|-------------|----------|-------------|
| Off-grid solar enterprises in BoP markets | Developing countries | Scott (2017) |
| Private sector approaches | Kenya, Uganda and Malawi | Davies (2018) |

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**Fig. 3.** Tradeoffs for off-grid solar enterprises. Numbers referring to the number of articles that mention this tradeoff.
4.2. Tradeoff 2: (Low) product price versus (low) product performance

Solar energy access should be affordable for all layers of society, but like in any product market, there is an inevitable payof between product prices and whatever value can be offered to customers at that price. This price-performance tradeoff is problematic, especially in solar product markets in Global South contexts. Challenges of customers' low purchasing power combine with relatively high costs of 'high-tech' solar solutions. For the poor the prices remain high despite the recent decline of global PV module prices and cheap mass production in (especially) China, from where bulk import to other Asian and African countries takes place (Hansen et al., 2015). User-focused studies have shown that the cheapest and most affordable solar products (lanterns) offer little more than a most basic lighting service; they can only sometimes charge a mobile phone (Azimoh et al., 2015; Collings and Munyehirwe, 2016; Peters and Sievert, 2016; Urpelainen and Yoon, 2016). Because of the price-performance tension it is practically impossible to develop solar products that score well on the core dimensions of SDG 7: ‘affordability’ and ‘for all’, and ‘modern and reliable energy access’. The latter is best achieved with large, high quality, and functionally rich systems that score high on the World Bank’s Multi-Tier Energy Access Framework (www.esmap.org).

This considered, scholars vary in their optimism about the advantages of off-grid small solar kits (Hossain et al., 2017; Wheldon et al., 2016). Despite their shortcomings some point out the relative benefits for users especially compared to alternatives, including electricity through a grid connection, which is expensive and not always reliable. Just like large solar systems, electricity from a weak grid is often also not well enough suited for cooking and productive uses (Gray et al., 2019; Sievert and Steinbuks, 2020). Implicitly the tradeoff forces companies to walk a tightrope, balancing between ‘leaving no one behind’ and the global ambition to bring everyone to Energy Access Tier 4 or higher (Wheldon et al., 2016).

Lower-income segments of the BoP struggle to afford even the smallest solar systems – regardless the availability of PAYG services and people who have less to spend get minimal energy services, placing a double burden on the energy poor and reinforcing structural inequality that existing solutions like PAYG cannot completely mitigate. Extending payment periods helps liquidity-constrained customers but not enough to enable them to pay cost-recovering market prices, leading Grimm et al. (2020) to conclude that to ‘disseminate off-grid solar to the rural poor via unsubsidized markets might be overly optimistic’ (p.30). At the same time, adoption is not only determined by income levels; word-of-mouth advertising and local sales representatives are important factors as well (Kennedy et al., 2019). End-user subsidies could potentially close the affordability gap but has yet to prove its success. Actors from the off-grid sector raise the concern that it may create unfair competition, and that a shift towards structural subsidies constitutes a step away from market-driven development (GOGLA, 2021; Conway et al., 2018).

Importantly, several scholars attribute unaffordability of systems partly to the decision of the PAYG companies to strive for high-quality Lighting Global-certified solar systems. This contrasts with products from ‘nonaffiliate’ small local suppliers who tend to opt for a price-over-quality market strategy and offer lower cost, improvised solar home systems, assembled from readily available solar parts (Balls, 2020; Groenewoudt et al., 2020; Samarakoon et al., 2021; Sanyal et al., 2020). Compared to certified products, their open-source systems are more cost-effective and physically larger. Owners of the small-scale and informal solar shops operate independent of any subsidy or support program – and are no franchise of grassroots initiatives like Solar Sisters and Barefoot’s Solar Mamas. They have no international linkages to the Global North apart from their supply chain of solar parts that runs via importers and wholesalers in capital cities (Groenewoudt et al., 2020).

Balls (2020) argues that most of the recent energy literature frames certified products as ‘good solar’ and challenges the assumption based on the grounds that the uncertified solar solutions are functionally flexible (new appliances can be added on) and more easily repairable locally. Similarly, Groenewoudt et al. (2020) conclude that solar products from the affiliates are advertised as ‘high quality’ but do not necessarily perform well in Global South diffusion contexts. Many uncertified lower-cost alternatives that are proclaimed to be of ‘low quality’ (according to representatives of global development agencies) tend to perform well enough for users. Moreover, they find that the suppliers were already on the market before products of subsidized affiliated businesses diffused on a large scale and are still holding their own in the face of that competition, despite the absence of support, whereas the same cannot be said for the affiliates (Balls, 2020). These conclusions from field research in Uganda and India tally with findings by Samarakoon about ‘Somewhat original’ products that are more widely available to the rural masses in Malawi (2021), and from Bensch et al. (2018)’s study of branded and non-branded solar home systems in Burkina Faso, on the basis of which they question the need for promotion programs for Lighting Global quality-verified branded products. The findings suggest that Western-minded organizations opt for a one directional remedy to treat the price-performance tradeoff – at least when compared to local solar initiatives.

The studies discussed above seem to signal the beginning of a debate around global quality standards for solar markets (see for instance: Samarakoon et al., 2021). The Lighting Global Quality Standard seeks to ensure truth in advertising, durability, system quality, lumen maintenance, and 2-year minimum warranties (Lighting Global, n.d.; Harrington and Wacera Wambugu, 2021) and is currently put forward as the “golden standard”. It acts as the main instrument to protect customer markets from unreliable, unwarranted solar products, but the standard is increasingly questioned. Samarakoon (2021) concludes that ‘the affiliated products that pass certification are ultimately products with significantly shorter lifespans than systems sold in the Global North’ (p.9), and user reports indicate challenges with warranties that are not granted in cases of incorrect use or tampering with systems (Groenewoudt et al., 2020). Furthermore, Samarakoon argues that the standards are not only developed for, but also by, leading solar companies, and this creates a biased market device that risks unfair competition and rules out local vendors. Unlike international companies, they have no access to laboratories and equipment to conduct measures for certification, and few have the skills to comply with the international standards (Davies, 2018).
4.3. Tradeoff 3: Distribution of solar products versus zero waste

Another dilemma for off-grid markets is posed by a tradeoff between the aim – or indeed exigency – for wide distribution of solar products and the production of waste that results from it e.g., through end-of-life product disposal, early breakdowns, littering of packaging. With the diffusion of products off-grid companies expose user and local environments to e-waste. The toxic content of solar parts, and batteries in particular, has shown to have a harmful repercussion on health and the environment (Cross and Murray, 2018; Hansen et al., 2021; Sovacool et al., 2020). Rapid growth of off-grid solar markets has led to an increased pressure on the natural environment and the people living the polluted areas. Most pronounced is the impact on low-income countries that lack a central and well-functioning waste management system like Uganda, and (rural) areas where collection of waste is the hardest and broken batteries end up unattended in homes and homesteads (Bensch et al., 2017). This raises yet another fundamental ethical question of fairness towards the energy poor (e.g. Kumar and Turner, 2020; Sovacool et al., 2020).

The linear trajectory from distribution to consumption to waste is exacerbated by the need by companies to maximize sales volumes at the lowest possible profitable prices and provide warranted products. Short-lived systems are increasingly cluttering landfill, and studies by Balls (2020) and Groenewoudt et al. (2020) suggest that the focus on high quality and quality certificates and pressure on affordability has increased the problem because it has led to the design of closed ‘temper-proof’ solar technologies. Such plug-and-play solar home systems are the most sold affiliated product in off-grid markets, and while the functionally fixed solar kits prevent users from wrong use and enhance high sales volumes and rural distribution, they are harder to repair locally.

So far, the response from the industry have been focused on efforts to minimize the impact of solar home system kits through a western-inspired circular-economy approach. Mitigation of the technology distribution-waste tradeoff goes hand in hand with the ideal sequence for avoiding waste, namely through (Brix-Asala et al., 2016:415):

1. waste reduction – such as extending product durability, reducing use of (packaging) materials and use of biodegradable materials;
2. waste re-use – such as remanufacturing products for a second life;
3. waste recovery – such as raw material recycling, and;
4. waste landfill – as a last resort.

The Global Off-Grid Lighting Association (GOGLA) is one of the lead institutions in addressing the increasing e-waste problem in this manner. It strives for a circular approach to reduce the footprint of the off-grid solar market with a voluntary ‘extended producer responsibility’ agreement, a requirement for all its members (Lighting Global, 2020). In GOGLA, efforts are solely targeting affiliated solar enterprises, not the earlier discussed nonaffiliate suppliers. The organization is in favor of certified products and attention has been directed towards after-sales care, circularity along the entire value chain through repairability and recyclability in design, extending product lifecycles and by working with trained technicians, high quality spare parts, promoting repair practices, and responsible product disposal through take-back schemes, recovering valuable parts for re-use and fostering responsible recycling practices. As a representative of the private sector, GOGLA seeks cost-recovering waste management solutions and suitable economic inventive structures (Hansen et al., 2021; GOGLA, n.d.). There is also a scheme for establishing new processes for high-quality refurbishment of broken or returned off-grid solar products can help to serve customers with lower-priced products for higher-tier energy access.

However, the initial steps taken by the industry are still in its infancy (Hansen et al., 2021). Re-use of energy technologies or parts has only recently gained attention and adequate safe recycling is still relatively new (Bensch et al., 2017; Hansen et al., 2021). A zero-waste scenario is unlikely given that solar technologies consist of hard-to-recycle parts like batteries and many hazardous materials. Permanent sustainability is hard to operationalize because it requires a ‘closed loop’ where materials are not subject to downcycling or disposal. Waste reduction through “cutting down” in materials is only possible to some extent, and durability of batteries, which are a critical component in solar products, remains a major challenge in tropical countries (2–6 years max, depending on battery type and use) (Groenewoudt et al., 2020; Jacobson and Kammen, 2007). Setting up adequate reverse supply chains in vast rural areas with poor infrastructure is also unwieldy and can become a very costly affair.

Some are exploring the potential of open, modular designs that can postpone end-of-life disposal of entire products through possibilities for local repair or replacement of individual parts and repairability standards rather than quality standards (Spear et al., 2020). Yet, this requires different business models with more advanced supply chains that are unattractive for big international solar companies which seek financial breakeven by moving as many new products as possible. Mitigation of the distribution-waste tradeoff is further complicated by the need for ever cheaper products and commitments to product certification that together may be causing a lock-in locked solar kits around which dominant supply chains and service models are structured.

Hence, a limitation of the market-based development strategy for the off-grid sector is that companies so far have been unable to distribute products without putting an ecological burden on local environments. This problem is not limited to corporate market-based technology diffusion (NGOs and public initiatives would run into it too), but particularly hard to resolve in a market where certified hard-to-repair technologies have been favored and given that business costs for waste related activities need to be absorbed while conditions for attaining economic viability are already unfavorable. Studies focused on nonaffiliated suppliers have shown that uncertified component-based systems have repairability and revaluing benefits (re-use of solar parts, battery ‘refurbishing’) (Cross and Murray, 2018) although the environmental benefits are diminished by the existence of fake solar parts and spare parts of extremely low quality (Groenewoudt et al., 2020).
4.4. Tradeoff 4: Short-term quantitative output targets versus long-term sustainability impacts

A final tradeoff that emerged from the review is between chasing short-term quantitative performance targets and pursuing long-term sustainability impacts. The short-term targets refer to outputs like return on investments, commitments to growth in sales, or the number of people to whom systems are sold. Long-term sustainability, on the other hand, relates to the broader concept sustainability, as defined in the Brundtland report (1987) that describes it as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This tradeoff is interwoven in all three tradeoffs discussed above but should still be mentioned explicitly here because it explains to a large extent how companies deal with the tradeoffs the way they do. Demonstrating this, off-grid solar companies tend pursue quick wins that are ‘evidence’ of their contribution to SDG 7. Success in those terms is measured as profit and sales units and number of newly connected customers that benefit from what Kumar et al. (2019) describe as a ‘drop-and-go’ type of intervention that fails to secure proper maintenance and after-sales services for customers (and resulting in more breakdowns and thus waste).

Achieving short-term and long-term goals simultaneously requires investment of resources in competing directions and this is hard to accomplish, especially in resource-constrained settings. Multiple studies have shown that private-sector led electrification programs aimed for rural development became mere household connection projects providing little more than basic lighting and (just like public-sector led programs) missed out on meaningful progress with addressing energy poverty and achieving productive use through energy connections (Cross and Neumark, 2021; Derks and Romijn, 2019; Mesina, 2016; Peters and Sievert, 2016). Setting up support networks and investing in technological capacity building are time consuming and resource intensive processes. Consequently, emphasis on these activities would imply that the time to market, break-even points, and return on investments are milestones that may need to be postponed further into the future. Possibly similar mechanisms are at work in other resource intensive processes with long pay-back times, such as setting up waste recycling systems. Business models that enable long-term sustainable impact can be more difficult to scale and grow fast due to their context-specificity and the managerial complexities that come with it (Almeshqab and Ustun, 2019; Korten, 1980).

The motivation to emphasize short-term quantitative outputs over the pursuit of long-term sustainability appears market driven as well as politically driven. Companies are frequently forced to aim for high sales volumes due to the low unit profit margins, while other goals in the design of their businesses models have to take a backseat. Donor pressure can aggravate the situation and political priorities can enforce short-term goals by placing a focus on, and providing incentives for, quantitative output targets in line with the way goals in the design of their business models have to take a backseat. Donor pressure can aggravate the situation and political priorities can enforce short-term goals by placing a focus on, and providing incentives for, quantitative output targets in line with the way they do. Demonstrating this, off-grid solar companies tend pursue quick wins that are ‘evidence’ of their contribution to SDG 7. Success in those terms is measured as profit and sales units and number of newly connected customers that benefit from what Kumar et al. (2019) describe as a ‘drop-and-go’ type of intervention that fails to secure proper maintenance and after-sales services for customers (and resulting in more breakdowns and thus waste).

Hence, the tradeoff between short-term and long-term achievements affects the overall sustainability transition that unfolds over time. It reveals a limitation in the ability of corporate-led development to produce pathways that are sustainable, now and in the future, and tends to prioritize short-term goals. The review suggests that strategies to mitigate the tradeoff are an unexplored research area in the solar research and we found no plausible options. Overcoming this tradeoff appears particularly hard because firms deal with limited resources and the interrelatedness with other entangling tradeoffs makes it extremely complex to combine the best of all possible worlds.

5. Discussion

The review shows the limitations of the corporate-led market-based approach to off-grid solar energy access and the underlying reasons for this and highlights four main tradeoffs that make it difficult to realize progress towards various SDGs through one single off-grid solution. While the study is likely to underreport tradeoffs because of the used method and there could be more, it is clear that alternative, complementary solutions are necessary to address the shortcomings of the current model and the social and environmental injustices that it gives rise to. This is increasingly recognized by academics as well as people from within the solar industry (Cross and Neumark, 2021). The situation calls for more holistic and pluralistic approaches by Romijn and Caniels (2011) and scholars from the Science Policy Research Unit (SPRU) and points out a need for ‘pluriform pathways’ to address global sustainability and developmental challenges (steps-center.org) (Delina and Sovacool, 2018; Ely and Bell, 2009).

More specifically, we see a role for the small-scale and informal sector entrepreneurs, the nonaffiliate solar technology suppliers, in closing the affordability gap that could be further explored. They appear to contribute substantially to universal energy access and reach the masses with more cost-efficient and cheaper solutions and do so without subsidies. Beyond product supply, the informal sector can be important for better waste management, recycling and e-waste handling (Cross and Murray, 2018) – although due to the nature of the materials used in renewable energy technologies it is unlikely that the sector can completely solve the problem of waste by itself. Arguably these enterprises have not been granted the credits that they deserve (although drawbacks are to be acknowledged) (Balls, 2020; Bensch et al., 2018; Groenewoudt et al., 2020; Sanyal et al., 2020). Yet, this phenomenon of ‘under the radar’ innovations can make a valuable contribution to sustainability transitions (Hanlin and Kaplinsky, 2016; Kaplinsky, 2011). This is done through adaptation of technologies of external origin to local settings in search of solving specific local problems, sustaining local livelihoods and enhancing local technological capabilities in the process (Bhaduri and Kumar, 2009; Kaplinsky et al. 2009). The contributions and further potential of actors in this area have been recognized and documented by many scholars working in the domain of frugal,
inclusive and grassroots innovation research in development contexts, already since the advent of the appropriate technology discourse and movement in the 1970s (for more recent contributions see, e.g.: Chataway et al., 2014; Bhaduri and Talat, 2020; Knorringa et al., 2016; Leliveld and Knorringa, 2018; Pansera and Sarkar, 2016; Papaioannou, 2014). However, the implications from this work still remain to be translated into substantial change in support strategies for international energy and development projects by those in executive positions.

Another avenue for further research is the integration of non-market-based routes like non-profit and government-led interventions in the off-grid energy access (and e-waste) solutions in the off-grid sector, especially for those trapped in poverty who remain unserved through a market approach. Research has shown that such approaches have limitations as well and are constrained by, for example, incentives for meeting short-term energy access targets, and weak governance (Derks and Romijn, 2019; Feron, 2016), and should be mindful to avoid running into the same old pitfalls that led to the shift away from donor- and government-led approaches in the first place. Policymakers currently explore end-user subsidies to strengthen the market-based route, but this may not help the segments that firms perceive as too high risk. In this regard, hybrid collaborations between government- donor- or market-led approaches could be further explored as alternatives as well (Conway et al., 2019; Sovacool, 2013). Multistakeholder collaborations are highly complex, and the design of such coalitions may benefit from a design-oriented pluralistic stakeholder approach, as proposed by Kemp and Ramani (2020). Future research should also dive deeper in financial gains of (partially) market-based initiatives to establish a more precise and fine-grained picture of when and where profitability is feasible and realized, and when it is not (e.g., what income levels; what areas; what time frame).

The normativity that the contemporary development paradigm brings to market formation processes and transitions in the Global South can be brought into sustainability transitions research by taking a ‘Pathways Approach’ (Ely et al., 2013; Köhler et al., 2019; Leach et al., 2012). We see this as particularly promising in exploring alternative models because this approach casts aside the idea of one single, normatively ‘good’ development pathway and argues that any development intervention has its strengths and weaknesses (there is thus no such thing as ‘win win’). It opens up the possibility of pursuing a pluriform pathway that draws on the complementarities of multiple different approaches and in this way compensate for the limitations of individual approaches. This study offers a potential starting point by exploring one route of the potentially more pluriform pathway towards off-grid energy access.

Beyond the key findings for the off-grid solar sector, this study offers some insights that are relevant to extant literature on market formation and transition processes in Global South contexts more in general. Social constructivists point out that market formation is a socially and institutionally embedded process, involving the interaction of diverse actors in social arenas (Pflgstein, 2001; Pflgstein & Dauter, 2007). Transition processes revolving around the same technological innovations can unfold substantially differently in different spaces, owing to the specificities of the social-institutional market formation dynamics (Dewald and Truffer, 2011; 2012). This study shows that in Global South contexts, donors, global development agencies and affiliate companies are important shapers of market formation processes, for example through their attempts to regulate markets by enforcing instruments like global quality standards which downplay local non-affiliate enterprises, or designing financial support instruments in such a way that small players need special assistance to develop the capacity to meet the requirements (Hüls, Raats, Se1astian, Veen, and Ward, 2017). This resonates with findings from previous transition studies in developing countries that have highlighted that donor interventions sometimes hamper radical change and sustainability transitions (Wieczorek, 2017).

Another critical actor in the Global South is the informal sector entrepreneur. Although transition scholars recognize the importance of local actors in effective sustainability transitions, this group is frequently overlooked in energy transition research (Hansen et al., 2015; Nygaard et al., 2017; Tigabu et al., 2015). This calls for a more critical reflection on all actors taking part in transitions, especially those who are not involved in such processes the Global North, and stresses the importance of place centric, bottom-up research (Hopkins et al., 2020). Insights from this study show that systems for basic energy services are ‘splintered’ in developing countries (national grids, microgrids, solar home systems, solar lanterns), similar to what van Welie and colleagues (2018) observe in the Kenyan sanitation sector, and stress that the heterogeneity in solutions is substantially larger and involves also informal actors and unregulated and uncertified technology variants (Balls, 2020; Groenewoudt et al., 2020).

6. Conclusion

Markets and market formation processes are crucial enablers for sustainability transitions (Bergek et al., 2015; Boon et al., 2020) but shape their ‘sustainability’ outcomes as well, a fortiori in the Global South. This study engaged critically with the role of markets in areas of the world that are characterized by extreme poverty, and where a ‘corporate-led market development model’ has been strongly advocated and embraced by development actors as the only and only feasible solution for basic services provision for the Base of the Pyramid for several decades. In the current era of liberalized global markets, international policy and development interventions are widely framed around the promise of market-based development and rely on international companies affiliated to donors and development agents from the Global North for technology diffusion. This market-based approach to technology dissemination is expected to produce the wins for people, profit and planet that are needed for a veritable sustainability transition.

The study explored the limits of this contemporary market model by means of a systematic literature review of off-grid solar business literature and identified multiple critical sustainability tradeoffs that are hardwired into companies’ business solutions that prevent them from producing the anticipated triple wins, raising concerns about the reproduction and reinforcement of structural forms of human and environmental injustice: solar companies are unable to reach the lowest-income and isolated populations and foster a just energy transition, and cannot adhere to the cultivation of energy justice principles by producing dangerous waste. The findings from the energy sector thus suggest that the internationally supported corporate private sector approach cannot support a sustainability transition as such. At this point we did not find sufficient evidence to support the idea that the solar enterprises cannot
become profitable at all, like some have suggested (Conway et al., 2019; Ockwell et al., 2017). Rather, the corporate-led market-based model is inadequate to serve the poorest and rural populations and puts pressure on firms to choose short-term sales and profit targets over longer-term and less measured sustainability goals.

Statement of interests

One of the authors reviewed another contribution to the Special Issue ‘Markets for Sustainability Transitions’. We have no other conflicts of interest to declare. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

We confirm that this manuscript has not been published elsewhere and is not under consideration by any other journal. Before submission of this manuscript one of the authors reviewed another contribution for the Special Issue. We have no other conflicts of interest to declare. Both authors agreed with the submission to Environmental Innovation and Societal Transitions and as corresponding author, I confirm that I am the person held responsible for all aspects of the paper during and after the publication process. With this submission I adhere with the standards for Ethics in publishing.

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