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# Harnessing finance for a new era of decentralised electricity access: A review of private investment patterns and emerging business models

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ABSTRACT

Achieving the Sustainable Development Goals (SDGs) requires ensuring universal energy access. Yet, governments of low-income countries face significant budget constraints for the capital-intensive infrastructure required to reach the hundreds of millions of households and businesses without grid electricity. In this context, private investors are the key actors capable of channelling such large capital requirements. Compared to the previous decades, the 2010s witnessed a growing mobilization of private funding in the off-grid electricity access sector, including some success stories. Nonetheless, with less than ten years left until the SDGs horizon, off-grid companies systematically struggle to ensure the financial sustainability of projects, as the industry still seeks to demonstrate its maturity and profitability. In this paper, we critically review the main business approaches adopted by private decentralised electricity access service providers. The aim of the analysis is to identify the main drivers of risk and failure which have been hindering sectoral investment. We then propose and discuss four potential game-changing factors that could foster the next generation of private investment in decentralised electricity solutions: (i) anchor-businesses-community (ABC) models; (ii) the design of integrated business models centred around income generation; (iii) the growing role for "local" financiers; (iv) the securitization of assets. Our paper targets private infrastructure developers and financiers aiming at fostering investment in financially sustainable decentralised electricity access projects.

## 1. Introduction

Achieving universal electricity access – a key pillar of SDG 7 – is a crucial development and political priority for low and lower-middle-income countries [1]. According to the most recent estimates, sub-Saharan Africa (SSA) is home to about 592 million people without electricity [2]. Namely, it accounts for more than two thirds of the global population without electricity. The remainder of the gap is distributed among few Asian countries (India, Pakistan, Myanmar, Bangladesh, and North Korea) and in circumscribed areas of Latin America. While several national governments have laid out ambitious targets to reach universal access within this decade (e.g. Ethiopia [3]) by 2025; and Kenya [4] by 2022), many countries are struggling to achieve steady progress, also due to a quickly growing population and urbanization pressure. In addition, since 2020 the COVID-19 pandemic has been slowing the rollout of electrification and pushing many people back into energy poverty [5].

In this context, it is increasingly understood and accepted by national governments that expanding national distribution grids into every corner of the many sparsely populated settlements, and chiefly in the wide SSA region, [6] is not financially viable [7–9], at least over the medium-run. Remoteness, terrain obstacles and lack of road infrastructure, coupled with the low energy demand and ability-to-pay of many rural dwellers represent the main barriers [10,11]. On this backdrop, the precarious economic status of most public electric utilities of SSA countries due to inefficient management and large subsidy expenditures make it unlikely that costly large-scale infrastructure expansions can be achieved in areas with very low revenue collection potential

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[12–14]. Several region-wide analyses have quantified the costs of expanding the national grid to all settlements [9,15–17], showing that investment requirements skyrocket compared to a scenario of optimal balancing between grid expansion and decentralised electricity access solutions. A mix of both mini-grids and standalone power generation systems has in fact been projected [9,15,16] to play a key role in contributing to efficiently provide universal access to modern energy services to a large part of the regional population currently without access. In this context, the main challenge is thus to implement business and financing models which are both profitable for private decentralised electricity system providers and economically acceptable for the rural poor, as well as attractive for return-seeking investors [18,19].

Decentralised electricity access systems are generally differentiated between mini-grids and standalone systems, such as solar home systems (SHS). From a technical point of view, the two systems cannot be considered as substitutes as far as their scale, power availability, supply reliability and therefore appliance compatibility and energy services enabled are concerned [20]. Standalone solutions can rather be thought of as steps below in the energy ladder [21,22], which might eventually lead households to (mini) grid connection. The energy ladder concept refers to *"the change in energy-use and demand patterns in accordance to the variations in economic status of the household"* [23]. Mini-grids and SHSs also differ from a financing, regulatory and distribution model point of view, as mini-grids are generally regulated through tariff policies and need to be licensed as electricity sellers [24,25]. They are therefore based on an ESCO (energy service company) model and generally find substantial issues in setting cost-covering tariffs to end customers, as several regulatory restrictions are found [26]. Conversely, providers of electricity through small-scale standalone systems that are asset or receivables-financed (or consumer-financed) are usually free to price their services, making this sector potentially attractive enough for private sector investors [18]. In addition, mini-grids have higher up-front costs and are seen as infrastructure-type investments, compared to SHS that are considered as retail businesses, with the possibility to combine electricity services with the provision of other products or services. The combination of technology distribution with financing services of the systems has unlocked a new market segment of capital-poor consumers in need of basic services and spurred expansive growth of the sector [27].

Despite these promising prospects, a first series of company failures have shaken up the sector and raised the question whether the asset-financed growth model can be financially sustainable [28,29]. For instance, the insolvencies of Mobisol and Solarkiosk (both are German companies active in several SSA countries), once courted by public and private investors alike, cast doubts about the viability of the off-grid PAYG model as such. Going back two decades, in what we define the '*first wave of investment*' in decentralised electricity access (1990s – 2000s), donors and foreign development finance have represented the main source of electricity access project financing [30]. These early-day projects have experienced high rates of negative outcomes, mainly because most underlying investments were lacking a clear outlook to the projects' financial sustainability and solid business models for contexts of widespread poverty and low regulatory quality [31]. Recent literature [29,32,33] highlights that the crucial barriers which have prevented the success of these investments are consistent across different countries and settings, namely: the priorities set by the political agenda, the process of awarding projects (with tendering seldom adopted and direct negotiations preferred), the lack of stakeholder co-operation, the scarce weight attributed to planning and implementation, the limited planning and carrying out of recurrent maintenance as well as the insignificant if not negligible assessment of public acceptance and inclusion [34–36]. A '*second wave of investment*' in decentralised electricity access (2010s) has been observed in the wake of the establishment of the UN SDGs and global energy transition targets [37]. The challenge of universal electricity access has since then gained significant attention in the public sphere and in investment priorities of development banks [38,39]. In the last decade, several mini-grid [37] and SHS companies have been created [27]; innovative business models such as pay-as-you-go (PAYG) and microcredit loans have been established [18]; strategic partnerships (strategic investors, microfinance institutions) have been signed [24].

Nevertheless, irrespective of this recent surge in the interest and activity in decentralised electricity access solutions, mass uptake is still far from being achieved [40]. According to Gogla [41], investment flowing into the sector is insufficient and too concentrated among the large players, while seed and early-stage financing remain in short supply. Growth pressure and high expectations from stakeholders clash against the substantial issues related to the effective use of these energy systems once put into place as well as to their financial viability over time [42]. It is increasingly clear that as the understanding of the risks involved in decentralised electricity supply models grows, debt financiers are severing conditions for lending, introducing financial covenants to ensure liquidity or capital adequacy [19]. At the same time, companies are introducing risk management tools, updating internal guidelines, and deploying newly available data analysis methods to make their business decisions more transparent [43]. Whether these measures will make the sector more risk-transparent and therefore appetizing also to less specialised capital providers will be seen soon through refinancing rounds.

Previous research discussed the main issues ahead for rural electrification, dealing with technical, economic, and regulatory challenges. For instance, Peters et al. [26] and Suri et al. [44] focused on barriers encountered in the planning of mini-grids such as formulating realistic electricity demand projection (a crucial variable for assessing the payback period of projects) or abating transaction costs driven by regulatory issues, payment default and lack of skilled staff. While some recent research has focused on the importance of a sound business model design for electricity access provision [45,46], relatively few studies have put explicit attention on reviewing the business- and financing-related roadblocks faced by private investors for channelling decentralised electricity access investment.

While investments in renewable energy infrastructure in emerging markets has long been the realm of publicly funded investors, DFIs, and other investors whose mandate has predominantly been on maximising social impact [40], the sector is increasingly attracting corporate investment as well as fund managers who are seeking to diversify their portfolios. Though we argue that the sector is "open for business" to any profit-seeking investor, a growing tendency among final investors to seek financial returns alongside social impact is a strong driver and should play in favour of fund-raising entrepreneurs in this area [47,48].

To fill this gap, this article analyses the business model-related causes of the high rate of project failure in the decentralised electricity access sector. In parallel, based on the identified challenges, it proposes and critically discusses potential game-changing strategies for decentralised electricity access companies aimed at increasing attractiveness from a financial perspective by strengthening business models. The overarching objective is to discuss the measures that ought to be considered by private players in the 2020s if the SDG 7 target of universal access to electricity is to be achieved. An important remark is that although distributed embedded energy is becoming more relevant also for grid-connected businesses and households (for various reasons such as reliability of supply), in this article we focus on underserved areas with little or no perspective of connection to the national grid within the near future.

The remainder of this paper is structured as follows: Section 2 provides a context to the analysis by presenting and discussing recent trends in decentralised electricity access investments while also devoting specific attention to the implication of the COVID-19 pandemic for the sector. Section 3 then describes the methodological approach adopted in reviewing the existing literature and in the sourcing of the case studies upon which the paper refers. In addition, the section provides technological and economic definition for both solar home systems and mini-grids. Thereafter, Section 4 presents the results of the review, which are divided into a description of the dominant business models in distributed electricity supply and a mapping of the related risks and failure causes. Section 5 then presents four potential strategies to mitigate the identified drivers of risk and project failure as well as foster sectoral investments. Finally, Sections 6 and 7 summarise the results discussing their operationalisation, and conclude the paper, respectively.

## 2. Background

### 2.1. Pre-Covid investment trends in electricity access

According to the available estimates, between 1990 and 2013 only \$31 billion has been invested in grid-connected power generation in SSA (excluding South Africa), with less than 16 GW of generation capacity added [49]. This figure is strikingly low when compared to the regional required additional annual power sector investments (including T&D lines) needed to provide electricity to the ~575 million without access in SSA, estimated at \$30 to \$55 billion [9,15]. Several studies [50,51] argued that a set of institutional, market-related and financial barriers are the main factors responsible for the lack of electricity supply infrastructure investments.

In response to regulatory hurdles and other key obstacles such as the limited ability to pay among energy poor households [10], private players have been seeking other approaches to enter the electricity access market and overcome some of the challenges found when procuring utility-scale power plants and transmission and distribution infrastructure. As seen in Fig. 1, the last decade has witnessed a surge in global investment trends in decentralised electricity access systems, with both solar home systems and mini-grid markets having grown substantially. Fig. 1 shows that in the context of standalone solar, PAYG financed solutions have been growing very fast between 2017 and 2019 compared to the cash market. An even more impressive development was observed in the mini-grids market between 2012 and 2019, where - albeit with fluctuations - investments have grown from about 25 million in 2012 to nearly 500 million in 2017.

Yet, when examining the funding sources for such mini-grid projects in the African region (Fig. 2), it becomes evident that the main ones have so far been international institutions such as development banks. A similar situation is found in the SHS sector, where external private investors still represent a minority among funding sources [52]. While these are important actors in the process of fostering SSA's electrification [53], private companies - both international and national - should take the lead in investment flows in the sector if ambitious electricity access objectives such as those of SDG 7 are to be achieved, because public utilities simply cannot afford large-scale investments in remote areas with low revenue collection potential due to their precarious deficit status [12].

### 2.2. Effects of the COVID-19 pandemic on the off-grid market

The COVID-19 pandemic has exerted a significant negative impact on investment flows worldwide. It is thus worth to provide an overview of the implications for the investment in the off-grid electricity access sector, which makes no exception. For instance, in late 2020 the IEA showed that the pandemic has negatively affected the rate of electrification in SSA after nearly a decade of steady progress [5]. The drop in distribution of systems is not only due to lock-downs and loss of purchase power by customers, but also to price increases in hardware and components. Despite a recent slow recovery since the second half of 2020, the short- and mid-term impact of the pandemic are still being felt: GOGLA estimates that due to the impacts of COVID-19, new or improved access to energy has been stalled for an estimated 10–15 million people and 300,000–450,000 enterprises [41].

According to recent surveys by Gogla [27,41], 57% of electricity access companies recorded lower sales in the first half of 2021 compared to the second half of 2019 as shown in Fig. 3. Shortages and shipping disruptions were the main factors that led to a decrease in sales, affecting mainly small companies. While remaining an important source of concern, the situation has improved compared to 2020, when about two-third of electricity access companies reported lower sales in the second semester compared to the year before [41]. Moreover, in April 2020, a survey was conducted by GET.invest among about 70 portfolio companies in Sub-Saharan Africa [54,55]. Opposed to the Gogla survey

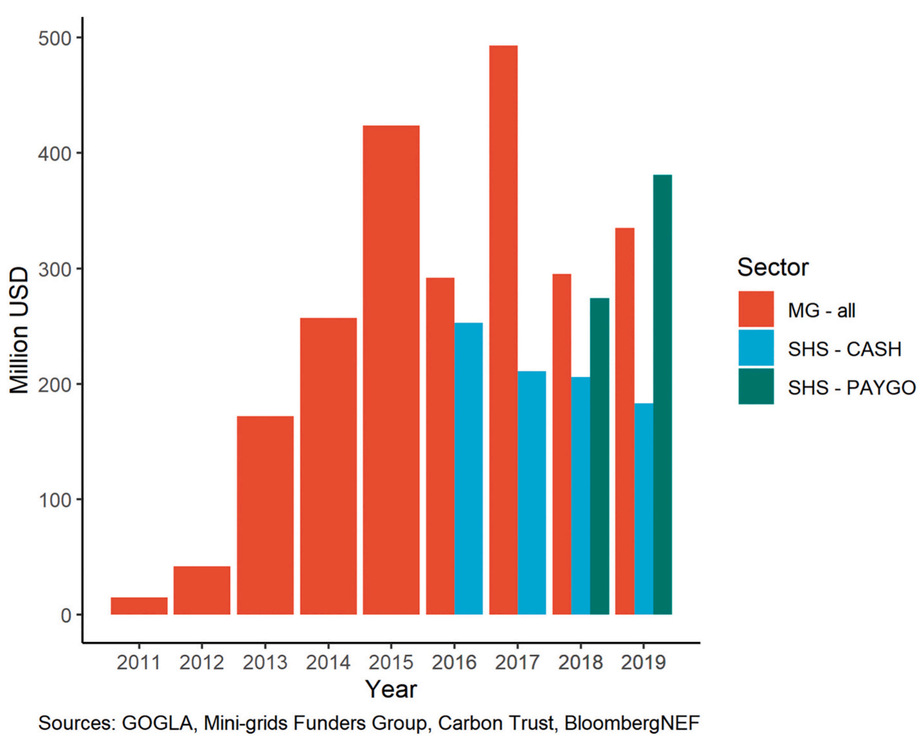


**Fig. 1.** Global investment trends in mini-grids and solar home systems.

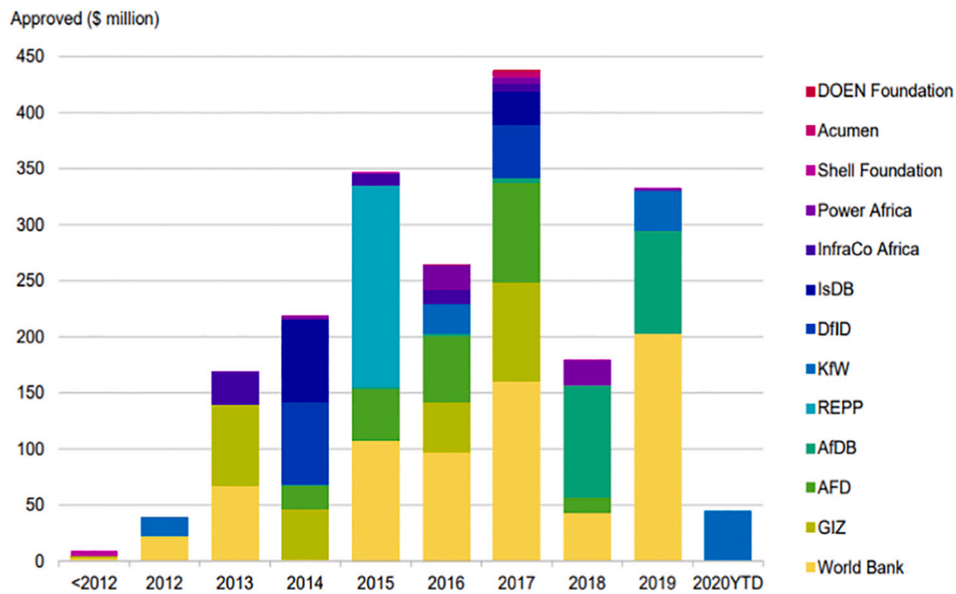


**Fig. 2.** Historical evolution of approved mini-grid financing by funder.

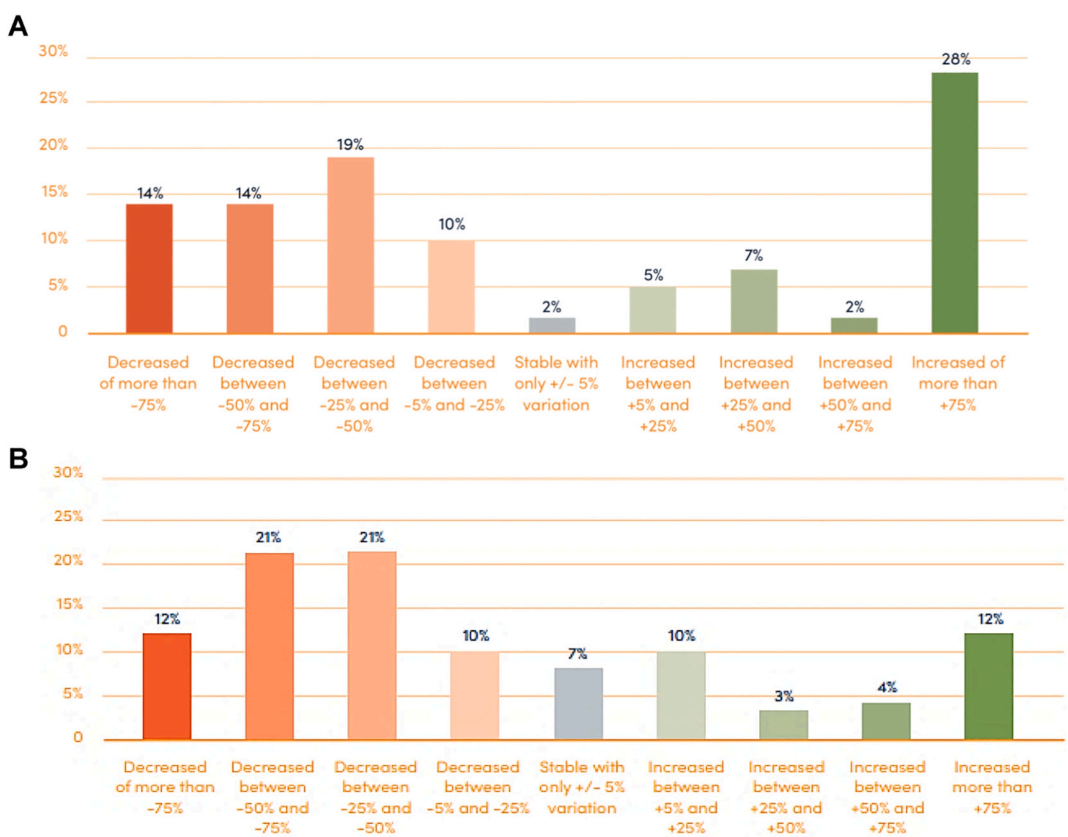


**Fig. 3.** Variation in Off-grid Solar Lighting Sales Volumes in H1 2021 (panel A) compared to H2 2019 (panel B) for Electricity access Companies – World (GOGLA).

carried out two months earlier, 97% of respondents reported an impact of COVID pandemic on their business. While impact on revenue and workforce logistics were stated as the greatest concerns, 84% of respondents saw the implementation of relief funds in form of grants as the most adequate measure to address the negative financial impact on their companies [41].

Though effects can be felt across the entire industry, the pressure from drops in sales and cost increases has been experienced particularly by smaller companies. While several Covid-related relief funds have been announced by a number of public financiers and technical assistance facilities (e.g., Electricity access Relief Fund managed by Social Investment Management and Advisors SIMA), relatively little has been disbursed in reference to date. Rather than reflecting a lack of need for those funds, this might also be due to lengthy approval processes, often taking up to a year for most development finance institutions (DFIs).

## 3. Methodology

### 3.1. Review approach

The main research questions addressed in this article rotate around the causes of the high rate of project failure in the decentralised electricity access sector. Based on those findings, the overarching purpose of this paper is to explore innovative strategies to reinforce the attractiveness of electricity access companies, with in particular in the context of SSA. Namely, we investigate measures and actions that ought to be considered by private investors in the 2020s if the SDG 7 target of universal access to electricity is to be achieved.

To address these questions, we rely on three main sources of analytical insight: (i) the provision of a clear definition of the technological and economic characteristics and financing specificities of both solar home system solutions and mini-grids, the two decentralised electricity supply options here considered; (ii) a literature review of both peer-reviewed publications and of grey literature (such as reports from decentralised electricity system developer consortia, very relevant in the business and financing context inquired) covering challenges and opportunities for the financing off-grid electricity in developing countries; and (iii) a set of real-world case studies (of which 4 are detailed in the Appendix and referenced, where possible) in which the authors have been professionally involved and have collected important insights.

While the methodological foundation of the article is reviewing existing literature, we add value to our findings by bringing in data and observations from cases in our professional practice. This combination of qualitative and quantitative methods, also known as mixed method research, was originally applied mostly in fields like education or health sciences [56]. Over recent years it has been widely used in contexts where practical constraints on data collection exist including policy as well as business problems and questions [57]. Thanks to this complementary approach, results and observations that we obtained from our professional practice could be clarified and embedded into a wider theoretical framework derived from other cases described in the literature.

In particular, the case studies described in the Appendix stem from one of the authors' advisory experience with GET.invest, a European programme that mobilises investment in renewable energy in developing countries. Whilst they all fall within the off-grid PAYG business model, representing both Solar Home System and minigrid models, the case studies represent different strategic approaches to manage assets and access finance (see Appendix). The OnePower case highlights how entrepreneurial engagement is able to trigger policy change in the minigrid space, reaping an “early bird” reward against competitors. FENIX and SIGORA, though active in different geographies, make use of cloud technology to control payment flows and revenue streams. The case of Dutch DFI FM highlights how the use of data processing technology is already acceptable by institutional financiers as an alternative to costly solutions like legal ring-fencing, providing a head-start to innovative smaller PAYGs.

The approach adopted in the paper is thus problem-and-solution based. Namely, Section 4 seeks to describe the dominant business models in decentralised electricity access investments, for solar home systems and mini-grids, respectively, and – based on the above-mentioned sources – to highlight the main drivers of risk and failure. In Section 5, we then proceed by proposing potential solutions to mitigate the identified drivers of risks. These business approach proposals are made with reference to ongoing discussions in the relevant literature and in sectoral reports and are then summarised against the historically dominant financing approaches to highlight their value added.

### 3.2. Theoretical framework

Based on the business model canvas (BMC) concept [58,59], Fig. 4 conceptualizes the core elements of a decentralised energy access business model. The BMC seeks to fill information and communication gaps that may exist between enterprises and investors, especially at early development stages. It has the objective to provide an overview of the most crucial business opportunities and challenges, as well as how the enterprise plans to generate profit. In this specific case, the value proposition (central pillar of the figure) is the provision of electricity at an affordable price to communities currently without access. The right-side focuses on the customers, including how the company plans to reach its clients, and the revenue model. On the other hand, the left side emphasizes on the company's activities and operations, the resources used and the business partners, as well as on the overall cost structure. Finally, factors external to the energy company are represented on the top of the figure, and encompass elements characterized by a macro dimension such as environmental factors (e.g., flood, drought), policies and regulations, as well as macro-financial elements (e.g. exchange rate). Throughout our paper, we implement this framework to those business models that have become the most relevant approaches targeting access to energy, mini-grids and solar home systems, also in combination with Pay-As-You-Go payment models.

### 3.3. Solar home systems: technological and economic definition

Solar home systems (SHSs) are electricity supply devices designed for enabling energy services in areas beyond reach of national grids or with an unreliable power supply. They can operate with or without storage capacity and enable the use of several small-scale appliances (Tier 1 and above according to ESMAP and the World Bank Multi-Tier classification of electricity access; see [60]), including lighting, phone charging, power for household appliances as well as micro- and small-scale businesses (i.e. refrigeration, irrigation, small agro-processing) (e.g. see Fig. 1.9 in [20]). According to recent estimates of the International Energy Agency, by 2030, stand-alone systems (including SHSs) might represent the least-cost electrification option for nearly 25% of the African continent's population [9].

While specialization has recently started to emerge in the SHS sector, so far the market remains mainly vertically integrated [27]. Namely, individual companies tend to coordinate business operations along the entire SHS value chain, rather than specific companies specialising at different levels. Nonetheless, business models in the sector have evolved and undergone significant changes during the last decades [61–64]. Indeed, many project developers have started to adopt innovative solutions enabling products and services to be customized to the electricity consumption and financial affordability of targeted customers [41]. In particular, the latter have the possibility to cover their energy-related costs through different schemes, including service-based and PAYG models, as well as through single or multiple payments spread over time. Those demand-driven payment mechanisms combined with the increasing availability of mobile money and consumer finance across SSA have facilitated the access to SHS for many households in the region [65].

On top of that, the constant evolution of the SHS sector has reinforced the competitiveness of the market in the subcontinent, pushing some SHS companies to differentiate themselves by pairing the provision of energy devices with the selling of other products [27]. Like mini-grids, SHS target a potentially significant addressable market, mainly in rural and peri-urban zones [41]. As a matter of fact, certain SHS companies have reached important customer portfolio sizes, encompassing individuals located in several geographical areas and with distinct socioeconomic profiles, thus benefiting from diversification opportunities [27].

One particular distinction from grid-tied technologies is that SHS business models are less dependent on specific regulations than mini-grids as well as present lower up-front costs and shorter payback periods [66]. However, although many SHS companies have significantly improved their unit economics as well as benefited from increasing reliability and decreasing costs of technologies [67], most of those

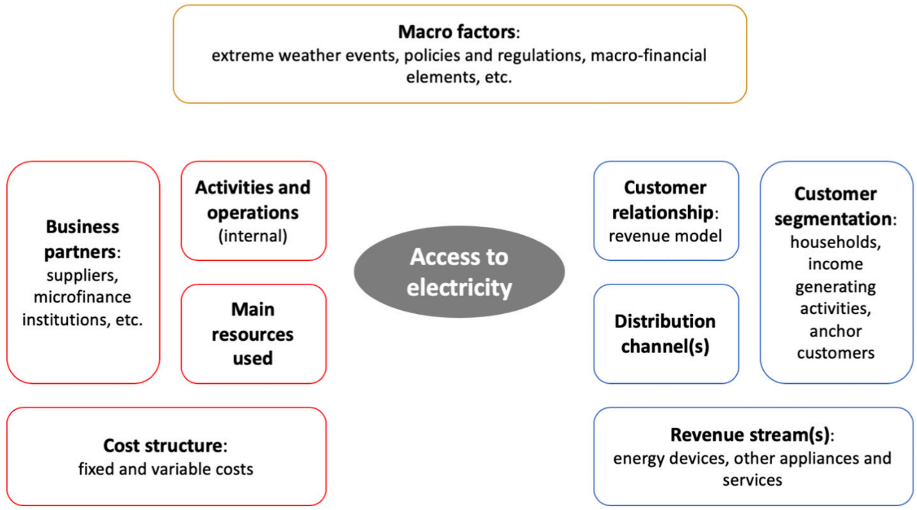


**Fig. 4.** Simplified business model canvas adapted to decentralised energy access companies.

operating in SSA have not reached profitability yet. This is primarily due to elevated costs related to hardware development as well as expensive and possibly complex last-mile distribution. SHS are also working capital intensive, as they generally hold substantial inventories combined with client receivables, which increases with the size of the customer portfolio [65]. As it is impractical to satisfy this need for capital with equity financing alone, the growth of the sector will largely depend on having debt funders stepping in to cover capital requirements. Large and long-term debt investors will most probably be cornerstones for the SHS sector in emerging economies.

A basic strategic decision to take for a SHS company is the distribution channels used to reach their last-mile customers. While hiring and training their own staff may lead to better control over the value proposition to the customer, it has an adverse effect on the left side of the Business Model Canvas: Creating higher fixed costs in a very price-sensitive market. Most SHS companies today choose to use 3rd party distribution partners with existing sales infrastructure, usually sacrificing to a degree the creation of a strong brand consciousness among their customer base.

In order to attract more debt funding to the sector, assets are increasingly used as collateral to secure loans, decreasing risks to lenders and improving (in theory) financing terms. Asset securitization for off-grid solar has first been tried out by SHS provider BBox in Kenya [68]. Several other companies have followed, and asset financing has become a commonly-used feature among SHS providers also in other geographies [69]. The "ring-fencing" of customer receivables into a special purpose vehicle (SPV) allows financiers to lend against a specific set of underlying assets without having to enter into the economics and specific risks of the operating SHS company itself [70]. While this segregation mitigates risks for the investors and hence should result in lower cost of funding, it is also a complex and costly transaction, generally only efficient once a SHS company has reached a considerable scale.

### 3.4. Mini-grids: technological and economic definition

Within the scope of this study, mini-grids are defined as decentralised and small-scale utilities providing power to a cluster of people and/or enterprises without connection to the national grid, against a service fee based on individual consumption. Mini-grids can provide a significant and stable source of power (Tier 1 to 5) [60], thus enabling electricity access not only to households, but also to small- and medium-scale businesses as well as anchor consumers such as health centres, telecom towers or schools [71]. On top of that, mini-grids offer a certain flexibility as project developers may adapt the installed capacity to the community served.

Mini-grids are considered as a crucial technology for the achievement of SDG 7 [9] and have witnessed a decrease in costs of technologies as well as an improved reliability, providing the potential to support local economic development in emerging countries. According to the International Energy Agency they will provide access to electricity to over 30% of the African continent's inhabitants by 2030 [9].

Mini-grids target rural and peri-urban zones, consequently operating in an important addressable market in SSA [26]. Nevertheless, project developers require concentrated settlements to power a certain number of customers to become financially viable. Frequently, project developers manage a portfolio of mini-grids, allowing economies of scale as well as diversification opportunities by serving heterogeneous communities across different geographical areas. Unlike SHS, mini-grids have characteristics close to an infrastructure investment as they face important up-front costs and are highly sensitive to the cost of capital [25]. Moreover, they need to comply with specific regulations regarding licensing, permitting and in some cases tariff setting, which altogether constitute key barriers and sources of risk for mini-grid business model design. In addition, the ownership structure of mini-grids is also an important feature that can vary significantly, ranging from privately or publicly owned and managed models to community-based entities.

Critical factors within the Business Model Canvas for the mini-grid model are upfront costs ("CAPEX") on the left side and stable revenue streams on the customer side. Opposed to SHS PAYGE where systems can be repossessed, total investment in infrastructure is largely decoupled from future revenue streams, making it crucial to understand customer segments and abilities to pay before investing.

Based on case studies from Uganda, Tanzania, Nigeria, India, Philippines and Indonesia, the recently published "*State Of The Global Mini-grids Markets 2020*" report by Bloomberg [37] identifies the lack of enabling regulatory frameworks as a key hurdle for the sector to be successful within a given geography. The ability to charge tariffs that are cost-covering has been identified as the single-most important requirement in terms of policy framework - a requirement that often runs counter social and political agendas aiming at maintaining equal tariffs for urban and rural dwellers [26].

## 4. Results

### 4.1. Dominant business models in distributed electricity: mini-grids

Despite representing the preferred alternative for areas where grid expansion is not a viable option from a policy-making perspective, mini-grid business model has been struggling to attract private investment. The mini-grid market has in fact long been the realm of purely grant and highly concessional funding by public institutions (i.e., the African Development Bank and Green Climate Fund). However, in recent years the sector is slowly starting to attract interest from private investors looking to diversify strategic energy portfolios. Among those are Deutsche Bank, who committed 3.5bn USD over 15 years [72], Facebook and Microsoft seeking to loan 50 M USD over the next three years through their Microgrid Investment Accelerator [73], or Shell Technology Ventures with a 20 M USD investment into Husk [74].

Unlike other cleantech sectors where return-seeking VC firms are seeding promising start-up outfits, investments in the mini-grid sector are characterized by long-term, infrastructure grade returns and a stronger focus on impactful ESG scores [75,76]. Public as well as specialised private investors usually start investing at later development stages (avoiding a large part of development risks) and at amounts well above 1 M USD, thus highlighting a yawning gap for early- and medium-stage funding [77]. For early-stage investors, either expected financial returns are too low, or the investment amounts required at later development stages allowing their exit are too small for most international lenders.

Among SSA markets, Bloomberg's 2020 *Mini-Grid Market Status Report* identified Nigeria, Uganda and Tanzania as the most conducive environments currently for successfully implementing commercial mini-grid businesses. Moreover, an internal survey among the advisory network of GET.invest aimed at identifying the most attractive mini-grid markets to direct future funding was conducted in June 2020 [54], selected Nigeria, Rwanda, Uganda, Malawi, and Tanzania. While the "stable political and economic climate" combined with the committed institutions in Rwanda was mentioned as a contributing factor, Malawi found its entry into the list of selected countries due to a "democratizing political climate" and the abundance of donor support.

Nigeria in particular has received praise not only for its significant market size, but also for its legislative framework allowing to set tariffs considered as fair. Nevertheless, as highlighted by Butu et al. [78], the Nigerian government is also known for policy abandonment in the energy sector, increasing the risk perception of potential investors. For instance, the Nigerian Multiyear Tariff Order II (MYTO2), aimed at supporting profitability of energy companies, put the price of on-grid solar at \$0.263 per kWh. Yet, power purchase agreements (PPAs) between the government and energy companies reported tariffs at \$0.115 per kWh, illustrating the implementation challenge for the public sector. Tanzania, though generally considered a pioneer in including mini-grids into its national generation landscape, is however considered to fall back recently due to an implementation gap of an otherwise positive regulatory framework.[1]

### 4.2. Dominant business models in distributed electricity: solar home systems

With PAYG, the focus has changed from a supply-driven financing approach to demand-side, where microfinance has emerged to cater the financial needs of end-users [28]. With traditional financing mechanisms being unable to progress access-to-energy rates especially in poorer rural areas, PAYG businesses emerged as part of the energy distribution landscape. PAYG companies offer accessible energy solutions to households that neither have the capital nor a solid credit rating for either leasing or direct payment solutions (multiple payments spread over time), through the use of digital information and communication technology (ICT). Yet, PAYG businesses need significant amounts of working capital to pre-finance the power systems.

Thanks to PAYG deployment in access to clean energy, investments had reached over 500 M USD by 2018 [40]. Despite some significant setbacks of the young PAYG solar sector, it has quickly become the dominant business model for last-mile electricity access. However, due to the complex and relatively new nature of this asset call, financiers still struggle to understand the risks involved in this sector.[2] The definition and diffusion of industry-wide standard metrics has been on the agenda of the World Bank since 2016 [37]. The establishment of common key performance indicators (KPIs) will be crucial to increase transparency of the sector and help financiers assess real and perceived portfolio risks.

According to Sonntag-O'Brien & Usher [79], capital is required at various stages of an off-grid electrification investment: upstream of the project, to run the project, and downstream to support customer and/or specific business transactions. Concerning project-level financing, namely the start-up capital and the ability to take risks in the new business, the following financing options fall in the basket of what has been observed so far in the sector [75]: (i) equity or (concessional) debt financing by public agencies; (ii) asset-based lending: project developers borrowing funds from banks or financial institutions by mortgaging PV assets or additional assets; (iii) non-recourse financing: the company borrows money based on its project cash flows instead of relying on the parent company's balance sheet; and (iv) supplier credits: PV suppliers offer credits to dealers or aggregators to improve cash flow in the short run.

On the other hand, for the end-use level financing, the most prevalent sources of capital have consisted of (i) small-scale lending; (ii) micro credits by specialised institutions, aimed at bottom-of-the pyramid income group; (iii) leasing arrangements, where the company supplies the appliance with upfront investment and receives a monthly charge from the consumers towards recovery of the cost; and (iv) revolving funds (generally provided by philanthropic organizations or donors) that are operated by community-based organizations that lend funds to individuals often at a more favourable rate than banks do [80].

While much literature has recently focused on the potential of mini-grids as an alternative to grid-extension [37,81,82], SHSs often distributed in connection with a pre-financing solution have gained significant market share over the past years, and are now representing a dominant way of bringing electricity to off-grid users in SSA. Yet, to a part of rural users and the international donor community – also supported by some academic research –, SHS is perceived as a cheap replacement for "real" on-grid power, unable to impact development or trigger economic growth [83,84]. Negative experiences during the first wave of solar village projects during the 1980s, 1990s, and early 2000s have contributed to build the reputation of SHS as a cheap fix with no lasting impact – which is contradicted by recent systematic evidence [85]. While a good part of the blame of early failures can be attributed to a lack of institutional and regulatory support, technological advances from low-consuming LED lighting, battery storage and of course the decline of cost for PV have shifted the market in favour of individual power supply. However, the most significant technological achievement is the availability of mobile money to a large part of Africa's rural population, paving the way for pre-financed and PAYG solutions, taking away the necessity for significant down payments.

[1] The existence and effective cooperation between the Rural Electrification Agency (REA) and the regulatory authority (EWURA) were considered crucial for the success of the Tanzanian mini grid market, leading to over 200 mini grids (including diesel and hybrid technologies) being implemented to date, accumulating approximately 250 MW generation capacity [37].

[2] Valuation of a PAYG company has been a point of much controversy among entrepreneurs and potential equity investors. General practice to use multiples of key financial indicators has its limits in a young company with (still) volatile revenue streams. The common approach of using multiples underestimates the value of an industry expecting exponential growth. A discounted cash flow analysis could deliver a more reasonable value assessment.

### 4.3. Risks and failure in decentralised electricity access investments

#### 4.3.1. Previous systematic evidence

Previous literature contributions have shed light on the main barriers encountered by private investors in developing countries facing energy access issues. The studies discussed below have been identified and selected among the relatively scarce but growing academic literature investigating the risks and reasons for failure associated with off-grid energy access projects.

For instance, Ika et al. [86] discuss international development projects and project management problems in Africa, highlighting four main traps as the key reason for the high rate of project failure: (i) the one-size-fits-all technical trap, i.e. utilising traditional approaches in a normative way without evaluating the heterogeneity of local contexts; (ii) the accountability-for-results trap, i.e. a strong focus on procedures and guidelines and little attention of management "for results"; (iii) the lack of project management capacity in the region for project implementation and stakeholder involvement; and the (iv) cultural trap, namely the failure to relax the traditional top-down approach that dominates development interventions. Similar insights are offered by Okereke [87], who reviews a series of recent failure and abandonment of projects and project deliverables in Africa. The author highlights that the most frequent reasons being hazardous project management, incapability of collecting the required financing, corruption, lack or poor quality of feasibility studies, and lack of expertise to operate and maintain the infrastructure.

With regards to the specific case of the off-grid electricity sector, Ikejemba et al. [29] carried out an ethnographic study among 29 local communities benefitting or expected to benefit from RE-based decentralised electrification projects in 10 countries of SSA. They find that irrespective of cultural and context factors, the reasons for failure of the projects are similar across different countries, namely issues related to: (i) the political agenda, (ii) the process of awarding projects, (iii) stakeholder co-operation, (iv) planning & implementation, (v) maintenance and (vi) public acceptance & inclusion. Ikejemba et al. [33] propose potential solutions to each of those issues, namely: (i) transparency, (ii) ownership, (iii) shared responsibility and (iv) community involvement. Subsequently, Ikejemba and Schuur [32] observe the societal impact of those projects and compare them with ex-ante expected impacts. This type of pre-post comparison study allows to identify a number of project failures as well as investigate their reasons. The authors find that most of the projects investigated in this study had few to no societal benefits within a short period of time after their commissioning.

#### 4.3.2. Risks associated with SHS and mini-grids

Due to the complexity and relatively new nature of SHS and mini-grids business models (with flexible payment methods), financiers still struggle to understand the risks involved in these sectors and the associated portfolio of customers [88–90]. Broadly speaking, mini-grids and SHS present five core risk features: (i) economic and financial; (ii) political, legal and regulatory; (iii) business environment; (iv) social acceptance risks; and (v) environmental considerations [10,18,26].

The first risk category includes the currency risk, namely the mismatch between revenues collected in local currency and financing expenses generally paid in foreign tenders. On top of that, government restrictions that limit or even remove currency convertibility add uncertainty, especially in SSA contexts. The liquidity risk is also relevant for SHS and mini-grids as cash-flow constraints may appear due to high up-front costs, long negative cash-flow periods as well as lack of access to affordable capital, tailored financial instruments and ticket sizes (either for financing or refinancing). Capital scarcity may come from the limited experience of many capital providers to invest in the clean energy sector in the subcontinent. In the context of equity-like investments, no or little exit options preventing investors to generate financial returns adds a major obstacle for the financing of clean energy companies in SSA.

Secondly, the overall country situation is key for the conduct of any businesses around the world. In SSA contexts, different political and legal aspects significantly increase the risk perceived by many investors, ranging from instability and turmoil to corruption and poor public governance [51,91]. Specific policies and regulations, including potential changes over time, also add uncertainty to the analysis of SHS and mini-grid business models. Moreover, particular technical requirements may limit the access to the market and/or suppliers, and extensive bureaucratic hurdles and time-consuming procedures can hinder the development and scaling of businesses. Public policies may also provoke market distortions in certain cases, affecting the competitiveness of SHS and mini-grid companies. For instance, fossil fuel subsidies incentivise customer to acquire alternative energy devices, rendering clean solutions less attractive from a financial perspective.

When it comes to business environment risks, a first important aspect in SSA is linked to the customers. In many cases in the subcontinent, information regarding their potential energy consumption and socio-economic situation is sometimes not clear, therefore adding complexity to the development and analysis of off-grid electricity companies [42,92]. In particular, financial affordability and willingness to pay of targeted users, combined with a lack of financial channels in some areas, increase the customer risk. The operational risk is also important for potential investors as it can lead to suboptimal performances. It includes internal operations, workforce and stakeholder management. On top of that, external factors can affect operations, mainly the counterparty risk (i.e., breaches of contract, delays and technological risk) that may negatively impact clean energy projects and increase the social acceptance risk.

Regarding mini-grids, installation, operations and maintenance can be complex due to implementation in remote locations that may be difficult to reach. Moreover, unexpected and unplanned grid arrival before complete amortization of a mini-grid project may lead to significant financial losses, and even stranded assets, since the national grid is normally cheaper mainly thanks to economies of scale [93]. In the SHS sector, distribution and after-sale services, as well as end-of-life cycle management are particularly crucial for the conduct of businesses. Furthermore, competition is increasing in the sector, encompassing several players operating in the same market(s), as well as alternatives such as diesel and kerosene.

Another risk component stems from unfamiliarity with mini-grids (mainly) and SHS as well as a lack of awareness regarding the advantages and disadvantages of these clean electricity systems, that can hinder market penetration and product acquisition, and thus slow down the scaling of companies in certain territories [94]. Community and stakeholder management is of high importance for mini-grids as they are installed to serve a group of customers. The whole community where the mini-grid is implemented should thus be involved in the development and management of the project, in order to avoid negative consequences on the installation and the services provided.

Finally, potential environmental disasters as well as climate change concerns may affect the overall performance and maintenance of energy devices. For instance, severe drought will affect the performance of a hydro-powered mini-grid, or an unexpectedly prolonged cloud coverage period will lead to an underperformance of a SHS.

## 5. Towards the next generation of investment strategy in decentralised electricity access

### 5.1. Mini-grids and anchor customers

As discussed so far, mini-grids have become an attractive solution for rural communities in developing countries, mainly thanks to technological innovation allowing cost-efficient and small-scale power production, as well as improved reliability. Nevertheless, the development and implementation of underlying business models need to be adapted to the specific needs of the targeted community while presenting an adequate risk-return profile for potential investors during the entire life cycle of the project.

In the SSA case, especially in rural zones, the customer risk is particularly high, and demand is usually low and difficult to predict. Thus, anchor customers as well as productive users offer an interesting opportunity to develop innovative business models for mini-grid systems, able to support socioeconomic development and provide reliable power at an affordable price thanks to cross-subsidization [95]. Models involving anchor customers are particularly well-suited when expected revenues emanating from residential users are limited, unstable, and uncertain. Potential anchor loads, ranging from public agencies to telecom towers and health centres, may guarantee the necessary demand level and revenue stream to project developers and investors. The community can then access reliable power supply while providing additional revenues to the business model.

In addition to anchor customers, project developers may also connect local businesses to the mini-grid, creating a so-called ABC model (A: anchor customers; B: businesses; C: community) [96]. In many contexts, local productive uses may be key success factors by allowing the mini-grid project to reach optimal sizing and financial viability, mitigating low and unpredictable demand of residential customers as well as decreasing the customer risk. For instance, Ngowi et al. [97] analyse empirical high-resolution data from a mini-grid site and find that a mixture of household uses and productive uses of electricity provides both technical and economic benefits for the operator. Namely, in the case study under analysis, they estimate that while productive use customers represent only 25% of the customer portfolio, they generate 44% of the operator's income. Furthermore, business customers are also likely to be responsible for the peak demand in the mini-grid system, which occurs during the daytime.

Of course, the design of a specific business model should depend on the socio-economic context in which it is implemented. Yet, we argue that the involvement of anchor customers and/or productive users may strengthen potential revenue streams and improve risk-return profiles of mini-grid systems.

### *5.2. Untapping the income generation potential through integrated business models*

While mini-grids developers mostly face issues of collective nature, such as economic sustainability under a low demand (and thus limited profit potential) and free riding among mini-grid beneficiaries, providers of standalone solutions (such as SHS) generally encounter challenges related to the regularity of payments from individual private end-users, e.g., households and small-scale activities. In the context of SSA, these two categories of user tend to geographically coincide, as many micro-enterprises are home-based [98].

Very high discount rates faced by developers are the consequence of the large degree of risk incurred from the demand-side: high discount rates in fact create a negative feedback loop, as they raise the cost of capital and therefore discourage individual households and business activities themselves to make upfront payments for the infrastructure or create substantial struggle to pay regular installments [51]. These issues are responsible for a large part of the obstacles encountered by the standalone electricity access sector over the last decades.

While new business models, such as PAYG, are aimed at mitigating this type of issue (i.e., hedging from risk and thus decreasing the investor discount rate), we argue that to ensure profitability of the sector and thus mass uptake of decentralised solutions (which in purely techno-economic electrification modelling studies are shown to be the optimal electricity access solution for hundreds of millions), more structured and integrated strategies are required. In particular, these business solutions must be able to explicitly consider the electricity-development-agriculture nexus that is found in rural areas (i.e. where standalone solutions bear the greatest potential) [99]. Ex-post empirical evidence has confirmed the crucial role and potential development impact of energy access projects putting productive uses at the core [100–102].

Recent studies have explored this paradigm shift. For instance, Kyriakarakos et al. [103] show how a number of households owning agricultural land or working in the fields could meet the high cost of rural electrification through the increased value of locally produced products thanks to electricity-enabled artificial irrigation and crop processing, and thus cross-subsidize the cost of household electrification. In parallel, Kyriakarakos and Papadakis [104] show that the use of the PAYG model in conjunction with smart meters and internet platforms can be exploited to facilitate access to, and payment of, services provided by decentralised electricity access operators, realizing a local virtual marketplace.

In our opinion, the keyword here is conditionality. While on an ethical level universal access to modern energy is a fundamental right [105,106], we argue that in communities living in energy poverty and without near-term possibility of being reached by the (state-owned) central grid, it is crucial to find business models that are able to ensure profitability and reduce risks for profit-seeking private providers of decentralised electricity access solutions. Here by conditionality, we refer to business models that aim at lowering the discount rates faced by developers and providing advantageous pricing schemes conditional on the purchaser (i.e., household and/or small-scale commercial businesses) committing to using part of this electricity for income-generating activities, i.e. not limiting the use to household basic needs.

A broad range of potential income-generating uses fall under this umbrella: for instance, non-agricultural activities such as handcrafting, barber shops, welding, online jobs, or agricultural activities such as increasing cropland productivity through water pumping for irrigation or crop processing for increasing the added value and thus the revenue of the yield. Business models inclusive of conditionality of supply based on electricity provision for productive uses and potential income generating activities can then act as a trigger to climb the energy ladder with higher consumption levels as income grows and more appliances are purchased. The key barrier is thus ensuring that decentralised electricity access solutions are purchased and installed in combination with appliances that enable those income-generating energy uses to occur. It is in this sense that developers should seek to sell bundles including e.g. a SHS and an appliance with productive use potential, or a solar water pump capable of providing also some basic household energy supply [107,108].

Of course, the design of this type of integrated business models requires an ad-hoc, local analysis of the characteristics of the community (e.g. potential electricity demand, existing productive activities, market growth potential) [103,109]. This process is itself generally costly and it might imply higher distribution costs than traditional projects, due to the custom product and appliance needs and the potentially higher maintenance costs once in place. Data-intensive decision-support tools can play a crucial role in diminishing these cost components and standardise the process of ad-hoc business model design.

### *5.3. A growing role for "local" financiers*

Thanks to the growing use of customer receivables and other assets as collateral to mitigate risk and improve lending conditions, investing in renewable energy will become accessible for a wider range of lenders. If formerly investing e.g. in a SHS distributor meant having to understand and assess the risks of technology manufacturing, asset-finance, as well as sales and operations of products, thanks to securitization this has become an asset-backed lending operation familiar to commercial banks. Yet, this will also involve the need for a change of perspective from local financial institutions, who often still see themselves as redistributors of DFI credit lines, rather than providers of their own funding.

This development could present a particularly interesting opportunity for local and regional African banks, while in the past unfavourable cost-to-asset ratios and resulting prohibitive lending rates have kept local finance out of the clean energy sector. As a recent study by McKinsey states [110], the African banking sector is relatively robust despite heavy economic fallouts that came out of the pandemic. However, given the still uncertain trajectory of economic recovery, banks will likely look for new opportunities for growth, scaling up technology and "strengthening the risk management muscle" [110]. Besides the general sector risks, it will be crucial for lenders ́ risk departments to develop capacity to assess the value of the given collateral. In case of receivable finance, this value directly depends on the individual credit risk of the underlying base of customers included in the receivable's portfolio.

In order to assess the inherent portfolio risk in the receivables of a distribution company, the bank will have to be familiar with the different types of asset financing used by their investees. One established distribution model by off-grid solar companies is through asset-backed lending, using the asset acquired as collateral for the loan. This type of assets can range from quality-of-life enhancing assets like SHS, solar fridges etc. to productive assets like farm equipment. Owning assets is also an impactful way of poverty alleviation, as *"a growing body of evidence suggests that assets help poor people capture opportunities and become resilient, with effects that advance several Sustainable Development Goals"* [111].

The distinct types of asset finance can be differentiated in low-value assets, whose primary purpose is to enhance quality of life (smart phones, lighting kits, tier 1 SHS) and high-value productive assets (water pumps, freezers, farming equipment, etc). For high-value equipment, providers use a more stringent underwriting process to ensure ability to repay. As these assets are often depreciating less rapidly as well, the collateral value of a cohort of customers owning high-value assets can be considered to be higher. Asset-backed lending and rent-to-own deals typically include higher value asset classes, while asset-as-a-service, buy-now-pay-later and micro leasebacks are usually done for smaller systems. PAYG was usually done for tier 1 or tier 2 type SHS, but companies have increasingly included higher value and productive equipment in their PAYG product ranges.

### 5.4. Ring-fencing assets

Almost all business models within the PAYG sector presented to financiers assume extremely high (>100%) growth at least during the first years of operation [27]. These are often backed by market studies showing large addressable markets driven by high demand from presently underserved customers. However, whether a large market opportunity translates into strong growth of a particular company largely depends on the capacity the enterprise's operational base has to grow. Also, recent years have brought in a lot of adverse events which are hard to predict, from climatic adversities, economic downturns, to pandemics. At the same time, entrepreneurs in fundraising mode are unlikely to pre-emptively lower growth figures and hence predict capital needs as they would see their company ́s "real" capacity being misrepresented.

For financiers to ensure that debt services are paid out of revenues rather than subsequent financing rounds, receivables-backed lending has become a common approach: the ring-fencing of a special purpose company that holds the demand against end-customers ("receivables") which serves as a collateral against the loans. As debt payments are done out of this separate entity rather than the company accounts, a Ponzi-scheme like growth is avoided as only revenue from actual business operations is used to pay off debt. Despite the value this type of lending adds in terms of control and risk-hedging, its original setup is relatively sophisticated: not only needs another entity to be created (usually in the country where activities occur), but also contractual agreements between the different companies, all-lender agreements and deeds for the collateral at local company houses are required. The rather high legal costs are the reason why this is usually done at later development stages, when a certain scale has been reached.

### 5.5. Advantages and limits of securitization

Currently, PAYG company's culture is perceived to be that of a "sales culture" by most industry insiders, putting growth first, risk of undue indebtedness second [40]. As PAYG companies are indeed a hybrid of manufacturer, distributor and asset-financier, there is often a lack of tangible data to properly quantify credit default risk among the customer portfolio. While some PAYG companies have been able to grow rapidly thanks to secured debt, some spectacular failures have sent shockwaves through the industry like Mobisol and Solar-Kiosk [112]. Though it has been argued that these problems were to a large part related to runaway costs and distribution strategy, the high debt burden and high payment obligations unaligned with revenue streams likely played an important role.

By separating certain risks emanating from the originator (e.g., business development risks), securitization has the potential to foster the financing of energy service companies. This mechanism pools homogeneous assets with predictable payment streams and sells their underlying cash flows as asset-backed securities (secured by the unpaid portion of sales contracts) to a special purpose vehicle (SPV). Accordingly, SPV investors mainly focus on default and delinquency rates, payment collection systems, as well as on the quality of underlying assets and customer services.

Securitization may bring significant advantages for the financing of energy service companies in SSA. It particularly suits organizations with large customer portfolios using alternative payment approaches such as PAYG or rent-to-own (see more revenue models in Table 1), by covering working capital needs linked to asset receivables. Indeed, equity financing may not be well-adapted in such situations. Moreover, it provides access to new asset classes and potential capital providers, especially large-scale and commercially-oriented investors, as companies with sufficient asset-backed securities are usually in more advanced development stages. Therefore, it diversifies potential financing options, including those with hedging instruments, and may provide additional opportunities for financing in local currency (see Section 5.3). On top of that, Alafita et al. [113] reveal that securitization can significantly reduce the cost of capital and improve financing conditions in the PV solar market.

However, certain challenges need to be addressed for an efficient scaling of securitization in the clean energy sector. Indeed, securitization played a central role in the early phases of the financial crisis in 2007–09 [114] and generally increases credit market volatility [115], underlying the importance of ethics and risk management. Moreover, some clear impediments to the successful launch of large-scale securitization in SSA still exist. First, legal frameworks supporting the creation of SPVs as well as standardisation of contracts and processes are lacking in most countries across the sub-continent [113]. Second, liquidity may be limited as capital markets are often underdeveloped in the region [19]. Finally, certain hurdles are directly linked to energy service companies, as large customer portfolios are still rare (few companies have reached the required size in SSA) and transaction costs are high (especially for the creation of a SPV) [18]. In addition, the horizontal integration characterising the electricity access market across the region limits asset isolation.

Nevertheless, these hurdles can be addressed and monitored, with the aim of benefiting from the advantageous aspects of securitization. In

**Table 1**
Revenue models for asset finance. Source: CGAP 2020.

| Loan | Lease | Rent |
|---|---|---|
| Buy now, pay later<br>Asset-backed lending | Rent-to-own<br>Pay-as-you-go; micro leaseback | Digital marketplaces<br>Asset-as-a-service |

particular, its potential to decrease the cost of financing is highly interesting, considering the importance of financial expenses for energy service companies [116].

## 6. Discussion and outlook: operationalising the new financing strategies

Overall, when it comes to lowering the cost of capital, there are several options to be considered, as summarised in Table 2. By pooling SHS loans into a tradable asset-backed security and providing solar developers access to more liquid capital markets, the developers' ability to leverage could be increased and allow a rapid expansion of the solar market, meeting the clean electricity access needs of many households and businesses. This idea has been pioneered in the commercial and industrial sector in urban areas, through Solar Investment Trusts. A trust is similar to a mutual fund, with the primary difference being that it can have a direct holding of the SPVs while mutual funds usually hold the shares of the company at corporate level and not at the project SPV level. By opening up to new investor classes with different time horizons and risk appetites, a solar investment trust could increase the supply of capital and eventually lead to greater capital mobilization. For investors themselves, credit risk may be reduced through diversification by pooling various projects. Such an instrument is currently tested by the Bank of Development of Rwanda [117], a high-growth economy where only 34% of the population has access to on-grid electricity.

Lenders also can do a lot to increase availability of capital to (energy) SMEs. A largely untapped resource so far is the availability of local financial institutions. A recent Greenmax study [118] revealed that although only 14% of companies surveyed have been able to raise debt from a local bank, unlocking this source of capital could have a huge impact. So far, a high share of overcollateralization and a first loss tranche to be carried by the developer asked by banks are often cited as the major obstacles holding back this source of funding. Initiatives like Green4Access̀s first loss cash deposit are trying to alleviate these barriers [119].Another angle to address the shortcoming of local financiers are technical assistance initiatives aimed at building capacity among financial institutions in the target regions. The GIZ/GET.invest programme “Renewable Energy Financing – Capacity Development for Local Financiers (CDLF)” in Mozambique and Rwanda that was launched in early 2021 is an example of a cooperation that aims to support domestic financing institutions such as domestic banks that are interested in lending and investing in renewable energy sectors (i.e., solar in agriculture, self-generation, equipment leasing, etc). Local currency financing is one of the missing links to scale up investment flows into renewables and is particularly important for domestic enterprises. Hedging currency risk by seeking a greater role for domestic finance could be a win for entrepreneurs and financiers alike.

**Table 2**
Proposed financing approaches in decentralised electricity access: opportunities and challenges of the different measures.

| Approach | Opportunities | Challenges |
|---|---|---|
| ABC models | • Predictable revenue streams<br>• Necessary electricity demand level to reach financial viability for household electrification<br>• Cross-subsidization potential<br>• Decrease the customer risk | • Locations with relatively dense population required<br>• Usually, business models with high upfront costs |
| Productive uses | • Decrease the customer risk as the energy demand is not limited to basic household needs<br>• Cross-subsidization<br>• Social impact (trigger to climb the energy ladder) | • Higher distribution costs due to customized products<br>• Larger investment requirement to provide appliances<br>• Maintenance-intensive (e.g., solar irrigation) |
| Securitization | • Separate investment risks<br>• Investment opportunity for non-specialised investors, in particular lenders<br>• May decrease the cost of capital | • High transaction and legal costs<br>• Underdeveloped capital market in SSA<br>• Large customer portfolio needed<br>• Limited asset isolation |
| Ringfencing | • Separate investment risks<br>• Investment opportunity for non-specialised investors, in particular lenders<br>• May decrease the cost of capital | • High transaction and legal costs<br>• Large customer portfolio needed<br>• Lack of clear processes and frameworks<br>• Limited asset isolation |
| Local financiers | • Decrease the currency risk<br>• Investment opportunity for local investors<br>• Opportunity to access untapped financial resources | • Lack of internal skills in some local financial institutions to assess investment opportunities in the off-grid power sector, resulting in poor lending conditions<br>• Local financial institutions often still see themselves as re-distributors of DFI credit lines rather than providers of their own funding |

The outcome of the Covid-19 pandemic might provide the innovative push that is needed to bring local bank financing in a more prominent position. Besides the “low-hanging” fruit to catch up on productivity and improve cost-to-asset ratios (like cost control, move towards cloud-based services and mobile banking), there is an opportunity to open up new sectors through technology. The use of “analytics and real time reporting” might have a potential to improve banks ́risk management. “Enriching systems with additional data sources, including publicly available data, as well as data sets from proprietary partnerships, could help banks gain a more acute understanding of market and customer dynamics, and open up new avenues for differentiation” [110]. Not just consolidating losses but real growth opportunities in formerly untapped markets, e.g., agricultural sector, rural businesses and non-salaried workers.

While in times of below-zero interest rates investors ́global quest for return heated, it has provided a renewed opportunity for e.g. African businesses. The rapid adoption of digital payment alternatives, in the wake of exponential growth of mobile phone usage, and non-banking solutions in blockchain and cryptocurrencies have a potential to permanently transform the way payments are handled. With over two thirds of adults not having a bank account in SSA, it provides an ideal background for distributed ledger solutions. It could simultaneously have a lasting impact on the inclusion of new users that had been ignored by the traditional banking system so far.

Admittedly, the speed of adoption of blockchain and cryptocurrency largely depends on enabling regulation, which so far has advanced at uneven pace in different countries. For instance, while South Africa, Sierra Leone, Mauritius and Senegal have been frontrunners in designing an enabling regulatory framework, Zimbabwe, Zambia and Namibia prohibit the use of virtual currencies. However, blockchain technology has an abundance of applications beyond cryptocurrencies that could be relevant to decentralised energy services and potentially enhance transparency and security of payment transactions. A few of these areas have been analysed, such as KnowYourCustomer and Customer Profile Management, Service Personalisation and Claims Management. The role of securitisation in bringing down capital cost has been discussed in this article. With blockchain infrastructure providing a more trusted data sharing among institutions, it is easy to imagine how a more effective combination of formal and informal information sources could provide a basis for improved credit risk analysis, without forgetting the potential negative consequences of these technologies (e.g. environmental impact).

## 7. Conclusions

Building on the conjecture that catalysing private investment is a key success factor to universal electricity access, this article has the objective to provide solutions aim at raising the attractiveness of investment opportunities in distributed electricity access endeavours in rural and peri-urban areas in developing countries to foster the next generation of private investment in decentralised electricity solutions.

While the public sphere has an important role to play, de-risking private initiatives in the SHS and mini-grid sectors should be implemented to reinforce financial sustainability and attract capital at affordable cost. Accordingly, we identified and analysed the four following topics: (i) anchor-businesses-community (ABC) mini-grid models; (ii) the design of business models centred around income generation; (iii) the growing role for "local" financiers; (iv) the securitization of assets.

While development impact of access to electricity has become synonymous with productive usage, it is of particular importance to track and highlight the progresses achieved through the access to modern energy services in agricultural, small-scale industrial and commercial uses. Traditionally, the realm of mini-grid models enables higher and more flexible electricity consumption patterns, while SHS-focussed businesses have come under pressure to account for progress on this front vis-à-vis their mostly publicly backed sponsors.

The learning of developers and financiers in public and community mini-grid models has been steep, which partly explains that the focus on anchor customers has become an absolute precondition in almost every financial model. In order to alleviate the customer credit risk, the inclusion of anchor customers has become an interesting solution to provide more predictable and stable revenue streams. Meanwhile, it will be left to policy makers to push the agenda of universal electricity access for those remote communities where productive anchor customers are scarce and fewer opportunities exist to generate cash for energy access companies. Yet, the presence of income generating activities could play a significant role to reinforce these business models.

Regarding de-risking strategies, we foremost analysed different tendencies around the securitisation of assets and receivables, and how collaterals can be used in a cost-effective way. Crucial actors include domestic financial institutions, whose role in renewable energy finance has so far been limited. With more transparency on receivables and assets, credit risk can become more assessable for those institutions, allowing them to take on a major role in future lending and financing rounds. Besides the legal ring-fencing into separate entities, technology has also paved the way to process customer data in a manner that allow greater security and transparency of customer credit risks, ultimately opening the sector to less specialised investors.

As an unregulated PAYG sector is effectively an asset-finance / consumer-finance sector, some boundaries might have to be overcome for financiers that are versed in more traditional infrastructure projects. The establishment of self-regulation frameworks by industry leaders (in the absence of regulators) and the role of best practices (e.g. similarly to the *Lighting Global*'s technical best practice standard) will most probably play a crucial role. In addition, the presence of capital in domestic currency has the potential to bring down capital cost by mitigating the currency risk, as it allows financial institutions to play their natural role of local financiers. The arrival of new, less process-heavy players like neobanks as well as the use of blockchain and cryptocurrencies might also present opportunities for those that will leverage the innovative push in domestic financial sectors in post-Covid times.

Our analysis targets private infrastructure developers and financiers, with the objective of fostering investments in financially sustainable decentralised electricity access projects. The challenge – including for future research – is to further investigate the key obstacles for operationalising the potential solutions proposed in our article.

**Declaration of competing interest**

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

## Appendix A. Case studies (data source: GET.invest advisory work 2020/21)

### *A.1. OnePower*

OnePower, a US-Lesotho developer, used the proceeds of an on-grid plant after having successfully closed a 20 MW PV IPP project to further the access-to-energy agenda. Due to Lesotho's unique geography, with many settlements isolated on mountain tops, an extension of the transmission grid to connect remote locations is unviable, making mini-grids a strong alternative. The original plan to start implementing a single mini-grid was modified after strategic discussions, as bundling several mini-grids into a portfolio would allow to attract interest of a wider part of the investment community. The actual plan includes 25 villages, increasing funding needs to 10 M USD, providing access to about 20,000 formerly unconnected new users. The implementation of a new energy regulation by the Ministry of Energy (aided by policy support from EU and US economic cooperation programmes) and the financial return expectations of the developer were crucial success factors, allowing to design an acceptable tariff for all stakeholders and enabling financially sustainable operations of the sites. This project also shows how private sector engagement can drive market development and ignite necessary regulatory changes, without necessarily having to wait for all frameworks to be in place first.

### *A.2. FENIX*

Fenix is a company manufacturing, distributing and operating SHS and offering pre-financing services to end customers, thus being able to reach formerly unelectrified regions where neither grid expansion nor commercial mini-grid solutions would be viable due to low income levels and scattered population. Since the start of operations in Uganda in 2009, the company has expanded into other SSA countries. In 2018 it became the first SHS company acquired by a large energy corporation (Engie). Engie's entry into the SHS PAYG sector is yet another sign of a professionalising sector having reached a certain level of commercial maturity. While by 2018 the sectoŕs main investors were still DFIs or specialised funds, various private investors are increasingly weighing in, including energy behemoths like Engie, Shell, Total, EDF and Schneider. Moreover, the interest in electricity access solutions of strategic players like Facebook, Microsoft and VISA is also growing. As the sector matures further, it is becoming increasingly relevant to understand the risks business models entail. As PAYG companies are indeed a hybrid of manufacturer, distributor and asset-financier ("Strange Beasts", Wood MacKenzie, 2019), there is often a lack of tangible data to properly quantify credit default risk in customer portfolios.

Fenix Solar, in collaboration with the Frankfurt School of Finance and Management, has approached the issues of providing credit losses and pricing credit risk by introducing the metrics "Expected Loss via Impairment Allowance" and "Implied Default via Unit Economics", achieving a more stable assessment of future risks adapted to multiple market environments. Based on the historical loss rate within a given asset class, a share of unimpaired loans is being calculated and used to estimate default for the next 12 months. Credit risk assessment is then made on a loan level, using the historical default rates within the asset class. While gaps in historical data might often be encountered in practice, this approach could be a first step to reflect more accurately on the profit and losses related to default, and be compliant with international accounting norms like IFRS-9. So far, Fenix Solar consider the new approach as a supportto calculate the impact of defaults, besides sparking a much deeper sensitivity within the company on how to better manage credit risk [120].

### A.3. FMO

The public Netherlands ́ Development Finance Company, FMO, has gone a different way in putting up clients ́ receivables as collateral for lenders in some of their investees. In order to avoid time and resource-intense legal ring-fencing of assets during early and growth stages, in their Nasira programme they opted for cloud-based Hypoport software to divide receivable assets into customer segments according to risk-profiles, monthly contributions and seniority, allowing lenders to track the performance of their assets. Portfolio data is entered into the database. The software then automatically decides the eligibility of loans, reports on performances, and calculates the cashflow waterfall based on seniority.

While some lenders might insist on having a legally separated set of assets, cloud-based tracking of individual asset cohorts is an interesting solution for specialised lenders looking for high-growth opportunities post-VC investments. FMO provides guarantee facilities to financial investors, but requires them to share portfolio data into softwares.

Cloud-based systems can be used for all sorts of asset-backed securities including receivables, real estate and car leases. It presents an easier and less expensive route, despite providing less security for lenders from a financial perspective. As PAYG companies' ability to raise debt are based not on conventional return-on-asset ratios but rather on existing client portfolios, efficient ways of keeping track on cash-flow cycles may help avoid “debt traps”.

### A.4. Sigora Haiti

Sigora Haiti, a subsidiary of Sigora Solar, designs and deploys mini-grids to power and empower Haiti with clean, reliable and fairly-priced energy. It aims at providing 24/7 access to electricity to households, businesses and industries in underserved and unconnected communities using solar and wind energies. The company developed a small-scale and fully-vertically integrated utility structure tailored to frontier markets, enabling to propose final prices to end-users lower than alternatives such as candles and kerosene. Its business model allows a rapid deployment of electricity access solutions and an efficient last-mile distribution, in both urban and rural areas. Thanks to the use and integration of innovative solutions, Sigora Haiti was able to transform electricity access for underserved markets into a bankable business and enticing investment opportunity. Indeed, each mini-grid comprises a smart-metering hardware, a revenue and demand management software, and a remote monitoring system, allowing the company to decrease connection costs as well as ensure efficient energy delivery and management. Since the start of its activities in Haiti, the company has reached a high bill collection rate (near 100%) compared to the national utility (around 30–40%), mainly owing to a streamlined PAYG system, strong anti-theft capabilities and the provision of flexible payment options, ranging from mobile money and online purchasers to direct street vendors. In addition, Sigora Haiti leverages its power infrastructures and expertise to implement a portal for internet access. This additional and high-margin revenue stream strengthens the company's financial viability and offers broader opportunities to clients. Furthermore, Sigora's business model includes technologies connecting energy devices (Internet of Things), providing transparency and visibility for customers on their energy consumption as well as a potential highly precise demand response from the company. Through these innovative elements, Sigora Haiti created a business model covering CAPEX and OPEX while ensuring fairly-priced and cost recovery tariffs. On top of that, it has the ability to scale it in both urban and rural zones, offering customer and geographical diversification.

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