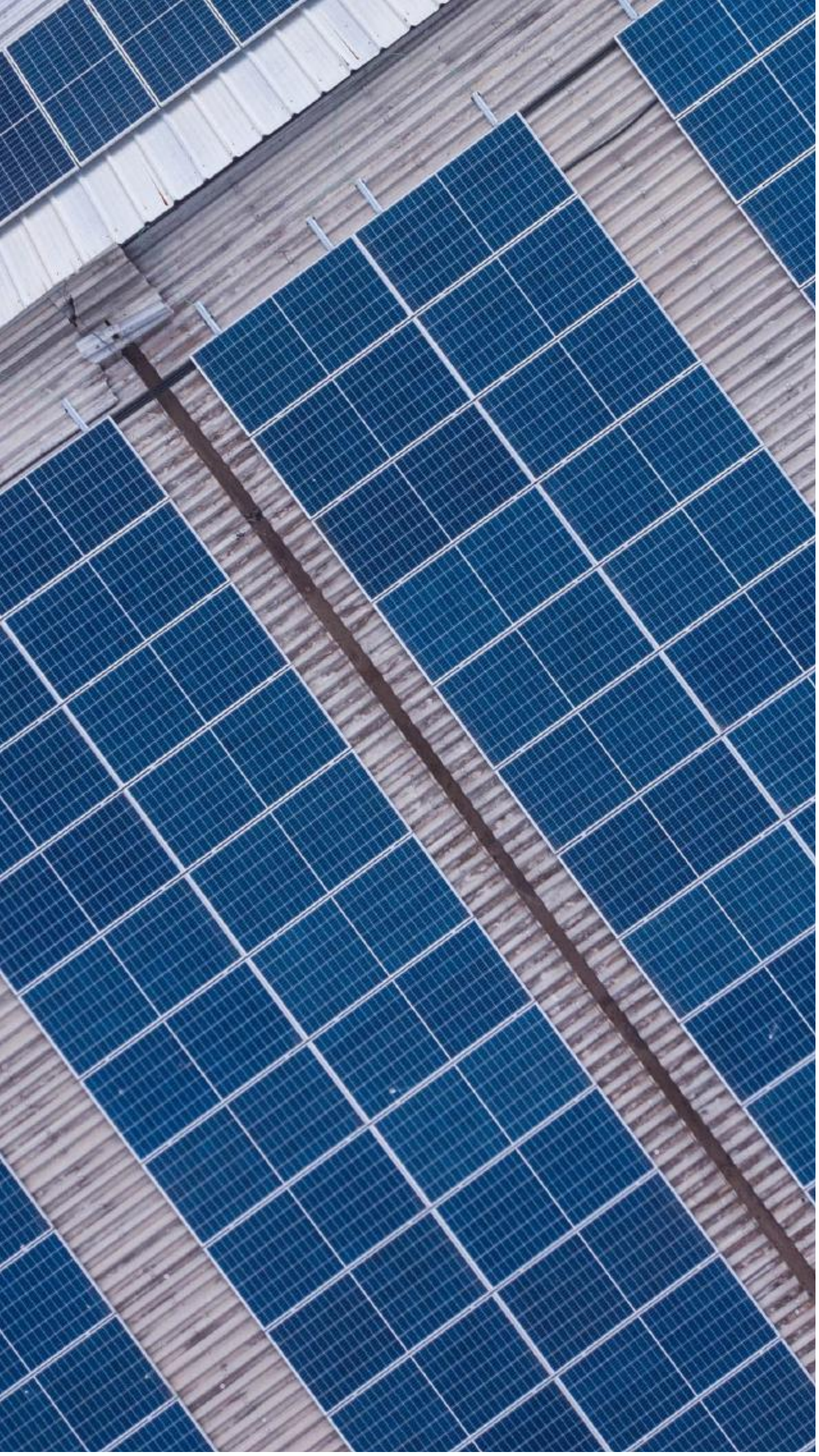

Toward actionable electrification frameworks:

Reassessing the role of stand-alone solar

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A new generation of business models for energy access, namely the integrated distribution models, is now gaining ground among academics and practitioners. In contrast with grid-based approaches, integrated frameworks aim at harnessing the potential of all electrification technologies and rely on the coordinated development of three electrification techniques, namely grid extension, the deployment of mini-grids, and solar home system, to attain universal electricity access at the national scale. However, these approaches have been defined so far at a broad level, and more practical guidance is now necessary to overcome the hurdles that a naïve interpretation or adoption of integrated distribution models may encounter as countries move to the implementation stage.[1]

More specifically, integrated distribution frameworks should provide clear guidance on incentives for mini-grid and solar companies to engage in integrated electrification programs. As a matter of fact, solar companies have long perceived their independence from top-down electrification initiatives and regulatory regimes as two critical factors of success. Building on past experiences, this paper mainly focuses on the solar sector and describes avenues to involve solar companies into meaningful integrated universal electrification frameworks; it delineates attractive policies providing political, operational, and financial guarantees to solar companies in exchange for new obligations going beyond their current business. We demonstrate the opportunities offered by incentives to expand solar systems in currently untapped regions and by financial and operational cooperation between solar companies and mini-grid and grid operators to accelerate electrification efforts at national scale.

We show in this paper that solar home systems could experience unprecedented diffusion and foster new grid or mini-grid projects under adequate regulatory regimes. Targeted and timely subsidies under strong government leadership would allow for the expansion of solar into the most remote areas. Specific subsidization schemes for solar-powered productive uses of electricity – such as irrigated agriculture - in remote areas would allow solar companies to act as demand aggregators and to create new demand hubs, thereby offering new prospects for economic growth. Solar companies should consider sharing consumer data with mini-grid developers. Solar companies could leverage data sharing mechanisms to monetize their market insights while de-

[1] A brief description of what we mean by an "integrated distribution framework" in the present document can be found in at the beginning of the next section I. The "Inception Report of the Global Commission to End Energy Poverty", MIT Energy Initiative, 2019, provides a complete description. See https://www.endenergypoverty.org/reports. The terms "integrated electrification" or "integrated approach to distribution" can be found in other contexts and publications, but in these cases the terms have a more local scope and less far reaching implications, merely showing the desirability of jointly deploying and operating the three electrification modes, but without proposing how to achieve it at scale. See, for instance, "Integrated electrification pathways for universal access to electricity. A primer", by Sustainable Energy for all, May 2019. Also the "integrated energy" concept in the "Utility 2.0" proposal, https://www.powerforall.org/campaigns/utilities.

risking mini-grid and grid extension projects and facilitating pre-feasibility studies for energy access projects in currently unreachable areas.

The joint implementation of these measures would (i) accelerate the electrification of currently non-electrified urban and peri-urban regions through solar systems, (ii) render possible the electrification of and aggregation of demand in remote areas, presently left behind by most electrification schemes, and (iii) facilitate the deployment of mini-grids in high-risk rural markets.

I- From planning to action: towards actionable integrated distribution strategies

Failures in the distribution sector have long hampered national electrification strategies. However, a conjunction of technical, operational, and financial innovations and the rich experience derived from nearly fifty years of electrification attempts provide the academic community and practitioners with unprecedented insights into possible business models best able to further push the frontiers of electrification and achieve universal energy access by the earliest possible deadline.

The key features of integrated distribution models

A new generation of business models, or integrated distribution models, has been gaining ground gaining ground since the late 2010's (Arriaga et al., 2019a and Arriaga et al., 2020). Informed by recent innovations and designed in the light of half a century of electrification attempts in Africa, Latin America, and Asia (Debeugny et al., 2017), these integrated approaches could make a significant contribution towards universal energy access – provided that sufficient practical guidance is provided to developers about concrete implementation plans.

Integrated distribution approaches can help in three ways: achieving inclusive energy access in financially sustainable national utility concessions; fostering the emergence of a financial and regulatory regime best able to support the design and implementation of these concessions; and accelerating the overall pace of electrification to meet SDG7.

Responding to this challenge would require adherence to a set of critical requirements that could be defined as follows (Arriaga et al., 2019a and Arriaga et al., 2020):

1. *Clear universal electrification mandates:* Inclusive and quality electrification is unlikely to be achieved without an explicit electrification mandate, and responsibility for providing universal energy access should fall on a clearly defined party. One possibility would be to give this responsibility to an entity utility operating under a regional or national concession.
2. *Integrated and coordinated planning:* Careful preliminary planning leveraging all possible electrification strategies—i.e., grid extension, mini-grids, and solar home systems—plays a decisive role in successful electrification programs. Energy access strategies would benefit from being developed from a holistic manner at the national level, leveraging all possible electrification techniques in a timely and coordinated manner.
3. *Long-term vision:* Electrical supply must be permanent in time, meaning indefinitely available. This indispensable component of sustainability requires an institution in charge,

with a long-term vision and commitment. We characterize this structure as "utility-like," meaning a similar level of service commitment as traditional utilities, even if a different business format is adopted.

4. *Harnessing the potential of external resources:* To exit the vicious circle where they are trapped, incumbent distribution companies —whether they are privately or publicly owned—may need to partner with external structures owned structures best able to provide capital, advanced technologies, and sound management practices so that reliable service, loss reduction, and a new consumer engagement approach can be achieved in a timely manner.
5. *Integration of electrical supply and the services that electricity can provide:* The final objective of electricity supply is the provision of services with impact on the wellbeing of the beneficiaries. Delivery of electricity must be accompanied of support for its use in domestic, community and productive activities.

A key feature of the IDF is the deep integration of all three modes of electrification – on-grid, mini-grids, and standalone systems. Integrated distribution frameworks and the regulatory arrangements allowing for implementation will greatly depend on the specificities of each territory. More specifically, while there seems to be an overall consensus over the importance of an obligation for a local DISCOs to take responsibility for the electrification process and ultimately serve all consumers in the long term (Arriaga et al., 2019b), the role and involvement rules for mini-grids will likely be tailored to local contexts. Two options are typically considered by local planners:(i) laissez-faire policies relying on market incentives and well-designed public subsidization schemes to foster the free development of mini-grids, and (ii) tighter regulatory schemes allowing DISCOs to "outsource" their functions and pass their obligation to connect all households to mini-grids as part of territorial sub-concessions. Meanwhile, solar companies have long been operated as independent actors in the energy access sector and their involvement within integrated distribution frameworks remains unclear. (Debeugny et al, 2017)

Integrated distribution frameworks remain challenging to implement in practice, as the three electrification solutions have been developed in a mostly uncoordinated manner with different entities involved, leading to competition rather than complementarity (Debeugny et al, 2017). This situation serves neither business nor consumers' interests and has resulted in inefficient infrastructure investment, poor service standards, sub-optimal resource utilization and, importantly, limited progress in electrification rates. Today, most electrification programs leverage GIS-based least cost planning computer models to coordinate all electrification modes, under the assumption that all stakeholders would naturally adhere to the static long-term and least-cost plans that the computers will produce. (Arriaga et al., 2019a and Arriaga et al., 2020)

While showing great promise, computer-based electrification plans and integrated distribution approaches to business and regulatory models for the implementation of electricity access still need more research to overcome the hurdles that a naïve adoption may encounter in practice. In addition to the high-level recommendations that are emerging throughout the academic and business environment, planners would greatly benefit from more down-to-earth insights and guidelines for the effective coordination of all electrification modes.

Such research appears all the more urgent, as several countries are now moving towards the concrete implementation of integrated distribution models.

Rethinking the role of off-grid solar solutions in universal energy access strategies

While most efforts have focused on restructuring DISCOs, and to a lesser extent on possible regulatory regimes for mini-grids, integrated distribution frameworks have paid little attention to the effective ability of solar initiatives to participate in integrated electrification programs stimulating economic growth.

Integrating solar within integrated distribution models faces a number of challenges. First, off-grid initiatives lack incentives (if any) to join regulated regimes typical of integrated electrification programs; second, solar companies are currently unable to fill the electrification gap left by the grid national grid and mini-grids while maintaining minimum profitability standards; third, the fast-changing structure of the distribution sector with the ongoing unbundling of solar companies into specialized entities[2] opens several challenges and opportunities left unanswered or untapped by integrated approaches; lastly, the expansion of solar companies' activities towards water pumping and irrigation on market terms is now breaking the monopoly of wire-based solutions over productive uses of electricity. All four challenges could be turned into as many opportunities for innovation and unparalleled breakthroughs in energy access through lower-level and actionable policy recommendations grounded in field experience.

More specifically, more research is needed on the development of practical and actionable bottom-up electrification strategies complementing high-level electrification frameworks. Given the ambitious time frame imposed by SDG7, efforts should first focus on the fastest-growing segments of the power sector best able to achieve massive electrification and stimulate economic growth in remote areas unlikely to be connected to the grid in the short to medium term – i.e., solar.

Integrating solar initiatives within integrated electrification strategies is a key challenge in the implementation of integrated distribution approaches. Pay-as-you-go (PAYG) solar companies constitute the only segment of the distribution sector that flourished because they were profitable on their own, far from the fickle grant-based programs, and can develop and thrive independently from local regulatory frameworks. However, while the very idea of integrated distribution models goes against what the PAYG solar sector stands for, it could also provide the solar industry with the only incentive for which it might voluntarily want to engage into national electrification

[2] Current proposals include unbundling PAYG solar companies into different entities specialized in technology development and manufacturing, logistics of product delivery and installation, financing, and retailing activities plus facilitation of appliances and services to the end customers. The main objective is to increase efficiency, to segment risks and ultimately channel investments into more targeted financial vehicles specialized in well-defined parts of the energy access business. See https://www.pv-magazine.com/2019/11/23/the-weekend-read-offgrid-goes-global/

programs, namely to open new markets for solar and support its extension into previously unprofitable regions on market terms.

Balancing benefits and obligations will thus be critical to involve solar companies into meaningful integrated universal electrification schemes, i.e., in attractive business models and regulatory approaches that provide political, operational, and financial guarantees to solar companies.

Therefore, this paper focuses on possible business models allowing for the integration of solar initiatives within integrated electrification programs and details avenues for cooperation between solar, mini-grid and grid in attaining sustainable and meaningful universal energy access and fostering economic growth.

We demonstrate the opportunities offered by financial and operational cooperation between solar companies and grid operators to accelerate electrification efforts and expand access to electricity into previously unreachable zones. More specifically, we show that:

1. Current PAYG solar models allow for flexible and win-win partnerships between solar and mini-grids operators in the short, medium, and long run.
2. Two complementary approaches – mandatory cross-subsidies between customers and attractive cross-financing mechanisms based on data sharing between PAYG solar companies on the one side and mini-grids and the incumbent disco on the other – would reduce the need for external financing and permit a timely expansion of solar-based electrification for households and local industries. Implementing data sharing across the distribution sector will be instrumental in expanding mini-grids in targeted and previously unserved areas with minimal risks and maximal impact.
3. Solar-powered irrigation could further increase the value of consumer data and allow for the expansion of mini-grids in new regions while stimulating economic growth in the short term.
4. Planning and implementation of these cooperation strategies would greatly benefit from a precise segmentation of the regions to be electrified depending on their characteristics, each calling for specific solutions and cooperation arrangements.

II- Accelerating electrification through solar-driven electrification programs

Rethinking solar concessions: new zoning methods for a timely allocation of resources

The development of solar initiatives may occur within a range of regulatory environments, from a complete laissez-faire policy to tightly regulated concessions models. The Moroccan experience in energy access has shown that well-designed concession contracts can effectively support solar-driven electrification[3]. Concession terms can be tailored to the structure of the power sector in any

[3] Nygaard, I. and Dafrallah, T. (2016), Utility led rural electrification in Morocco: combining grid extension, mini-grids, and solar home systems. WIREs Energy Environ, 5: 155-168. In Morocco the utility has been responsible for the entire rural electrification programme, extending the grid to reach more than 95% of the population. Unusually for

given country – from fully integrated companies to a vertically unbundled power sector – while providing higher legal security to investors and local companies. Therefore, we specifically elaborate on the design and implementation of concession agreements best able to attract solar initiatives and harness their full potential for energy access.

We propose a set of bottom-up strategies aiming at complementing high-level frameworks and providing short and medium-term guidance to solar companies seeking to reach the long-term objectives as defined in least-cost electrification models.

From high-level territorial concession to local zoning

Most energy access programs now rely on GIS information systems to derive optimal and least-cost electrification plans at a local or national scale. These plans represent an unprecedented breakthrough in energy access planning and allow policymakers to envision the countries' ideal future "electrification mix" as defined by geospatial planning tools. However, the static plans provide little guidance for local companies on the progressive expansion of their activities before reaching this ideal final state. What is more, such least-cost plans usually assume that all cooperation mechanisms have been implemented, that markets and policies have remained efficient at all steps of the electrification process and are highly sensitive to critical factors such as local demand, the availability of affordable public and private funding and to the ability of local companies to engage into integrated electrification plans.

In practice, what is usually designated as a "solar concession" can be implemented in diverse contexts defined by different electrification rates, population densities or abilities to pay, not mentioning the possible coexistence of several electrification modes within a close radius. Each setting calls for specific financial, operational and technical electrification mechanisms and cooperation models between electrification modes.

Acknowledging the need to provide actionable guidelines to local companies with a certain level of granularity, planners could consider dividing concessions into roughly three geographical areas of operations to properly account for different challenges facing solar companies in each environment.[4]

First, "Area 1" could be defined as the current area of operations of the national grid and mini-grids, where the electrification rate, average population density, and ability to pay are high. Unconnected households are likely to be electrified in the short term. However, those connected may suffer from the unreliability of the grid or the local mini-grid. Within an area 1, solar companies enjoy low operational costs and can deploy their systems quickly. Electrification with solar systems will likely require limited subsidies per household.

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an African context, they have also provided electricity to dispersed villages comprising about 10% of the villages. These isolated or dispersed settlements have been supplied by Solar Home Systems (SHS) through a fee-for-service model, which is overseen by the utility, but operated and managed by private service companies through ten-year concession contracts.

[4] This partitioning of the territory into areas can be understood and implemented in strict physical terms or just as a conceptual form of organizing the discussion and strategies to be adopted, without ever recurring to an actual division.

Second, "Area 2" could correspond to regions neighboring the existing grid and the mini-grids. This area is characterized by limited electrification rates, and high to medium population density and ability to pay. Households are likely to be connected to the grid or local mini-grids in the medium term. Solar companies operate at higher costs than in urban settings, and firms could deploy solar home systems as a more or less temporary electrification solution depending on the socio-economic situation of each household. Electrification with solar systems is likely to require moderate subsidies per household.

Lastly, "Area 3" would be defined as the remaining remote areas unlikely to be electrified by the grid or by mini-grids in the medium term. Solar companies suffer from high operating costs and typically tend to focus their activities on the wealthiest households. Significant subsidies per household should be expected to achieve universal energy access in this area.

The exact boundaries between the three areas can be roughly determined by GIS-based computer models and must be defined more precisely by local authorities. Furthermore, the geographic delimitation of these three areas of operations will evolve as the national grid and mini-grids extend over time.

Prioritizing limited human, technical and financial resources available

Limited funding opportunities and local abilities to plan electrification at the national scale may call for a more complex and nuanced approach to the three abovementioned areas of operations.

One of the critical improvements necessary in energy strategies is to streamline funding to distinct regions and target populations, and thus to achieve more granularity in the design and implementation of electrification programs. To this end, each of the three areas of operation could be divided into sub-areas, or "zones of action" structured according to population, ability to pay, or any other relevant criteria. To avoid addressing the entire electrification challenge (i.e., areas 1, 2 and 3) at once, and to pace electrification efforts according to the amount of human, technical and financial resources available at a given time, efforts could focus on subdivisions of each of these areas.

The universal electrification requirement of the integrated distribution frameworks implies that A1, A2, and A3 should be addressed simultaneously – although most likely in a gradual way, by focusing on sub-zones of A1, A2, and A3. Such timing would ensure that companies do not fall into the current pitfall of focusing on low-hanging fruits (e.g., A1 only) and will benefit from generous subsidy schemes in exchange for *actual* electrification efforts in remote and previously unreachable areas (A2 and A3).

Enhancing cooperation and synergies between solar companies and other electrification modes

Each of the three areas of operation calls for different and specific financial cooperation frameworks best suited to integrated electrification strategies. Here, two financing mechanisms to support solar companies are discussed, namely monetized exchange of data (or "cross-financing" mechanisms between energy access companies) and cross-subsidization arrangements between solar companies and mini-grid or grid operators.

Opportunities and advantages of data sharing in the energy access sector

Data sharing and selling could play a structural role in the design and implementation of financially viable universal electrification schemes and limit the need for external capital. Mini-grid and grid operators interested in expanding their activities into risky markets could purchase valuable solar customer data from solar developers and provide PAYG solar companies with additional financial resources to expand their activities.

The value of data for on-grid electrification solutions largely depends on the specific features of the integrated distribution model adopted in each territory. While grid operators typically remain in the obligation to provide electricity to all potential customers within pre-defined areas, the involvement model of mini-grid developers is more flexible. In the case of sub-concessions in which a mini-grid has the obligation to serve all the population within the concession territory, data on existing solar consumers would prove valuable to de-risk and adequately pace investments. The value of data would increase in a laissez-faire model – i.e. more flexible and market-driven models - letting mini-grid operators operate on their own terms wherever they see financial opportunities.

As a matter of fact, the lack of information on potential customers to be connected represents a substantial risk in grid extension and in the deployment of the main grid and mini-grids. In order to address large uncertainty over local demand and ability to pay, current risk management strategies mostly rely on purely financial solutions and the design of heavy public-private funding and guarantee mechanisms aiming at lowering the cost of capital for grid and mini-grid investments – with limited results to date.[5]

However, the large amount of data acquired by solar companies since the early 2010's may dramatically change the energy access landscape and offer interesting prospects for the development of mini-grids in peri-urban and remote areas. The customer data acquired by PAYG solar companies provide unprecedented insights into customer consumption, credit history, and ability to pay, and would prove of particular relevance to grid and particularly for mini-grid operators looking for information to plan and adequately pace electrification efforts on financially viable terms. More specifically, customer data will prove extremely valuable to pace electrification efforts, de-risk investments and channel lower-cost funding into remote rural territories, thereby incentivizing grid-based solutions to expand into areas defined as grid or mini-grid territories by geospatial tools but that currently remain in practice unreachable on market terms.

The electrification by solar home systems within area 1[6] and area 2[7] could be partly financed through the sale of solar customer data to mini-grid operators and DISCOs trying to expand their

[5] A few companies have recently emerged to challenge this status quo. Among them, we can mention Nithio, venture-backed energy finance platform performing data analysis for governments, businesses and public institutions involved in the energy access sector.
[6] Defined as the current area of operations of the national grid and mini-grids.
[7] Defined as regions neighboring the existing grid and the mini-grids.

activities on the best possible financial terms. The terms and conditions of this data sharing – duration of the time series, number of customers, number of data points per series, series to be considered (consumption, pre-payment track-record, etc.) – are flexible and can be adapted to local contexts.

In practice, area 1 offers large opportunities for data sharing. Mini-grid operators will likely have a great interest in customer data from area 1, where connection charges are lowest, the grid reliability low and and the ability to pay comparatively high. Data sharing would allow for timely and extensive electrification by solar systems within this area until all of them are eventually connected to a local mini-grid or to the national grid.

Area 2 holds the largest potential for data sharing. The type of obligation of grid and possibly mini-grid developers – depending on the IDF model chosen by local planners – to connect all customers in areas 1 and 2[8] will likely spark interest in local solar customer data. The sale of customer data by solar companies to mini-grid and grid operators may allow for a faster and more widespread diffusion of solar systems among remote households previously unable to afford them.

Area 3 offers the least potential for data sharing and related funding opportunities for solar companies (thereafter "cross-financing" mechanisms must be adopted predominately).

Additional financing opportunities for solar-based electrification

Another source of funding for solar companies is cross-subsidies. The Moroccan experience has shown that well-defined cross-subsidization schemes between large already electrified pools of consumers with reasonable population targets to be electrified yielded unprecedented positive results[9], provided that additional financing is available to fill remaining funding gaps. (Jacquot, 2020)

First of all, mandatory cross-subsidies between grid/mini-grid and solar consumers would lead to the quick and universal electrification of urban areas. However, operation costs of solar companies are already low in these regions and cross-subsidies may be reserved to finance energy access in more challenging environments, namely areas 2 and 3.

Second, solar companies will need substantial subsidies to make any significant contribution towards universal energy access in area 2 due to high operating costs and limited ability to pay. Mandatory cross-subsidies between mini-grids and the national grid on one side, and solar companies in the other, will constitute a significant source of revenues for solar companies and should be seriously considered by local regulators and public agencies.

The potential for cross-subsidies between areas 1 and 2 should be carefully weighted given the population unbalance between electrified households in area 1 and the number of unelectrified households in area 2. Sub-dividing area 2 within target zones may further help local authorities in

[8] According to the guidelines provided by GIS-based electrification softwares such as MIT's REM, or similar programs developed by Columbia University or KTH.
[9] Nygaard, I. and Dafrallah, T. (2016), Utility led rural electrification in Morocco: combining grid extension, mini-grids, and solar home systems. WIREs Energy Environ, 5: 155-168

timely addressing the universal energy access challenge in a structured and financially viable fashion.

Lastly, the electrification of area 3 will prove to be the most difficult of all three areas and will likely require substantial subsidies.

It will be the responsibility of the national government, local ministries and regulators to balance subsidies for areas 1, 2 and 3 according to the government's priorities and the fiscal space available.

Prioritizing funding mechanisms for solar-driven electrification programs

Solar companies could leverage three cooperative internal funding mechanisms to effectively fulfill the role assigned to them by geospatial planning softwares. These three mechanisms include public subsidies, cross-subsidies and cross-financing – i.e. putting financial burden on public finances, existing grid/mini-grid/solar consumers, and grid/mini-grid operators, respectively. Planners have the opportunity to balance each of these three mechanisms differently in each of the three zones depending on the local social, political, financial and economic context.

In other to limit the burden on public finances in countries already hit by several public deficits and high sovereign debt levels, planners should emphasize intra-private sector financing mechanisms, namely cross-subsidies and cross-financing. Cross-financing opportunities, driven by market forces, should be complemented by cross-subsidies whenever necessary and possible. Public subsidies could lastly come into play and fill remaining gaps.

An overview of a tentative balance between these three financing mechanisms in each area of operations is provided below.

In area 1, large cross-financing opportunities should be complemented by cross-subsidies and *marginally* supplemented by public subsidies, while area 2 will require significantly more financial support from public institutions per customer. Limited cross-financing opportunities will be complemented by cross-subsidies and public subsidies. Lastly, area 3 will likely be the most subsidy-intensive per customer. Cross-financing opportunities will be limited by the probably scarce data collected in area 3 by PAYG companies and will have to be extensively complemented by cross-subsidies and public subsidies.

The next frontier in energy access: the electrification of remote communities

The electrification of the most isolated populations remains the next frontier of energy access and has not been addressed yet. No successful business model has yet been developed in order to electrify and serve these populations on financially viable terms at a national scale[10]. Two challenges are now preventing the electrification of these communities (i.e., of area 3 as defined above). First, the lack of information on households' ability to pay and potential consumption patterns. Second, considerable logistical and financial challenges preventing solar companies from reaching remote populations on competitive market terms.

[10] The MIT -Comillas Universal Energy Access Lab is currently working with the government of Colombia to electrify all remaining unelectrified populations through solar systems. A working paper is currently under development and will detail possible strategies to achieve universal energy access in the country.

However, the exponential diffusion of PAYG solar home systems in rural areas and the more recent emergence of PAYG solar-powered irrigation systems paves the way for innovative business models and unprecedented opportunities for universal energy access in previously unreachable areas.

From electrification to economic growth: harnessing the potential of solar for irrigation

The recent development of solar-powered irrigation systems for agriculture has reshuffled the cards of electrification and questions the assumed monopoly of grid-based solutions in allowing for productive uses of electricity. Such systems would nicely fit into the cooperation schemes detailed above and enhance synergies between solar companies and grid operators, at the cost of additional capital requirement for solar companies.

PAYG solar-powered agriculture would provide solar companies, and ultimately grid operators, with insightful data and create valuable anchor loads as "demand aggregators". Irrigation typically requires systems of higher power than what is usually offered by PAYG solar company, thereby allowing for the creation of new consumption centers and increasing the value of the consumption and credit history data derived from the systems by solar companies – and grid or mini-grids operators ready to purchase them. Efficient pumps would range anywhere from 500W to a few kW while most household PAYG sales fall within the 5-30W range, and the load and payment profiles of farmers would thus prove much closer to that of typical mini-grid and grid consumers than 10W PAYG SHS consumers would.

Leveraging solar-powered agriculture to electrify remote communities

Well-coordinated cooperation strategies between grid and solar operators and the development of solar-powered irrigation may allow for unprecedented breakthroughs – provided that adequate governance and cross-subsidization are in place.

First of all, the affordability issue could be partially solved by offering local customers to choose between RTO (rent-to-own) and EAAS (energy-as-a-service) models. EAAS monthly usage fees are typically lower than for RTO and would allow for the widespread dissemination of solar systems wherever typical PAYG solar business models could not thrive. Such affordability could be enhanced through mandatory "solidarity" subsidies paid by all grid (and potentially mini-grid) consumers nationally and channeled into specific zones of operations of area 3 in order to maintain a minimum level of subsidies per household.

Second, the deployment of EAAS solar home systems would provide critical data on electricity usage and the local ability to pay and allow for the development of high-power electrification systems best suited to the characteristics of each territory. Most importantly, the value of these data for mini-grid development will largely depend on the ability of solar developers to identify and serve anchor loads, usually associated with farmers' irrigation-driven demand. Solar companies' ability to deploy PAYG solar irrigation systems will provide solar companies, and eventually mini-grid developers, with critical insight into possible deployment sites building on local anchor loads to electrify small communities according to pre-defined service and profitability requirements.

From solar to mini-grid: creating a new dynamic in remote areas through data sharing and solar-powered irrigated agriculture

A possible electrification strategy could proceed as follows.

Entry-level electrification by solar systems: first, solar companies could proceed to the targeted and subsidized electrification of well-defined zones of area 3 under RTO or EAAS terms. These individual SHS are quickly deployed at minimal cost, thereby fulfilling the local company's obligation of universal electrification, and meeting essential electricity services such as lighting, phone charging, ventilation, and potentially television. The choice of an RTO vs. EAAS model will largely depend on the populations' preferences and ability to pay.

Targeted development of solar-powered irrigated agriculture or any other high-load productive use of electricity: second, solar companies could proceed to the identification of (i) existing and potential agriculture sites and (ii) financially liable entities – i.e., a person, a cooperative, or any structure able to pay for PAYG solar pumps' monthly usage fee. The identification of these agriculture zones could be made via geospatial tools to ensure consistency between this electrification process and the higher-level guidelines provided by GIS-based electrification maps.

Solar companies will then be in a position to proceed to the highly-subsidized, *and therefore well-targeted*, development of irrigation systems on an RTO or EAAS basis in the zones previously identified.

Transitioning from solar to mini-grid: Third, solar companies could selectively sell some of their consumer data to mini-grid developers interested in leveraging data on local consumption and on the ability to pay to de-risk their investments. The timely deployment of mini-grids may allow for lower subsidies per consumer compared to solar-driven initiatives while providing superior service. The ability of mini-grids to thrive in such environments will largely depend on the value of the data used for pre-feasibility studies – and, ultimately, on the PAYG model. EAAS would prove much more insightful, as these data would probably better mimic the monthly payment patterns typical of grid-based services.

Planners are then back to the overall electrification scheme detailed in this paper. The deployment of mini-grids in new rural areas leads to the development of a "new area 1[11]" in previous area 3 territories. The classical coordinated electrification mechanisms described in chapter 2 of the GCEEP Inception Report can then be applied to expand energy access around the mini-grid.

[11] Area 1 being defined as a zone covered by the national grid and/or mini-grids.

Conclusion

An integrated distribution framework would define solar systems as "entry-level default solutions" for the electrification of areas that remain out of reach to mini-grid developers or the national grid in the medium term. However, significant efforts from local regulators and planers will be necessary to harness the potential of solar companies and incentivize them to join integrated distribution frameworks.

Taking the two vantage points of local solar companies and the local planning authority, we have shown that solar holds the potential to drive electrification and drive economic growth in peri-urban and, perhaps most importantly, in remote areas. Gathering customer data and aggregating demand in underserved regions may prove invaluable in the subsequent design and pacing of grid extension or mini-grids projects in risky markets that may otherwise either be electrified at higher costs or simply left underserved.

Strong public leadership will be necessary to design territorial concessions and implement well-targeted subsidization schemes aiming to *accelerate* the electrification of peri-urban and rural areas and *make possible* the electrification of remote communities. We identified a combination of financing approaches to fill the "viability gap" for solar: i) direct governmental subsidies, either to the solar companies or the customers themselves depending on local contexts; ii) tariff cross-subsidization mechanisms among different types of customers served through different electrification modes; iii) the monetization and sharing of customer data collected by solar companies with the incumbent concessionaire for its mini-grid and grid extension activities. A partition of the concession territory into roughly three types of areas – urban, peri-urban and remote rural – is helpful to design financing mechanisms and pace resource allocation.

In addition to further reducing the need for subsidies to solar companies, data sharing mechanisms would also provide mini-grid developers and the national grid with valuable information to de-risk investments and pace their deployment in risky markets. Solar-powered productive uses of electricity, such as irrigated agriculture, are possible stepping stones towards mini-grids in remote areas identified by geospatial planning tools and may warrant specific subsidization programs.

Taken altogether, the partition of territorial concessions, targeted subsidization schemes, data sharing mechanisms, and promotion of productive uses of electricity offer a possible narrative for the electrification of remote communities. The success of solar-driven electrification programs will largely depend on the ability of local stakeholders to design comprehensive subsidization programs and adequately balance the rights and obligations of local solar, mini-grid, and grid companies willing and able to drive electrification at scale.

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