Article

Powering the Commercial Sector in Nigeria Using Urban Swarm Solar Electrification

Abisoye Babajide * and Miguel Centeno Brito

Instituto Dom Luiz, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016 Lisbon, Portugal; mcbrito@fc.ul.pt
* Correspondence: ababajid@sloan.mit.edu

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Abstract: The commercial sector in Nigeria has been greatly hampered due to the poor availability of reliable electricity. In a 2014 World Bank report, nearly half of the firms doing business in Nigeria identified electricity as a major constraint, with over a quarter of them listing electricity as their biggest obstacle. The business losses due to electrical outages have been significant, with losses averaging about 16% of annual sales. The lack of access to reliable electricity is one of the biggest challenges to economic growth in Nigeria. This paper proposes a means of powering the commercial sector in Nigeria using urban swarm electrification. It outlines a conceptual framework for using a distributed network made up of grid-connected home solar PV systems as a viable option for providing the commercial sector with more reliable access to electricity. It further addresses the policy implications for the commercial sector with the enablement of more electrification options, implications that include strong economic impact, as well as the expansion and creation of new industries.

Keywords: renewable energy (RE); developing countries; solar home system (SHS); electricity generation; distributed network; microgrids

1. Introduction

Nigeria is Africa’s most populous country and its biggest economy in nominal GDP, yet it is plagued with frequent power outages that have adversely impacted living standards and are one of the biggest challenges to economic development. The World Bank reports that private sector firms experienced as much as 33 electrical outages in a typical month, with the duration of a typical electrical outage being about 12 h [1]. The same report further states that the proportion of electricity from diesel generators was 59%, and almost half of the firms doing business in Nigeria (48%) identified electricity as a major constraint, with 27% of firms listing electricity as their biggest obstacle. Losses due to electrical outages averaged 16% of annual sales. Clearly, more reliable access to electricity will have a knock-on effect in spurring economic growth.

The lack of reliable electricity in much of Nigeria and sub-Saharan Africa has driven the need for self-generation of electricity for consumption. Given the abundance of the natural resource of solar radiation in this part of the world, solar photovoltaic (PV) systems offer a viable solution for individuals and businesses alike, where they can be used for primary and backup power generation instead of fuel-powered generators. More households in urban communities in Nigeria are turning to solar PV systems for power generation. Solar PV is well suited for generating electricity in sub-Saharan African countries and panels can be installed on rooftops to directly supply households. While the households with solar home systems (SHS) are self-generators and have the benefit of self-consumption, we postulate that a framework can be established that will allow for a distributed generation network or microgrid, enabling collective generation that can be used to power the country’s commercial sector. It is important to clarify on the use of the terms microgrids and mini-grids as they are often
used interchangeably and can have varying definitions. This is because there is no consensus in the industry on the definition of both of these terms. The Federal US Department of Energy (DOE) defines a microgrid as “a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode” [2]. However, in emerging microgrid markets like Africa and India, what North America calls a ‘microgrid’ would likely be considered a ‘mini-grid’. The Indian Ministry of New and Renewable Energy (MNRE), defines a mini-grid as a renewable-based distribution with a capacity of 10 kW and above, with a microgrid defined as being similar to a mini-grid but with a capacity below 10 kW. While mini-grids and microgrids operate independently, they can be connected with the grid to exchange power, in which case it would be termed grid-connected mini- or microgrid [3]. Yet another definition comes from the World Bank which defines mini-grids as: “Isolated power generation-distribution systems that are used to provide electricity to local communities (power output ranging from kilowatts to multiple megawatts) covering domestic, commercial and/or industrial demand.” Mini-grids are stated to exist in three states: isolated (off-grid), grid-connected (on-grid) or integrated (integrated into the grid system both technically and operationally) [4]. For the purpose of this paper, microgrid and mini-grid refer to the same type of system, adopting the definition from the World Bank.

While the concept of microgrids is not new, we explore in this paper the novelty of residential microgrids in urban communities in developing countries like Nigeria to generate power for both themselves as well as industry. In much of literature, there are mainly two types of microgrid systems described in practice. The first has to do with microgrid systems in rural communities, typically where a third-party sets this up and sells electricity to the rural community because they are not connected to the grid. There are several papers in the literature on this, such as Bhagavathy et al’s paper on PV microgrid design for rural electrification [5], or Kyriakarakos et al’s paper on microgrids in rural areas [6] to name a few. In a similar vein, other authors have looked at microgrid systems in rural communities with self-consumption from PV systems and surplus sold to its neighbors whenever possible, and then to the grid—a practice that has been named swarm electrification [7,8]. The second main type of microgrid system described in the literature has to do with microgrids in urban communities in the developed world. In these urban communities, residents are well-connected to reliable grids but may want to generate their own electricity to be free from utility companies and/or make money [9–11]. While all microgrid systems are somewhat similar, in this paper the context is very different to others, as well as the motivation and concept described. There is a different challenge in urban application in Nigeria because, while there is a grid, it is not reliable and thus introduces more challenges compared to other urban applications in the developed world. Challenges of the unreliable electricity supply from the grid in urban communities in Nigeria adversely affect people’s standard of living, and for the commercial sector amounts to billions of dollars in losses, discussed more in the subsequent section.

This paper hypothesizes that the use of home solar PV systems used in a collective fashion for distributed generation can greatly reduce or eliminate power outages in the commercial sector in Nigeria, accelerating economic growth as well as the dissemination of solar PV systems. The definition of the commercial sector in this paper refers to the part of the country’s economy that includes all businesses except those involved in manufacturing and transport. This paper proposes a framework where a beneficial and symbiotic relationship can be formed with the homeowners of solar PV systems and the businesses they support.

2. Methodology

Due to constraints in setting up a test group community in Nigeria to test implementation, an exploratory, qualitative approach was taken. In so doing, the authors aim to challenge the status quo and encourage novel lines of inquiry that enable further research opportunities to emerge. This paper is structured as follows—firstly, a brief background on the power sector in Nigeria, the ongoing
power outage problem and its impact on the nation’s commercial sector. Secondly, a conceptual framework is provided for how the use of home solar PV systems in urban communities in Nigeria can form a microgrid system to support powering the commercial sector. Thirdly, a discussion and recommendation are provided on the policy issues and enabling approach for the proposed concept implementation in Nigeria.

3. Background

3.1. History of Nigeria’s Power Sector

Wide-spread power outages have become the norm in Nigeria, affecting all parts of its society. While the more affluent locations in urban communities experience relatively lower power outages compared to others, no one has been spared from the unreliable access from the grid. These severe power outages have had a detrimental economic impact. For example, in 2015, Nigeria’s telecommunications giant, MTN, which has over 62 million subscribers, reportedly spent 70% of its operating expenditure on diesel, more than 10 million liters a month, for self-generation [12]. To understand Nigeria’s power problem, it is important to understand the history of power generation in Nigeria.

The Nigerian Electricity Regulatory Commission provides a history of Nigeria’s power development [13]. Electricity generation started in Nigeria in 1896 with the first electric utility company, known as the Nigerian Electricity Supply Company, established in 1929. Most of the substations and electrical networks still in operation today were established in the 1950s and 1960s. By 2000, the state-owned National Electric Power Authority (NEPA) oversaw the generation, transmission and distribution of electric power in Nigeria and had a total generation capacity of about 6200 MW from two hydro and four thermal power plants fueled by gas. NEPA’s operations were plagued with unreliable electricity supply due to “lack of maintenance of power infrastructure, outdated power plants, low revenues, high losses, power theft and non-cost reflective tariffs” [13]. In 2001, the National Electric Power Policy was created to establish an efficient electricity market in Nigeria and with an overall objective of transferring the ownership and management of the infrastructure and assets of the electricity industry to the private sector. In 2005, the Electric Power Sector Reform Act (EPSRA) was enacted and the Nigerian Electricity Regulatory Commission (NERC) was established as an independent regulatory body for the electricity industry in Nigeria. In addition, the Power Holding Company of Nigeria (PHCN) was formed as a transitional corporation that comprised of 18 successor companies (6 generation companies (GenCos), 11 distribution companies (DisCos) and 1 transmission company) created from NEPA. By 2015, the privatization of all generation and distribution companies was completed with the Federal Government retaining ownership of the transmission company of Nigeria, TCN. The process of unbundling the TCN into an Independent System Operator (public) and a Transmission Service Provider (private) began in 2015.

According to a 2015 report by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on the Nigerian energy sector, the main barrier to stable and reliable energy supply in Nigeria is the widening gap between power stations’ nameplate capacity and the actual generation capacity [14]. The gap is due to the lack of investment in the nationalized power section which was severely reduced in the early 1990s and was exacerbated by reduced maintenance budgets and no new capacity added. The 2015 Nigeria Power Baseline Report states that the country’s power sector is plagued with structural issues in all key areas: generation, gas supply, transmission and distribution, stating: “Chronic vandalism has crippled oil and gas pipelines, creating gas shortages at power plants. Underinvestment in maintenance and infrastructure has constrained our transmission grid. Finally, high collection and commercial losses have impacted the financial viability of the privatized distribution companies” [15]. The resulting impact of the failing national grid is the lack of reliable power access experienced throughout the country.
3.2. Impact on Nigeria’s Commercial Sector

Amadi et al. [16] estimate the economic costs of power outages among Nigerian industries, ascertaining both the direct cost of power outages to the respective industries and the costs incurred by each industry as it invests in backup facilities to mitigate power outages. The study applied both the direct costs and the captive costs assessment methods, and relevant data in simulations in the Statistical Package for the Social Sciences (SPSS). The study found that the direct cost of power outages incurred by Nigeria’s industries amounted to 387 billion Naira (NGN) (1.3 billion USD), while the indirect cost was 2.2 trillion NGN (7.2 billion USD). This means that in 2014 alone, Nigeria’s industries spent 2.6 trillion NGN (8.5 billion USD) as a result of power outages. This amount is equivalent to 2.26% of the nation’s gross domestic product (GDP) in 2014 or 57% of the nation’s budget for 2015. The results of the study further showed that Nigeria’s industries suffer low capacity utilization, a significant reduction in productivity, loss of revenue and lack of competitiveness in the international market due to persistent shortages in energy supply. As Nigeria’s industries continue to face acute shortages of energy from the national grid, many more industries are forced to resort to self-generation of electricity, mainly from fuel-based generators, which further increases operational costs and reduces profit margins. Addressing the power outage issue for industries will be vital for the economic growth of Nigeria.

The power sector in Nigeria is seen by many analysts as the key constraint on economic development. In its 2018 Doing Business report, the World Bank ranked Nigeria 172 out of 190 countries in terms of ease, or lack thereof, of getting electricity [17]. This is an improvement from its 2015 ranking of 187 and 2017 ranking of 180. The number of days to obtain a permanent electricity connection also showed improvements, from 260 days in the 2015 rankings, 195 days in the 2017 rankings and 150 days in the latest 2018 rankings. In 2016, the World Bank Doing Business report added indicators of quality to four indicator sets, including ‘getting electricity’. The quality indicator for the getting electricity category is known as ‘reliability of supply and transparency of tariffs index,’ and has a range from 0 to 8. Since the introduction of this electricity quality index in 2016, Nigeria has had a rating of 0 out of 8, including in the latest 2018 report. Whereas the time to obtain a permanent electricity connection has significantly improved, the reliability of this electricity has not. In other words, when businesses finally get connected to electricity, they experience erratic power outages. The severe power outages remain one of the biggest challenges to Nigeria’s economic development. Unreliable power supply forces both households and industry to rely on privately owned generators for much of their power. Electricity from these generators is more than twice as expensive (NGN 62–94/kWh, approx. $0.20–$0.31/kWh) than grid-based power (end-user tariff of NGN 26–38/kWh, approx. $0.09–$0.12/kWh) [15]. The exchange rate used in this work is the average for 2017 as quoted by the World Bank, which is 305.79 NGN to 1 USD [18].

Table 1 provides an overview of the biggest obstacles experienced by private sector firms in Nigeria. According to the Enterprise Survey’s World Bank report, in 2014, in the private sector there were as many as 33 electrical outages in a typical month, with the duration of a typical electrical outage being 12 h [1]. The report also stated that the proportion of electricity from a generator was 59%, and almost half of the firms doing business in Nigeria (48%) identify electricity as a major constraint, with 27% of firms listing electricity as their biggest obstacle. Losses due to electrical outages averaged 16% of annual sales. A key enabler for economic development in Nigeria will be access to continuous and reliable electricity.
Table 1. World Bank report on an overview of the biggest obstacles experienced by private sector firms in Nigeria [1].

| Indicator                                                                 | Nigeria | Sub-Saharan Africa | All Countries |
|---------------------------------------------------------------------------|---------|--------------------|---------------|
| Percent of firms experiencing electrical outages                          | 77.6    | 79.1               | 59.4          |
| Number of electrical outages in a typical month                           | 32.8    | 8.9                | 6.4           |
| If there were outages, average duration of a typical electrical outage (hours) | 11.6    | 5.8                | 4.5           |
| If there were outages, average losses due to electrical outages (% of annual sales) | 15.6    | 8.5                | 4.7           |
| Percent of firms owning or sharing a generator                           | 70.7    | 53.3               | 34.6          |
| If a generator is used, average proportion of electricity from a generator (%) | 58.8    | 28.6               | 20.4          |
| Days to obtain an electrical connection (upon application)                | 9.4     | 36.7               | 33.1          |
| Percent of firms identifying electricity as a major constraint            | 48.4    | 40.7               | 31.7          |

4. Solar PV Home System Based Microgrids for Electrification

In this paper, we explore using residential solar PV systems to form a microgrid for the distributed generation of power to help power the commercial sector. The benefit of solar power is evident to the Nigerian government. The Federal Government is planning for solar power to “outstrip all sources of electricity generation other than gas and thus become the second key pillar of energy delivery in the nation” [14]. The diffusion of solar PV in Nigeria stands to make a major step change in the reliability of electricity generation for both individuals and businesses by adding more, cleaner and renewable power generation options to the mix.

The concept of using a network of home solar PV systems for electrification has been covered in the literature on swarm electrification [7]. Swarm electrification is based on swarm intelligence, where information and electricity flow between neighbors to achieve a compounding network effect, whereby each household is linked together to form a microgrid but at the same time can operate independently. The concept is heavily geared toward rural communities not connected to a national grid, and where the neighborhood network created is used to form a microgrid to support the community. However, swarm electrification by nature is organic and unplanned. A key benefit of such a system is that it is likely to grow fast as people come up with their own cost-effective way of implementing their solar home systems. However, lack of planning, standardization and regulation will likely mean that such a system will be challenging to connect to the grid and optimize to ensure grid stability. Furthermore, swarm electrification has been primarily geared towards rural electrification. In this paper, a hybrid approach is proposed that: (1) allows better planning and organization compared to the traditional organically grown and unorganized premise of the swarm electrification concept, and (2) promotes its utilization as a balancing network for power outages in urban communities for self-consumption, as well as to further support the commercial sector. This paper explores an urban community-planned and government- and industry-facilitated approach to electrification from home solar PV systems as a supporting system in the reduction or elimination of power outages in urban communities.

Similar to the swarm electrification concept, a distributed generation network of home solar PV systems firstly requires an infrastructure base of solar home systems to create a microgrid. Households with solar PV systems can act not only as consumers of electricity, but also feed excess electricity into the microgrid. Parties that both produce and consume electricity at the same time are known as prosumers. Prosumers then can cash in on the excess electricity supplied.
Figure 1 shows the concept of a SHS-based microgrid, a network of home solar PV systems used to form a distributed generation network for electrification.

Figure 1. Distributed generation network of home solar PV systems.

The model proposed in this work is one in which individual household solar PV systems are connected to form a microgrid in urban communities that can be connected to the national grid and/or businesses to help power the commercial sector. The microgrid can be operated to buy power from the national grid when there is not enough power generated from the network of homes in the microgrid and sell power when the power generated is in excess. Government enabling policies in this area are further discussed in the section on policy implications.

While the electricity generated from household solar PV systems will likely first be used for own consumption, a detailed study conducted by Enertech from 2012 to 2013 showed that there is far less use of electricity by households during the daytime. In a first-of-its-kind undertaking, the project by Enertech represents the first measurement campaign ever carried out in Nigeria to monitor a large number of households for their electrical consumption of lighting, cold appliances and air conditioning [19]. The project was also able to assess the frequency, duration and time of day of the power outages experienced by the monitored households. The monitoring campaign was carried out from 2012 to 2013 and was split between six areas with 35 households per area. The six monitored areas cover different geographical and geopolitical zones in the country and were: Abuja (North Central), Lagos (South West), Benin (South South), Enugu (South East), Bauchi (North East) and Sokoto (North West). Based on the Enertech monitoring campaign data, it can be observed that electricity demand is generally lowest during the daytime when solar PV systems would get the most benefit from solar radiation. The low residential usage period ranges from about 8 a.m. until the early or late afternoon depending on the geographical area. In contrast, in a study conducted by Adesanya and Schelly, a case study of the electricity usage pattern of three companies showed peak usage in the daytime, primarily from the hours of 9 a.m. to 8 p.m. [20]. These results show a viable option for capturing the excess electricity from household solar PV systems to be available for use by the commercial sector, in particular when the use of local batteries, which would enable evening consumption of locally generated solar energy in the households, is too expensive for wide dissemination.

To illustrate the feasibility and benefit of the proposed SHS-based microgrid for powering the commercial sector, we provide a case example from Lagos, Nigeria, the commercial hub of the country. Lagos households showed the highest electricity consumption of all households in the Enertech study. To assess the load profile for different periods throughout the day, in Figure 2 the Enertech data of the power access and outage periods is overlaid against the average load profile for Lagos households when there is power access throughout the same period. The energy used can be calculated for the period where power is drawn from the grid, as well as when power is drawn from another source, such as solar PV systems, when there is no power access from the grid. The solar PV system can be sized for the household’s own usage as well as for excess electricity to be supplied to the microgrid for
access by local businesses. The benefit to businesses can be seen as twofold: (1) more access to power, (2) less spend on fuel-powered self-generators.

![Figure 2. Lagos: part of power access vs average load during power access.](image)

The scenario assessed here is a SHS without batteries, operating during daylight hours, with the excess electricity sold to local businesses. The energy used during periods of power access from the grid can be calculated as follows:

\[
\text{Energy used from the grid (Watts-hour/day)} = \text{Power drawn (Watts) \times Hours used per day (h/day)} \times \text{Part of power access from grid (%)}
\]  

(1)

Conversely, the energy used from an alternate power source, such as a diesel generator or solar system, during periods of no power access from the grid can be calculated as follows:

\[
\text{Energy used from an alternate source (Watts-hour/day)} = \text{Power drawn (Watts)} \times \text{Hours used per day (h/day)} \times (1-\text{Part of power access from grid} \%) 
\]  

(2)

The solar system design was created using the household load and power access times from the Enertech study conducted for households in Lagos. A summary of the results can be seen in Table 2.

| Case Description                              | Grid Power Access | Average Energy Use, kWh/d | Peak Capacity (kW) |
|-----------------------------------------------|-------------------|---------------------------|--------------------|
| **Full day**                                  |                   |                           |                    |
| Assuming 100% power access from the grid throughout day | 100%              | 24                        | 21.6               | 1.088               |
| Average grid power access throughout day      | 72%               | 17.3                      | 15.6               | 1.088               |
| **CASE 1: Average No-grid power access throughout day** |                   |                           |                    |
| Sun-up period only, 6:30 a.m.—6:30 p.m.       | 28%               | 6.7                       | 6.0                | 1.088               |
| Assuming 100% power access from the grid during sun-up period of day | 100%              | 12.0                      | 11.1               | 1.027               |
| Average grid power access during sun-up period of day | 67%               | 8.0                       | 7.4                | 1.027               |
| **CASE 2A: Average No-grid power access during sun-up period of day** |                   |                           |                    |
| Sun-down period only, 6:30 p.m.—6:30 a.m.     | 33%               | 4.0                       | 3.6                | 1.027               |
| Assuming 100% power access from the grid during sun-down period of day | 100%              | 12.0                      | 10.5               | 1.088               |
| Average grid power access during sun-down period of day | 77%               | 9.2                       | 8.0                | 1.088               |
| **CASE 2B: Average No-grid power access during sun-down period of day** |                   |                           |                    |
|                                                  | 23%               | 2.8                       | 2.4                | 1.088               |
The following equations are used to calculate the energy, fuel consumption and total cost per year for a diesel generator.

First, to calculate the output power of the diesel engine, the following equation is used:

\[
Active\ power\ P = S \times \cos(\phi)
\]

\[
Apparent\ power\ S = \frac{P}{\cos(\phi)}
\] (3)

where \(P\) = active electric power in output of the diesel generator in kW; \(S\) = apparent electric power in output of the diesel engine in kVA; and \(\cos(\phi)\) = power factor (usually between 0.8 and 1).

To calculate the output energy and consumption of the diesel engine, the following equation is used:

\[
Energy\ in\ output: E = P \times h \times d\ (kWh)
\]

\[
Consumption\ of\ fuel: C = E \times C_{kwh\ (liter)}
\] (4)

where \(E\) = active electric energy in output of the diesel engine in kWh; \(P\) = active electric power in output of the diesel engine in kW; \(h\) = number of hours per day in which the genset runs; \(d\) = number of days the power generator runs; \(C_{kwh}\) = consumption of fuel per kWh; and \(C\) = consumption of fuel in liters.

Power Calculation online provides a simple excel file that can be used to calculate electricity production from a diesel generator and daily cost based on the input data on load, fuel consumption, number of hours run and cost of fuel per liter [21].

The inputs for this calculation are shown in Table 3:

| Table 3. Input data for diesel generator energy and fuel cost calculation. |
|----------------------------------------------------------------------|
| Apparent Power, S (kVA) 2.5 |
| Cos(\phi) 0.80 |
| Active Power, P (kW) 2 |
| Load, %, residential/commercial 50% /75% |
| Ratio consumption L/h * 1.1 |
| Number of hours running, h/d (CASE 1/2/3) 6.7 /2.8 /4.8 |
| Cost of fuel per liter, USD/L ** 0.97 |
| Caloric value of diesel (PCI), kWh/L 0.98 |

* The fuel consumption for a 2kW/2.5kVA diesel generator was obtained from a diesel generator manufacturer [22];
** Average pump price for diesel in 2012–2013 for the same period in which the Enertech study was done [23].

The cost of diesel fuel usage during outages in the periods specified in case 1, 2A and 2B is shown in Table 4.

The costs for a solar PV system for use during sun-up periods are shown in Table 5. In addition, two cases are added to reflect a solar PV system designed to allow for excess electricity to be sold.
Table 4. Cost of Diesel Usage During Power Outage.

| Model Description                                      | Apparent Power S (kVA) | Cos (ϕ) | Active Power P (kW) | Load % | Ratio Power Consumption L/h | Ratio Fuel Consumption L/kVAh | Cost of Fuel Consumption L/kWh | Cost of Fuel Per Liter L | Calculated Cost kWh | Nb hour Running h/d | Electric Production in kWh | Consumption Fuel in Liter/day | Total Cost Per Day USD/d | Total Cost Per Year USD/yr |
|--------------------------------------------------------|------------------------|---------|---------------------|--------|-----------------------------|-------------------------------|-----------------------------|--------------------------|----------------------|----------------------|-----------------------------|----------------------------|---------------------------|--------------------------|
| Residential - DG use during outages throughout day     | 2.5                    | 0.8     | 2                   | 50%    | 1.1                         | 0.88                          | 1.1                         | 0.97                     | 1.07                 | 6.7                  | 6.7                         | 7.4                       | 7.1                       | 2609                     |
| Residential - DG use during outages when sun-up        | 2.5                    | 0.8     | 2                   | 50%    | 1.1                         | 0.88                          | 1.1                         | 0.97                     | 1.07                 | 4                    | 4                           | 4.4                       | 4.3                       | 1558                     |
| Residential - DG use during outages when sun-down      | 2.5                    | 0.8     | 2                   | 50%    | 1.1                         | 0.88                          | 1.1                         | 0.97                     | 1.07                 | 2.8                  | 2.8                         | 3.1                       | 3                         | 1090                     |
| Commercial - DG use during outages when sun-up         | 2.5                    | 0.8     | 2                   | 75%    | 1.1                         | 0.59                          | 0.73                        | 0.97                     | 0.71                 | 3.2                  | 4.8                         | 3.5                       | 3.4                       | 1246                     |

Table 5. Solar PV system costs.

| SOLAR PV SYSTEM DESIGNS | Up-Front Cost | Battery Replacement Cost (Present Cost) | Total Capital Cost | Operations and Maintenance Cost | Solar Capacity (kW) | Storage Capacity (kWh) |
|-------------------------|---------------|----------------------------------------|--------------------|-------------------------------|---------------------|-------------------------|
| CASE 1: Daily load = 6.5 kWh/d, Peak = 1.5 kW | 6043          | 488                                    | 6531               | 327                           | 2.0                 | 3.50                    |
| CASE 2: Daily load = 4 kWh/d, Peak = 1.5 kW (enough electricity generated for own use during daylight from 6:30 am–6:30 pm) | 3220          | 0                                      | 3220               | 161                           | 0.92                | 3.84                    |
| CASE 3: Daily load = 5 kWh/d, Peak = 1.5 kW (1.4 kWh/d excess electricity generated) | 4188          | 0                                      | 4188               | 209                           | 1.15                | 4.80                    |
| CASE 4: Daily load = 6 kWh/d, Peak = 1.5 kW (2.4 kWh/d excess electricity generated) | 4506          | 0                                      | 4506               | 225                           | 1.38                | 5.75                    |
For the financial assessment of the various cases, Net Present Cost (NPC) is used. The NPC represents the lifecycle cost when all costs for the life of the project are adjusted to present day cost. The present-day cost can be calculated as follows:

$$NPC = -C_0 - [C/ (1 + r)^1] - [C/ (1 + r)^2] - [C/ (1 + r)^3] - \ldots - [C/T/ (1 + r)^T]$$  

where $C_0$ = initial investment, $C$ = cash flow; $r$ = discount rate and $T$ = Time.

In this paper, we look at the opportunity presented to both households and small businesses through the sale of excess electricity generated. In the example presented in Table 6, during the daylight period of 9 a.m.–6 p.m., the household is able to generate enough electricity for its own consumption (3.6 kWh/d), as well as sell 1.4 kWh/d of excess electricity. While the higher capacity solar PV system is 30% more costly to install, it becomes a more economical option for the household to generate part of its electricity needs and reduce diesel usage.

Table 7 shows another example of an even higher capacity solar PV system which can generate 2.4 kWh/d of excess electricity to be sold.

### Table 6. Solar PV system selling 1.4 kWh/d excess electricity.

| SOLAR PV SYSTEM WITHOUT BATTERY SELLING 1.4 kWh/d EXCESS ELECTRICITY - LAGOS | USD/YEAR | USD/MONTH |
|---------------------------------------------------------------------------|----------|-----------|
| Household - Diesel genset used during sun-up                              | 1558     | 130       |
| Household - Diesel genset used during sun-down                            | 1090     | 91        |
| Commercial - Diesel genset used during business hours, 9 a.m.–6 p.m.     | 1246     | 104       |

**Diesel Generator for Household - comparison of fuel spend without solar PV system**

| Year | Cost of fuel, usage during daytime outages | Discounted cost |
|------|-------------------------------------------|-----------------|
| 1    | $1558                                     | $(1558)         |
| 2    | $1558                                     | $(1558)         |
| 3    | $1558                                     | $(1558)         |
| 4    | $1558                                     | $(1558)         |
| 5    | ...                                       | ...             |
| 10   |                                           | $(1558)         |
| 20   |                                           | $(1558)         |

**Household Solar PV system WITHOUT battery, generating 1.4kWh/d excess electricity**

| Year | Cost of solar PV system, NOT financed | Discounted cost |
|------|---------------------------------------|-----------------|
| 0    | $(4188)                               | $-              |
| 1    | $(4188)                               | $(4188)         |
| 2    | $(209)                                | $(209)          |
| 3    | $(209)                                | $(209)          |
| 4    | $(209)                                | $(209)          |
| 5    | ...                                   | ...             |
| 10   |                                        | $(209)          |
| 20   |                                        | $(209)          |

**Net Present Cost (NPC)>>** $399

**Cost saved over project life >>** 55%

### Table 7. Solar PV system selling 1.4 kWh/d excess electricity.

| FUEL SPEND USAGE CASE | SOLAR SYSTEM DETAILS |
|-----------------------|----------------------|
| Household Solar PV system WITHOUT battery, generating 1.4kWh/d excess electricity | Daily load (kWh/day) 6 |

**Diesel Generator for Household - comparison of fuel spend with solar PV system**

| Year | Cost of fuel, usage during daytime outages | Discounted cost |
|------|-------------------------------------------|-----------------|
| 1    | $1558                                     | $(1558)         |
| 2    | $1558                                     | $(1558)         |
| 3    | $1558                                     | $(1558)         |
| 4    | $1558                                     | $(1558)         |
| 5    | ...                                       | ...             |
| 10   |                                           | $(1558)         |
| 20   |                                           | $(1558)         |

**Household Solar PV system WITH battery, generating 1.4kWh/d excess electricity**

| Year | Cost of solar PV system, NOT financed | Discounted cost |
|------|---------------------------------------|-----------------|
| 0    | $(4188)                               | $-              |
| 1    | $(4188)                               | $(4188)         |
| 2    | $(209)                                | $(209)          |
| 3    | $(209)                                | $(209)          |
| 4    | $(209)                                | $(209)          |
| 5    | ...                                   | ...             |
| 10   |                                        | $(209)          |
| 20   |                                        | $(209)          |

**Net Present Cost (NPC)>>** $5967

**Cost saved over project life >>** 55%

### Table 8. Solar PV system selling 1.2 kWh/d excess electricity.

| FUEL SPEND USAGE CASE | SOLAR SYSTEM DETAILS |
|-----------------------|----------------------|
| Household Solar PV system WITHOUT battery, generating 1.2kWh/d excess electricity | Daily load (kWh/day) 4 |

**Diesel Generator for Household - comparison of fuel spend with solar PV system**

| Year | Cost of fuel, usage during daytime outages | Discounted cost |
|------|-------------------------------------------|-----------------|
| 1    | $1558                                     | $(1558)         |
| 2    | $1558                                     | $(1558)         |
| 3    | $1558                                     | $(1558)         |
| 4    | $1558                                     | $(1558)         |
| 5    | ...                                       | ...             |
| 10   |                                           | $(1558)         |
| 20   |                                           | $(1558)         |

**Household Solar PV system WITH battery, generating 1.2kWh/d excess electricity**

| Year | Cost of solar PV system, NOT financed | Discounted cost |
|------|---------------------------------------|-----------------|
| 0    | $(4188)                               | $-              |
| 1    | $(4188)                               | $(4188)         |
| 2    | $(209)                                | $(209)          |
| 3    | $(209)                                | $(209)          |
| 4    | $(209)                                | $(209)          |
| 5    | ...                                   | ...             |
| 10   |                                        | $(209)          |
| 20   |                                        | $(209)          |

**Net Present Cost (NPC)>>** $6111

**Cost saved over project life >>** 54%
Table 7. Solar PV system selling 2.4 kWh/d excess electricity.

| FUEL SPEND USAGE CASE | USD/YEAR | USD/MONTH |
|-----------------------|----------|-----------|
| Household - Diesel genset used during sun-up | 1558 | 130 |
| Household - Diesel genset used during sun-down | 1090 | 91 |
| Commercial - Diesel genset used during business hours, 9 a.m.-6 p.m. | 1246 | 104 |

Discount rate = 10%

| Diesel Generator for Household - comparison of fuel spend without solar PV system | | |
|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 10 | 20 |
| Cost of fuel, usage during daytime outages | $ (1558) | $ (1558) | $ (1558) | $ (1558) | $ (1558) | ... | $ (1558) |
| Discounted cost | $ (1416) | $ (1288) | $ (1171) | $ (1064) | $ (967) | ... | $ (601) |

| Household Solar PV system WITHOUT battery, generating 2.4 kWh/d excess electricity | | |
|---|---|---|---|---|---|---|
| Year | 0 | 1 | 2 | 3 | 4 | 5 | ... | 10 | 20 |
| Cost of solar PV system, NOT financed | $ (4506) | $ - | $ - | $ - | $ - | ... | $ - | $ - |
| Cost of operation and maintenance | $ - | $ (225) | $ (225) | $ (225) | $ (225) | ... | $ (225) | $ (225) |
| Total cost | $ (4506) | $ (225) | $ (225) | $ (225) | $ (225) | ... | $ (225) | $ (225) |
| Discounted cost | $ (4506) | $ (225) | $ (186) | $ (169) | $ (154) | $ (140) | $ (97) | $ (33) |

From a business standpoint, the cost of power access from a diesel generator would be more expensive than from the proposed SHS-based microgrid. The World Bank reports that over 70% of businesses in Nigeria own or share a generator, and source nearly 60% of their electricity from a generator [1]. Assuming a negotiated price of half what a small business owner would have paid for similar electricity generation from a diesel generator, the business saves half of their spend in this area, and the households get extra income. This scenario presents a win-win situation for both parties. Where space allows, another option for the business owner is to invest in purchasing a solar PV system for their own use, where additional electricity needed over time may be sourced from the SHS-based microgrids. In this scenario, the business owner may also participate in the SHS based microgrid to sell its excess electricity to homes during weekends when the business may not be open and when usage from the residential sector is expected to be higher. Some examples of small to medium-sized businesses that may benefit from sourcing electricity from SHS-based microgrids are shown in Table 8.
Table 8. Examples of small to medium-sized businesses that can benefit from SHS-based microgrids.

Examples of Commercial Load for a Small to Medium Size Business
Assumes working hours in daytime, from 9 a.m.–6 p.m. (9 h)
Estimated total duration of grid power outage during business hours = 3.2 h (reference Table 4)

Small office example (e.g., accounting firm, real estate, internet café, etc)

| Source of power Rating | Appliance                          | Power Rating (W) | Quantity | Hours Used | Total Active Power Used (W) | Energy Consumed (Wh) | Total (kWh) |
|------------------------|-----------------------------------|------------------|----------|------------|----------------------------|----------------------|-------------|
| 1                      | Lighting Bulb -Energy Saving      | 15               | 2        | 9          | 30                          | 270                  |             |
| 1                      | Air Conditioner, Small (1HP)      | 746              | 1        | 9          | 746                         | 6714                 |             |
| 2                      | Desktop Computer                  | 100              | 4        | 9          | 400                         | 3600                 |             |
| 2                      | Printer (Inkjet)                  | 20               | 1        | 1          | 20                          | 20                   |             |
| 2                      | Paper Shredder                    | 200              | 1        | 0.5        | 200                         | 100                  |             |
| 2                      | Fax                                | 70               | 1        | 0.5        | 70                          | 35                   |             |

Daily total energy consumed: 10,739 10.74
Estimated daily energy from non-grid source: 3.82

Small Restaurant/Café example, e.g., catering to lunch time customers

| Source of power Rating | Appliance     | Power Rating (W) | Quantity | Hours Used | Total Active Power Used (W) | Energy Consumed (Wh) | Total (kWh) |
|------------------------|---------------|------------------|----------|------------|----------------------------|----------------------|-------------|
| 1                      | Lighting Bulb -Energy Saving | 15               | 2        | 9          | 30                          | 270                  |             |
| 1                      | Standing Fan  | 70               | 2        | 9          | 140                         | 1260                 |             |
| 1                      | Medium Size Refrigerator | 100              | 1        | 9          | 100                         | 900                  |             |
| 2                      | Rice Cooker   | 200              | 2        | 4          | 400                         | 1600                 |             |
| 2                      | Pressure Cooker | 700              | 1        | 4          | 700                         | 2800                 |             |

Daily total energy consumed: 6830 6.83
Estimated daily energy from non-grid source: 2.43

Barber shop example

| Source of power Rating | Appliance          | Power Rating (W) | Quantity | Hours Used | Total Active Power Used (W) | Energy Consumed (Wh) | Total (kWh) |
|------------------------|--------------------|------------------|----------|------------|----------------------------|----------------------|-------------|
| 1                      | Lighting Bulb -Energy Saving | 15               | 2        | 9          | 30                          | 270                  |             |
| 1                      | Ceiling Fan        | 85               | 1        | 9          | 85                          | 765                  |             |
| 1                      | Standing Fan       | 70               | 1        | 9          | 70                          | 630                  |             |
| 2                      | Electric Shaver/Clippers | 15               | 4        | 7          | 60                          | 420                  |             |
| 1                      | Medium Size Refrigerator | 100              | 1        | 9          | 100                         | 900                  |             |
| 1                      | Television         | 100              | 1        | 9          | 100                         | 900                  |             |

Daily total energy consumed: 3885 3.99
Estimated daily energy from non-grid source: 1.38

* Source of power rating information: (1) Ikeja Electric (Lagos, Nigeria) [24]; (2) Generatorist [25].
5. The Pros and Cons of Solar PV Home Systems

There are several benefits to implementing microgrids based on household solar power systems. The Solar Home System (SHS) based microgrids can provide for a business model where end-users can be compensated for energy that is produced by their system and consumed by other end-users in the microgrid as well as provided directly to the national grid or businesses. The ability to generate income from their SHS also means that households are incentivized to use electricity more efficiently as they maximize their earnings by reducing their own consumption and selling more electricity. Another particularly important benefit for urban areas is that this style of rooftop decentralized generation is better suited for densely populated areas, compared to centralized solar panel installations occupying large areas of land.

Electricity generated from household solar power systems, combined with the distributed generation concept, has several more advantages, including:

- Additional generation: production of additional electricity that may allow adding to or freeing up generation resources for the utility company.
- Grid stability: creates a distribution system for local use of the electricity which avoids the losses associated with the transmission lines, as currently experienced by the Nigerian national grid. Decentralized generation can assist in stabilizing the grid, allowing for more reliable access to electricity for customers.
- Additional income: generation of income stream for households.
- Supporting the commercial sector: providing access to more reliable electricity for the commercial sector. Also, it supports job creation for the larger community through a more vibrant commercial sector.
- Savings: there is potential for customer savings on fuel cost compared with solely running the more widely used diesel generators for self-generation.
- Environmental impact: solar PV systems are a cleaner source of energy.

While there are several benefits of electricity generated from household solar power systems, there are challenges associated with this as well. These challenges include:

- Network profitability: the sell-back price to the grid may be unattractive compared to selling directly to a business or your neighbor. The detailed design and economics for each geographical location will have to be done to maximize profitability for the SHS-based microgrid member households, such as the design work proposed by Chiu et al. [26].
- Regulation: regulation on solar systems in Nigeria is still evolving. In November 2017, the Nigerian Electricity Regulatory Commission (NERC) released the ‘Eligible Customer Regulation’. Key highlights of the new policy and regulations allow for end-users to combine multiple sites and apply to the commission for eligibility status to contract with Generating Companies (GenCos) for supplying electricity. However, the regulation also mandates technical and financial obligations that end-users may be challenged to meet [27]. For SHS-based microgrids, it may be more beneficial to supply local businesses directly.
- Potential loss of revenue: utility companies may be negatively impacted as consumption from the grid is replaced by self-generated power. However, in the context of Nigeria, this is likely to be less of an issue as additional sources of power generation are more likely to help stabilize the overloaded grid and thus be beneficial to individuals and utility companies alike.
- Grid stability: where there is connection to the grid, the increased use of RE power sources can threaten grid stability, though this may be mitigated by having a central/main microgrid connection point to the grid that feeds the excess electricity from the collection of member households.
6. Policy Related Issues and Enablers

The causal relationship between electricity consumption and economic growth in Nigeria was explored by Okorie and Manu [28], using Johansen co-integration and VAR-based techniques. The results show that in the long run there is a positive relationship between electricity consumption and economic growth in Nigeria. The Granger causality test is a way to investigate causality between variables in a time series and is a probabilistic account of causality using empirical data sets to find patterns of correlation. Okorie and Manu’s application of the Granger causality test to the Nigerian case revealed a unidirectional causal relationship between electricity consumption and economic growth. The authors recommended the increasing demand for power, including alternatives to the power supply by the national grid which should be made more competitive to spur economic growth. Akomolafe and Danladi [29] reach a similar conclusion in their multivariate investigation of electricity consumption and economic growth in Nigeria. Their study revealed that in the long run, electricity consumption is positively related to real gross domestic product in Nigeria.

Enabling uptake of household solar PV systems can make a tremendous impact both in the residential and commercial sectors. Uptake can be greatly facilitated by effective policy and conducive enabling frameworks. For example, if policymakers guarantee the purchase of the excess electricity generated, these systems become much more affordable for urban households.

Failure to have an appropriate policy for home solar PV systems can have both short- and long-term consequences, which include reduced uptake in installation of new solar PV systems, reduction in existing home solar PV systems due to poor maintenance and lack of a supportive infrastructure, continued and increased use of diesel generators which increases greenhouse gas (GHG) emissions, as well as the associated health and environmental effects.

By effecting appropriate policy, the government can support reducing and possibly eliminating the power outages currently experienced by the commercial sector. Some of the policy issues and enabling recommendations are further discussed below.

6.1. Financing Options

Enabling the installation of household solar PV systems can be greatly facilitated by the availability of financing given the high initial capital cost. While these systems have a high initial investment cost, there is low maintenance required and the modularity of the system means that the system size may be increased as demand and financing become available. However, the high initial investment cost for SHS is a big deterrent for many households. With the option to have a guaranteed income stream by selling electricity to the grid or neighboring businesses, government and private financing should be made more readily available with enabling financing structures. For example, one approach may be financing that can allow offsetting the initial cost of the PV systems over time with the income generated from selling electricity. Another flexible financing option can be made possible by the fuel savings from households that eliminate or reduce their existing use of diesel generators. Another funding option may be supplier-provided financing where a supplier loans out the solar unit and consumers pay based on their usage or pay towards the unit’s outright purchase over time. Given that the median monthly salary of Nigerians is 300,000 NGN (980 USD) [30], what is evident is that some form of financing scheme, whether government or privately backed, is essential for the wider adoption of home solar PV systems.

6.2. Minimum Technical Requirements

As more individuals and businesses look to solar generated electricity for improved electricity availability, a key consideration should be what standards need to be set in place, both on the technical side and regulation, to allow connection to the grid and the sustainability of these systems. Both technical and regulatory capacity is needed to ensure that SHS are installed correctly, that distribution networks can accommodate SHS-based microgrids and that appropriate regulation is developed and implemented.
Taking a longer-term view on what standards need to be set in place is particularly important as solar PV use rapidly grows. It will be important to establish minimum technical requirements for systems connected to the grid to help ensure the quality and performance of the feed, as well as the reliability of the supply once it is online. In the microgrid concept proposed in this paper, grid stability issues related to supplying excess electricity to it can be mitigated where there is a central or main microgrid that is connected to the national grid, and that microgrid meets the stringent requirement for feed-in to the national grid. Solar home system owners would, in turn, be required to meet minimum (likely less stringent and less costly) requirements to be connected to the microgrid to obtain the right to participate in and gain the financial benefits of the SHS-based GenCo. By doing so, individual households could possibly be alleviated from covering the cost of what may be more demanding requirements for connecting to the national grid directly.

6.3. Feed-In Tariffs

Establishing a feed-in tariff that guarantees that excess electricity produced will be bought at a fixed price for a given period of time can aid in the expansion of solar PV home systems. Based on Japan’s experience with a similar policy, 10 years should support establishing renewable energy (RE), and specifically solar PV among residents, and incentivize them to purchase solar PV systems that meet the feed-in system’s technical requirements. It will also incentivize self-generators to be more energy efficient in order to maximize the surplus electricity that can be sold. In the Nigerian urban community-based microgrids concept shared in this paper, the government can support such a model, whereby households with solar PV systems form a SHS-based microgrid system and effectively act as a Generating Company (GenCo) and also receive similar benefits that have so far been reserved for the privatized GenCos generating power from ground-mounted PV plants that utilize a large land mass. It will be beneficial if SHS-based microgrids can also take advantage of the proposed commitment by the government to buy any excess power generated, where the urban community-based GenCos also gain access to more favorable rates for feed-in tariffs. The wholesale contract prices for GenCos with feed-in tariff for electricity generated from solar PV plants is significantly higher than other renewable sources [14]. Assuming a feed-in tariff equivalent to those offered by the Nigerian government to the privatized GenCos was also offered to SHS-based microgrids, this would make this option more economically attractive for households to adopt. Alternatively, SHS-based microgrids can connect directly to local businesses, where market competitive prices can be reached for supplying the businesses with power.

6.4. Service Sector Growth

Aside from increased access to power benefitting the status quo of existing businesses in Nigeria, the reduction in power outages and increased access to electricity for the commercial sector can have wider implications in terms of propelling new businesses not already present in Nigeria or without significant footprint, thereby growing certain sectors faster. To examine this theory, we take for an example some developing nations and assess the impact more access to electricity has had on their commercial sector.

China’s access to electricity has been growing, and with that, there has been a significant shift from construction and manufacturing to the service industry. China’s GDP can broadly be described to be contributed by three broader sectors or industries: primary industry (agriculture), secondary industry (construction and manufacturing) and tertiary industry (the service sector). A 2014 report indicated China’s primary industry accounted for 10% of GDP, while the secondary industry accounted for 44%, and the tertiary industry for 46% [31]. China’s service sector has doubled in size over the last two decades to account for about 46% of GDP, surpassing China’s secondary industries for the first time. While growing at a rapid rate, the services sector’s share of GDP in China is still much lower than that of countries like the U.S. (79%), Japan (73%), Brazil (69%) and India (57%). However, China’s service sector is expected to continue to grow and play a bigger role in powering the world’s second
largest economy, as increasingly affluent Chinese consumers desire more diverse and better-quality services [32].

In April 2018, the Electric Power Research Institute (EPRI) published a report in collaboration with many stakeholders to examine the forces that are transforming the world’s energy systems [33]. Key insights from the EPRI report were that in the United States electricity has grown from 3% of final energy in 1950 to approximately 21% today and electricity’s role continues to grow. This growth has been driven primarily by lighting, cooling, refrigeration, entertainment and communications. For developing countries like Nigeria, still in the earlier wave of economic growth from electricity, using the United States’ earlier growth as a proxy of what to expect, an area of possible expansion in Nigeria outside of the basic necessities is in the area of entertainment. The growth of the entertainment industry can greatly contribute to Nigeria’s economic growth. According to the U.S. Department of Commerce Bureau of Economic Analysis, the ‘Arts, entertainment, recreation, accommodation, and food services’ sector contributes over 1.5 billion USD to the US economy, or 5% of GDP, and is increasing. According to the Nigerian Gross Domestic Product Report Q4 & Full Year 2018 issued by the National Bureau of Statistics, the ‘Arts, Entertainment and Recreation’ and ‘Accommodation and Food services’ sectors contributed approximately 1.2% to the real GDP for the whole of 2018 [34]. There is presented an opportunity for real economic growth in Nigeria through the expansion of the ‘Arts, entertainment, recreation, accommodation, and food services’ sector. More electricity results in less food spoilage and greater food access options. Through the availability of more and reliable electricity, consumers can expect better and more comfortable accommodations, which in turn can increase tourism. Thus, policy that incentivizes additional power generation and growth in the Nigerian service sector presents opportunities for strong economic growth.

7. Conclusions

The adverse economic impact due to power outages in Nigeria is enormous. In the private sector alone, losses due to electrical outages averaged 16% of annual sales. A key enabler for Nigeria’s economic growth will be access to more reliable electricity. This paper presents a conceptual framework of urban household solar PV-based microgrids as a feasible and implementable option for enabling more reliable power access for the commercial sector. It does so by framing how a microgrid made up of household solar PV systems can form a balancing network for more reliable power access. While this paper presents one opportunity amongst others in this space, by taking on board and effecting strategies like this, Nigeria and other similar economies can start to build a pathway towards achieving more positive economic and environmental impact. The use of solar PV home systems as an ‘urban swarm network’ to form a microgrid for electrification has strong potential for increasing electricity availability and reducing or eliminating power outages experienced by businesses across Nigeria. The combination of solar PV home systems and power from the grid can help create the balance needed to achieve a more reliable power supply for the commercial sector. Implemented effectively, the desired outcome can be achieved within the next decade, based on the successful deployment of residential solar PV systems in other countries like Japan.

This paper also addresses policy issues related to the proposal and recommends policy enablers for the diffusion and adoption of residential solar PV, the foundation of which is needed for an effective distribution network. The policy recommendations include expanding the current financial support mechanisms for feed-in tariff to not just be offered for solar PV plants that are ground-mounted, but also to solar microgrids based on solar home systems. This should allow SHS-created microgrids to operate as GenCos with the benefit of being able to sell electricity to the national grid or directly to businesses. Additionally, offering more financing options is proposed to ease the financial burden of the initial investment cost for solar PV systems.
There are some limitations to this paper that provide grounds for further research. For example, the approach taken in this work was an exploratory methodology prior to a proposed next step of testing through quantitative methods. Testing this approach out in a community in Nigeria or a similar developing country would be an appropriate next step. Furthermore, the approach suggested by this work most supports businesses that are closest to the urban areas, thereby being somewhat disadvantageous for businesses in the outskirts of urban areas or in rural areas. Expanding the available options for businesses outside of the urban areas will help achieve the benefits of economic growth across all areas of Nigeria. A further area of research would be a detailed analysis of the expected growth rate in solar PV adoption in the residential sector and expected amount of additional electricity made available to the commercial sector, whilst reviewing the cost of creating and accelerating such a distributed network system against the tradeoffs and cost of an alternate means of electricity generation.

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