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ACCELERATING THE ADOPTION OF SOLAR ENERGY IN NIGERIA:

A MARKET-CREATION STRATEGY

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TABLE OF CONTENTS

A SHORT NOTE ON INNOVATION THEORIES

Shortly after publishing his research on disruptive technologies, the late Harvard Business School professor Clayton Christensen received a call from Andy Grove, then CEO of Intel Corporation. Grove wanted to understand how Christensen's research applied to his company, and Christensen obliged.

When Christensen arrived at Intel's campus, Grove explained that something important had come up and he and his team only had 10 minutes for the meeting. In essence, Grove was looking for Christensen to tell him *what to do* based on his research. Thankfully, Christensen fought the urge and instead explained that he needed to describe how the disruption phenomenon played out in other industries first.

Christensen started his example with an industry so irrelevant it may have seemed like a joke: steel. He explained how Nucor, an upstart in the industry, was able to disrupt much larger and more heavily-resourced integrated steel companies. Nucor achieved this by selling rebar, the lowest-margin steel product at the time, to customers whom the integrated steel companies were all too happy to ignore. These customers, however, provided Nucor with enough business and cash to enable the company to spend more on technology and improve its operations. Over time, and as Nucor grew, the company began producing sheet steel, one of the most sophisticated and highest-margin steel products. Once this happened, it was game over for many integrated steel companies. This was the process of disruption.

Christensen described how the process played out in a few other industries, and like a light bulb turning on, Grove got it. Grove explained how there was a small upstart company called Advanced Micro Devices (AMD) that was like Nucor. Their processors weren't as good as Intel's and they generally went after customers Intel was happy to ignore. But if Intel didn't respond to the "disruptive threat," AMD could someday disrupt Intel. The interaction led to Intel developing the Celeron processors to fend off the threat from AMD.

Reflecting on the meeting years later, Christensen described how the experience taught him an invaluable lesson. He explained that if he had simply told Grove and the Intel executives what to do, they might have been defensive. They might have responded that their industry was different and that Christensen didn't understand the peculiarities in semiconductor manufacturing. Instead, by learning how the phenomenon played out in other sectors, they were able to come to their own conclusions.

We have taken a similar approach to writing this paper on accelerating market creation for solar energy in Nigeria. We will first describe the process of market creation and then apply the insights to solar energy in Nigeria.

> Understanding *how* disruption plays out in industries allows for leaders to apply theory-based insights to their specific context, and come to their own conclusion.

EXECUTIVE SUMMARY

Nigeria, often referred to as the Giant of Africa, is a country of "largests." It has the largest economy in Africa; it has the continent's largest population; it is Africa's largest oil exporter; and it has the largest percentage of immigrants with a university degree living in the United States.[1] Unfortunately, Nigeria is also home to the largest number of people living in poverty in Africa and the world. In addition, the country has the largest energy deficit—the number of people living without electricity—globally. (See Figure 1 for some demographic information about Nigeria.)

Figure 1. Select demographics for Nigeria

Nigeria at-a-glance	
Population (2021)	213.4 million
Gross Domestic Product (GDP) (2021)	$440.8 billion
GDP per capita (PPP) (2021)	$5,408
Government spending per capita (2021)	$220 (For reference, US government spending per capita: $29,583)
Rural/Urban Divide (2021)	47/53
Minimum wage (2023)	~$38/month (N30,000/month)
Number of people living in extreme poverty (2022)	88.4 million
Electricity generation (2021)	31.5 TWh (For reference, US generation: 4,152 TWh)
Electricity consumption (2020)	27.6 TWh (For reference, US consumption [2022*]: 4,050 TWh)
Electricity consumption per capita (2020)	115.8 kWh (For reference, US consumption per capita: 11,757 kWh)
% of urban population with access to electricity (2020)	83.9%
% of rural population with access to electricity (2020)	24.6%

*The 2022 US electricity consumption data reflects a more accurate source than anything found for 2020. The rest of the US and Nigeria equivalents reflect data from the same year.

Sources: Energy Information Administration, International Energy Agency, Our World in Data, Statista, USA Facts, Wage Indicator, World Bank, and World Data.

More than 92 million Nigerians don't have access to electricity, and most who do have access experience unreliable and intermittent electricity at best.[2] As a result, millions of Nigerian households and businesses supplement their precarious access to power with alternative sources including expensive, loud, and environmentally polluting gasoline or diesel generators. This not only increases the cost of doing business in the country, but it also significantly decreases the quality of life of the average citizen. From schools and hospitals to homes and factories, the lack of access to electricity poses a significant challenge to growth and progress.

For decades, Nigeria has invested billions of dollars in improving access to power.[3] Yet much of the country remains dark. There is, however, significant potential to firmly integrate solar power into Nigeria's energy mix. The question is *how*? That is what we hope to tackle in this paper by applying innovation and market-creation theories in a context where progress has been elusive.

Much has been written about solar energy adoption in Nigeria and the typical barriers are well known.[4] The most common are technical (a lack of technical capacity and a shortage of investment in research and development to grow the sector); financial (a lack of investment to finance solar projects and low earning or purchasing power, which makes solar products too expensive); social (a lack of awareness of the value of solar products and competing existing norms and customs); and political (a lack of political will to support the growth of the sector and limited clarity on existing regulations).

Categorizing the barriers to solar energy growth as financial, technical, social, and political implies that the solution to growing the sector is more funding, better policies, raising awareness, and improving investments in solar energy R&D. Making improvements in any of those dimensions will definitely help (just as they would help for any sector in Nigeria), but will not accelerate the adoption of solar energy because there are other barriers that need to be addressed first.

For example, over the past decade, development stakeholders and the Nigerian government have been working hard to remove the aforementioned barriers to solar adoption. From a policy standpoint, the government introduced several plans and agencies, such as the Rural Electrification Agency (REA) to accelerate the adoption of solar energy in the country. From a financing standpoint, development banks (such as the World Bank and the African Development Bank) and the Nigerian government have increased their investment in this space. Nigeria's REA for instance, has spent more than half a billion dollars on solar and other off-grid initiatives.[5]

These investments have resulted in some gains.

Nigeria's off-grid solar market has been growing at a 12% compound annual growth rate (CAGR) since 2018, with Pay As You Go (PAYGo) products growing at more than 30% CAGR. Solar deployment has reached more than 200MW, from just 70MW in 2016. Nigeria seems to be making progress.[6]

Yet Nigeria's installed solar capacity is lacking when compared to peer countries. India, Egypt, and Ghana, for instance, have per capita solar capacity of 28.4W, 16.4W, and 3W, respectively, while Nigeria's hovers around 1W per capita. In addition, experts projected solar energy would account for 15% of Nigeria's energy mix by 2020. It currently accounts for less than 3%.[7]

Why has Nigeria's solar market not grown faster—and how can it be accelerated?

To answer these two questions, we have taken a different approach and have analyzed the sector through the lens of market creation. This lens reveals five primary barriers to adoption: 1) misunderstanding between infrastructure and innovation, 2) executing a push strategy, 3) designing modular business models instead of interdependent ones, 4) prioritizing discovery and democratization over distribution, and 5) intense competition from power generators.

This paper is divided into two main parts. The first section introduces theories and principles of market creation. We describe what market creation is, how it happens, and provide some examples of how markets have been created in Nigeria. By unpacking the process of market creation, we present a clear, realistic, and context-specific approach to innovation in the Nigerian context.

The second part of the paper will apply the principles of market creation to solar energy in Nigeria. Our hope is that stakeholders committed to the development of the solar energy market in Nigeria can apply these principles and accelerate the adoption of solar innovation across the country.

Why has Nigeria's solar market not grown faster—and how can it be accelerated? This report uses the lens of market creation to find the answers.

PART 1. THE PROCESS OF MARKET CREATION

"One of the things that people don't understand is that markets are creations. They are not something which we can [just] find. A market has to be created."[8]

—Ronald Coase, 1991 Nobel Laureate in Economics

From discovery to democratization: How market creation happens

The creation of a market is rarely foreseen but, like all good ideas, it's taken for granted after it appears; and, when fully formed, seems impossible to live without. For example, imagining an Africa where the average person doesn't have access to a mobile phone is difficult. The creation of the mobile phone market, or any market, may seem like a fluke, but there's a predictable path to market creation.

First, a discovery must occur. Discoveries happen through experimentation, failure, learning, and (ultimately with enough perseverance) success. Most new discoveries are built on prior advances in human knowledge and an understanding of how the world works and what motivates people. Discoveries can be an invention or technology, a new business model, a new process, or a new product. **Discoveries typically take the world from *zero* to *one***. Or at most, zero to a few. They make a product or service available to a few people who have access to the discoverer. Those with access to discoveries are typically the wealthiest and most connected in society.

For example, in the 1990s, there were fewer than 10 million mobile phones in Africa and only the wealthy had access.

Therefore, a discovery by itself isn't enough to change the world. At best, it benefits a few people close enough to the discovery or those wealthy and networked enough to access the discovery. For the vast majority of people in society to get access, another phase of market creation must happen.

The second phase is the development of a distribution mechanism that enables widespread adoption of a discovery, provided the discovery has the potential to solve a Job to Be Done for many more people, or nonconsumers. Nonconsumers are people who would benefit from having access to a discovery but can't because of cost, time, skill, or access barriers.

From an access standpoint, **distribution takes the world from *one* to *many***.

Understanding Jobs to Be Done and nonconsumption

The theory of Jobs to Be Done is a framework for better understanding customer behavior. While conventional marketing focuses on market demographics or product attributes, Jobs Theory goes beyond superficial categories to expose the functional, social, and emotional dimensions that explain why customers make the choices they do. People don't simply buy products or services; they pull them into their lives to make progress. This progress is called the "job" they are trying to get done, and understanding this opens a world of innovation possibilities. When a discovery fulfills a Job to Be Done for the masses, it has the potential to be distributed to nonconsumers.

Nonconsumption is the inability of an entity (person or organization) to purchase and use (consume) a product or service required to fulfill an important Job to Be Done. This inability to consume can arise from the product's cost, inconvenience and complexity, along with a host of other factors—none of which tend to be limitations for the rich, skilled, and powerful in society.[9]

The following activities—directed at making products available to nonconsumers—typically occur in the distribution phase of market creation: mass production, marketing, distribution, financing or credit availability, consumption, after-sale support, casualties, and regulations.[10] These activities necessitate the creation of a new value network focused directly on nonconsumers.

It's also in the distribution phase that standardization occurs. Once this begins to happen, organizations can create scalable architectures to further grow an industry. For this phase to be successful, the aforementioned activities must occur concurrently—or at least before funding runs out. As a result of the difficulty of realizing distribution, many discoveries never get to the masses.

For example, in the 2000s the rapid development of the mobile telecommunications sector across Africa began to occur. In two short decades, access has jumped from barely nothing to more than 600 million subscriptions.[11] To fuel distribution, entrepreneurs (such as Mo Ibrahim and Strive Masiyiwa) and companies (such as MTN and Safaricom) invested heavily in **distribution**. In Nigeria alone, investors poured in more than $75 billion to build out the distribution component—mass production, marketing, advertising, financing, training, consumption, regulation, maintenance, etc.—of this market.[12] Unfortunately, across Nigeria, few products and services are truly distributed to serve the average person.

The third phase of market creation is democratization, which is typically heralded and led by governments, international organizations, and nonprofits. This phase happens when an innovation is deemed so important or critical that it's decided that everyone should have access to it. **In democratization, the hope is to take access from *many* to *all***. (Note that this third phase—democratization—doesn't necessarily occur all the time. It is often associated with products and services that government or development organizations deem important, such as water, financial services, electricity, education, healthcare, and so on.[13])

Nigeria finds itself in the midst of many democratization efforts, especially as it relates to electricity. Yet, as important as democratization is, it's impossible to achieve if the first two phases don't occur.

Distribution, it turns out, is the unsung hero of market creation. It makes discovery profitable and democratization possible. Although everyone celebrates discovery, and we all stand behind democratization initiatives as we seek to live in a more just and equitable world, without distribution, discoveries languish, and democratization programs never succeed.

Electrification in the US

The history of electrification in the United States and other countries that engaged in early industrialization is instructive in how markets are created, especially in considering infrastructures. The process of producing and transmitting electricity was discovered in 1831, but it was expensive for individual families to have electricity in their homes. At the time, not only were most people poor, but there was little demand for electricity as they had no electrical appliances. It was also a difficult transition to execute because most homes hadn't been designed with electrical wiring. However, by the late 1910s some of these obstacles were being overcome. Once in place, the electric grid reduced the cost of lighting by orders of magnitude, since candles, lamps, or gas pipes that burned fuels for light were extremely costly for anything more than a few minutes of use. New, mass consumption of electric lighting, in turn, created markets for new appliances and new activities.

Labor-saving appliances that used electricity were quickly introduced. Electric vacuum cleaners, irons, stoves, and washing machines all reduced the amount of time families used to perform daily chores. Homes became cleaner, safer, and more efficient. Additional products created new demand and, hence, new markets: bread toasters, waffle machines, hair dryers, electric kettles, radios, and phonographs allowed people to do things which were either extremely difficult to do or were never done before at home. In other words, electric-powered markets not only improved efficiency or productivity, they created new demand.

Electric refrigerators also had a profound impact on day-to-day life. Food could be purchased fresh and stored for longer periods of time. Refrigerators made food safer to eat and also allowed families to enjoy foods that previously could only be found seasonally in shops, if at all, depending on where they lived. Stores and markets could offer a wider variety of foods which, in turn, led to the concept of supermarkets.

Even the structure of residential architecture began to change. Maximization of natural light was no longer an essential element of design. Windows became a convenience rather than a necessity. Buildings could be taller as elevators allowed people of all abilities to reach the top floors.

These changes, however, were not instantaneous. From electricity's discovery in 1831, the first "grid" based network was established in 1882, and by 1908, just 10% of US households were connected. It took until 1924 for 50% and 1949 for 90% of US households to have electricity. The 10% to 90% diffusion took roughly 40 years— a period including the Great Depression and World War II.

Rural communities were the slowest to be connected to the grid, and most questions related to adoption speed were focused on how quickly rural areas could be electrified.

Retrospectively, and with an eye toward bringing this innovation to all of humanity, the focus has been on the role of planning and government investment in the sector. The story of electrification is considered a triumph of government planning and investment, and the intensity of planning is correlated with the rapidity of adoption by households.

However, the planning and execution of widespread adoption strategies are late-stage questions. The US Rural Electrification Act was enacted in 1936, only four years before saturation was reached. The act provided federal loans for the installation of electrical distribution systems to serve isolated rural areas of the US. The funding was channeled through cooperative electric power companies, hundreds of which still exist today. These member-owned cooperatives purchased power on a wholesale basis and distributed it using their own network of transmission and distribution lines. The Rural Electrification Act was one of many New Deal proposals by President Franklin D. Roosevelt to remedy high unemployment during the Great Depression.

It was a successful program, but when looking at emerging technologies and at competition with nonconsumption, using a market-creation lens is critical. It's important to understand the early-phase of electrification and what drove demand creation. The critical period is thus between 1889 and 1916. That period was prior to household electrification but well into the electrification of industry.

Understanding the different Jobs to Be Done helps illuminate why industry was interested in electricity. Whereas households initially desired lighting and radio as early applications, industry needed to power machines used in manufacturing. These machines or tools had been around since the early Industrial Revolution, starting in the 1820s. These manufacturing machines had been initially powered by animals but many had transitioned to steam. It may seem that steam was the solution for all industries, but a close review shows that steam plants were neither universal nor cheap enough for all industries.

To be efficient, steam engines needed to be several hundred horsepower. Steam engines and boilers also required operators and maintenance. For these reasons, the smallest commercial steam engines were about two horsepower, which was above the need for many small shops. Also, a small steam engine and boiler cost about $7,000, while an old blind horse that could develop one-half horsepower cost $20 or less. Machinery to use horses for power cost $300 or less. Many power requirements were less than that of a horse. Shop machines, such as woodworking lathes, were often powered with a one- or two-man crank. Factory sewing machines were steam-powered from a line shaft. Dogs were even used on treadmills adapted to churn butter.

In the late 19th century, specially designed power buildings leased space to small shops. These buildings supplied power to the tenants from a steam engine through line shafts. It was an inflexible option for many industries, requiring co-location and long logistic chains. For this reason, when electric power became available, it wasn't just a cost reduction but an increase in flexibility and accessibility that sold investors.

Electric motors were several times more efficient than small steam engines because central station generation was more efficient than small steam engines. Also, line shafts and belts had high friction losses. Electric motors were more efficient than human or animal power. The conversion efficiency for animal feed to work is between 4% and 5% compared to over 30% for electricity generated using coal.

Note that the electrification described is one where electric power would be generated on-site in a factory through the use of a boiler and steam-powered generator. The power would then be distributed through the factory to electric motor-powered machinery. The factory didn't need connection to a "grid" and, thus, no need for high-tension, long-distance transmission lines.

As a result, electrification of industry was rapid within various industries studied. Among the earliest was printing, with electric printing presses use well under way in 1893; apparel, with the use of electric sewing machines and looms by 1897; quickly followed by leather, chemicals, instruments, rubber, petroleum products, stone, clay, glass, primary metals, furniture, textiles, beverages, food, paper, and lumber.

Because of the industry's large-scale adoption of electrical power, individual household adoption increased. This is due to the development of generators, wiring harnesses, circuit breakers, electric motors and a myriad of other technologies that, therefore, made grid-scale development possible. Power plants that served cities were scaled-up versions of power plants that served factories. They were, in other words, de-risked by the industrial demand.

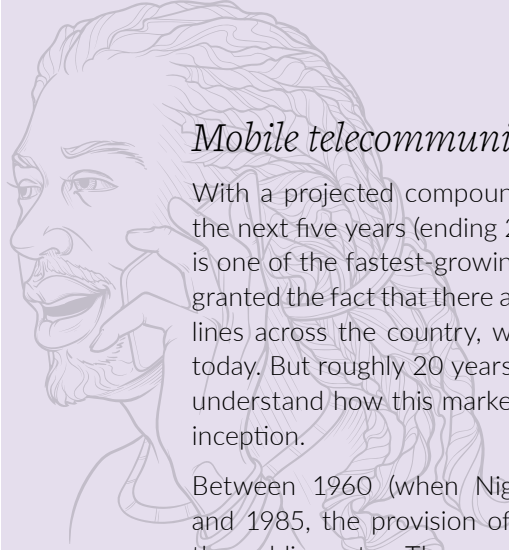
Later, countries that adopted electric grids followed patterns from the US and UK, applying them to both industry and residential areas, and thus, obscuring the origin of the market. In looking at new infrastructures today, it's imperative to appreciate the leverage effect of market creation in an early stage that leads to universal adoption.

One of the most important lessons from studying electrification in the US is that it's less about electrification and more about the Job to Be Done it helps nonconsumers accomplish.

The history of electrification in the US provides some insights about the importance of understanding the Job to Be Done, the process of market creation, and the focus on democratization after distribution has been accomplished. (See "Electrification in the US" for an overview of this process.) Although the context and country are different, there are several similarities that can enable solar energy stakeholders in Nigeria to increase their odds of market creation.

One of the most important lessons from studying electrification in the US is that electrification is less about electrification and more about the Job to Be Done it helps nonconsumers accomplish. Electricity is only as valuable as what it is able to power and, thus, the value it is able to create. From more productive workers and factories to more efficient and comfortable homes, it is only by understanding the Job of electrification that the market was able to take off. Once stakeholders understand the Job to Be Done, innovation and market creation can become more predictable.

Similarly, looking at how both the telecommunications and instant noodle markets were created in Nigeria can lend a deeper understanding of the process of market creation. In the following two accounts, the country is the same though the markets are markedly different. First, "Mobile telecommunications for the average Nigerian" provides a detailed look at the history and growth of telecommunications in Nigeria. Second, "Noodles in Nigeria" reviews the interesting history behind how one company transformed its unknown product into a staple food within Nigeria.



Mobile telecommunications for the average Nigerian

With a projected compound annual growth rate (CAGR) of 6.54% over the next five years (ending 2028), the Nigerian telecommunication market is one of the fastest-growing sectors in the country.[14] It's easy to take for granted the fact that there are more than 300 million connected telephone lines across the country, with more than 227 million lines in active use today. But roughly 20 years ago, there were fewer than 1 million lines. To understand how this market was created, it's important to go back to its inception.

Between 1960 (when Nigeria gained its independence from Britain) and 1985, the provision of telecommunications services was housed in the public sector. The service was regarded as a "social good," and thus necessitated the heavy regulatory arm of the government. For a myriad of reasons, during this period the government struggled to grow the sector. In 1985, Nigeria Telecommunications Limited (NITEL) was created and given monopoly status in an attempt to further grow the sector. Despite the establishment of NITEL, the Nigerian Communications Commission (NCC), and several attempts at privatization and deregulation, the sector still experienced gross inefficiencies—network congestion, inefficient billing, and low call-completion rates for both short- and long-distance calls.[15] This resulted in fewer than 700,000 phone lines in 2001 for a population of approximately 126 million.[16]

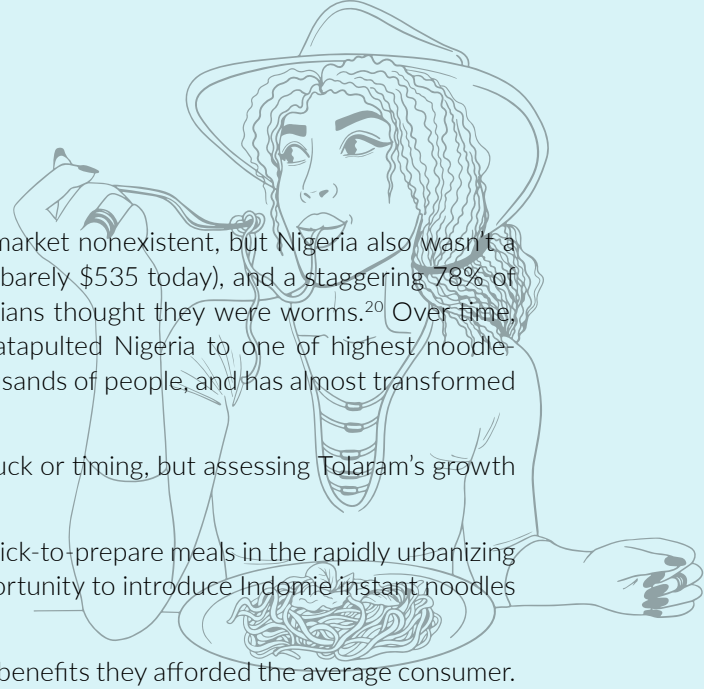
In 2001, the government privatized the sector and opened it to competition and market forces by auctioning licenses to operate telecommunications businesses in Nigeria. Two companies, Econet Wireless Nigeria Limited and MTN Nigeria Limited, purchased licenses for $285 million each. In 2003, another company, Globacom, entered the market and in 2007, Emerging Markets Telecommunications Service (operating as Etisalat) paid $400 million for a license to operate in Nigeria. By simply opening up the market, the government was able to raise more than $1 billion and shift responsibility for providing a service previously deemed a "public good" to private sector companies.

With an incentive to generate a return for their investors, the companies participating in nascent Nigerian telecommunications naturally had an incentive to grow the market. In the first year of operations, experts expected the companies to connect roughly 100,000 lines. By the end of year one, more than 2 million lines were connected. Their quest for growth and to set themselves apart as market leaders also caused them to invest in innovation. In 2013 for instance, Globacom introduced per-second billing while other companies were limited to per-minute billing. Considering the low income and relative poverty experienced by many Nigerians, this innovation fueled access even further.

By 2010, there were 87 million mobile phone subscriptions in Nigeria; in 2020, 204 million; and today, approximately 227 million.[17] According to the NCC, there are four main telecommunications service providers in the country: MTN (92.7 million subscribers), Globacom (60.7 million subscribers), Airtel (60.3 million subscribers), and 9Mobile (13.1 million subscribers). The impact of this market in Nigeria has been immense. From an investment standpoint, companies have poured more than $75 billion to grow the market over the past two decades. Mobile towers, VSAT turnkey networks, fiber optic infrastructure, data centers, call centers, and service centers are some examples of where these investments have gone. To create this market, companies needed to invest in distribution, which focused on getting service to the Nigerian nonconsumer.

In late 2022, the NCC reported that the telecommunications sector boosted the Nigerian economy by over $70 billion, created over 500,000 jobs in both official and unofficial sectors, and enhanced the quality of life for millions of Nigerians. The sector also provides billions of dollars in taxes annually.[18]

Looking back, several factors emerge as catalysts for the creation of this market. First, the government's decision to deregulate and privatize the sector created a welcoming environment for investments. Second, telecommunications companies invested relentlessly in distribution—mass production, standardization, marketing, after-sale support, regulations, financing, and so on—to tens of millions of nonconsumers across Nigeria. This helped create and scale the market. Third, companies modified their business models to fit the local context and reduce whatever barriers to consumption existed. For example, providing per-minute and, thereafter, per-second billing and selling airtime minutes via scratch cards made the service more accessible. Fourth, companies and the government didn't try to democratize access before building out the necessary distribution infrastructure. As described earlier in this paper, democratization without distribution is not possible. Fifth, companies didn't outsource operations too early and instead built an interdependent architecture.[19] This ensured they could control all aspects of their business in order to reduce cost and serve customers in a predictable way.



Noodles in Nigeria

When Tolaram introduced Indomie instant noodles into the Nigerian market in 1988, not only was the market nonexistent, but Nigeria also wasn't a prime investment destination. The country was under military rule, annual per capita income was $257 (barely $535 today), and a staggering 78% of people lived in extreme poverty. In addition, noodles were not a popular food in Nigeria, so many Nigerians thought they were worms.[20] Over time, however, and with focused market-creating investments, Tolaram created a noodle market that has catapulted Nigeria to one of highest noodle-consuming nations per capita. Today, the company sells billions of packs of noodles annually, employs thousands of people, and has almost transformed instant noodles into a staple food in Nigeria.

Like mobile telecommunications in Nigeria, it may be tempting to attribute the success of this market to luck or timing, but assessing Tolaram's growth through the lens of market creation theory provides several insights.

First, in 1988, managers at Tolaram identified a gap in the food market in Nigeria—they couldn't find any quick-to-prepare meals in the rapidly urbanizing country. Recognizing that, as nations urbanized, more people would be pressed for time, they saw an opportunity to introduce Indomie instant noodles to Nigerians. Indomie noodles can be cooked in less than three minutes by just adding water.

Second, Tolaram invested significantly in educating the population on what Indomie noodles were and the benefits they afforded the average consumer. This was critical as many Nigerians initially thought Indomie noodles were worms. Noodles were not a part of the average Nigerian's diet and so, seeing the thin, long, and windy noodle on a plate was off-putting to many. The company "invested heavily in sampling" and other below-the-line advertising channels to ensure each marketing dollar was spent as efficiently as possible. At the onset, the company avoided television or "above-the-line" advertising as it needed to build trust with its product. To date, Tolaram still spends millions of dollars annually on marketing and provides between 4 to 8 million free samples a year to children in schools and poor communities.

Third, Tolaram had to modify the taste of Indomie noodles to fit the Nigerian palate. Even though managers at Tolaram saw the value of Indomie noodles being a quick-to-prepare meal in a country where there was no national brand with a similar product, they still focused on ensuring it tasted flavorful to the average Nigerian.

Fourth, Tolaram implemented an interdependent architecture to control costs and create the market. Tolaram began by importing noodles, but after demand soared—and to deal with Nigeria's depreciating currency and other macroeconomic factors—Tolaram began backward integration, or the process of fulfilling tasks usually done by other companies in the supply chain. Initially, to test the market, importation worked. But to grow the market, domestication was necessary. To date, the company has invested close to half a billion dollars in manufacturing, sourcing raw materials, logistics, packaging, and other components of its business model.

Fifth, Tolaram targeted Nigerian nonconsumers by making Indomie noodles accessible, affordable, and available. This necessitated investments in every state in the country to ensure the average Nigerian in an urban or peri-urban area could access Indomie noodles whenever needed.

Lastly, Tolaram focused almost exclusively on creating the market for Indomie noodles before introducing other products into its portfolio. Today, the company sells milk, snacks, oils, cereal, and other consumer goods through its vast distribution channel. But the initial focus on ensuring Indomie noodles were accessible, affordable, and available enabled the company to make the necessary investments to create the market without getting distracted.

The World Instant Noodle Association estimates that Nigeria has consumed more than 11.6 billion servings of instant noodles since 2018.[21] And in no small way, each pack of noodles has contributed to the development of Nigeria. This is the power of market creation.

Figure 2. Factors related to the creation of the telecommunications and instant noodle markets in Nigeria

Category	Factor	Telecommunications	Instant noodles
The Market	Nonconsumption	Visible (Nonconsumption is visible when consumption of the product or service is widespread in other parts of the world. It is invisible when dealing with an entirely new product or service that hasn't been invented or experienced)	Visible
	Market-creating investment	$75 billion since 2001	$500 million by Tolaram since 1988
	Importation dynamics	Heavy: Most products used are imported	Heavy: Initially, heavy reliance on Indonesian imports, later raw materials were locally sourced
	Primary competition	No comparable product existed	No comparable product existed
	Key companies at inception	Econet, Globacom, MTN	Nestle, Tolaram
	Pricing	Government regulated floor	No pricing regulation
	Marketing expenditure	MTN: ~$35 million (2020)	Tolaram: ~$20 million annually
The Innovation	Job to Be Done (Customer value proposition)	Facilitate communication while saving time	Quick meal solution while saving time
	Solution architecture	Interdependent to Modular	Interdependent to Modular
	Compatibility	High: Easy to integrate into lifestyle	High: After significant expenditure on marketing and sampling
	Complexity	Low: Easy to use	Low: Easy to prepare
	Trialability	Free incoming calls	Free sampling
	Observability	High: Significant network effects	Low: People typically eat indoors

Although the telecommunications and instant noodle markets differ, they both provide important insights on what it takes to create new markets in Nigeria. (See Figure 2 for a comparison of factors that influenced each market at inception.)

Similar to the diffusion of electricity in the US, the initial customers for mobile telecommunications in Nigeria were primarily business leaders. Fulfilling this unmet demand introduced the novel product into the market in a way that instantly created value. Over time, consumption expanded from primarily business leaders to others in the economy.

Tolaram created Nigeria's noodle market. At first they only targeted the nonconsumption of noodles, but in doing so they had to build a completely new value chain that then gave them the opportunity to target nonconsumption of many other products in the country, creating even more market opportunities that could significantly impact the country.

At the core of these market creations is investment in the necessary distribution infrastructure that makes the products and services both easy to buy and easy to sell. The following section on conformability and collaboration goes into more detail about how companies can more predictably create new markets by making their products both easy to buy and easy to sell.

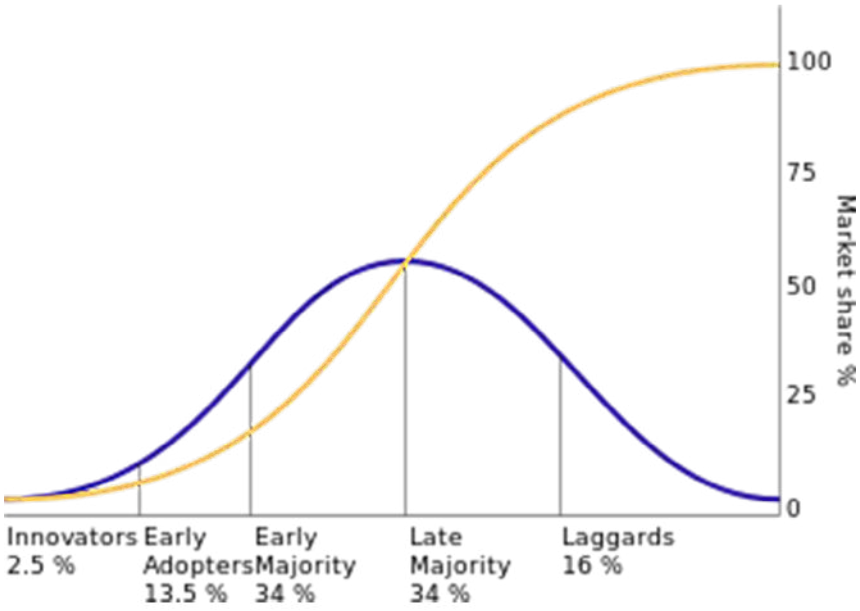
Accelerating market creation: The conformability and collaboration framework

How can innovators and companies accelerate the diffusion of innovations in society? Put another way, how can they speed up the process of market creation?

In his seminal book *Diffusion of Innovations*, the late Everett Rogers provided a set of activities which usually occur long before the diffusion process begins: "a perceived problem, funding decisions about R&D activities … invention of the innovation and then its development and commercialization, a decision that it should be diffused, transfer of the innovation to a diffusion agency, and its communication to an audience of potential adopters."[22] In effect, Rogers revealed that diffusions, or new markets, just don't happen. They must be carefully managed.[23]

Plotting the history of technological adoptions as graphs reveals a series of S-curves often referred to as diffusion curves. Each curve begins with a discovery (or an invention), a period of gestation as the idea is built into a product and, if the product solves an important customer struggle—or Job to Be Done—the formation of a vibrant market. If the technology is widely useful, then the products using it are adopted by a majority and the technology diffuses into the general population (see Figure 3).

Figure 3. Adopter categorization on the basis of innovativeness



Source: Reprinted from Everett M. Rogers, *Diffusion of innovations*. (New York: Free Press, 2005.)

Diffusion research has existed since the late 19th century, and is arguably one of the most important topics in innovation. Everyone invested in an innovation should be interested in understanding how and when that innovation can reach the masses. Yet our ability to predict how innovations might diffuse in society remains a challenging puzzle. (See "The puzzle of diffusion and market creation.")

The puzzle of diffusion and market creation

Technological diffusions have been observed for at least two centuries, beginning with the printing press in late 15th-century Europe. In the 19th century, with industrialization, diffusions became more common as transportation and communication innovations spread across Europe and the US. In the 20th century, new enablers in the form of motors, fuels, and production methods led to increasing consumer focus and miniaturization. Today, new technologies seem to appear very frequently.

But are technologies always adopted quickly? Has the speed of adoption matched the speed of introduction? Are ideas put to use as quickly as they're invented? Are new technologies in an age of quick adoption and were old technologies in an age of slow adoption?

Here is the puzzle: There were many older technologies that were adopted very quickly. In 1930s America, the radio was adopted very quickly. So was the TV in the 1950s. Conversely, there are many technologies today that are slow to rise. Electric cars are diffusing slower than the Model T, and new forms of energy production are growing more slowly than the original electric grid. The question is why?[24]

Comparing products with similar enablers but differing market development can help solve the puzzle of diffusion and market creation. In this pairing, a pattern emerges: rapid growth correlates with the absorbability of the innovation in the consumer's life. This correlation is called **conformability** to user behavior. For example, the refrigerator rose quickly in popularity because it was easy to fit into a kitchen, while a contemporary washing machine was slow to diffuse because it didn't easily fit into an urban apartment. Conformability can be tested by asking whether the adopter faced a minimum of five independences: purchase cost, assistance needed, time needed, space needed, and a learning curve (see Figure 4). "Independences" means that the adopter does not face these challenges when adopting a solution.

However, conformability alone—that is, an innovation's ability to easily integrate into a consumer's life—does not create a market. Another factor, determined in large part by a producer's ability to make and sell their innovations, is important.

To this end, we've observed a pattern of increasing granularity of value networks among the rapid diffusions. We call this **collaborative** producer behavior. Smartphones rose quickly because they leveraged modular software, components, distribution via network operators, and pre-existing internet content while electric cars are rising slowly because they require integration, defeat of the current distributors' business models, and the need to be driven on roads built without charging infrastructure. Collaboration can be tested by asking whether the producer could recruit ecosystems, obtain network effects, enlist both distribution and supplier networks, and leverage existing infrastructures (see Figure 5).

In combination, conformability and collaboration are powerful accelerants. In essence, conformability makes an innovation easy to buy while collaboration makes an innovation easy to sell. Therefore, a model that is both independent of purchase and dependent on reliable partnership will spur rapid adoption.[25]

Everyone invested in an innovaion should be interested in understanding how and when that innovation can reach the masses.

Figure 4. Consumer conditions for conformability

Purchase independence	Requires no other things to work. Independent of other products.
Help independence	Requires no help from others to install or use
Space independence	Requires no new space or saves space
Time independence	Requires no new time or saves time
Learning or knowledge independence	Requires no new behavior

Figure 5. Producer conditions for collaboration

New ecosystem	Incentives for collaborative innovation
Network effects	Value to producers increases with an increase in the number of consumers; or product/consumer becomes more valuable.
New distribution	Creates incentives for value-adding reselling
Supplier component architecture	Standardized interfaces for components; producers doing something they're already trying to do.
Ability to leverage existing stack or underlying infrastructure	Producer doesn't have to build entirely new infrastructure; can leverage its existing systems and processes.

In sum, the conformability and collaboration framework describes a modular business architecture that combines conformable demand creation and collaborative demand fulfillment. The duality of independence of purchase and dependence of supply explains the push and pull of market creation. For market creation to happen, both are necessary.

This framework helps shine a light on the deficiencies of the solar energy sector in Nigeria and, if adhered to, will accelerate market creation. However, it's important to caution that the model's acceleration, and subsequent success, isn't inevitable. It is the actions of entrepreneurs and policymakers that ultimately determine which conditions prevail and cause adoption to accelerate. If the causes for delay are understood, then action can be taken.

Part 2. MARKET-CREATION STRATEGIES TO ACCELERATE THE ADOPTION OF SOLAR ENERGY IN NIGERIA

Solar energy in Nigeria

Over the past decade, despite the growth of the solar energy sector in Nigeria, the market remains small.[26] In addition, experts projected solar energy would account for 15% of Nigeria's energy mix by 2020, yet it currently accounts for less than 3%.[27]

The solar energy sector in Nigeria is still in its infancy with many companies providing solar home system (SHS) products and services primarily to residential and micro, small, and medium size enterprise (MSME) customers. Although the sector has significant potential for growth, a fundamental shift in the need to provide energy to all—often at whatever the cost—must happen first. (See Figure 6 for an overview of the state of solar energy in Nigeria.)

Figure 6. The state of solar energy in Nigeria

Nigeria's solar sector at-a-glance	
Sector size and potential	• Nigeria is the 5th largest market in terms of volume of solar products sold. • The potential size of the minigrids and solar home systems (SHS) market is estimated at $10 billion annually in revenue and savings of $6 billion for Nigerian households and businesses. • The solar market in Nigeria grew at a CAGR of 22% between 2016 and 2021.
Sample investment activities	• The World Bank and the African Development Bank have invested $550 million toward the Nigeria Electrification Project (NEP), a federal government initiative that is private-sector driven and meant to provide electricity to households, MSMEs, educational, and healthcare facilities. • The Central Bank of Nigeria (CBN) introduced a N500 billion ($1.2 billion) Solar Connection Intervention Facility that provides long-term, low-interest credit facilities to the NEP prequalified home solar value chain players. This includes manufacturers and assemblers of solar components and off-grid energy retailers in the country. • In August 2022, the Nigerian government and the American company Sun Africa signed an agreement to install solar energy production systems in a dozen localities poorly served by the national electricity network. This project is expected to be implemented with a $1.5 billion loan from the US EXIM Bank.
Select solar companies	SHS: • Arnergy • D. Light • Lumos • SunKing • Zola Minigrid: • A4&T Power Solutions • Green Village Electricity (GVE) Projects Ltd • Husk Power Systems • Rensource • Rubitec Solar Limited

Nigeria's solar sector at-a-glance (continued)	
Agencies	• Nigerian Electricity Management Services Agency (NEMSA) • Rural Electrification Agency (REA) • Nigerian Electricity Regulatory Commission (NERC)
Sample of major initiatives	• The Renewable Energy Master Plan (REMP) • Africa Minigrids Program (AMP) • Nigeria Electrification Project (NEP)
Sample of solar goals for the country	• The Nigerian government, through the Rural Electrification Agency (REA), has a target to deploy solar PV systems (minigrids and standalone solar systems) to more than 10 million unelectrified households by 2030. • REA, through its Energizing Economies and Energizing Education Initiatives, plans to deploy 10,000 minigrids across the country by 2023, supported by development partners like the World Bank and African Development Bank through the Nigeria Electrification Project (NEP).
Solar goals deployment status	• 31,825 electricity connections through minigrids • 7,359kW PV capacity of renewable energy installed • 1,439,623 electricity connections through solar home systems • 6,182 MSMEs connections through solar home systems • 45,893kW total PV capacity of solar home systems

Sources: All On, Boston Consulting Group, Mordor Intelligence, Nigeria Rural Electrification Agency, and Netherlands Enterprise Agency.

Several barriers are preventing a more rapid acceleration of solar energy in Nigeria. The most common noted in various reports are technical, financial, social, and political barriers. Technical refers to a lack of technical capacity and a shortage of investment in research and development (R&D) to grow the sector. Financial barriers include a lack of investment to finance solar projects and low earning or purchasing power, which makes solar products too expensive. Socially, there is a lack of awareness of the value of solar products as well as existing norms and customs that complete with solar. And in the political arena, there is a lack of will to support the growth of the sector and limited clarity on existing regulations.

Categorizing the barriers to solar energy growth as financial, technical, social, and political implies that the solution to growing the sector is more funding, better policies, raising awareness, and improving investments in solar energy R&D. Making improvements in any of those dimensions will definitely help (just as they would help for any sector in Nigeria), but will not accelerate the adoption of solar energy because there are other barriers that need to be addressed first. To accelerate the adoption of solar energy in Nigeria, first stakeholders need to prioritize market creating activities.

As such, this report takes a different approach and studies the barriers to solar energy adoption in Nigeria through the lens of market creation. This lens reveals five primary barriers to adoption: 1) misunderstanding between infrastructure and innovation, 2) executing a push strategy, 3) designing modular business models instead of interdependent ones, 4) prioritizing discovery and democratization over distribution, and 5) intense competition from power generators.

1. Misunderstanding between infrastructure and innovation

Solar energy, like many other infrastructures, is simply an enabler. By itself, it has little to no value. But when attached to other things for which there is a market, such as machinery, appliances, and vehicles, its power becomes apparent. The benefits of solar energy are widely known, yet the relationship between solar energy and the innovations it powers is less understood.[28]

In the book *The Prosperity Paradox: How Innovation Can Lift Nations Out of Poverty*, the authors define **infrastructure** as the most efficient mechanism through which a society stores or distributes value.[29] For example, roads (infrastructure) are the most efficient means we have developed to distribute or transport vehicles (value). Schools (infrastructure) distribute knowledge and credentials (value). Financial systems (infrastructure) store and distribute credit (value). Similarly, solar electricity (infrastructure) stores and distributes power (value).[30]

The definition of infrastructure makes it clear that the value of an infrastructure is inextricably linked to what it stores or distributes. In addition, the value being stored or distributed must justify—and ultimately contribute to—the cost of construction and maintenance of the infrastructure. This means that every infrastructure investment must generate enough economic activity to pay back the capital used to build and maintain it. Too many solar energy infrastructure projects fail as a result of not adhering to this simple relationship.[31] Even if financial, technical, and other barriers are removed, solar energy projects will not be sustainable if the relationship between infrastructure and value is not adhered to.

2. Executing a push strategy for solar energy

Push strategies—sometimes referred to as deliberate strategies—are often driven by the priorities of their originators, typically experts in a particular field of development. They generate solutions from small- to large-scale solar energy projects that many, including local inhabitants, perceive as necessary for progress and development to occur. However, push strategies work only when three conditions are met:

- The strategy must encompass and correctly address all of the important details required to succeed, and those responsible for implementation must understand each important detail related to the strategy.
- If key stakeholders are to take collective action, the strategy must make sense to all involved so they act appropriately and consistently. In other words, incentives must be aligned to ensure every stakeholder is on board with the strategy.
- The strategy must be realized with little unanticipated influence from outside political, technological, or market forces.[32]

These conditions have been difficult to achieve in the context of Nigeria's solar energy sector, and, as such, many solutions haven't yielded long-term results.

Take, for example, the $2.5 billion 2016 Power Purchase Agreement (PPA) between the Nigerian government and 14 independent power producers. The PPA was meant to add significant power to the grid, but the project remains stalled today, partially due to tariff structures and concerns over the capacity of Nigeria's transmission infrastructure.[33] On paper, the PPA was a great idea; however, due to unanticipated influence from outside political, technology, and market forces, it hasn't been successful.[34]

3. Designing modular business models instead of interdependent ones

Modular approaches work when there are no unpredictable interfaces between the elements in a system.[35] In other words, different elements of the system fit and work together in efficient and well-understood ways. With modular systems, interfaces between elements in the system must be specifiable, verifiable, and predictable. When these three conditions are met, systems can be modular. In contrast, an interdependent approach is necessary when a change to one element in the system affects or necessitates a change to the entire system.

For instance, in the infancy of the mainframe computing industry, mainstream customers were not satisfied with the functionality and reliability of the products on the market. In addition, there were no predefined standards that connected one component to another (e.g., operating system to hardware design). As a result, most companies who wanted to compete couldn't simply choose to design or manufacture just one or two components. In their book, *The Innovator's Solution: Creating and Sustaining Successful Growth*, Christensen and Raynor put it this way: "You could not have existed as an independent supplier of operating systems, core memory, or logic circuitry to the mainframe industry because these key subsystems had to be interdependently and iteratively designed." To be successful in this market, companies had to wrap their arms around multiple components: operating system, hardware design, assembly, product design, and so on.

Nigeria's modular approach to leveraging solar energy has had limited progress. For instance, the Nigerian government privatized eleven electricity distribution and six generating companies, yet retained full ownership of transmission. If there was a breakdown in either transmission, distribution, or generation, companies could do little about it as they couldn't wrap their arms around the entire process. As a result, the distribution and generating companies' ability to create value was directly dependent on the government's ability to transmit electricity.

Consider how two Nigerian solar energy companies, SunFi and SteamaCo, pivoted to interdependent business models after struggling to serve their customers predictably with a modular strategy.

SunFi provides financing options for individuals and businesses who want to access solar energy products. Before starting SunFi however, the founders of the company, Rotimi Thomas and Tomiwa Igun, co-founded Aspire, a Nigerian solar installation company. While running Aspire, Thomas and Igun learned that most potential customers wanted their products but couldn't afford the high upfront cost. There were also no financing options available to them. Since they were just an installation company (and not a financing company), Aspire couldn't provide financing to the companies that needed it in order to access their products. After seeing firsthand the lack of financing options, Thomas and Igun decided to co-found SunFi to solve this problem.

SteamaCo provides another example. When SteamaCo started in 2012, the company set out to build and operate minigrids. But they quickly discovered that to build and operate minigrids sustainably, SteamaCo needed low-cost smart meters and IoT (Internet of Things) management software. And, unfortunately for SteamaCo, many of the available vendors were too expensive for the market SteamaCo was pursuing. Given the need to operate the systems at the lowest possible cost to ensure their long-term viability, SteamaCo couldn't rely on these companies. So, they made the decision to build the meters and software themselves. In 2015, the company became technology vendors and began selling their smart meter IoT technology to other minigrid developers. Today, SteamaCo partners with 35 different utility companies across 17 countries in Africa and Southeast Asia.[36]

Both Aspire and SteamaCo recognized that a modular architecture— which provided just one component in a market that was underdeveloped—wouldn't bring them success. As a result, they modified their business models to fit the needs of the market.

4. Prioritizing discovery and democratization over distribution

Today, there are several programs to support solar energy entrepreneurs and there are also programs designed to spread the use of solar energy in rural areas. Both these efforts fall under discovery and democratization, respectively. Unfortunately, without the necessary investments in distribution, the solar energy market will struggle to develop sustainably.

For example, the perception of solar energy products remains quite negative despite the sector's growth. One report notes that the broad perception is that "products are expensive and perform poorly."[37] These types of perception and cost issues are common during the initial stages of market creation. But investments in distribution activities of market creation often help mitigate perception and cost concerns. Initiatives such as the Standalone Solar Home Systems for Households and Micro Small Medium Enterprises (MSMEs) Output Based Fund, and the Market Scale-up Challenge Fund are helpful; however, these initiatives will struggle to become sustainable if the necessary investments in distribution are not made.[38]

5. Intense competition from power generators

Nigeria accounts for 3 million out of 6.5 million generators in the region annually.[39] As of 2019, there was an estimated use of 22 million small gasoline generators in Nigerian households.[40] The Nigerian diesel generator market—designed to serve larger households and businesses—was estimated at $445.1 million in 2021, with a 6.8% CAGR between 2021 and 2030, to reach $806.8 million by 2030.[41] The Nigerian generator market is not only mature; it also has a robust ecosystem designed to fuel its growth. There are easily accessible generator sales and repair shops; generator repair technicians; spare parts; and perhaps most importantly, a simple understanding of what a generator is, how it works, and what to do when it doesn't work (see Figure 7).

One of the most important questions for solar energy stakeholders is: how can we do for solar what generator stakeholders have done for the generator?

Figure 7. The often unspoken benefits of generators

Upfront cost	Relatively affordable. Within the past two decades, the smaller sizes of generators have ranged in price between N10,000 ($13) to over N100,000 ($129).
Fuel cost	Fuel is widely available at a low cost. Historically, this was because of the subsidization of the cost of gasoline by the Nigerian federal government, which ensured that consumers pay a fixed and relatively affordable price at the pump. (Note: This subsidy was removed May 29, 2023 during an inauguration speech delivered by the recently sworn-in president of Nigeria. It's yet to be ascertained what impact this will have on generator use and adoption.)
Setup	Generators are a complete package that require no additional component except for direct installation to household power changeovers. Easy half-hour installation without expert assistance.
Repair/replacement	Component parts that are found defective can be readily bought across small electronic local stores and replaced with ease. Self repairs are also a popular option.
Ecosystem	There is a robust generator ecosystem composed of importers, distributors/wholesalers, small-store retailers, roadside repairmen (who make a living from performing repair operations), and the ultimate users. Eighty-four percent of urban households use backup power supply systems such as fossil diesel/gasoline generators, and 86% of the companies in Nigeria own or share a generator.*
Perception	Generators are seen as a part of the household, regularly employed due to the unreliability of the power grid system. The wide availability of fossil fuel to power these generators makes generators a more realistic alternative to grid energy.

Source: IRENA.

General strategies for accelerating the growth of the solar sector

By studying the process of market creation for other markets in general and specific markets in Nigeria, this report identifies the following strategies for accelerating the growth of solar energy in Nigeria: 1) understand the Job to Be Done, 2) pull in solar energy, don't push; 3) invest in distribution, which prioritizes conformability and collaboration, and 4) leverage interdependent architectures to control costs and improve functionality and reliability.

1. Understand the Job to Be Done: People don't want solar, they want progress

With a minimum wage of 30,000 naira a month (approximately $38), the average Nigerian struggles to make progress in life. That is, basic necessities such as food, healthcare, transportation, and so on, are difficult to consume. And so, when solar energy is positioned as a necessity that they must have—without directly connecting solar energy to their more fundamental struggles—adoption becomes even more difficult. This is one of the reasons the Capacity Utilization Factor (CUF), or the percentage of energy sold by minigrids compared to total possible production across Africa, is 30%.[42]

Contrast the growth of solar energy with that of mobile telecommunications. There was a clear Job to Be Done with mobile telecommunications: Help me communicate with my colleagues, family, friends, and customers or vendors. This resulted in immediate cost savings or, for businesses, an increase in revenues. Before the proliferation of mobile phones, most people had to send physical messages, and businesses were less efficient. After mobile phones were introduced, communication became more efficient and people's lives improved.

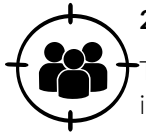
What is the progress solar energy is helping people make, especially those who are low income? When solar energy stakeholders wrestle with this question, it becomes clear that accelerating the growth of solar energy becomes less about solar energy itself and more about helping people make progress.

Analyzing the vast nonconsumption in Nigeria reveals a few struggles solar energy producers can help the average Nigerian resolve. For instance, the average expectant Nigerian mother doesn't have access to regularly scheduled prenatal appointments.[43] Deploying solar energy in healthcare centers could improve prenatal care coverage, guaranteeing a higher chance of catching and treating any developing pregnancy complications, and increasing the livelihood of unborn children and mothers. In fact, a study conducted by All On and Boston Consulting Group found that electrifying around 18,000 primary health centers without regular power supply would increase Nigeria's prenatal care by up to 20%.[44]

Millions of Nigerian students struggle with receiving any information and communications technology (ICT) education.[45] Deploying solar energy solutions in education would improve student access to reliable computer labs and longer ICT teaching time. Providing solar to around 1,200 public schools can increase ICT teaching hours by up to 60%. Earlier this year, the United Nations Refugee Agency installed solar energy in five schools in the state of Benue to ensure power, and improved access to ICT benefitting 6,000 teachers and students.[46]

Post-harvest losses cost Nigerian farmers N3.5 trillion (~$4.5 billion) annually.[47] Deploying solar in agriculture means that a farmer whose crops usually spoil during transportation to market can employ solar thermal systems to dry and cool perishable crops, thereby ensuring their profit.[48] Farmers who also employ solar-powered cold storage can reduce post-harvest loss by up to 30%.[49]

Solar solutions can not only improve the profit and productivity of these sectors, but also solve the struggles of the everyday Nigerian.



2. Pull in solar energy, don't push

This report has already highlighted how much of the investments in solar energy infrastructure across Nigeria are pushed onto communities that are not ready, able, or, in some cases, willing to absorb them. As more unsustainable solar energy projects are pushed into communities that can't extract the value from solar energy, this not only decreases the value of solar energy, but also increases the negative perception that's already pervasive. Also, if the goal is simply to get as many solar energy connections as possible, regardless of ability to pay, this creates perverse incentives.[50] Instead, a different approach is necessary: pull strategies.

Pull strategies often originate with innovators on the ground who are responding to the struggles of everyday consumers or specific market demands. These strategies have more of an investigative or inquisitorial approach to problem-solving, as opposed to a more advocating or assertive approach. In other words, the innovators are there to learn and then solve problems in a sustainable manner. Lastly, pull strategies focus on creating or responding to the needs of a market first. It is then the job of the market to pull in everything it needs to survive, including solar energy.

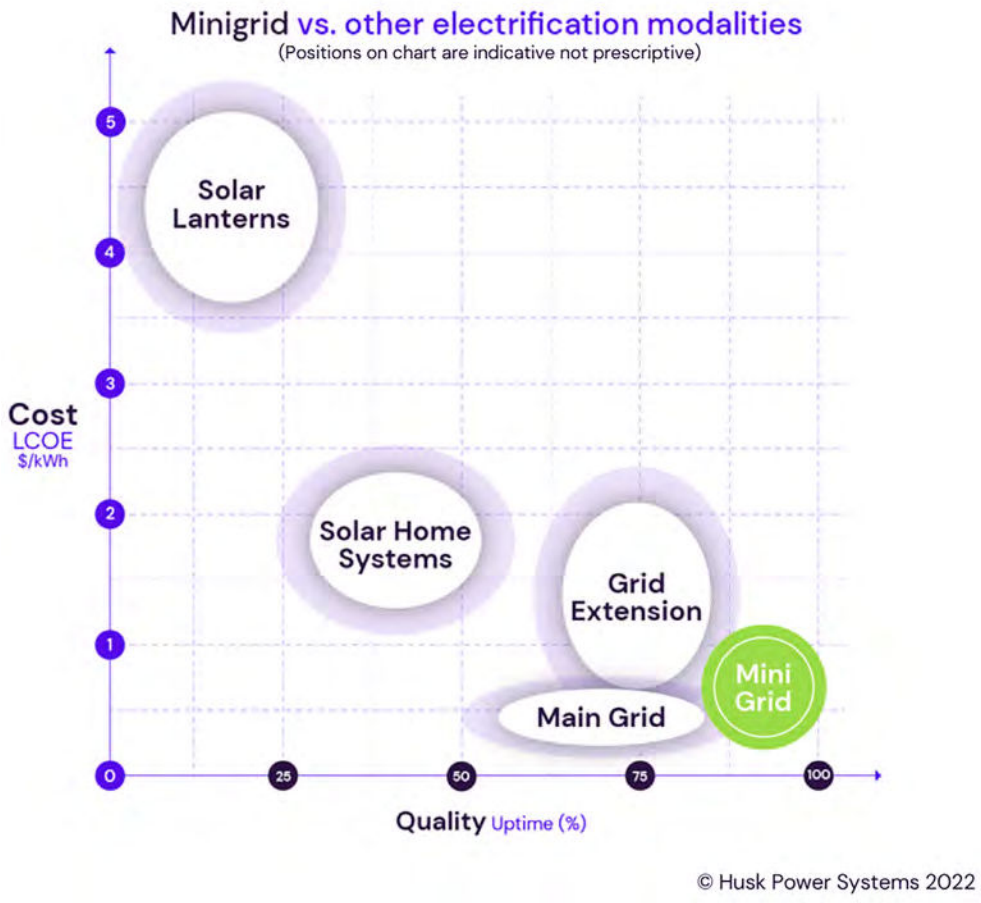
In the example referenced previously in this report, electricity in the US diffused primarily through business and industry. After businesses became more efficient, ultimately creating more prosperity, electricity began to diffuse in homes. As electricity diffused in homes, this fueled industry even further as appliances were developed to consume the electricity. Olu Verheijen, the special adviser on energy to Nigeria's President Tinubu, wrote an insightful piece about this issue, "For Nigerians Without Affordable Electricity, Job Creation Must Come First." In it, she writes, "A largely poor, residential customer base means limited revenue for utilities, which compounds reliability and affordability issues, as utilities cannot reinvest in expanding and improving electricity infrastructure."[51]

It's tempting to fund projects that provide solar energy for all; however, investors, development stakeholders, and public officials should prioritize projects that can answer these questions.

1. What market are we creating, enabling, or expanding?
2. Is the market able to pay for the solar energy investments today?
3. Will the market grow large enough to be able to pay for the solar energy investments in the future?
4. How large does the investment need to be to fit the needs of the market?

Solar solutions can not only improve profit and productivity, but also solve the struggles of the everyday Nigerian.

Figure 8. Cost and quality of minigrids in comparison to other electricity sources



Source: Reprinted from Brad Mattson, Manoj Sinha, and William Brent, "Scaling Solar Hybrid Minigrids: An Industry Roadmap," Husk Power Systems, 2022.

Ensuring that solar energy investments are directly tied to creating, enabling, and expanding markets that serve nonconsumers creates a pathway for sustainable solar energy investing. In effect, the market pulls in the solar energy investment and ensures sustainability. When this happens, issues around the cost of solar energy are no longer generic, but instead are tied to a specific market that can absorb the costs. For example, as important as it is to get the levelized cost of energy (LCOE) down, it matters more what market is absorbing the energy investment. (See Figure 8 for the respective LCOE for various energy sources). Different markets—retail, agriculture, healthcare, education, manufacturing, or hospitality—can absorb varying costs of solar energy investments. As such, tying solar energy investments to the markets they'll create is key to ensuring sustainability in the sector.

3. Invest in distribution, which prioritizes conformability and collaboration

One of the difficulties with developing a focused solar energy strategy that prioritizes creating, enabling, or expanding a market is that solar energy is currently operating in phase three of the market creation process—democratization. In the democratization phase, as described above, strategies are typically heralded and led by governments, international organizations, and nonprofits. This phase happens when an innovation is deemed so important or critical that it's decided by a nation's leaders that everyone should have access to it. In democratization, the hope is to take access from *many* to *all*. In other words, there is already the "need" to provide solar energy to "everyone," regardless of their willingness or ability to pay. In many ways, it's seen as a right.[52]

Democratization strategies are important. They foster equity and equality, and result in a more just world. However, democratization strategies can't work without proper investments in distribution. And investments in distribution are lacking in Nigeria.

In our research, for instance, we learned through interviews and from studying other papers that the perception of solar energy is largely negative in Nigeria. From a cost standpoint, many felt it was more expensive than the primary alternative option: generators. Also, from a reliability perspective, solar energy still suffers from substandard parts, untrained technicians, and unreliable service.[53] This creates a vicious cycle that can only be solved by investing in distribution.[54]

Investing in distribution should only happen after stakeholders have identified the markets that solar energy will enable. In other words, solar energy will then be pulled into the economy, not pushed. At that point, stakeholders can aggressively invest in mass production (or mass importation at the beginning of the process) of solar energy components, mass marketing, financing—for both solar energy producers and consumers—after-sale support, and working with the government to pass regulations that support the growth of the sector. Auxano Solar has the right idea. The company's first solar component factory served as an incubation hub, where it tested its components and strategies before deciding how to scale. It then invested in importation, production, after-sale support, and working with the government. Auxano was successful, and has grown from one 2016 solar component factory with a 10 MW capacity to an additional 2023 solar component factory with a 100 MW annual solar photovoltaic (PV) capacity.[55]

Studying the sector in Nigeria, we learned that most of these distribution investments are happening, but they are happening in a non-systematic way. As such, they aren't truly catalyzing the sector. For example, the Minigrid Regulation of 2016 allowed for organized minigrid development throughout the country, which established fair project-based tariffs, service quality standards, and dispute resolution frameworks.[56] More recently, the 2021 Solar Power Naija initiative, launched in response to the COVID-19 pandemic, will provide long-term, low-interest loans to solar entrepreneurs in hopes of rolling out 5 million new connections through solar home systems or minigrid connections. These loans are simultaneously facilitating the growth of local manufacturing industries and creating new jobs in the energy sector.[57]

Contrast these investment examples with those of the telecommunication companies and Tolaram in Nigeria. Their investments in distribution were not only focused, but targeted at specific geographies, populations, and markets. For example, in the past 20 years, telecommunications companies have spent more than $75 billion on creating and expanding

the market. From hiring technicians, engineers, and managers to building and maintaining telecommunications assets, these investments have fueled the average person's ability to communicate with others. Similarly, Tolaram has spent more than half a billion dollars in growing the instant noodle market.

In addition to focus, mobile telecommunications companies had little-to-no competition. Solar energy companies are competing fiercely with gas-powered generators and the many different combinations of solar panels, inverters, batteries, electrical wiring, and so on. As such, their investments to grow the market will likely surpass that of the telecommunications industry.

Also, investments in telecommunications and instant noodle markets were not diffused among many companies. There was (and remains) a handful of companies responsible for creating these markets. Focus enables companies to make deep investments in the necessary distribution to accelerate growth of markets. The solar energy sector is taking a different approach. Therefore, there is much breadth, but little depth in the sector. (See Figure 9 for an overview of factors influencing the creation of markets in Nigeria.)

To make sustainable investments in distribution to grow the solar energy sector:

- Identify the group of nonconsumers you're targeting.
- List all the activities necessary to serve people in this group at a reasonable cost.[58]
- Estimate the resources necessary to get your product/service to the average nonconsumer. This is a mixture of capital expenditure and operational expenses, such as production (importation), training, staffing, sales, logistics, inventory management, after-sale repairs and service, marketing, and financing.
- Identify key organizations that can reliably execute the activities listed in #2. If none exists for a particular activity, develop a plan to create it.

Once the list of activities necessary to accelerate the growth of a market is identified, it becomes clear that unless there's tight collaboration among the many companies for the purpose of market creation, growth will be limited. That's because most companies will duplicate efforts and as a result, will not be able to achieve economies of scale necessary to serve the vast majority of nonconsumers. As markets grow and mature, there often remains only a handful of major companies with the capabilities to serve the vast majority of nonconsumers.[59] These companies may be supported by many small businesses, but the function of those small businesses will be to plug into the necessary activities identified to serve nonconsumers.

4. Leverage interdependent architectures to control costs and improve functionality and reliability

As illustrated with the telecommunications and instant noodle example, market creation requires interdependent architectures, or business models. This ultimately means that companies integrate activities to control costs and improve functionality and reliability.

Tolaram, for instance, invested in, or created companies that invested in, the activities that enabled them to get their products to the average Nigerian. This included manufacturing, logistics, warehousing, retail, agriculture, marketing, packaging, and so on. It did this to control costs and improve reliability of the product. In our conversations with Tolaram executives, we learned that the company prioritized affordability, accessibility, and availability of its products. Other sectors bear this out.[60] Until solar energy stakeholders in Nigeria prioritize interdependence to create the market, it is unlikely to take off.

To determine which activities to integrate into their operations, solar stakeholders should ask if the activity is specifiable, verifiable, and predictable. When the answer is "yes" to all three questions, stakeholders can reliably outsource that particular activity to a partner or supplier. Answering "no" to any one of these questions puts the reliability of a product at the mercy of the partner and thus at risk.

Figure 9. Factors related to the creation of the telecommunications, instant noodle, and solar markets in Nigeria

Category	Factor	Telecommunications	Instant noodles	Solar
The Market	Nonconsumption	Visible (Nonconsumption is visible when consumption of the product or service is widespread in other parts of the world. It is invisible when dealing with an entirely new product or service that hasn't been invented or experienced)	Visible	Visible
	Market-creating investment	$75 billion since 2001	$500 million by Tolaram since 1988	*Difficult to estimate (At least $2 billion* has been invested and distributed among many companies and Nigerian states since 2014)*
	Importation dynamics	Heavy: Most products used are imported	Heavy: Initially, heavy reliance on Indonesian imports, later raw materials were locally sourced	Heavy: Most products used are imported
	Primary competition	No comparable product existed	No comparable product existed	Generators, the grid
	Key companies at inception	Econet, Globacom, MTN	Nestle, Tolaram	Arnergy, Auxano Solar , dLight, Husk Power Systems
	Pricing	Government regulated floor	No pricing regulation	Government-regulated ceiling
	Marketing expenditure	MTN: ~$35 million (2020)	Tolaram: ~$20 million annually	*Difficult to estimate*
The Innovation	Job to Be Done (Customer value proposition)	Facilitate communication while saving time	Quick meal solution while saving time	Solar provides energy that powers other products
	Solution architecture	Interdependent to Modular	Interdependent to Modular	Modular
	Compatibility	High: Easy to integrate into lifestyle	High: After significant expenditure on marketing and sampling	Low: Difficult to integrate
	Complexity	Low: Easy to use	Low: Easy to prepare	High: Comparatively, difficult to install
	Trialability	Free incoming calls	Free sampling	None
	Observability	High: Significant network effects	Low: People typically eat indoors	Low: Not easy to "see" that solar is power provider

*Our $2 billion estimate investment includes a $280 million investment from the CBN Solar Intervention Fund in 2020, $550 million from the World Bank and AFDB towards NEP, £66 million from the UK government in 2014, $1.5 billion loan from the US EXIM Bank in 2022, $1.5 million from the Austrian Development Bank in 2022, $90 million raised by Lumos, $9 million raised by Arnergy in 2019, and $1.5 million invested in Auxano Solar in 2020.

Sources: Mordor Intelligence, Netherlands Enterprise Agency, Nigerian Investment Promotion Commission.

So far, this report has applied market-creation strategies to the solar energy sector in Nigeria. But not all solar energy products are created equal. For the purposes of this paper, we categorize solar energy solutions into three main groups: small solar home systems, large solar systems, and solar minigrids. Each of these solutions has a different cost, product, and customer profile and, as such, will require a slightly different market-creation strategy. (See "Categorizing solar energy solutions" for an overview of each category.)

Categorizing solar energy solutions

Small solar home systems (SHS)

Small solar home systems (SHS) are complete solar panel kits that include all the necessary components to install and operate the solar energy system. These components typically include a solar panel, battery bank, power inverter, cables, and mounting hardware. Often the bundles come with the charging ports and appliances they power, such as light bulbs, fans, radios, or televisions. These self-installed small SHS vary in size and capacity, but usually have a capacity of up to 50 watt panels. These systems range in price from $50 to approximately $300. They are often targeted at low-income and rural populations who often don't require much energy. Sometimes, companies offer credit to customers or leverage a pay-as-you-go business model.

Large solar systems

Large solar systems are generally made up of a number of solar panels with a capacity of over 50 watts each, and often require site audits and third-party installation. The components are identical to small SHS, but these systems are often designed to fit specific energy needs—typically for larger homes and small- to medium-sized businesses. System providers also often offer after-sale monitoring, maintenance, and support. Similar to small SHS, payment plans include direct sale through a complete one-time payment, a monthly pay-as-you-go arrangement, or leases. Depending on the size, these systems cost several thousand to tens of thousands of dollars.

Solar minigrids

A solar minigrid is a set of small-scale electricity generators, and possibly energy storage systems, interconnected to a distribution network that supplies electricity to a small, localized group of customers, and operates independently from the national transmission grid. They range in size from a few kilowatts up to 10 megawatts.[61] Solar minigrids can be, but don't have to be, completely isolated from the grid, and are often used for rural electrification initiatives and for any communities seeking uninterrupted access to electricity. End users of electricity generated through the minigrids can purchase quantities or minutes of energy in advance through prepaid scratch cards and pay-as-you-go meters; or can be billed monthly through post-paid meters that record the energy consumed. Solar minigrids can be developed by public, private, or public-private partnerships. In Nigeria, grids with a distribution capacity below 100 kilowatts do not require a permit, only a registration; but grids with a distribution capacity over 100 kilowatts require a mandatory license from the Nigerian Electricity Regulatory Commission (NERC).[62]

Strategies for small solar home systems

The typical nonconsumers for small solar home systems (SHS) are often from low-income households, are part of the informal (or independent) economy, and have little to no access to electrical appliances. For these nonconsumers, solar energy entrepreneurs should prioritize conformability, standardization, and observability.

Conformability: As described previously in Figure 3 of Part 1, there are five main conditions for conformability. Small SHS entrepreneurs should develop business models where their potential customers can easily adopt their products. For example, their business model could provide financing, especially considering that most target customers live in low-income households. Also, their business model could provide necessary help or knowledge, so the consumer doesn't need to learn something new. One report notes that, "despite an evident need, most [SHS] traders do not offer after-sales service."[63]

More importantly, however, solar entrepreneurs must integrate themselves into the lives of the nonconsumers, understand specific ways in which SHS can help them make progress, and market their products accordingly.

Standardization: Serving the mass market is difficult and expensive since it requires the coordination of many components of a business. As such, companies are constantly seeking economies of scale opportunities. With a myriad of small solar entrepreneurs in the Nigerian market, it's difficult to take advantage of economies of scale, which limits the growth of the market. In addition, different entrepreneurs will attain different levels of quality, which will impact the perception of the product in the market.

However, there's an opportunity for consolidation. Identifying the most promising solar entrepreneurs, standardizing their product offering, and consolidating them with worse-performing companies could have a significant impact on the sector. The benefits of this approach have been documented by other researchers.[64]

Observability: According to Rogers, an innovation with increased observability (people's ability to see the innovation in action, solving a problem) is likely to diffuse faster.[65] Unfortunately, many of the observable solar projects, such as solar street lights or solar powered signs, aren't functioning. Solar entrepreneurs could band together and build model homes where they display their products for potential customers to see.

Strategies for large solar systems

Larger solar systems are typically installed by people with higher incomes and also by businesses seeking to grow. Depending on their size, manufacturing firms and industrial businesses also leverage large solar systems. Most of the people seeking large solar systems are part of the formal economy, or the part of the economy under government regulations and laws. Although leveraging the strategies for growing the market for small SHS will help, two additional strategies will also have an impact on this group.

Business model innovation: Large solar systems are often more expensive and complex to install than traditional generator solutions. In addition, the generator market is mature, with an ecosystem of retailers, distributors, repair shops, technicians, and replacement parts. For large solar systems to be competitive, they need to leverage business models that give potential consumers the following options: trialability, financing, simplicity, and guarantees.

Regarding trialability, more customers must be able to try out the innovation. Tolaram did this when creating the instant noodle market, and mobile telecommunications providers allowed customers to receive calls for free.

In addition to allowing people to try out the innovation, companies should integrate financing into their business models to accelerate growth of the sector. SunFi, a fintech company that provides financing options for solar energy products, did this when it learned that most of its customers didn't have access to the financing necessary to purchase solar systems.

Next, purchasing solar systems must be simpler. Since solar systems are newer and more complex products, solar system entrepreneurs should invest in educating their customers on the products, and also making acquisition of the products simpler. For example, at the onset, entrepreneurs could limit the number and variability of products sold.

They could clearly describe the energy by explaining what the solar system can power, and they could make the transaction straightforward by including audit, installation, and service.

Collaboration: One of the barriers to growing the solar energy market is low home or building ownership by occupants. As such, making a significant investment to install solar energy (especially compared to modular and portable generators) is unreasonable for occupants. If more solar energy entrepreneurs worked with owners of existing and new real estate developments and integrated their products into these buildings, they could create a new distribution channel and accelerate growth.

Strategies for minigrids

Although minigrids are the cheapest form of energy of all the different solar products, on a levelized cost of energy (LCOE) basis, they remain the most expensive to install. (See Figure 8 for LCOE of different energy sources). The costs of minigrids varies by geography and size, but in 2018, the general upfront investment for a 200kw solar minigrid exceeded $1 million, with operational costs adding up to $100,000 annually. The LCOE was roughly $0.60 per kWh.[66] In 2021, the LCOE had dropped to $0.38 per kWh, according to research by the World Bank.[67]

Even though there are more than 31,825 electricity connections in Nigeria through minigrids, no minigrid company has achieved profitability—with the exception of Husk Power Systems.[68] That's because minigrids are often pushed onto communities that are unable to pay for the installation and maintenance. They are also heavily reliant on subsidies.

As a result, the most important strategy for minigrid developers—because of the size of investment necessary to get a minigrid installation off the ground—is to identify an anchor market that can pull in the minigrid infrastructure into a community or region. As many stakeholders in the sector can testify, no amount of subsidies is able to reverse the simple economic equation that if a community is unable to pay for minigrid installations, the minigrid project will ultimately be unsustainable. (The Minigrid Investment Report, published in 2018, provides some ideas on how to scale the sector, with one being demand generation.[69])

Identify an anchor market to pull in minigrid investments: When economic development stakeholders work to develop markets that require minigrid infrastructure, the infrastructures have a much better chance of not only surviving, but also growing to serve many more customers. But the infrastructure must be tied to the market. And just as initial innovations are often not the most advanced—but are fit for the context—so too infrastructure should be fit for the context.

The most important strategy for minigrid developers is to identify an anchor market that can pull in the minigrid infrastructure into a community or region.

A growing opportunity with significant potential for the Nigerian economy to pull in solar minigrids is the data center industry. By having data centers serve as the anchor market pulling solar energy into a community, investors and entrepreneurs are more likely to build a sustainable business model while providing access to energy for other members of the community at an affordable rate. Consider the overall growth of the sector and how solar energy can play a role.

A cursory review of the market for data centers shows how much energy they demand. This market, which supports the storage and transmission of data, has increased demand for renewable energy, including solar power. Also, factors such as concentration of risk, demand for distribution of locations and governance, and the need for sustainability are shaping a decentralization and redistribution of data centers to locations that offer high access to solar power and are near the consumers being served.

For example, there is a worldwide shortage of available power which is slowing down the growth of the data center market and "sourcing power [has become] a top priority of data center operators across North America, Europe, Latin America, and Asia-Pacific," according to a July, 2023 CBRE report on Global Data Center Trends.[70] The lack of available power is not only limiting the growth of the data center market, but it is also increasing the cost of energy to power new and existing data centers. New technologies and innovations, such as artificial intelligence, autonomous vehicles, and movie, music, and video-game streaming—where the storage, processing, and transmission of large amounts of data are required—will only create more demand for data centers, not less.

As the world experiences a boom in data centers however, less than 1% of data centers are in Africa, home to more than 1.4 billion of the world's eight billion people. As mobile technologies, the Internet and these newer technologies become available in the region, companies will struggle to store and process their data. Most of the data generated across Africa and the Middle East today is stored in another country where the cost of energy to keep these data centers running is increasing. In the CBRE report, rental rates for data centers are rising in virtually every region globally.

Nigeria could set itself apart as a data center hub for Africa. In 2021, the data center market in Africa received more than $2.6 billion worth of investment and is set to surpass $5 billion by 2027.[71] By serving as an anchor market, in a community or region, a data center will pull in minigrid investments and reduce the cost of providing power to many in the region.

This approach, of finding an anchor market that can pull in minigrid investments, will also work for other sectors and industries. For example, there are roughly 200,000 cellular communications towers across Africa. By 2028, estimates suggest the number of cell towers will reach approximately 250,000.[72] These towers require electricity and are often connected to an emergency power supply provided by diesel generators. Minigrid providers can aggressively target this sector as an anchor market to introduce solar energy to communities.[73]

There are also opportunities in agriculture processing, education, and healthcare. A paper written by All On and the Boston Consulting Group—Socio-economic case for deepening solar PV deployment in Nigeria—makes the case for the integration of solar energy in these sectors.[74] The key to unlocking the benefits of solar energy in any sector is if there is already a market that can pull in solar. In essence, if a sector is unprofitable and therefore unsustainable, pulling in solar would not fundamentally change the dynamics of the sector's operations. And so, the minigrid investment will likely not last. Minigrids, at the onset, must be installed in settings where there is a sustainable business model that can pay for the installation and maintenance of the solar infrastructure.

A growing opportunity with significant potential for the Nigerian economy to pull in solar minigrids is the data center industry.

CONCLUSION

Accelerating the market-creation process for solar energy in Nigeria is possible. For this to happen, stakeholders in the sector—including investors, entrepreneurs, policymakers, and development partners—must first understand the Job to Be Done for why people hire solar energy.

When they are confident in this knowledge, they can invest in the distribution phase of market creation, help companies implement interdependent business models, and identify markets that can pull in solar energy into communities. These strategies will help grow the broader solar energy market, similar to the instant noodle and mobile telecommunications markets.

More specifically, for small solar home systems, stakeholders should prioritize standardization for economies of scale, observability for a change in perception, and conformability for more rapid diffusion. For large solar systems, business model innovation and collaboration activities among companies will fuel growth. And for minigrids, identifying—or creating—a large enough market that can pull minigrids into different communities is necessary for these small-scale infrastructures to be successful.

Actualizing these strategies will require different commitments from all solar energy stakeholders—governments, investors, and entrepreneurs. Governments will need to implement policies that focus on increasing access *and* also building a solar energy ecosystem. This necessitates policies that prioritize investments in the *distribution* component of the market creation process.

Investors, especially development finance institutions and philanthropies seeking to grow this space, should invest less in discovery and democratization efforts and more in enhancing promising innovators with the capacity to serve nonconsumers. This means investing in fewer companies that have the potential to grow large enough to take advantage of the economies of scale necessary to serve nonconsumers.

At this stage, entrepreneurs should employ an emergent strategy, much like SteamaCo, SunFi, and Auxano Solar. These organizations were flexible enough to change their strategy after they learned where true market gaps existed. SteamaCo became a components supplier for minigrid companies; the founders of SunFi set it up to provide financing after their previous solar installation company, Aspire Power Solution, struggled to grow because most of its customers couldn't access financing to access their services. Auxano, which is today building the largest solar manufacturing factory in West Africa, started out as an incubation hub where it tested its components and strategies before deciding how to scale. Auxano has grown from a small solar company to a major player in the industry with a 100 MW annual solar photovoltaic (PV) capacity.

"The goal of an economy, as Adam Smith taught us, is consumption, not jobs or production," is how famed economist Deirdre McCloskey put it in one of her papers.[75] Consistent consumption of solar energy products which ultimately enables progress in people's lives is vital to Nigeria's development. Solar energy, by itself, is not enough. Stakeholders must think beyond solar. Progress is the goal.

APPENDIX A. VOICES FROM THE FIELD

As part of this research, we conducted a survey with a few dozen solar energy stakeholders and had in-depth conversations with experts in the solar energy field in Nigeria. These conversations led to the following insights.

Figure A1. Voices from the field

5 Insights From Surveyed Producers and Nonconsumers	5 Insights From In-Depth Interviews with Stakeholders
1. According to solar producers, the biggest obstacle to solar adoption is access to funding for their business and the high costs of solar...	1. Aligned with our survey responses, our interviews also listed lack of access to consistent and sustainable funding, and low consumer knowledge and awareness as the most prominent obstacles to solar adoption in the country.
2. ...closely followed by a general negative perception of solar solutions by potential customers.	2. When asked what were key factors of successful solar companies or solar projects, many answered launching consumer awareness and education campaigns, and having flexible business models.
3. Similarly, the greatest obstacle to scaling a solar energy business was access to growth capital.	3. Employing a "do it all" business model —providing awareness campaigns, personnel and community training, installation, and maintenance options—was a key characteristic of both successful projects and companies.
4. From nonconsumer responses to their expected total cost of solar energy systems, we learned that there was no consensus; therefore, there is no clear expectation of what solar energy systems should cost.	4. Projects where solar energy recipients didn't have enough productive use resulted in a lack of sustainability for many projects.
5. Respondents were almost equally divided on whether solar systems would be cheaper or more expensive than generators.	5. Solar initiatives should focus more on creating productive use demand rather than advocating for energy access for all.

From our 11 one-on-one conversations with key players and stakeholders in the sector, the top two mentioned barriers to solar adoption in Nigeria were 1) provider's lack of access to consistent and sustainable funding and 2) low consumer knowledge and awareness of solar system options (including financing options). Consistent with that information, when asked what were key factors of successful solar companies or solar projects, many answered that launching consumer awareness and educational campaigns, as well as having flexible business models, had significantly helped successful projects. As an example, one company we spoke to had, over time, shifted its business model from minigrid developer to technology vendor. Another opted to engage in demand stimulation activities in addition to developing minigrids to become profitable. On the other hand, factors in stalled and failed projects often were not integrating enough productive use in solar initiatives and failing to establish sustainability mechanisms for when companies or agencies stepped away. Stakeholders emphasized that if communities had no way to profit from the solar systems, they often had no way to pay for them. When questioned on productive use demand, almost all of the key players we spoke to agreed that productive demand should be a big driver of the sector, and integrating productive use initiatives is key to creating an enabling environment and accelerating solar adoption.

From our 17 producer surveys, most respondents were located in Lagos or Abuja, and they classified their businesses as distributors. Almost half of producer responses listed funding and costs as the biggest obstacle to solar adoption, followed by consumers' negative perception about solar energy. When asked about the biggest challenges their organization faced after selling solar energy, the majority still listed funding, which included access to working capital to finance component acquisitions or payroll. And when asked about the biggest obstacle to scaling their solar business, the answer was, again overwhelmingly, funding related; more specifically, access to growth capital (for hiring and training staff, purchasing inventory, business development, etc.). The other scaling obstacles that followed were access to managerial talent and lack of industry connections, but both of these responses, although the next highest, were insignificant compared to all those who answered access to growth capital.

Regarding solar equipment, because most of the producers surveyed classified themselves as distributors and not original equipment manufacturers (OEMs), only seven reported making their own equipment, including inverters, electrical panels, meters, and racking. Three of those seven reported making all-in-one solar kits. Most of the other producers' top imports included solar panels, inverters, and batteries, and the equipment that was most purchased locally also included solar panels and batteries, but added racking equipment as a common local purchase.

From our 26 nonconsumer surveys, over three-quarters were from Lagos. Eighty-four percent would use solar energy for home purposes, with only 16% reporting they would use solar energy for businesses purposes. Over 70% would prefer owning their solar systems rather than leasing them. Sixty percent of respondents would finance their purchase themselves, 19% would prefer to receive financing assistance from the seller of their systems, and another 19% would reach out to a third party (bank or other financial institution) for financing options.

Regarding the installation and maintenance of solar systems, the majority of respondents expect installation to take 1–6 days, and expect to address maintenance issues (both that disrupt and don't disrupt service) only 1–3 times a year. The majority of respondents would only need smaller-sized systems, which is consistent with most respondents wanting to use solar energy for home purposes rather than commercial use.

When it came to cost, responses were more varied, indicating there might not be a firm grasp of what solar energy systems cost. Almost half of the respondents presumed installation costs would range from N1,000 to N30,000; however, the other half of respondents had scattered responses from N30,001 to N5,000,000. When asked about monthly leasing costs, responses were more consistent, with most respondents presuming monthly leasing costs would range from N1,000 to N30,000. Yet, when asked about total costs for owners of solar systems, the responses were thoroughly distributed from the lowest range starting at N1,000 to the highest range ending at N5,000,000.

Finally, when asked about comparing solar systems to diesel or gasoline generators, half of the respondents presumed solar energy would be both easier to use and more affordable. However, 38% of respondents admitted solar energy could be easier to use, but presumed it would be more expensive.

APPENDIX B. RESEARCH METHODOLOGY

To ensure a representative understanding of the solar energy sector in Nigeria, we leveraged innovation theories and employed a rigorous approach to primary data collection. Our approach included conducting surveys, in-depth stakeholder interviews, and desk research.

Innovation theories

We leveraged proven innovation theories developed over 25 years at Harvard Business School and the Clayton Christensen Institute to understand and apply the process of market creation to solar energy in Nigeria.

Surveys

We designed and distributed surveys for consumers, nonconsumers, and producers of solar energy. We received a total of 43 responses: 26 from nonconsumers and 17 from producers. The consumer and nonconsumer surveys included three sections: 1) the use of energy, 2) energy characteristics, and 3) conformability: consumer checklist. The producer survey consisted of two sections: 1) obstacles to growth and 2) collaboration: producer checklist. A sample of the questions asked in the consumer and nonconsumer surveys included inquiries regarding costs of solar, financing options, size of solar systems needed, and expected benefits or detriments of the system. A sample of the questions asked in the producer survey included inquiries regarding equipment and services provided, obstacles to starting and scaling a solar business, and the current solar sector ecosystem.

In-depth stakeholder interviews

We spoke to a total of 12 stakeholders in Nigeria's solar industry. These stakeholders consisted of six solar entrepreneurs, three employees in solar government agencies, and three employees in development agencies. Our conversations were guided by five main questions: 1) In their experience, what were the three biggest barriers to solar adoption in Nigeria? 2) How had they or how could other stakeholders overcome these barriers? 3) What was an example of a successful solar project? 4) What was an example of a failed or stalled solar project? 5) Do the solar projects they work on prioritize access for productive demand or are the projects mostly based on access for all?

Desk research

Our desk research consisted of finding and analyzing a series of reports, papers, and articles that would shed light on the current state of the solar energy sector in Nigeria. We used data collected to confirm the barriers of solar adoption in the country, to analyze other market-creation stories in the country, to identify nonconsumers in the country and what their Jobs to Be Done were, and to better understand what the process and acceleration of the creation of the solar energy market would look like.

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All ON Energy innovations. Powerful collaborations.

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23. Rogers went on to describe the four main elements in the diffusion of innovations: the innovation, the communication channel, the time, and the social system in which the innovation is diffused. He also provided a set of characteristics of innovations to help explain their different rates of adoption: the innovation's relative advantage, compatibility, complexity, trialability, and observability. In this paper, we will provide an additional lens to assess an innovation's susceptibility to diffusion that takes into account both the producers of a product and its consumers. See Rogers, *Diffusion*, 15–16.
24. Our data shows significant variations in adoption speed for technologies that got started around the same time. For example, the Kodak Brownie camera and the automobile both reached 10% of their markets around 1915. However, the democratization of photography took 20 years while the automobile took over 70 years. Refrigerators and TVs were quick while their contemporary washing machines and dishwashers were slow. Even toward the late 20th century and the rise of transistor electronics, the VCR was quick but the video game console was slow. As shown by these examples, the early 21st century is awash with internet/computing-based technologies which rise very quickly but there are innovations which seem slow and stubborn.
25. The notion of reliable partnerships is critical. Without it, as we describe later in the paper, it is in the best interest of the market-creating organization to wrap its arms around different components of the new business model necessary to solve the nonconsumer's problem. Modularity Theory explains this well.
26. It is difficult to get consistent data on the size of solar energy installations in Nigeria. Some reports estimate the country has an install base of roughly 40 MW while others estimate 200 MW. Regardless of which report is closer to the actual number, the general consensus with industry experts we spoke with is that Nigeria has significantly more potential for solar energy installations. In addition, Nigeria aimed at increasing renewable electricity usage to 23% of its energy mix by 2025. The country is currently behind as just 16.4% of its energy comes from renewable sources. See "Socio-Economic Case," All On and BCG; Doris Dokua Sasu, "Nigeria: Solar Energy Capacity 2012-2022," Statista, March 2023, https://www.statista.com/statistics/1278096/solar-energy-capacity-in-nigeria/; and "Renewable Energy Share of Electricity Capacity in Nigeria from 2011 to 2022," Statista, June 22, 2023, https://www.statista.com/statistics/1278245/renewable-energy-share-of-electricity-capacity-in-nigeria/.
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32. Clayton Christensen and Michael Raynor, "Chapter 8" in *The Innovator's Solution: Creating and Sustaining Successful Growth* (Boston: Harvard Business Press, 2013).

33. "Nigeria – Country Commercial Guide: Electricity, Power Systems, and Renewable Energy," International Trade Administration, updated June 6, 2023, https://www.trade.gov/country-commercial-guides/nigeria-electricity-and-power-systems.

34. Peter Uzoho, "Six Years after Signing 1125MW Power Purchase Deals, 14 Firms Fail to Get Funding," THISDAY, 2022, https://www.thisdaylive.com/index.php/2022/04/25/six-years-after-signing-1125mw-power-purchase-deals-14-firms-fail-to-get-funding.

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38. These NEP initiatives are meant to scale the SHS market by helping finance companies with strong and ambitious business plans capable of delivering at scale. Under the Output Based Fund, REA provides fixed incentive grants of up to 60% of the costs of the system to the grantees, per each eligible system installed and verified. Under the Market Scale-Up Challenge Fund, REA provides lump sum grants paid in quarterly tranches; the amount depends on business needs but can constitute no more than 20–30% of the business's total funding plan. Financial support programs like these can extend the life of a company but will not provide the necessary foundation it needs to create a new market for the average Nigerian over time.

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net-zero rural growth, Brad Mattson, Manoj Sinha, and William Brent describe how the practice of paying minigrid developers for how many connections they are able to install is prevalent. When this happens, there is little to no incentive to understand the conditions on the ground that can lead to more sustainable adoption of the technology. See Mattson et al., "Scaling Solar."

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(Theories and Previous Studies)," *Studies of Applied Economics* 39, no. 4 (2021), https://ojs.ual.es/ojs/index.php/eea/article/view/4627. The authors of this paper cite several papers on mergers and acquisition that describe the benefits of firms consolidating resources especially when going after the same customer base.

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About the Institute

The Clayton Christensen Institute for Disruptive Innovation is a nonprofit, nonpartisan think tank dedicated to improving the world through Disruptive Innovation. Founded on the theories of Harvard professor Clayton M. Christensen, the Institute offers a unique framework for understanding many of society's most pressing problems. Its mission is ambitious but clear: work to shape and elevate the conversation surrounding these issues through rigorous research and public outreach.

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