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BCG

Socio-economic case for deepening solar PV deployment in Nigeria

NOVEMBER 2021

Content Summary

Executive summary (I/II)

Nigeria's off grid solar market has witnessed strong growth and industry potential appears robust

- Growing at CAGR of 22% over the past 5 years, the solar market in Nigeria has grown rapidly and emerged as one of the fastest growing in Africa
- Growth has been supported by a combination of demand factors (inadequate and unreliable grid power supply, supportive govt. policies, growing adoption of clean energy sources) and supply factors (cost competitiveness of solar, increased investment into the solar, emergence of innovative business models)
- However, solar remains underpenetrated with installed PV per capita of 1W (~200MW) compared to peer average of 8W indicating significant opportunity for further growth. Nigeria's installed PV capacity likely to reach 5 – 8 GW by 2030 given key fundamentals are in place

Beyond electrification, Nigeria has realised several socio-economic benefits from increased solar deployment, and scaled deployment could unlock greater impact

- **Health:** Primary Health Centers (PHCs) with solar electricity witnessed 60-70% improvement in antenatal care coverage (ANC) and 40-60% reduction in vaccine waste. Electrifying ~18k PHCs without regular power supply will increase Nigeria ANC from 50% to 60-70% and reduce vaccine wastage by 10-20%
- **Education:** Public boarding secondary schools with solar witnessed 2.3x increase in student study hours, and 30% increase in ICT teaching hours. Providing solar to ~1.2k public boarding schools will increase avg. student study hours from ~8hrs/week to 18 hours/week and ICT teaching hours by ~50-60% to 0.7hrs/week
- **Food security:** Farmers using solar powered cold storage witnessed up to 30% reduction in post harvest loss (PHL) for perishable goods. Electrifying ~600k farmers w/o cold storage facilities could reduce PHL for perishable from 60% to 40%, saving ~4.4M tonnes of food – enough to feed 6.5M people annually
- **Environment:** ~500K households have adopted solar, leading to ~160k tons of CO_2e avoided. Assuming solar penetration among households in Nigeria reaches peer average of ~30% by 2030, ~5 million tonnes of CO_2e can be avoided, reducing emissions from households by ~30%
- **Trade:** MSME's in markets with solar witnessed ~20-40% increase in operating hrs. and reduction in fire incidents from generators; resulting in revenue uplift of ~30-40%. Deploying solar to ~15-20m MSME's in markets w/o reliable grid power supply, could increase MSME income by ~$7-10bn (~40% of annual MSME income)

Executive summary (II/II)

Despite the socio-economic benefits associated with solar deployment, solar market potential remains constrained by several challenges

- **Financial:** Limited low-cost financing for developers and consumers; difficulty in accessing and delays in disbursement of current concessional funds
- **Commercial**: Lack of centralized demand aggregation to create scale for viable use cases; limited consumer awareness on benefits of solar products
- **Operational:** Fragmented value chain; inadequate skilled human resources; complex importations process driving costs up; payment collection in-efficiencies
- **Enabling Environment:** Insufficient enforcement of quality standards resulting in influx of low-quality products in the market

To address these challenges, targeted interventions have been identified and structured into 4 pillars

- **Access to finance enablement:** Develop solar developer focused financing programs; create one-stop shop to support developers around access to funding issues in current programs; refine funding processes of existing programs to improve ease access; and, channel consumer debt financing
- **Institutional strengthening & capacity development:** Develop and provide standardized training programs focused on key skills required across the value chain; improve efficiency during payment collections by creating partnerships with existing agent networks; develop payment platforms; simplify importation process
- **Customer awareness & acquisition:** Launch awareness campaign on benefits of solar and how to identify quality solar systems; Create a mechanism to aggregate demand from various customer segments to create scale, hence reducing acquisition cost of solar products
- **Technical and regulatory reforms:** Introduce fiscal incentives to attract investment into the sector; enforce quality standards and ensure stricter monitoring of quality solar products; and introduce regulations to drive solar PV demand

Implementing these interventions could accelerate solar deployment in Nigeria significantly thereby unleashing additional socioeconomic benefits for the country

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Content Summary

Background & objectives

Context

Access to electricity continues to be a challenge with ~50% of the Nigerian population without electricity access. At the current electrification rate, leveraging conventional power solutions alone, ~30% of Nigeria's population would still be without electricity by 2030; resulting in a failure to achieve govt. ambition of ensuring access to sustainable and reliable energy for all (in line with UN SDG 7)

The Nigerian Government, through the Rural Electrification Agency (REA) has identified solar PV as a viable alternative to bridge this electricity access gap; with a target to deploy solar PV systems (mini-grids and standalone solar systems) to >10 million unelectrified households by 2030

Beyond addressing the direct electricity challenges, increased solar deployment in Nigeria has enabled several socio-economic benefits; scaling the deployment of solar could unlock greater socio-economic impacts

To validate these benefits, All On and BCG commissioned a joint study to assess the proven developmental benefits realized from solar projects deployed to date in Nigeria, and to present a case for deepening solar deployment in the country

Scope

The scope of this study covers off grid solar projects in Nigeria and the report is structured into three part:

1. Assessment of the Solar PV market in Nigeria and its future trajectory
2. Sizing of socio-economic benefits realised from solar deployment in Nigeria
3. key challenges inhibiting solar penetration and potential interventions to address them

Research methodology

Research approach

In this report, we assessed the benefits of solar across five (5) socio-economic dimensions - Health, Education, Food Security, Environment & Trade

Across each dimension, we assessed the benefits of solar at three (3) levels:

1. 1st order benefits – Direct electrification benefits from scaled deployment of off-grid solar PV in Nigeria
2. 2nd order benefits – Direct benefits of enhanced electricity access, on relevant developmental indicators (including additional jobs created)
3. 3rd order benefits – Wider benefits of improved developmental indicators on the economic wellbeing of the Nigerian society (i.e., impact on Nigeria's GDP)

Secondly, we defined the use cases (6 use cases) and indicators (7 indicators) for the dimensions selected, based on; relevance to Nigeria's context, potential scale for impact and availability of data to validate the impact of solar

Furthermore, we quantified the proven benefits of solar on developmental indicators, leveraging deployed solar PV projects across Nigeria for the identified use-cases. To estimate the benefits, the study leveraged in-depth interviews and surveys (N>100) and case studies (~3 per dimension)

Finally, we extrapolated the benefits from deployed solar projects to articulate the broader benefits assuming a wider deployment of solar PV across the relevant use cases in Nigeria

To access the comprehensive version of this study (including detailed explanation of methodologies used) you can download the file here

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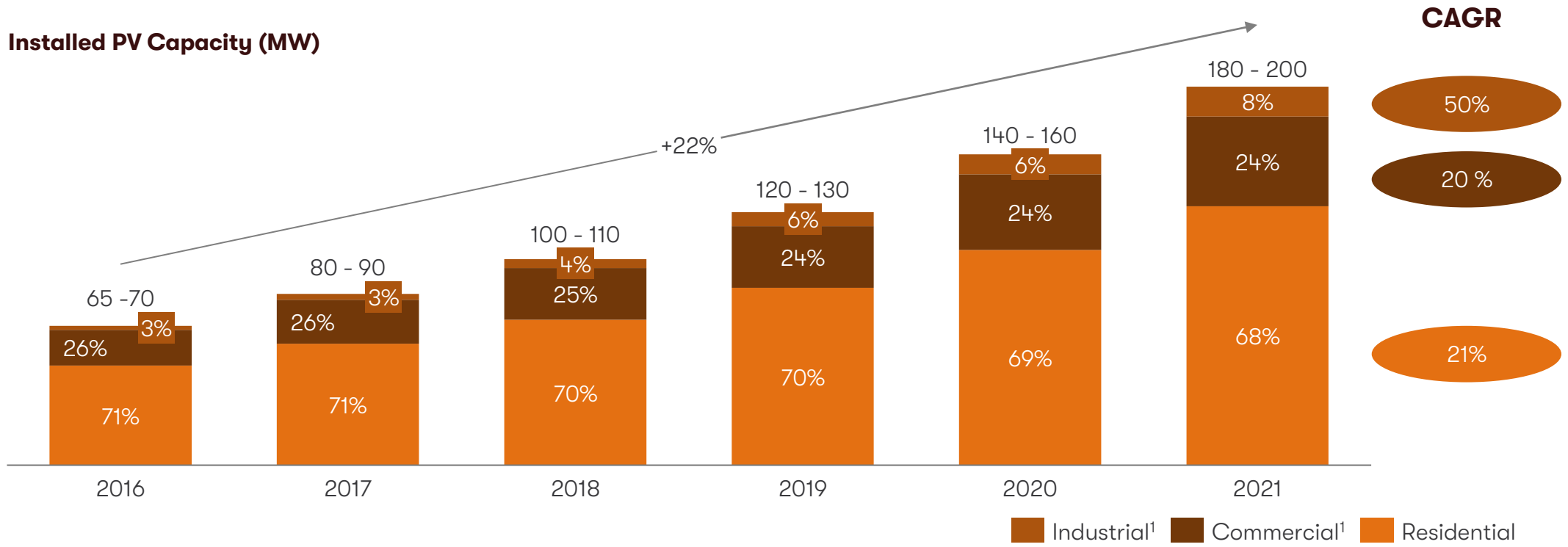
Content Summary

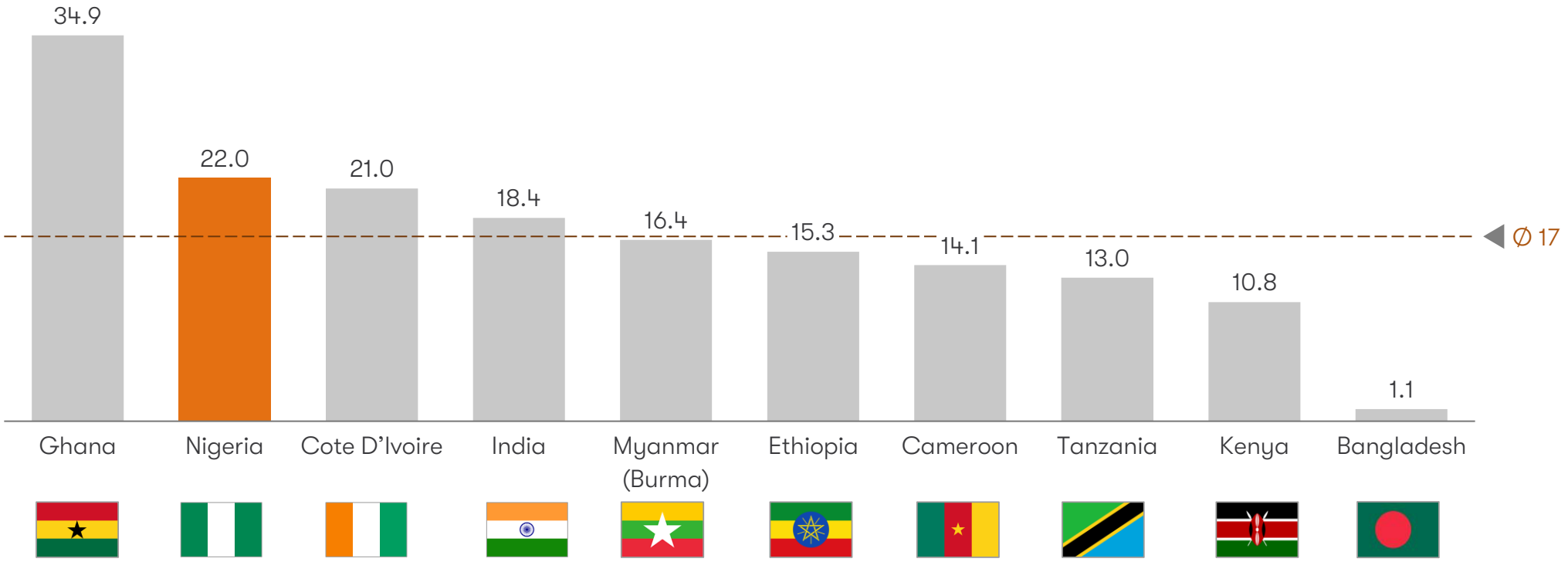
Nigeria has witnessed strong growth in solar deployment over the past 5 years…



Note: 1. Calculated installed PV capacity for 2016 and 2021, computed CAGR and estimated PV capacity values for 2017 – 2021. 2. Calculation assumes range of pico solar = 0.1-10W and ratio of commercial to residential use = 50:50, range of SHS = 10-160W and ratio of commercial to residential use = 20:80 based on CDC Impact Report on Lumos, range of Rooftop Solar = 1000 – 2000W; Assumes market share of SHS = 90%, market share of Rooftop Solar = 10%. 3. Calculation of Commercial and Industrial PV capacity based on ranges (of number of projects and average capacity of projects) gotten from PV developer interviews: no. of projects for systems between 10 – 100kW = 600 – 700, no. of projects for systems between 100 – 400kW = 20 – 25, no. of projects for systems between 500kW – 1MW = 15 – 20. 4. Mini-grid Capacity included in Residential Estimate
1. Industrial refers to capacity above 500 kW while capacity below 500 KW is classified under commercial
Source: Stakeholder Interviews, GOGLA Off Grid Solar Market Trend Report 2018, GOGLA OffGrid Solar Market Trend Report 2020 , Consultant Analysis

...and has emerged as one of the fastest growing solar markets; outperforming most of its peers

CAGR of Off-grid Solar PV Installed Capacity from 2015 - 2020 (%)



Note: Nigeria CAGR estimated from installed capacity calculation and different from CAGR calculated from IRENA values
Source: IRENA (2021). Renewable Energy Statistics 2021; Consultant Analysis

Growth has been driven by a combination of demand and supply factors

Demand factors

- Inadequate and unreliable grid power supply
  - Only 55% of HHs have access to grid electricity and of those with access, <20% have reliable power supply
  - Consequently, there has been increased demand for alternative sources of energy such as solar
- Supportive Government Policies
  - Government has introduced policies to promote adoption of solar particularly in off grid locations
- Growing adoption of clean energy sources by corporates
  - Large corporates in Nigeria are increasingly introducing solar into their energy mix to reduce their carbon footprint and achieve lower energy cost

Supply factors

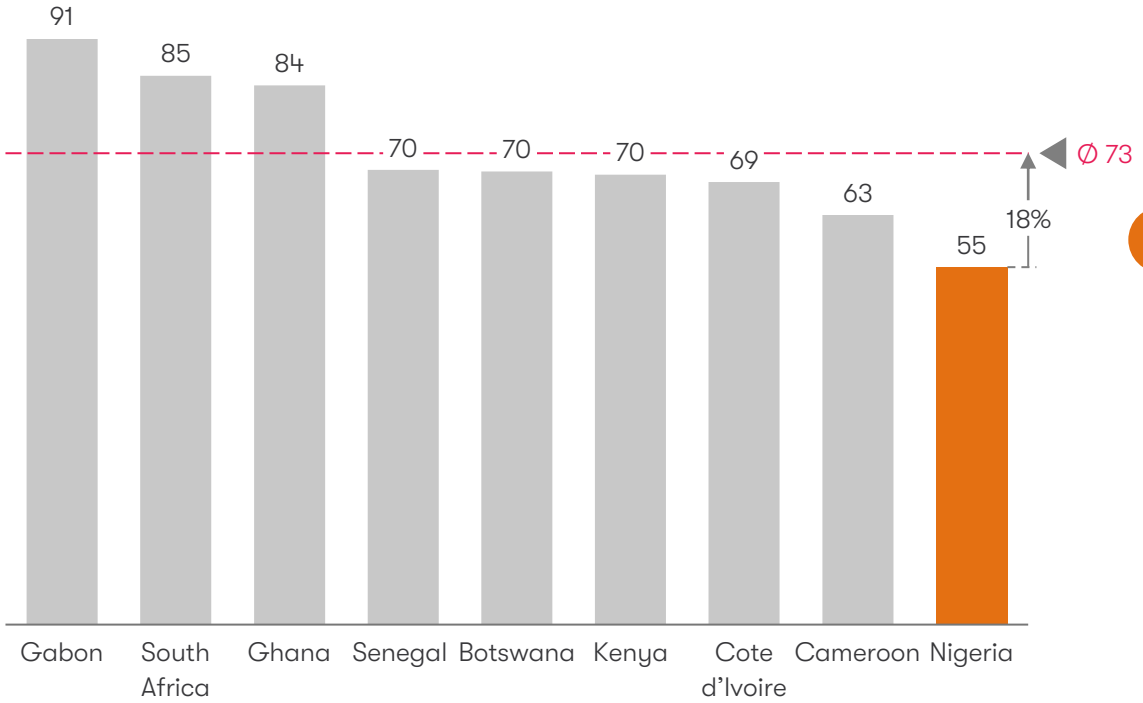
- Cost competitiveness of solar
  - Due to technological development, cost of solar systems have reduced significantly, making solar more cost competitive vs other energy sources
- Increased investments into the solar market
  - In recent years, there has been strong growth in investments and financing into the solar market providing required capex and working capital to players to scale their operations
- Emergence of Innovative Business Models
  - The growth of digital payment in Nigeria has spurred emergence of new business models such as PAYG[1], leading to an increase in solar sales for customers who are unable to make outright cash purchase

1. Pay-As-You Go
Source: Consultant Analysis

Inadequate and unreliable grid supply: Most households in Nigeria do not have access to adequate & reliable grid power supply resulting in dependence on alternative sources of electricity

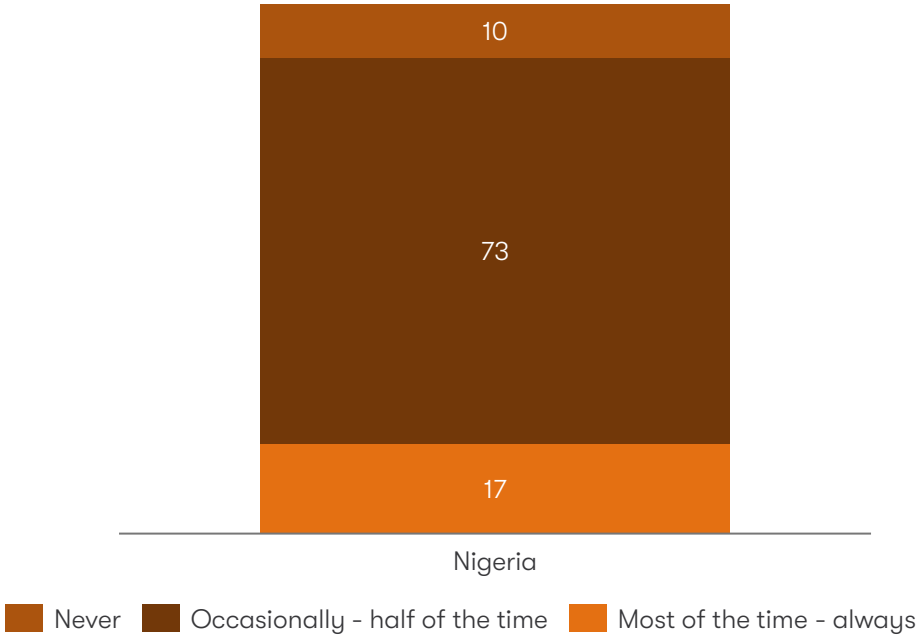
Nigeria has one of the lowest populations with access to electricity ...

Access to electricity (% of population)



...and for those with access in the country, only 17% get reliable electricity

Reliability of grid electricity in connected HH (%)



Source: World Bank Global Electrification Database from "Tracking SDG 7: The Energy Progress Report" led jointly by the custodian agencies: the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the United Nations Statistics Division (UNSD), the World Bank and the World Health Organization (WHO).; Afrobarometer 2014/2015 Survey Data

Supportive Government Policies: Over the last 6 years, Government has introduced policies to drive solar adoption in Nigeria

Non-exhaustive

Year	Policies/Regulations	Description	Implication for Solar
2015	National Renewable Energy and Energy Efficiency Policy (NREEEP)	Defines a guide for the renewable energy sector; Contains key government policies to promote solar development and its involvement in the country's energy mix	• Increased investment into the sector • Increased awareness of solar
2016	National Renewable Energy Action Plan (NREAP)	Implementation framework of the NREEEP ; Includes policies and measures to support off-grid renewable energy (e.g., solar) growth such as soft loans with low interest rates, subsidy of up to 30% of initial costs, etc	• Availability of low-cost debt for solar developers
	National Energy Efficiency Action Plan (NEEAP)	Outlines energy efficiency targets; Includes measures such as replacement of kerosene lanterns with solar lighting kits and training programs for staff of Standard Organization of Nigeria (SON) on test methods of off-grid efficient lighting	• Increased pico solar/SHS penetration • Increased consumer protection
	Rural Electrification Strategy and Implementation (RESIP) Plan of Nig.	Plan by the REA to increase rural electrification in Nigeria; Includes stand-alone solar systems and minigrids in rural electrification targets and projects which will encourage their development and rollout by communities and private enterprises	• Increased funding into the sector • Increased penetration of stand-alone solar systems and minigrids
	Minigrid Regulation	Provides the framework for the registration and operations of all mini-grids with capacity of up to 1MW	• Increased penetration of solar minigrids
2017	Eligible Customer Regulation	Electricity customers with an energy demand > 2MWh/h per month can directly buy power from a grid-connected GENCO, at a price that was mutually agreed	• Increased penetration of solar minigrids and larger solar systems
2020	NERC's Guidelines on Distribution Franchising	Defines a framework for approving franchising agreements under the distribution sector; outlines four franchising models recognized by NERC	• Increased penetration of minigrid systems for off/undergrid communities

Source: International Energy Agency; National Renewable Action Plan (NREAP), 2016; Ministry of Power Nigeria; NERC, Consultant Analysis

Growing adoption of cleaner energy: Several corporates are incorporating cleaner energy sources into their energy mix to reduce carbon footprints

"We are delighted to be a pioneer in the adoption of solar energy in Nigeria, the solar plant will help power our world-class brewery in Ibadan

Mr. Jordi Borrut Bel
Managing Director, Nigerian Breweries Plc

"We made significant strides in our quest to reduce diesel consumption and deploy alternative power solutions to our locations, increasing the number of solar-powered branches and ATMs to 111 and 500 respectively

Ogochukwu Ekezie-Ekaidem
Chief Brand and Marketing Officer, Union Bank

"We are very proud to be Nigeria's first mall powered with solar energy... the solar implementation at Jabi Lake Mall is one example of Actis' commitment to sustainable economic development in Nigeria

Tolu Sokenu
Principal, Actis' Real Estate Team (Jabi Lake Mall)

"As an organization, we are looking at how much green energy we can get, hence we are currently working on commissioning a 1 MW solar plant to service our needs

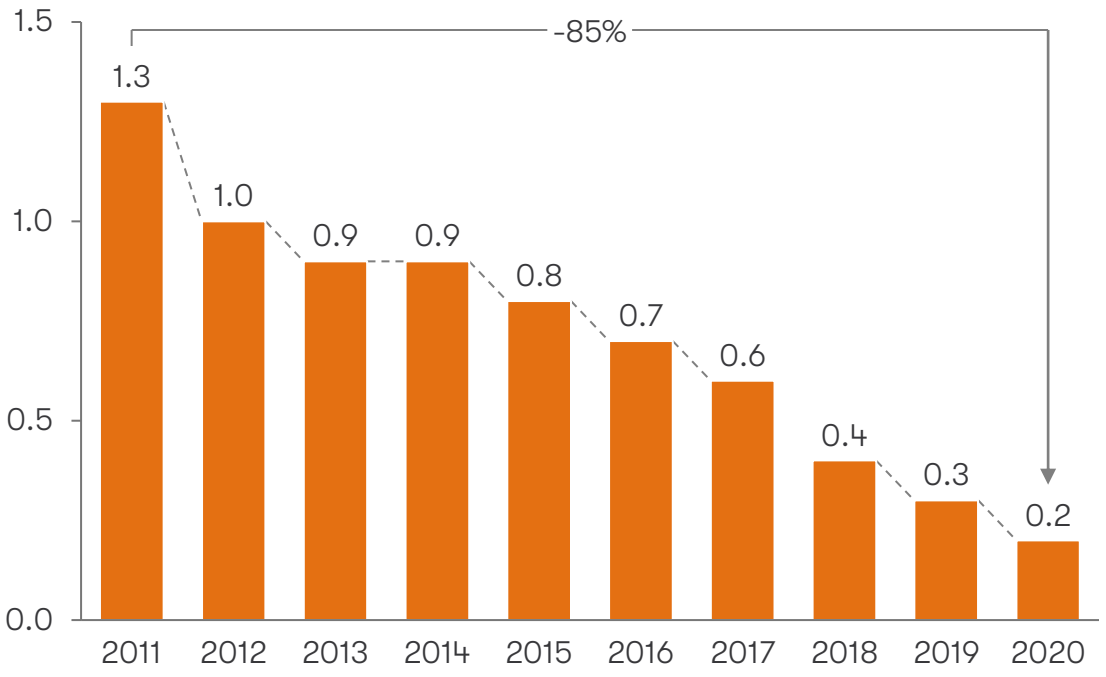
Prahlad K. Gangadharan
Chief Executive Officer, Big Bottling Company

Source: Union Bank of Nigeria Citizenship Sustainability Innovation Report 2020, Press Reports, Consultant Analysis

Cost competitiveness of solar: Current levelized cost of electricity (LCOE) of solar is lower than other energy sources due to reduction in cost of PV modules over the years

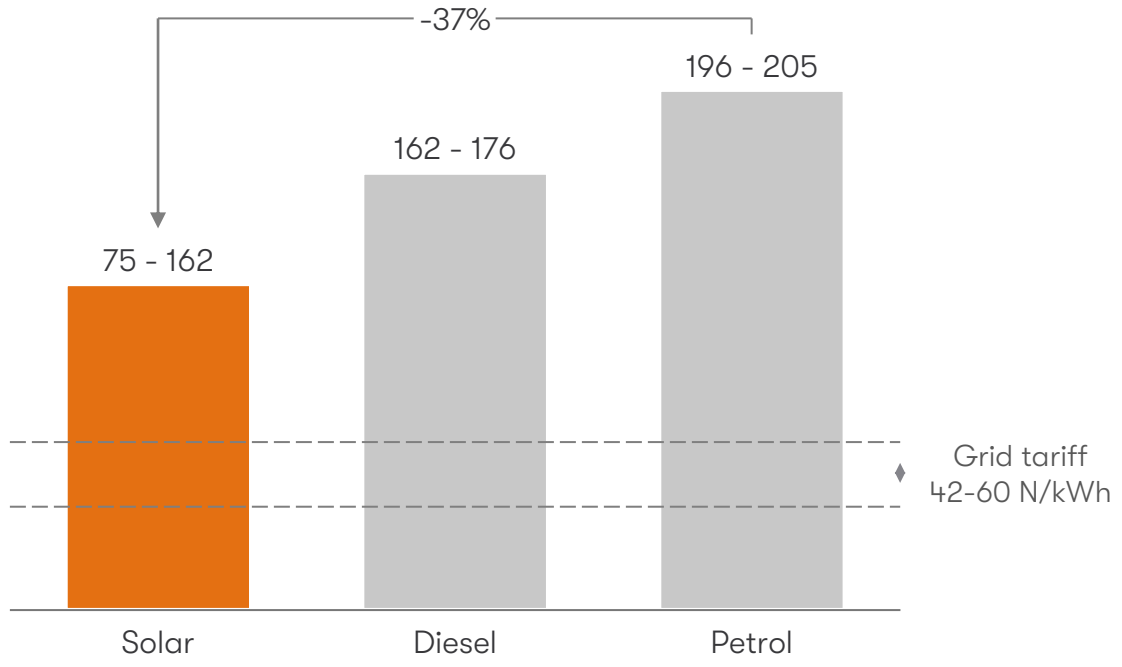
Since 2010, solar PV module price has decreased by ~85% ...

Solar Module Price (USD/W) [1]



...causing up to ~40% decrease in the LCOE of solar compared to widely used gensets

2021 Levelized Cost of Electricity (NGN/kWh)

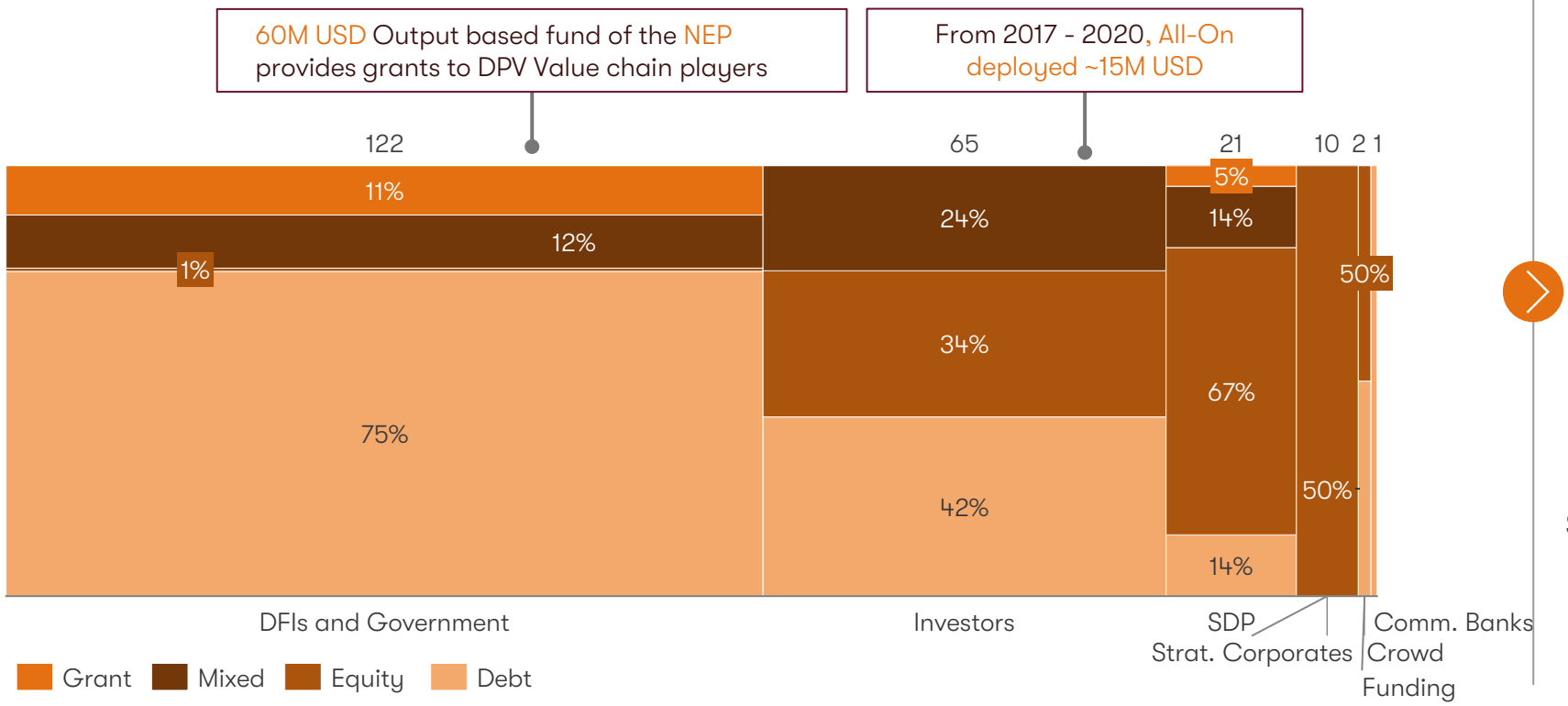


Source: IRENA Evolution of solar PV module cost, Consultant Analysis, BCG Experience

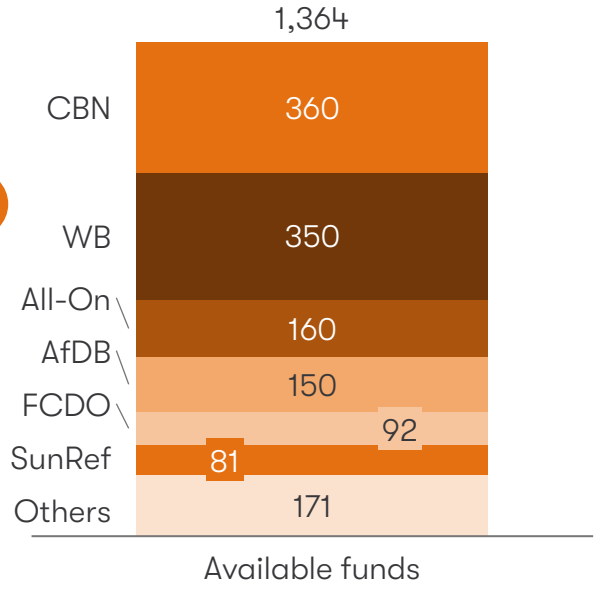
Increased Investment: In recent years, the total amount of investments into the Solar market is ~USD227M mainly comprised of debt, and ~USD1.3B still available mainly through the CBN, World Bank, All-On and AfDB

Sources of investment into the Nigerian PV sector (2015 - 2020)

USD, millions



USD, millions

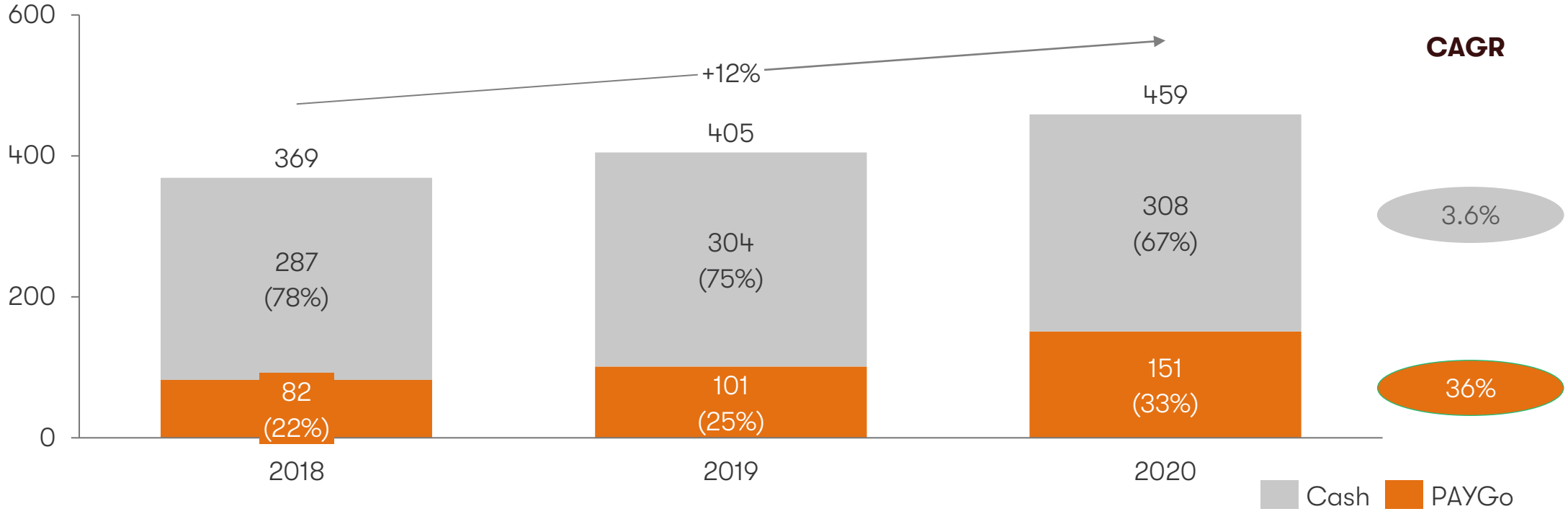


Note: SDP - Specialized Debt Providers , Others include GIZ, All-On, Bank of Industry, USAID's Power Africa, Rural Electrification Fund

Source: ACE-TAF Solar Investment map Nigeria study 2021, Consultant Analysis

Emergence of Innovative Business Models: Over the past three years, Pay As You Go's (PAYG) sales volume has increased significantly

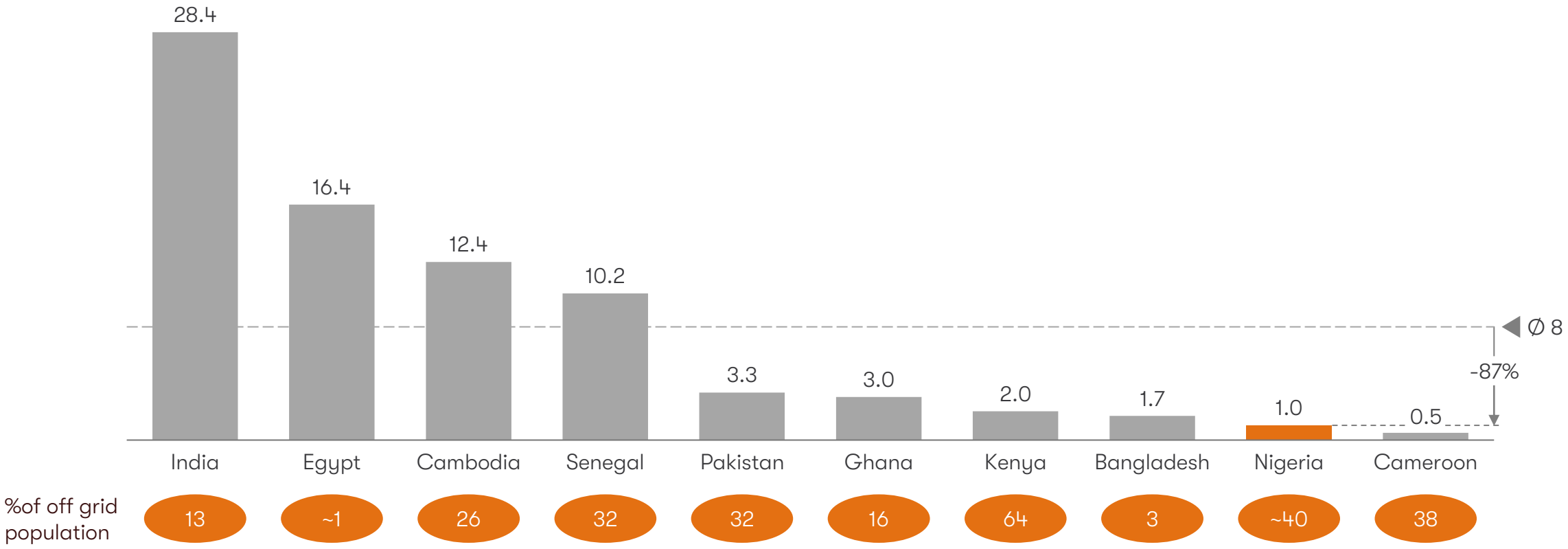
Volume of Off Grid Solar (OGS) Products sold
(1,000 units)



Source: GOGLA Off Grid Solar Market Trends Report 2020. Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data 2020

Although market has been growing, it is still greatly underpenetrated when compared with peers

Cumulative Solar PV capacity
(Wp per capita)

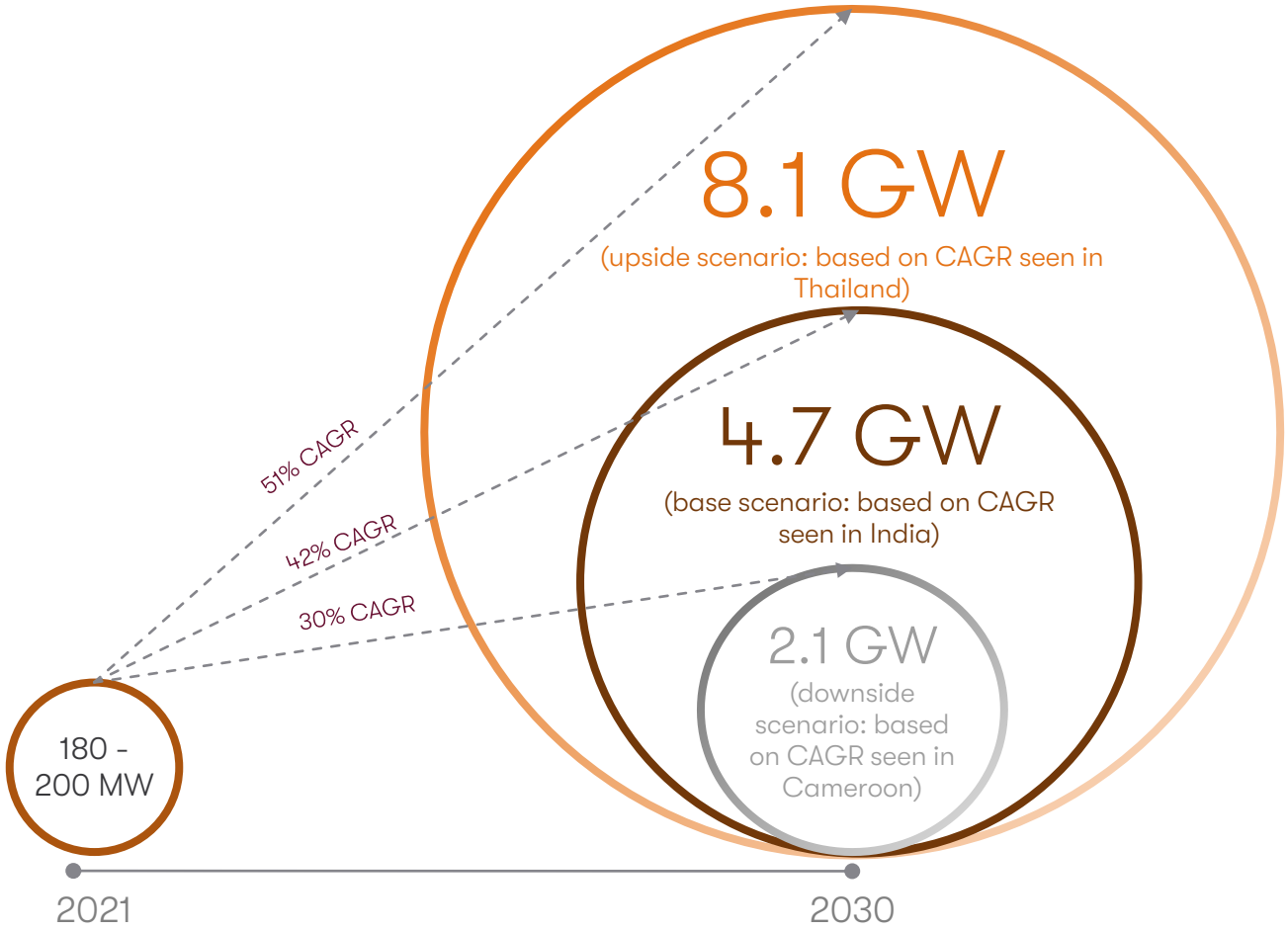


Source: World Bank; Renewable Capacity Statistics 2021, IRENA; Consultant Analysis

Solar market in Nigeria can reach between ~5-8 GW by 2030 based on evidence from archetypes

Three steps to project potential PV capacity

1. Select relevant benchmarks for NG
   - Countries with significant solar PV capacity
   - Similar stage of development as Nigeria
2. Identify archetypes from benchmarks to show range of growth outcomes
   - PV capacity of Thailand, India and Cameroon show varying growths over the past 10 years
3. Apply archetype potential to Nigeria to provide range of outcomes
   - Nigeria growth potential validated through:
     - High % of households located in off grid location
     - Unavailability of reliable grid power supply



Note: Off-grid PV capacity from 2010 to 2020 used to calculate CAGR for Thailand (51%) India (42%), Cameroon (30%). Computed 2030 value for all scenarios assuming a constant growth rate across the period.
Source: Renewable Capacity Statistics 2021, IRENA; World Development Indicators (2021), World Bank; Consultant Analysis

Content Summary

Developmental benefits of solar assessed across 5 socio-economic dimension, with 3 levels of benefits identified for each dimension

Social dimensions | Economic

Socio-economic dimensions

Health
Access to healthcare and healthcare outcomes

Education
Access to education and education outcome

Food security
Sustainable access, availability and affordability of quality food in a country

Environment
Quality of environment and policies aimed at preservation

Trade
Volume of economic transactions in a country

Levels of benefits

- 1st order benefits - Direct electrification benefit from adoption of off-grid solar PV
- 2nd order benefits - Direct benefits of improved power access on development indicators including additional jobs created
- 3rd order benefits - Wider benefits of improved developmental Indicators on the society i.e., impact on country's GDP

Source: BCG Experience

Socio-economic dimension

Health

1

Use case

- Deployment of solar in Primary Healthcare centres across the country

2

Rationale for use-case selection

- Primary Healthcare Centres should form the cornerstone of health services to attain social justice in any country, according to the Alma-Ata declaration
- Nigerian Primary Healthcare Centers report a lack of electricity, which inhibit their ability to deliver basic healthcare services...
- Leveraging solar to minimize electricity deficit could enable improved quality of healthcare and touch millions of lives

3

Impact Measures

1. Improved electricity access
2. Increased antenatal care and reduced vaccine wastage
3. GDP growth due to improved antenatal coverage and reduced vaccine wastage

Antenatal care coverage | Deploying solar in primary healthcare centers (PHC's) could improve Nigeria's antenatal care coverage by 10-20%pt

Antenatal care (ANC) coverage

Current state of indicator in Nigeria & role of solar

- Only ~50% of pregnant women receive ANC in Nigeria with rural areas having much lower coverage of 40%
- Most pregnant women rely on PHC's for ANC services, however most PHC's report being unable to adequately meet the ANC demands of pregnant women
- Inadequate power supply was identified as a main challenge to providing ANC with ~60% (18k) of PHCs w/o access to reliable electricity
- As a result of the power challenges, PHC's are unable to power lab equipment to conduct prenatal tests, and they also dedicate fewer hours per week for ANC (scheduled & unscheduled)
- However, findings from our primary survey reveal that enhancing PHC's access to power supply can increase no. of women receiving ANC at PHC's by ~1.2-2.5x
- Scaled deployment of solar to PHC w/o reliable elec. could increase the no. of pregnant women receiving ANC services through; reduced equipment downtime from grid power failure, and increased operating hours dedicated to ANC

Benefit from solar adoption

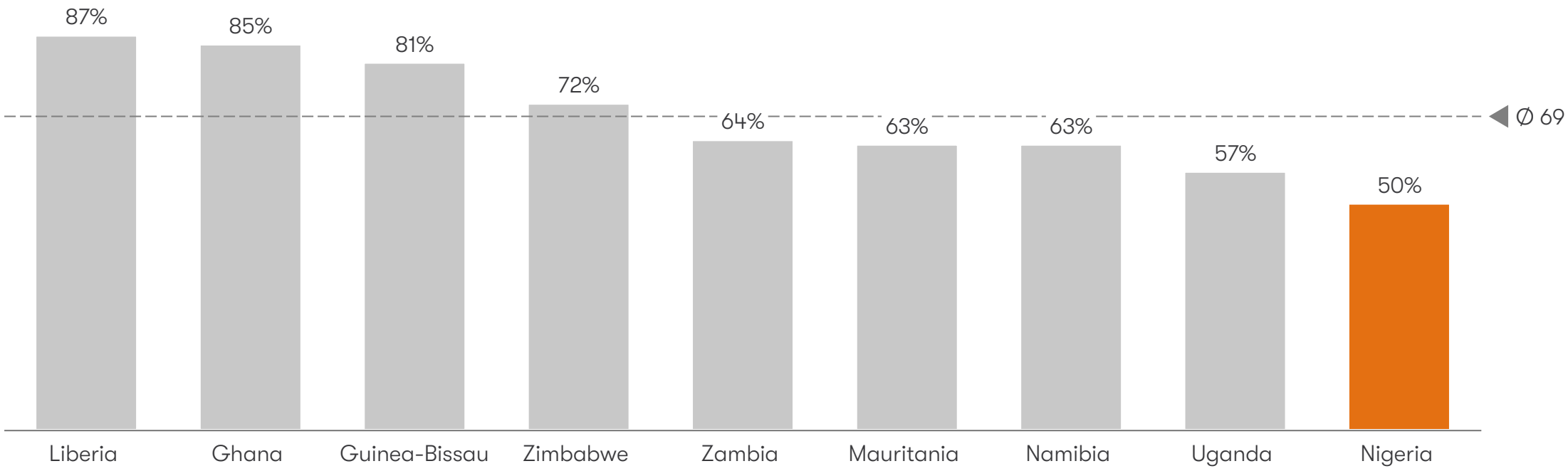
+10-20%pt — Increase in ANC coverage in Nigeria, assuming solar is deployed in PHC's

~0.01 % — Uplift in GDP (USD 26M) from improved maternal & child wellbeing

~5k — Additional jobs created from scaled deployment of solar across PHC's w/o reliable electricity

Only ~50% of pregnant women in Nigeria receive antenatal care (ANC) vs. peer average of ~70%

% of pregnant women receiving ANC in Nigeria

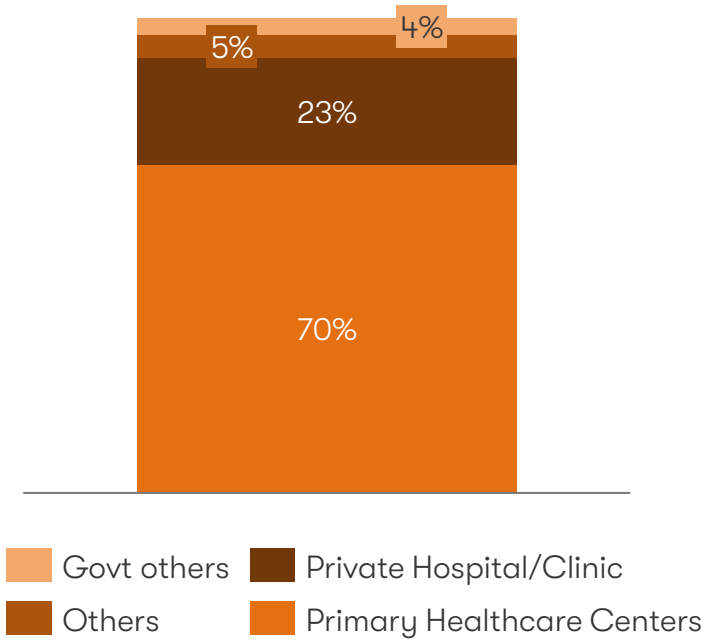


Source: Maternal & Newborn Health Coverage Database UNICEF; Consultant Analysis

Most pregnant women in Nigeria rely on primary healthcare centers (PHC's) for antenatal care (ANC), however findings reveal PHC's are constrained in providing ANC to visiting pregnant women

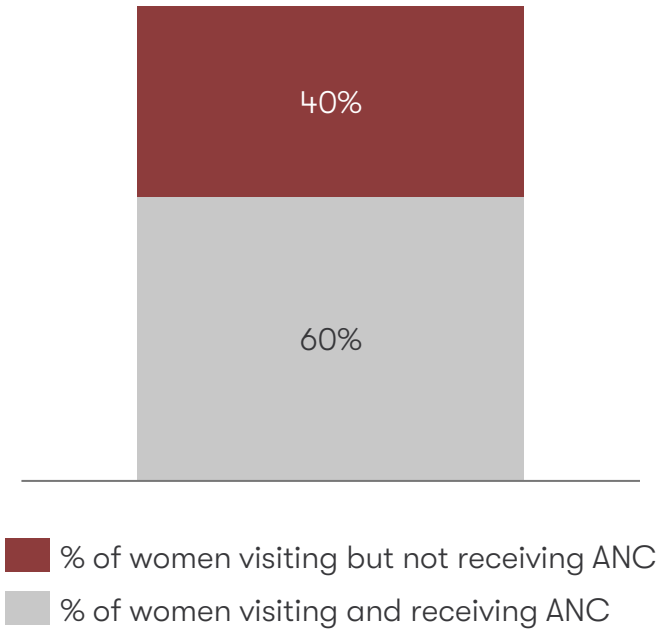
~70% of pregnant women in Nigeria rely on PHC's for antenatal care

Place of receiving ANC by pregnant women[1] (n=13k)



However, survey of PHC's reveal they are constrained in providing ANC services to all visiting pregnant women

% of pregnant women visiting PHC's and receiving ANC services[2]

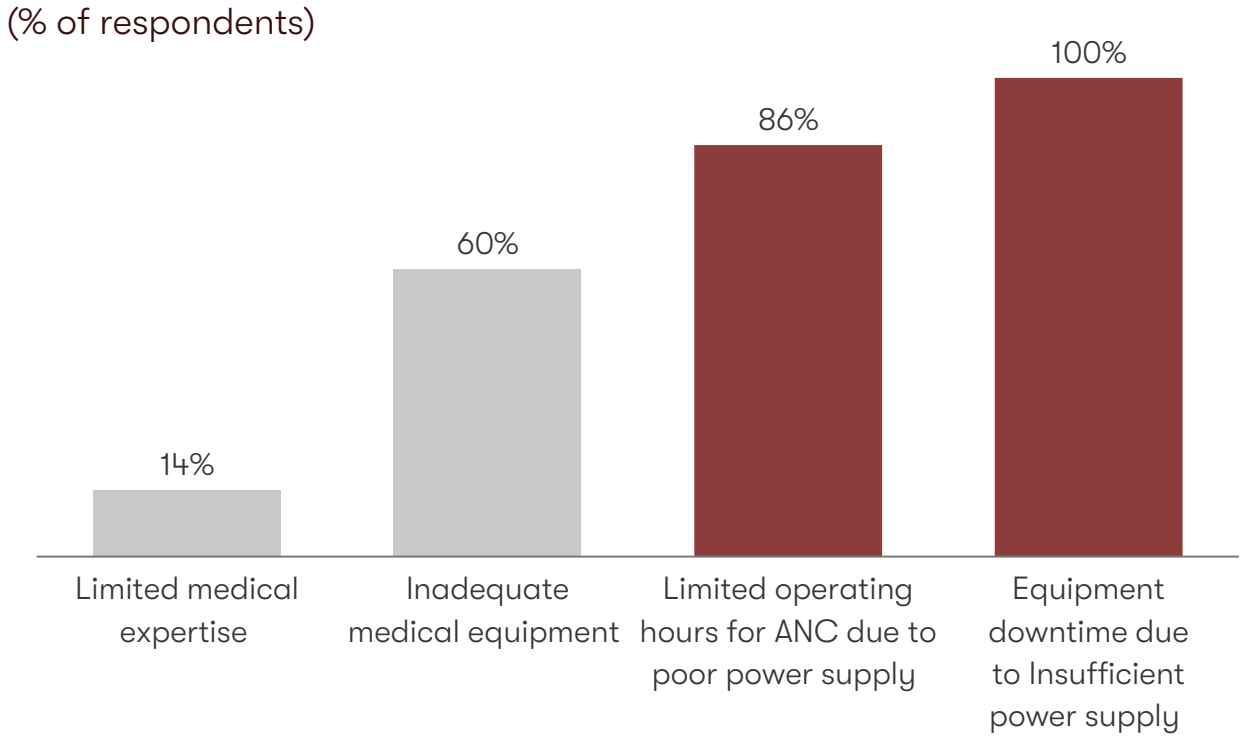


1. Leveraging 2013 Nigeria Demographic and Household Survey (NDHS) of >13k women in Nigeria; 2. Pre solar adoption, PHC Ijebu Owo provided ANC services to only 6 out of 10 pregnant women visiting

Source: Nigeria Demographic and Household Survey (NDHS), 2013; Federal Ministry of Health Website - Nigeria Health Facility Registry; Consultants Analysis; BCG PHC Survey, 2021

Inadequate power supply identified as a primary reason for PHC's being unable to meet pregnant women ANC demands

Poor power supply was indicated as a key limiting factor to providing ANC across PHC's surveyed

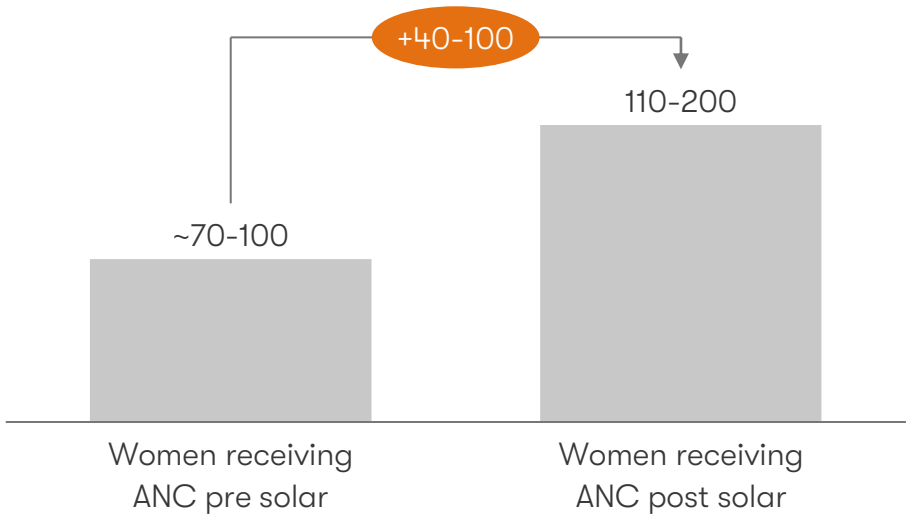


Question: 1: What are the major challenges you faced in providing antenatal care services before solar adoption? 2. What were the major impact of these challenges on your operations
Source: BCG PHC survey (September 2021) (N=17); Consultant Analysis

Survey findings reveal, enhancing PHC's access to elec. though solar could enable PHC's meet ANC demands, and increase ANC coverage by ~10-20%pt

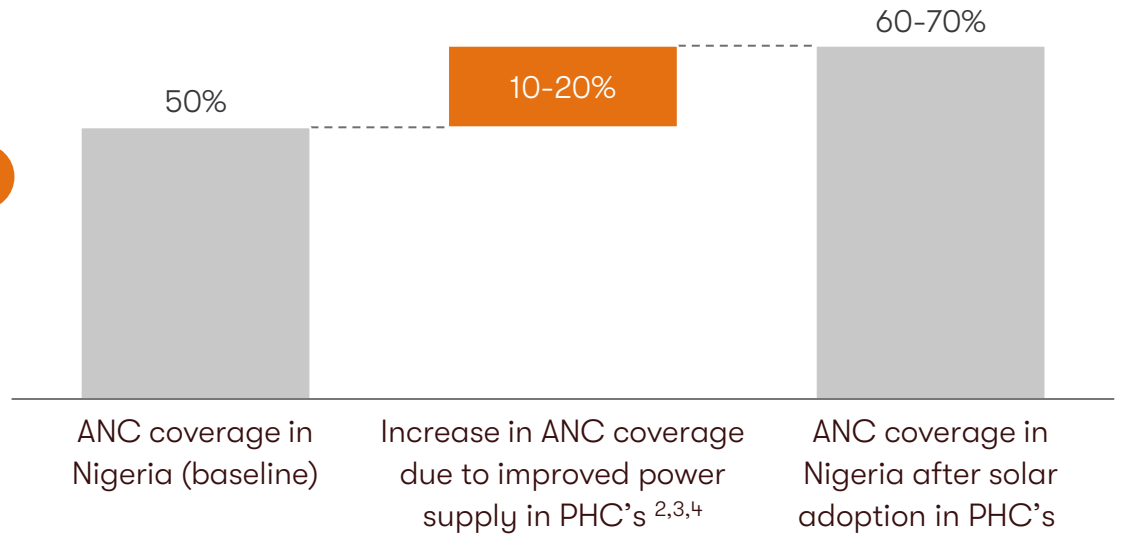
PHC's w. access to power supply through solar were able to meet their ANC demands, and provided ANC to ~40-100 more women

# of women receiving ANC's (p.a.)



ANC coverage in Nigeria could increase by 10-20%pt assuming scaled deployment of solar to PHC's w/o access to reliable elec.

Antenatal care (ANC) coverage in Nigeria (%)



Question: 1: How many pregnant women did you provide antenatal services to per week? (before and after solar adoption); 2. How many additional pregnant women do you provide antenatal services to due to improved power supply? (per week); 3. Of the additional women receiving ANC services at your facility, how many are first time ANC visitors?
NOTE: 1. Post solar figures are presented after adjusting for pregnant women that are not first-time users of ANC services; 2. Assuming ~60% of the 30,000 PHC's in Nigeria have no access to stable electricity. 3. Stable electricity has been defined to mean PHC's with over 8hrs of uninterrupted power supply; 4. Assuming the 18k PHC's w/o power supply provide ANC to ~40-100 additional pregnant women, ~ 0.7-1.8m additional women would receive ANC. Number of pregnant women (~8m) was calculated leveraging data from NBS Multiple Indicator Cluster Survey - (i.e., ~33.6% of women aged 15-49 years had at least one live birth in 2016-2017, and ~50mn women aged 15-49 years are in Nigeria). Overall, ANC would increase by ~10-29%pt
Source: UNICEFs ANC Service Coverage Database 2021; Federal Ministry of Health Website; World Bank Africa Human Development Series 2010; NBS Multiple Indicator Cluster Survey; BCG PHC survey (September 2021) (N=17); Consultants Analysis

Vaccine wastage | Deploying solar in Nigerian primary healthcare centers could reduce vaccine waste by ~40-60%, and lead to ~10-20%pt reduction in vaccine wastage rate

Vaccine wastage rate

Current state of indicator in Nigeria & role of solar

- Immunization coverage in Nigeria is low, with only ~20% of children (aged 12-23months) estimated to have received all recommended vaccine doses, vs. ~70% in peer countries
- Despite the abysmal immunization coverage, ~30% of vaccines delivered to PHC's waste, with poor power supply contributing ~50% to this waste...
- ...potentially reducing no. of vaccines available to provide immunization to children dying from vaccine preventable diseases annually
- However, findings from our study revealed that PHC's with solar were able to adequately power their refrigerators; which reduced avoidable vaccine waste and increased availability of vaccines at their facilities
- Solar powered refrigerators can ensure adequate refrigeration of vaccines to prevent wastage, and increase vaccine availability

Benefit from solar adoption

~40-60%

Reduction in vaccines wasted due to inadequate power supply

~10-20%pt

Reduction in vaccine wastage rate across PHC's in Nigeria, due to elimination of waste from inadequate power supply

~5k

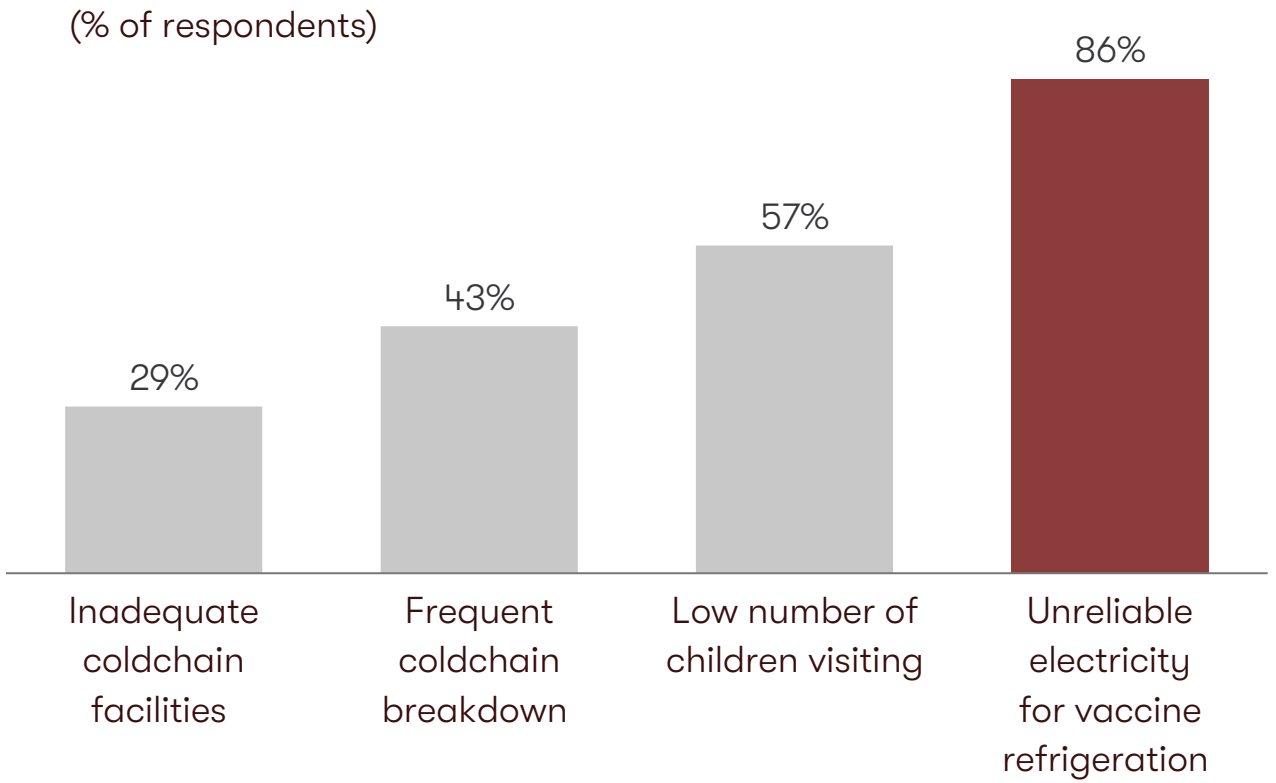
Additional jobs created from scaled deployment of solar across PHC's w/o reliable electricity

Vaccine wastage: Inadequate power supply identified as key driver of vaccine wastage across PHC's in Nigeria

PHC's were constrained in providing children with immunization access, due to vaccine wastage...

All PHC's surveyed reported limited capacity to provide vaccines to children, due to vaccine wastage

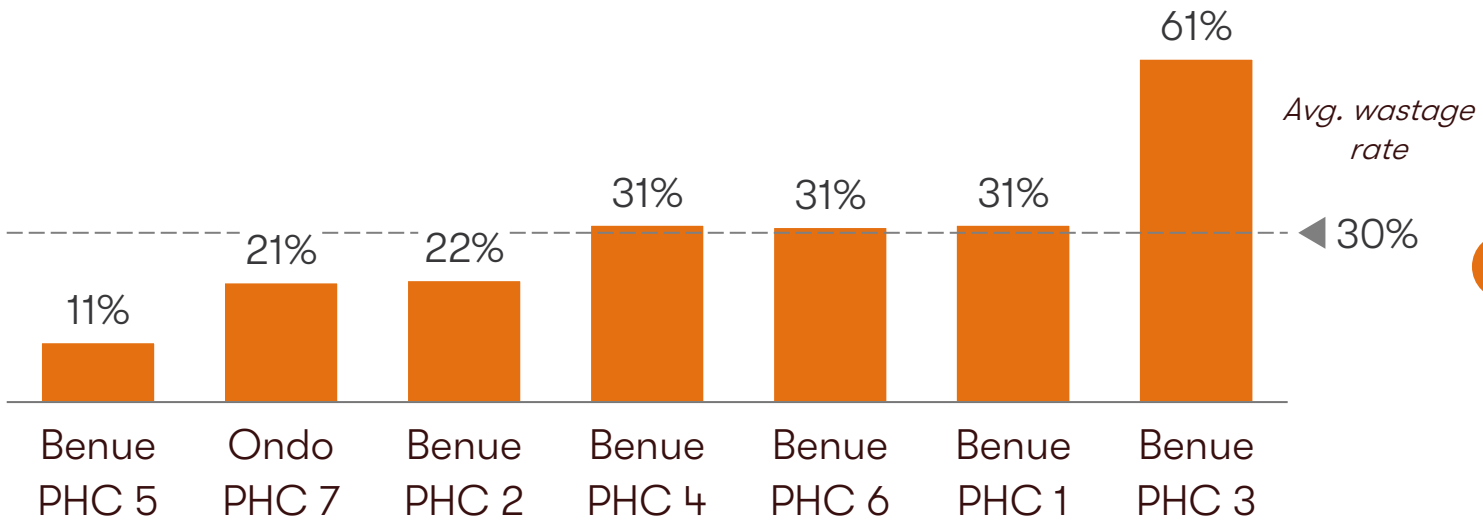
...with unreliable power supply identified as a key factor driving wastage



Question: 1: What were the major reasons for vaccine wastage at your facility (before solar adoption)? (please select top 3); 2. What were the major impacts of vaccine wastage at your facility?
Source: BCG PHC survey (September 2021) (N=7); Consultant Analysis

Vaccine wastage: ~30% vaccine wastage rate reported by PHC's before solar adoption, with poor power supply contributing ~40-60% to vaccine waste

Wastage rate across PHC's before solar adoption (%)



40-60%

Contribution of poor power supply to total vaccine wasted, across all PHC's surveyed

NOTE: 1. ~12-18%pt reduction in wastage rate possible, assuming complete elimination of waste due to poor power supply (i.e., contribution of poor power supply to vaccine wasted * avg. wastage rate); 2. Reduction in vaccine doses wasted assumes a complete elimination of vaccines wasted due to poor power supply
Question: 1: How many vaccine doses wasted per month? (before solar adoption)
1. Wastage rate calculated as # of vaccines wasted/# of vaccines received; 2. Wastage rate pre solar is calculated assuming vaccine waste due to poor power supply is eliminate
Source: BCG PHC survey (September 2021) (N=7); Consultant Analysis

Socio-economic dimension

Education

1

Use case

- Deployment of solar to public secondary schools (day and boarding)

2

Rationale for use-case selection

- Ensuring all children complete free, equitable and quality primary and secondary education is a key target in the United Nations SDG 4 goal
- However, public secondary schools in Nigeria report a lack of electricity supply which reduces the student's study time and ICT teaching hours
- Increased solar deployment to bridge the demand-grid supply gap could improve student learning outcomes by increasing students' study hours and ICT teaching time

3

Impact Measure

1. Improved electricity access
2. Increased students' study hours and ICT teaching hours
3. Increase in GDP due to improved learning outcomes

Study hours: Solar deployment in public boarding schools could double students' night-time study hours and improve academic performance

Student study hours

Current state of indicator in Nigeria & role of solar

- Boarding students in public secondary schools study for ~50% less hours than students in peer countries
- Inadequate power supply has been identified as one of the primary reasons for limited study time, as only ~50% of public boarding schools have reliable electricity
- Consequently, students rely on alternative lighting sources which are usually inconducive for learning (e.g., kerosene lanterns), and inadequate (e.g., generators - as schools ration lighting hours to save energy costs)
- Boarding students study for limited hours (<1hr each night), resulting in lower academic achievements
- Findings from our study reveal that in public boarding sec. schools with solar rooftop systems, students studied for ~90-130% longer at night than their status quo, and report improved academic performances
- A scaled deployment of solar across public boarding secondary schools (with limited energy access) will increase avg. study hours to ~18hrs/wk., in line with average of benchmark countries

Benefit from solar adoption

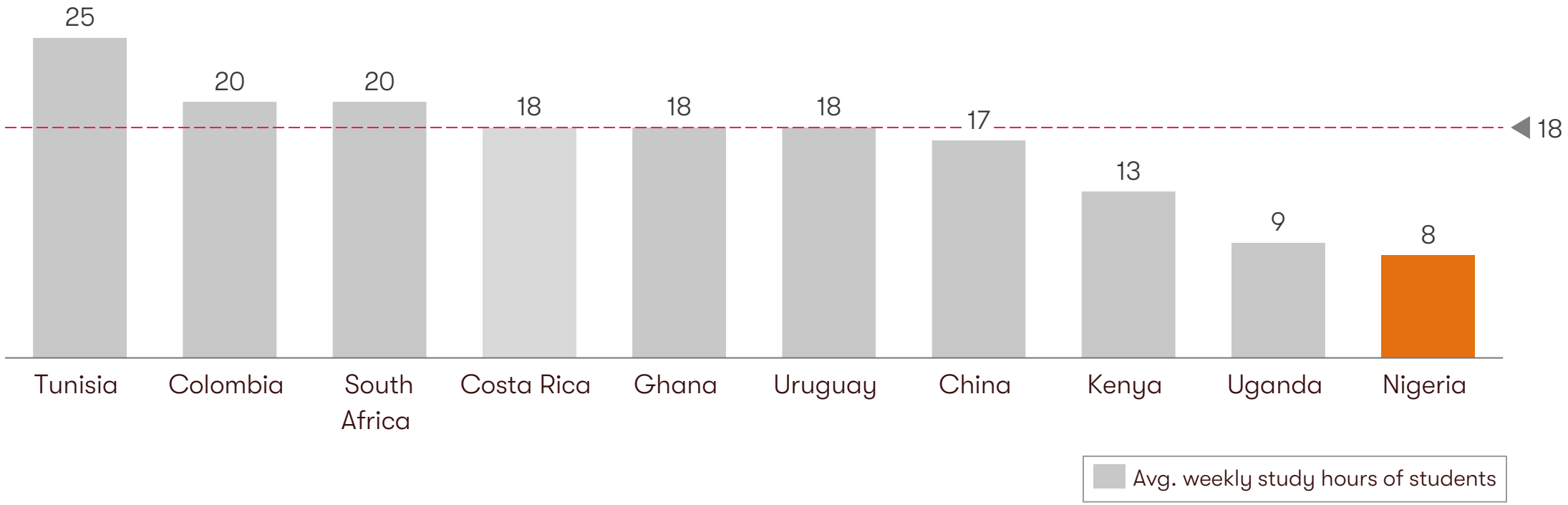
~2.3x — Increase in night-time study hours of sec. students in public boarding schools

+7-10 — Additional study hours per week, available for sec. students in public boarding schools

~0.4% — Uplift in GDP (USD 1.8Bn) as a result of higher future earnings potentials of students in public schools from improved learning outcomes

Study hours: On average, secondary students in Nigerian public boarding schools study less hours than benchmark countries

Avg. hours spent reading per student (in a week)[1]

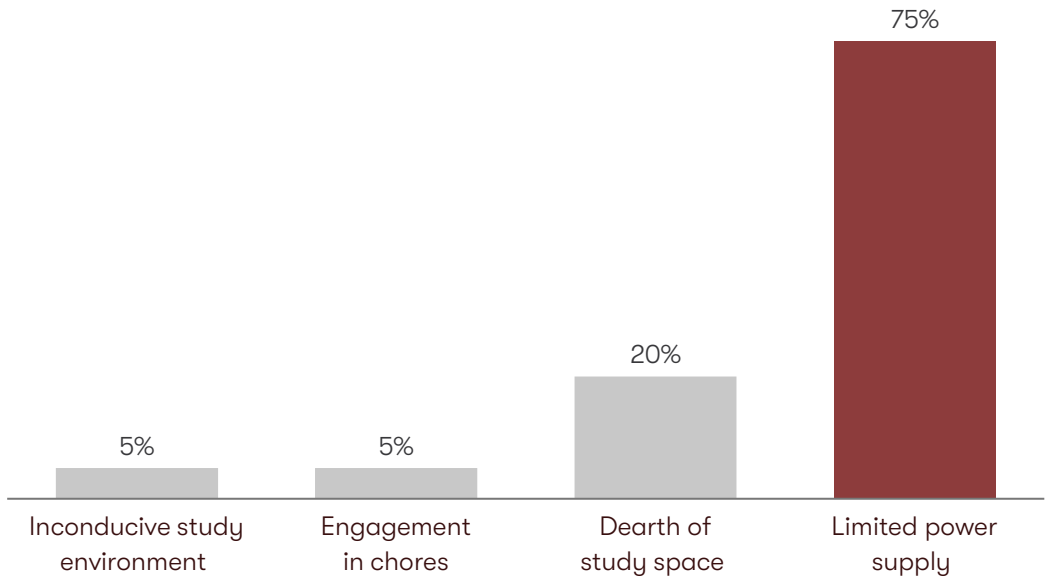


1. Data for Nigeria assumes students in public boarding schools read for ~90minutes per day on average; 2. Data for South Africa was estimated leveraging ratio of study time in SA vs Poland as presented in World Culture Index report
Source: OECD, PISA Report; World Bank Education Statistics; Consultant Analysis; Ameyaw, S. K., & Anto, S. K. (2018). Read or perish: Reading habits among students and its effect on academic performance

Study hours: Limited power supply is a major constraint to study time of boarding students, as several public boarding schools lack electricity access

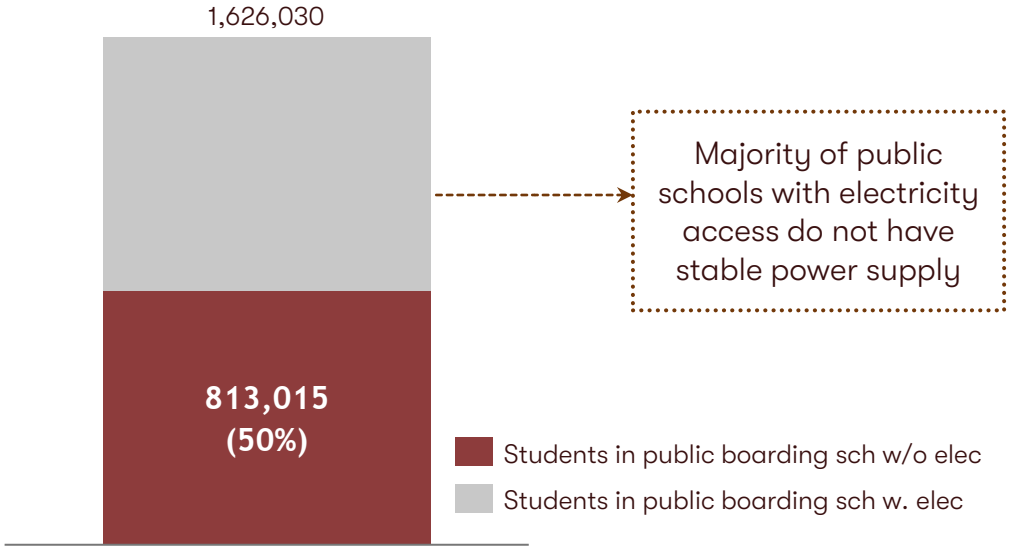
Survey of boarding students in public sec. school identify limited power supply as key challenge to students study time

Factors responsible for limited study hours
(% of respondents)



~50% of boarding students attend public sec. schools that do not have electricity access

% of public secondary schools in Nigeria without access to electricity



NOTE: 1. Estimated the # of students in public boarding sec. schools, by calculating the "portion of public boarding schools in total public schools in Nigeria", and multiplying the result by the avg. no of students enrolled in boarding schools 2. Four sample states were selected for this analysis; Anambra, Nasarawa, Gombe and Ogun state (~10% of students in Nigerian public schools are enrolled across these states); 3. On avg, % of public boarding schools across these states averaged ~6-17%; 4. An average # of students enrolled per public boarding school was determined and applied to the estimated # of public boarding schools across Nigeria; Questions: 1. What are the challenges that limited your study time before solar adoption? Source: Nigeria Education Statistics, 2019; BCG student survey (October 2021) (N=20, Valid Responses - 16)

Study hours: Poor power supply at public boarding schools' make learning environment inconducive for students and contributes to low academic performances

Non-exhaustive

Inconducive environment due to poor power supply limits students night-time studies in several ways...

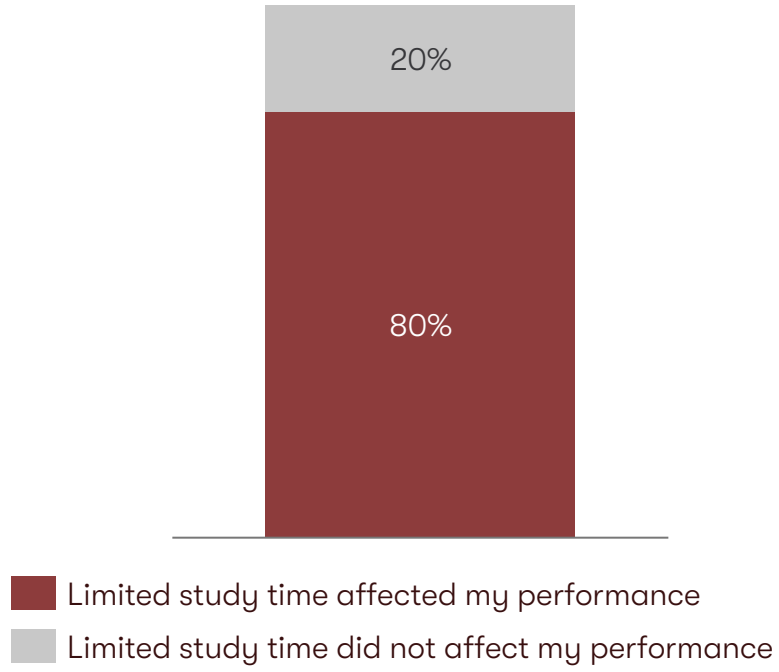
Inhibits students' concentration, as most public boarding sec. school students leverage alternative lighting sources; which are typically dim and polluting (e.g., kerosene lanterns)

Serves as a disincentive for students to leverage study centers as poorly lit centers raises safety concerns by students, who prefer to stay in their dormitory's (for safety) without studying

Limits hours of productive night-time studies of secondary students in public boarding schools

... resulting in low academic performance among students

(% of sec. students, n=16)

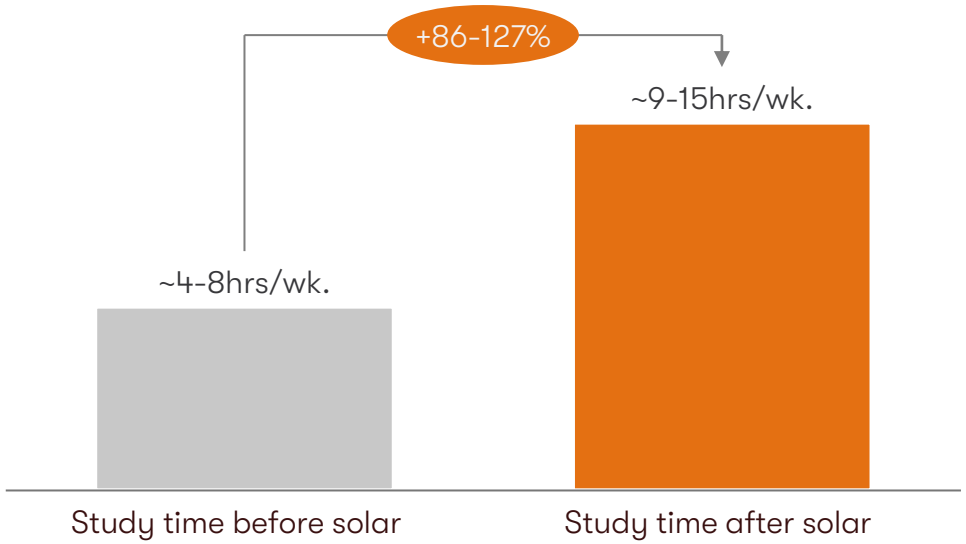


Questions: 1. Did you have challenges studying at night before solar adoption?; 2. Did your limited study time negatively impact your academic performance?
Source: BCG student survey (October 2021) (N=20, Valid Responses - 16)

Study hours: Enhancing power access in public boarding schools could extend student study time by ~86-127%, and improve students' education outcomes

~86-127% increase in study time of students in public sec. boarding schools due to availability of lighting for night-time studies

Time students in public boarding schools spend studying at night (hrs/wk.)



~50% of students with improved study hours, reported improvement in their academic performances after solar

Question: 1. How many did you study at night on a daily basis, before solar adoption?; 2. How many hours did you study at night after solar adoption?; 3. Did your night-time study hours improve after solar adoption?; 4. To what extent did your academic performance improve after solar adoption?
Source: BCG student survey (October 2021) (N=20, Valid Responses - 16)

Study hours: ~7-10hrs/wk. additional study hours available for sec. students in Nigerian public boarding schools, assuming scaled deployment of solar

Increase in weekly study hours of students in public sec. boarding schools (hrs/wk.)

Total weekly study hrs of students in pub. boarding

4-8m hrs	5-7m hrs	9-15m hrs

NOTE: 1. # of students in public sec. boarding schools is 0.5-1m. Estimated the # of students in public secondary schools, by calculating the "portion of public boarding schools in total public schools in Nigeria"; 2. Four sample states were selected for this analysis; Anambra, Nasarawa, Gombe and Ogun state (~10% of students in Nigerian public schools are enrolled across these states); 3. On avg, % of public boarding schools across these states averaged ~6-17%; 4. An average # of students enrolled per public boarding school was determined, and applied to the estimated # of public boarding schools across Nigeria; 5. Analysis concluded by dividing estimated # of public boarding school students by total # of students enrolled
Source: Nigeria Education Statistics, 2019; World Culture Index Score Report; Consultant Analysis

ICT teaching hours: Deploying solar in public sec. schools could increase ICT teaching time by ~30% and increase no. of students receiving practical ICT classes

Indicator

Avg. ICT teaching hrs at public secondary schools

Current state of indicator in Nigeria & role of solar

- On avg. public secondary schools in Nigeria (w. ICT Labs) teach ICT classes for ~30 minutes, ~50% lower than public schools in benchmark countries
- Epileptic grid power supply was identified as a key bottleneck limiting ICT teaching time, as ~60% of public secondary schools are without reliable power supply
- Most public schools rely on generators to power ICT facilities during ICT classes. Consequently, schools shorten their ICT teaching hours in order to reduce high fuel cost associated with generator usage
- As a result, only ~30-40% of students in public schools receive practical ICT classes, leading to fewer sec. students with fundamental ICT skills
- However, our findings reveal that schools w. solar can power ICT facilities & offer extended teaching hours (as classes occur during peak sun hours) thereby increasing the no. of students receiving practical ICT classes
- Wider deployment of solar across public schools with ICT labs could extend ICT teaching hours, increase no. of students receiving practical ICT classes, and enable Nigeria attain SDG 4.4 (increase the proportion of students with ICT skills by 2030)

Benefit from solar adoption

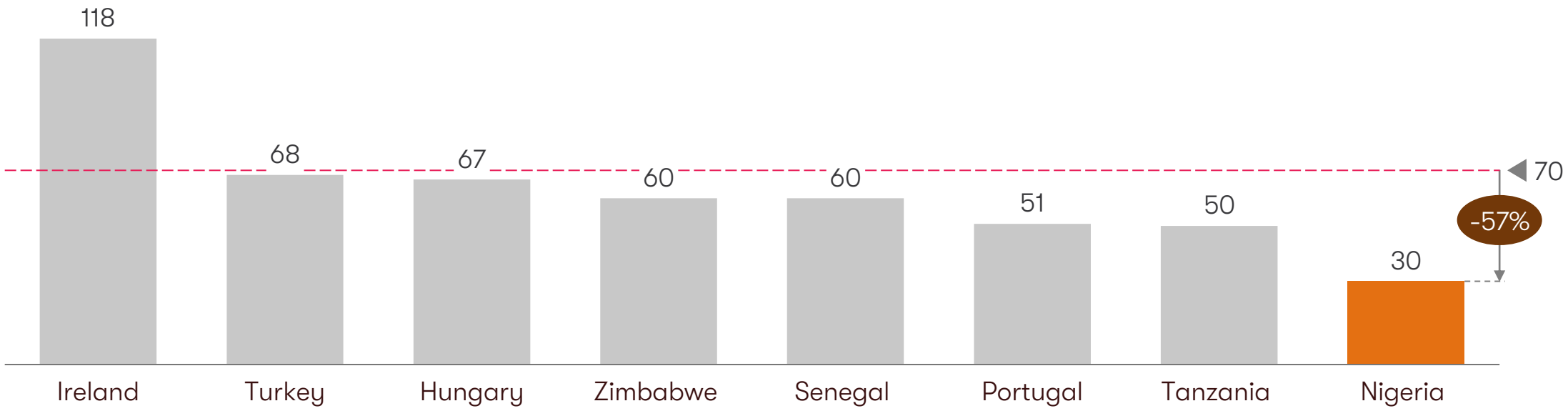
~30% Increase in ICT teaching hours in public schools with solar

~500k Additional students receiving practical ICT classes assuming scaled deployment of solar

32K Potential additional jobs created from deployment of solar across public schools

ICT teaching hours: On average, the duration of experiential ICT classes in Nigerian public sec. schools is >50% lower than benchmark countries

Avg. minutes spent teaching practical ICT classes (per week)[1]

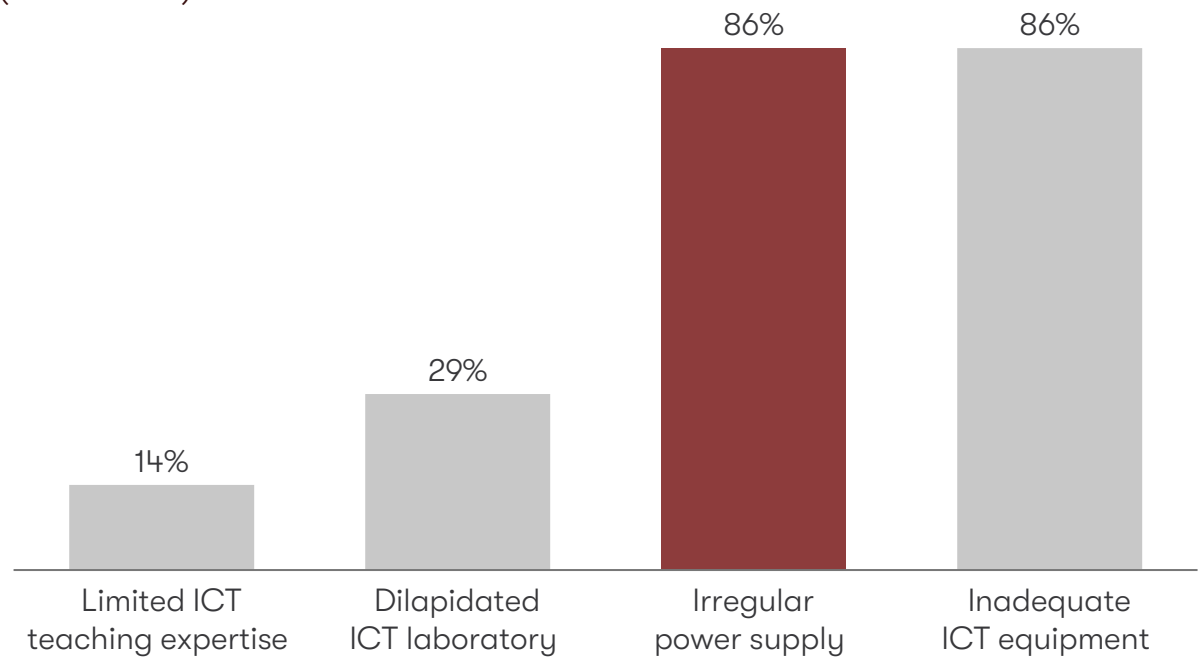


NOTE: 1. Calculated ICT instruction time across the benchmark countries leveraging data from OECD report on average instruction time spent per student on ICT subjects relative to the toral instructional time per school year. 2. Determined hours spent on practical ICT classes by applying OECD's stats on the ratio of hours teachers teach with ICT facilities relative to the total relevant weekly school hours available for ICT. 3. Total weekly hours available for ICT classes was assumed to be ~7hours, if ICT classes are held once in a week; 4. Data was Tanzania was proxied using avg. time students spend on the internet in school per week, determined to be ~50minutes from academic papers
Source: OECD Statistics Report; infoDev/World Bank Survey of ICT and Education in Africa, 2007; World Links For Development : a part of the World Bank Institute; OECD, Integrating Information and Communication Technology in Teaching and LearningConsultants Analysis

ICT teaching hours: Irregular power supply was identified as major challenge inhibiting ICT teaching hours

Survey of public sec. schools identify limited power supply as key challenge to reduced ICT teaching time

Factors responsible for limited ICT teaching time
(% of schools)



Questions: 1. Is your school connected to the grid?; 2. What were the major challenges limiting ICT use at your school before solar? Source: EdTech in Nigeria: A Rapid Scan, 2020; Press Release; BCG school survey (October 2021) (N=7)

> The situation of most public secondary schools w. elec. access is bad...there are several weeks of blackout, and when electricity is available, the current is too low to power the schools ICT facilities
>
> *Federal Ministry of Education, Nigeria*

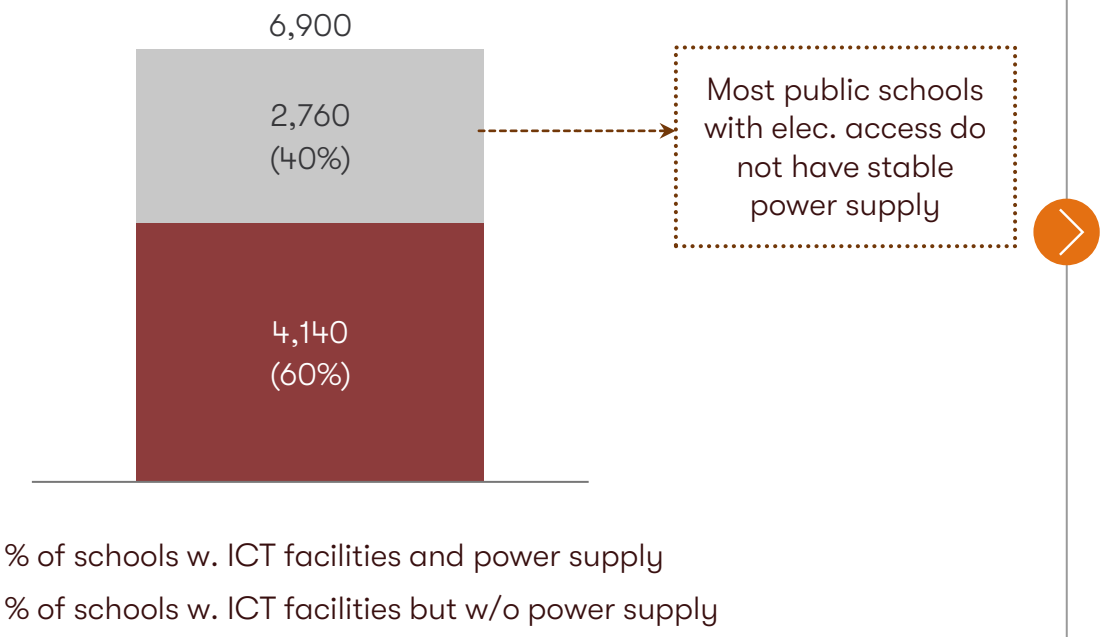
> Despite efforts to integrate ICT into education, public sec. schools face several challenges...incl. epileptic state of Nigeria's grid supply
>
> *Federal Ministry of Education, Nigeria*

> Unfortunately, Nigeria has been lagging peers, you supply computers to schools, but the schools cannot afford the electricity bills to power the computers...
>
> *Universal Basic Education Commission (UBEC)*

ICT teaching hours: ~60% of public sec. schools are w/o reliable power supply, resulting in a heavy reliance on generators as an alternative power source

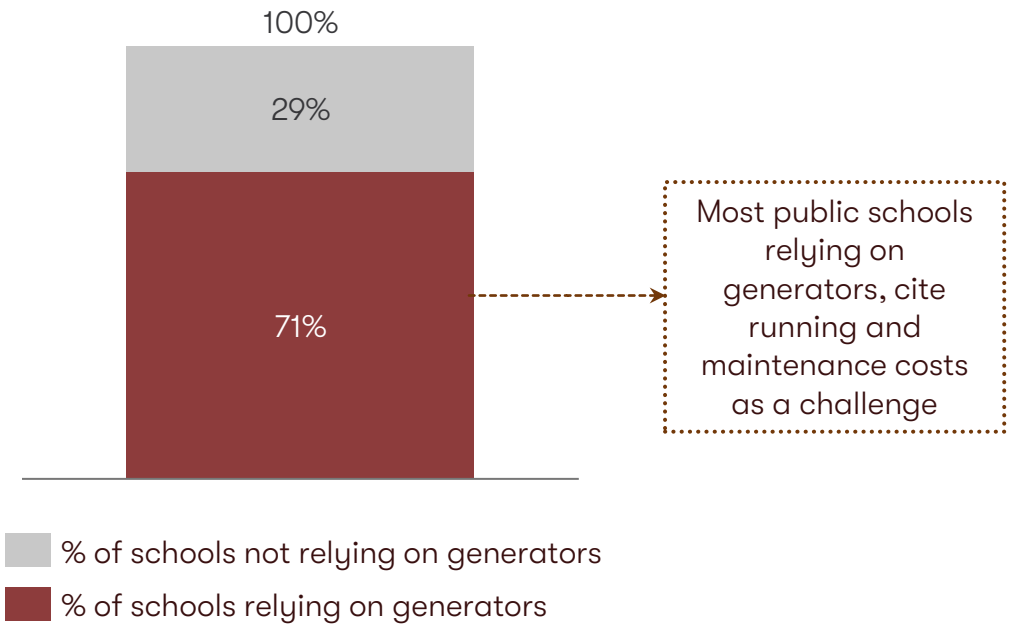
~60% of public sec. schools w. ICT facilities have no reliable source of power…

Breakdown of schools w. ICT facilities by power source availability



…resulting in a heavy reliance on generators by these schools

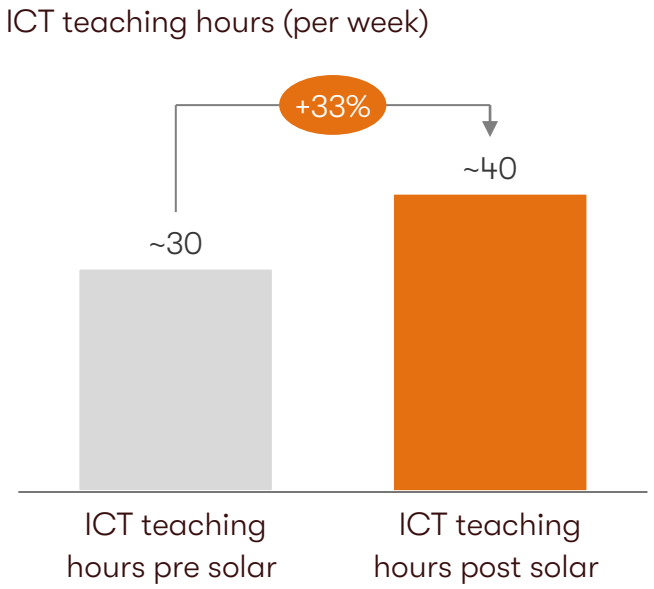
Schools relying on generators as a source of power (%)



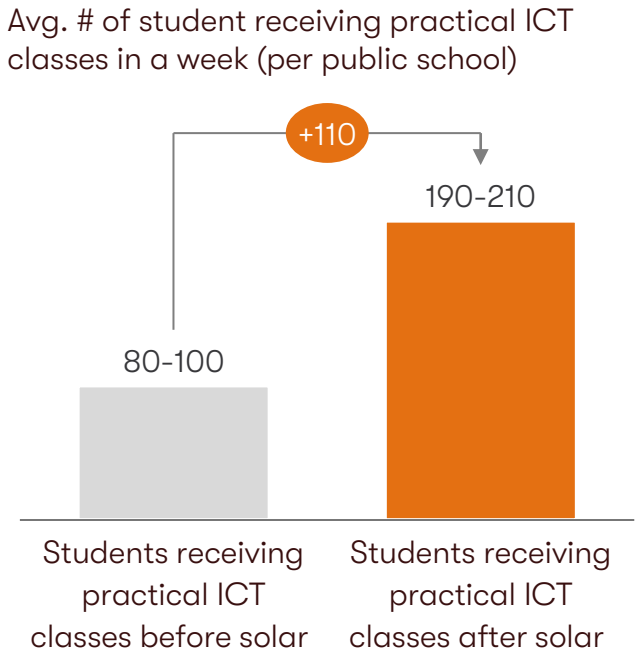
Question: 1. Why did your school adopt solar systems?. 2. Is your school connected to the grid?. 3. What source of alternative power does your school leverage due to poor power supply?
Source: BCG school survey (October 2021) (N=7)

Improving power supply could increase ICT teaching hours in public schools and enable ~500k additional students to receiving practical ICT classes

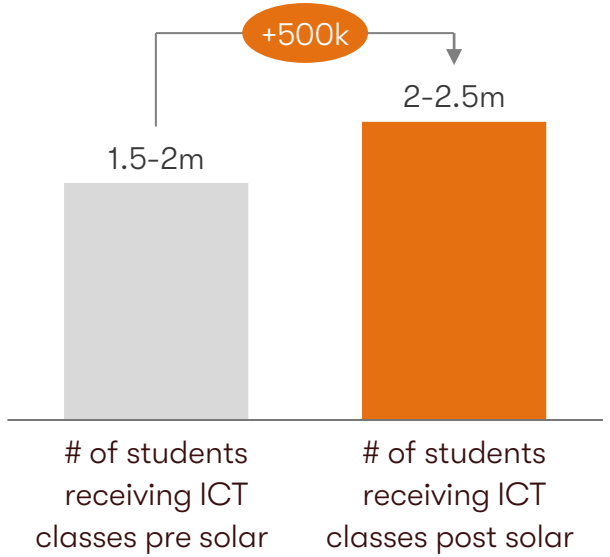
~30% increase in ICT teaching hours across public schools surveyed, post solar adoption...



...resulting in avg. of ~110 additional students receiving practical ICT classes at these schools



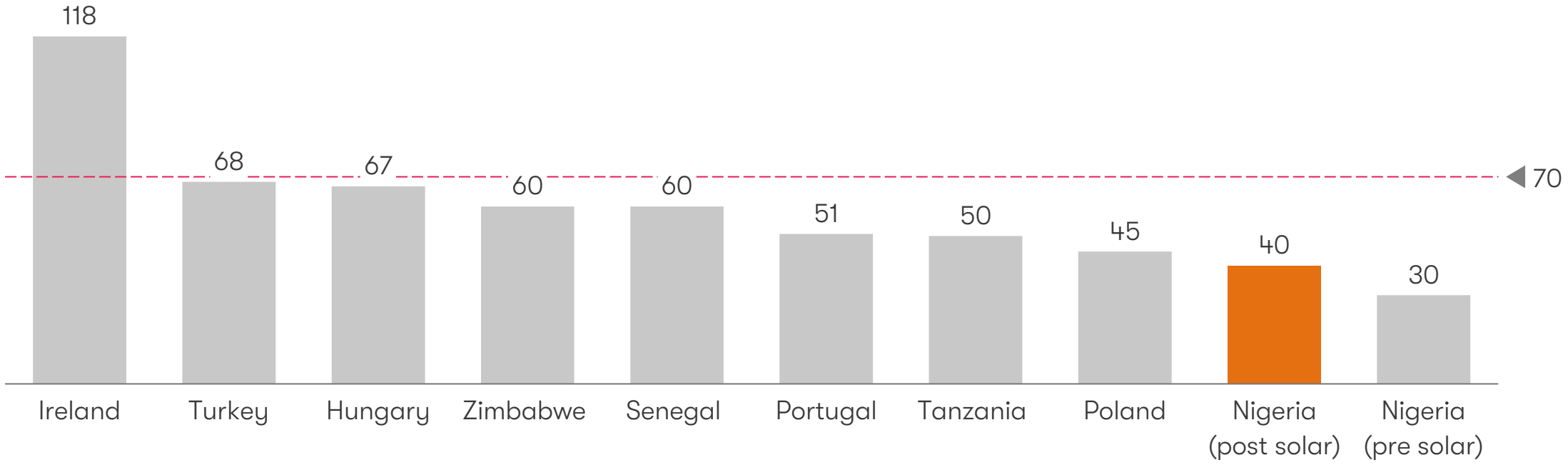
Deploying solar across public sec. schools could also increase no. of students receiving practical ICT classes by ~500k



Question: 1. How many hours in a week did you provide ICT training across all your classes post solar?; 2. What percentage of your students receive ICT classes after solar adoption (out of eligible students)?. NOTE: 1. No. of public sec. schools w. ICT facilities is 6.9k; 2. Avg. # of students per public sec. schools w. ICT facilities is ~700; 3. # of public sec. school w. ICT facilities and inadequate access to power supply is 4140 - Assuming ~60% of public secondary schools w. ICT facilities, do not have access to electricity ; 4. Potential increase in # of sec. students utilizing ICT facilities at govt. schools post solar is 0.5m
Source: BCG school survey (October 2021) (N=7)

ICT teaching hours: Deploying solar across public sec. schools could enable schools utilize their ICT facilities and increase their practical ICT teaching time

Avg. minutes spent teaching practical ICT classes in public schools (per week)[1]



NOTE: 1. Calculated ICT instruction time across the benchmark countries leveraging data from OECD report on average instruction time spent per student on ICT subjects relative to the toral instructional time per school year. 2. Determined hours spent on practical ICT classes by applying OECD's stats on the ratio of students utilizing ICT facilities in schools, on the total hours spent on ICT classes per students. 3. Data for Nigeria was derived by assuming that practical class is slated for 1 period during the week, the avg. dr for a period is 40mins, and the time is fully utilized
Source: OECD Statistics Report; OECD, Integrating Information and Communication Technology in Teaching and LearningConsultants Analysis

Socio-economic dimension

Food Security

1

Use case

1. Deployment of solar powered cold storage to small holder farmers and farm produce traders

2

Rationale for use-case selection

- Agriculture is at the center of Nigeria's economy providing the main source of livelihood for most of the population; Smallholder farmers account for 80% of the country agriculture output
- However, a substantial amount of food is lost due to lack of cold storage thereby weakening the country food system
- Increased deployment of solar powered cold storage facilities to increase the capacity of cold storage, could enable reduction in post harvest loss and improve income of hundreds of thousands of farmers and traders

3

Impact Measure

1. Improved access to cold storage
2. Reduced post harvest loss of perishable foods
3. Increase in GDP due to reduction in post harvest loss

Food Security | Deployment of solar powered cold storage could reduce Nigeria's post harvest loss in perishable foods by 30%

Indicator

Post Harvest Loss

Current state indicator in Nigeria & role of solar

- Nigeria has one of the highest post-harvest losses amongst peer countries at around 40%
- Consequently, Nigeria loses 80M tons of food annually along the value chain (production, wholesale, retail and consumption); equivalent to 9% of its GDP
- A sizeable proportion (20%) of this loss is from perishable foods; with an annual loss rate of 60%
- ~37% of losses in perishable food attributed to limited cold storage facilities and high rental cost of cold storage in Nigeria
- Due to lack of access to cold storage, small holder farmers typically use traditional storage methods such as use of charcoal room, a shed or sprinkling water on the produce over night, etc.
- To address food loss & waste, FGN, under the Malabo Declaration, has set an ambition to halve post harvest loss by 2025
- Solar powered cold storage has its advantages over the conventional diesel-powered cold storage including lower rental cost, lower operating costs, etc.
- Farmers with solar-powered cold storage experience up to 80% reduction in food loss and if deployed across the country, can save up to 4.4 million tonnes of food, ~30% of perishable food loss
- Wider deployment of solar powered cold storage can bridge existing deficit and enable FGN achieve 11% of its post harvest reduction target

Benefit from solar adoption

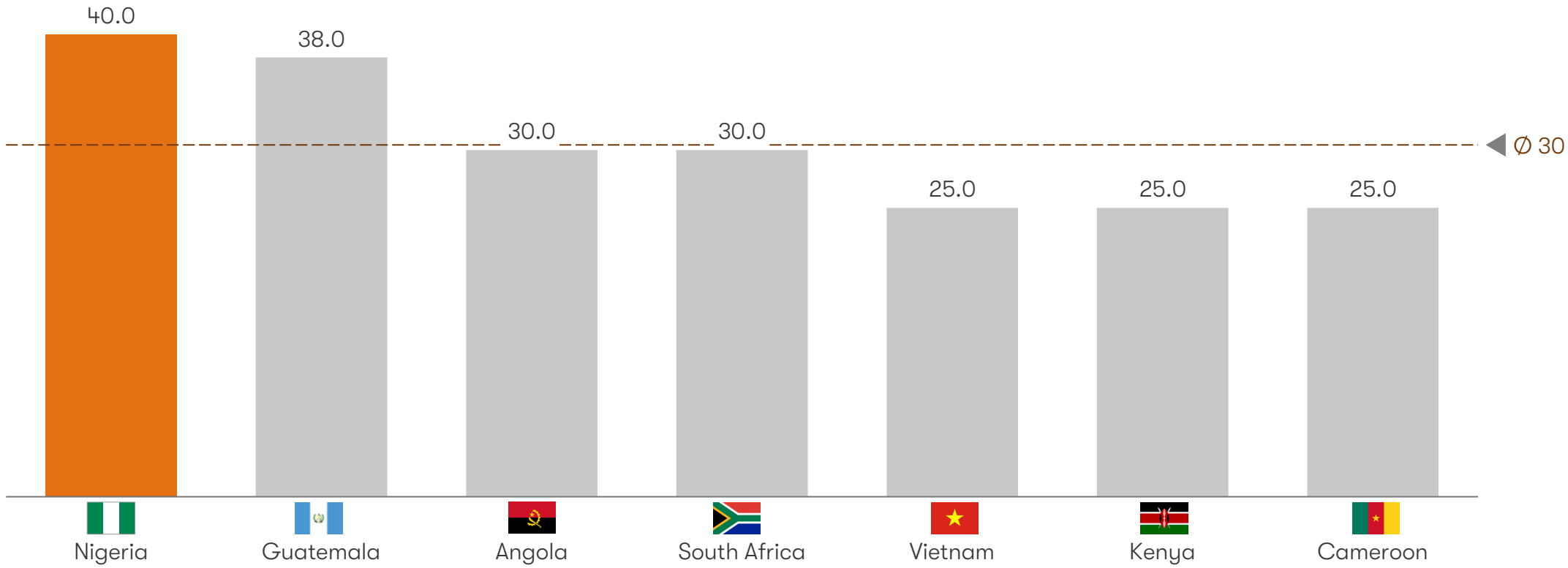
~4.4 Million — Potential tones of food to be saved

~34K — Additional jobs created from deployment of solar powered cold storage across the country

0.5% — Potential GDP uplift (2.3Bn USD) from reduction in post harvest loss

Nigeria has one of the highest post-harvest losses amongst peer countries

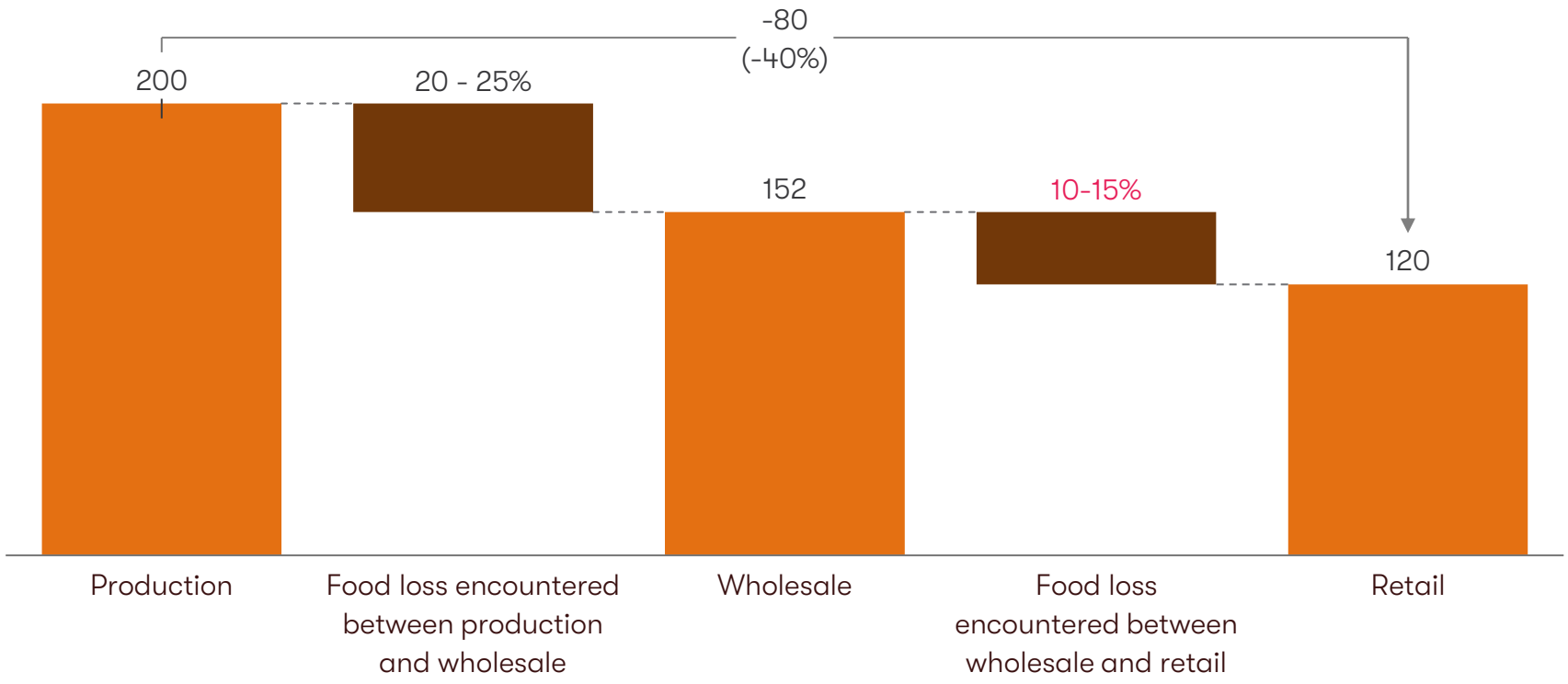
Food Loss Per Country
(% of agricultural produce)



Note: Kenya figure taken as average of range 20-30% post harvest loss
Source: FAO, World Bank 'Food Smart Country Diagnostic' Report, Australian High Commission in Kenya, International Trade Centre, Centre for Scientific and Industrial Research Consultant Analysis

Nigeria loses 80M tons of food annually along the value chain; equivalent to 9% of its GDP

Food Loss In All Agricultural Produce
(Million Ton)



~39

billion dollars lost annually

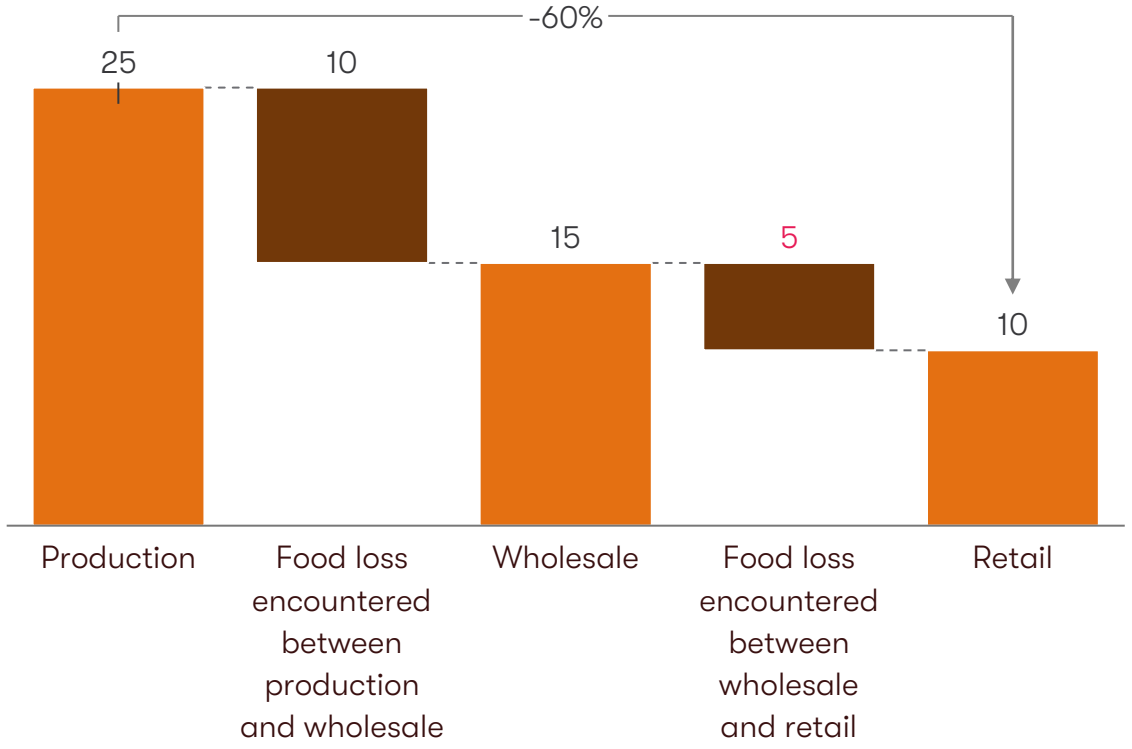
~9%

of GDP annually

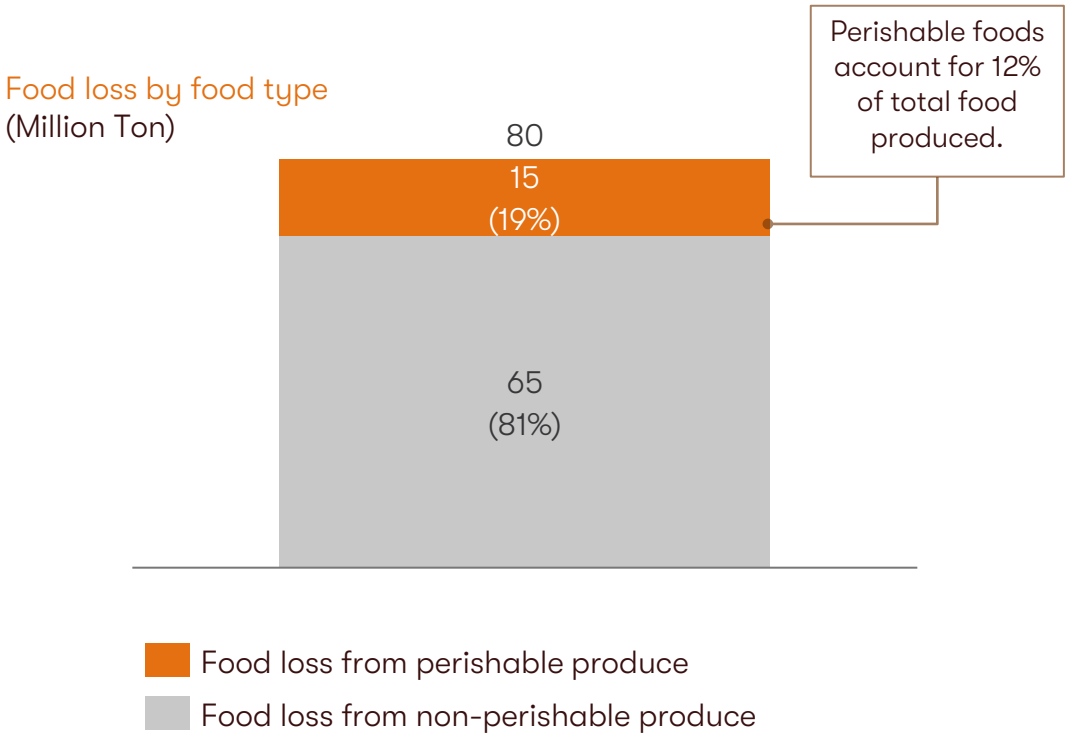
1. Perishable foods refer to foods with high moisture content that require refrigeration, includes fresh fruits and vegetables, but not fish, dairy, meat, or poultry
Source: Press Search, World Bank 'Food Smart Country Diagnostic' Report, BCG Experience, Consultant Analysis

Although they account for 12% of food produced, perishable foods contribute 20% to total food losses in Nigeria

Perishable foods[1] have a higher loss rate at 60% ...



... and contribute ~20% to total food losses



1. Perishable foods refer to foods with high moisture content that require refrigeration, includes fresh fruits and vegetables, but not fish, dairy, meat, or poultry
Source: Press Search, World Bank, BCG Experience, Consultant Analysis

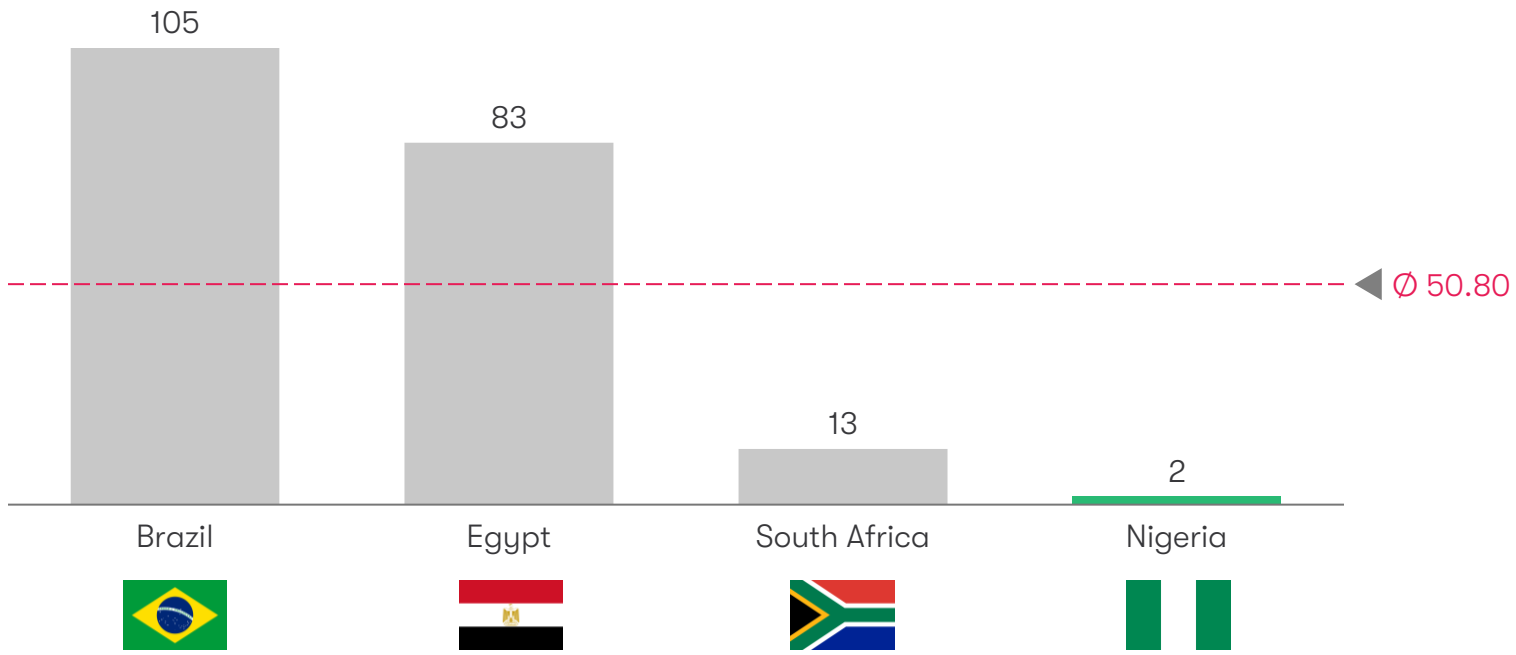
~37% of losses in perishable food is attributed to limited cold storage facilities...

37%

of food requiring refrigeration[1] is lost due to limited and poor cold storage facilities

Cold Storage Capacity per urban population

(m³/1000 urban resident)

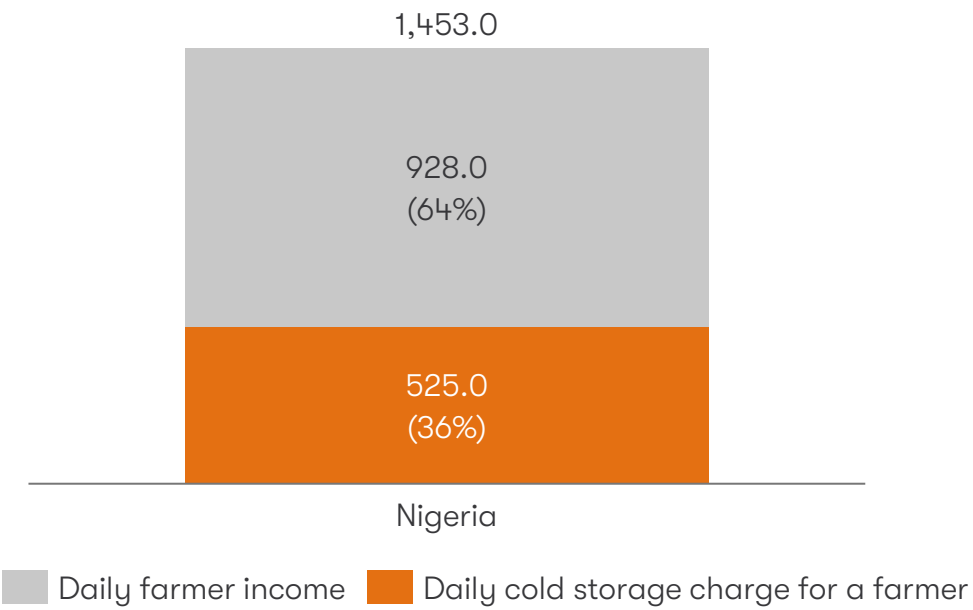


1. Foods requiring refrigeration include perishable produce such as fresh fruits and vegetables, but not fish, dairy, meat, or poultry
Source: World Bank 'Food Smart Country Diagnostic' Report, Global Cold Chain Capacity Report 2018, BCG Experience, Consultant Analysis

...and high rental cost of cold storage in Nigeria

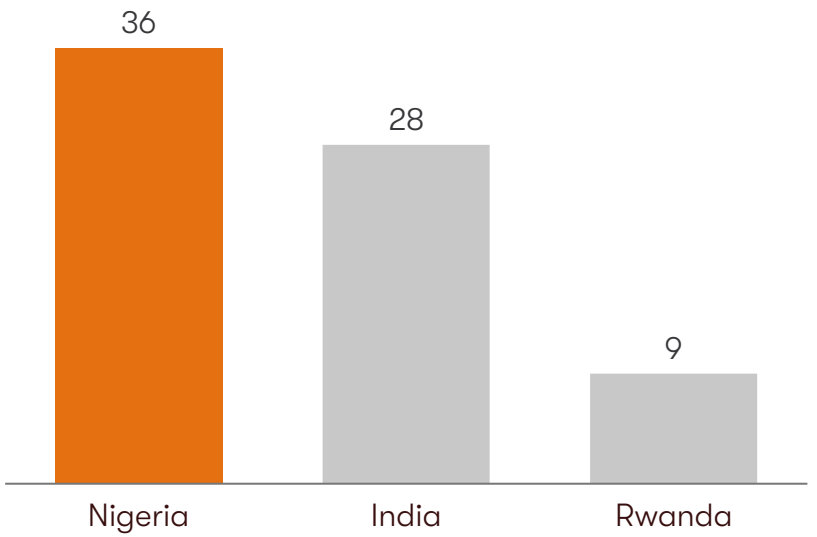
Cold storage charges per day cost around 36% of a farmer's daily income...

Average daily income of small holder farmer in Nigeria
(Naira)



...higher than cold storage charges in other regions

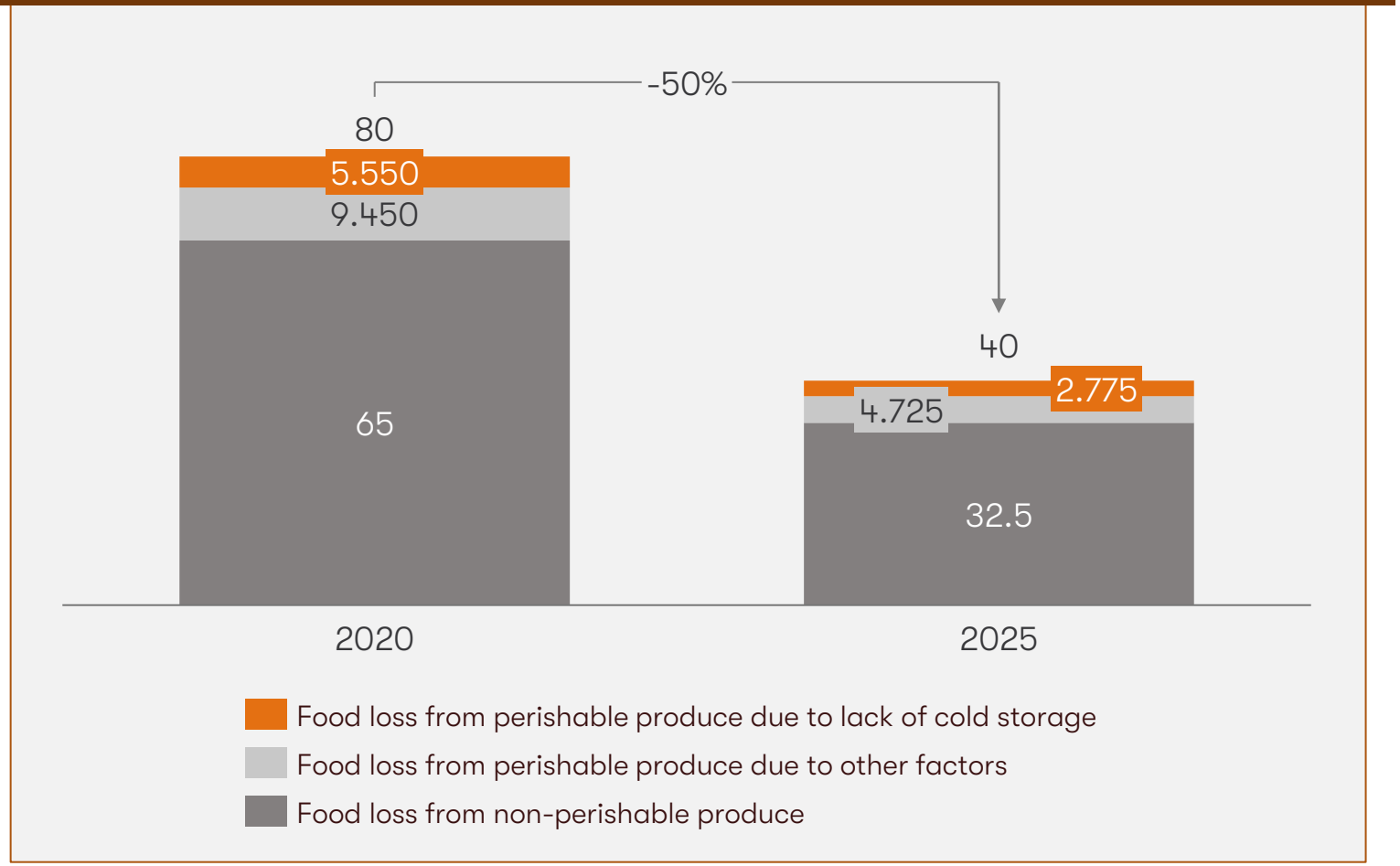
Cold Storage rental charge as a % of farmer's income



1. Assumes a small holder farmer produces 7 crates of produce a day, selling 50% and storing the other 50%
Source: Global Cold Chain Capacity Report 2018, FAO Small Family Farms Country Sheet, Cold Chain Assessment 'Status of Cold Chain Infrastructure in Rwanda' (NAEB), Journal of Agricultural, Life and Environmental Sciences - October 2020, 'Impact of Saving and Credit Cooperatives (SACCOs) on the Income of Smallholder Farmers in Rwanda: A Case Study of Busasamana Sector', Expert Interviews, Press Search, Consultant Analysis

To address food loss and waste, FGN has set an ambition to halve post harvest loss by 2025

Total Food Loss Reduction Target
(Million ton)

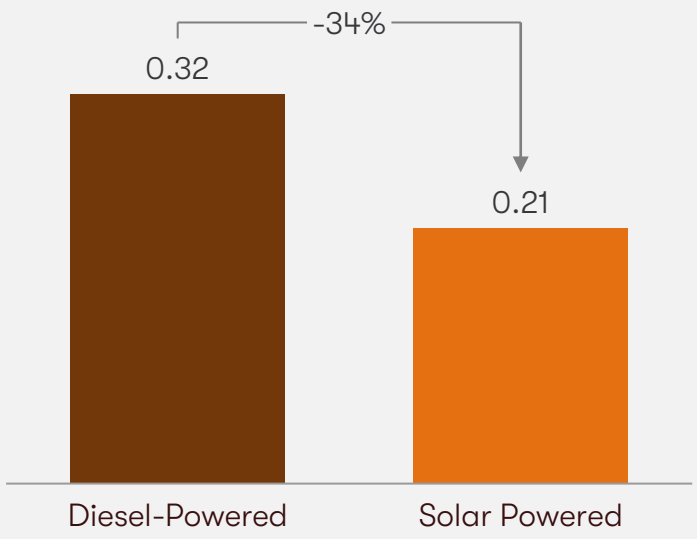


Note: Perishable produce refers to agricultural crops like fresh foods and vegetable but not fish, dairy, meat, or poultry
Source: World Bank 'Food Smart Country Diagnostic' Report

Solar powered cold storage has several advantages over the conventional diesel-powered cold storage; hence better suited to support FGN ambition

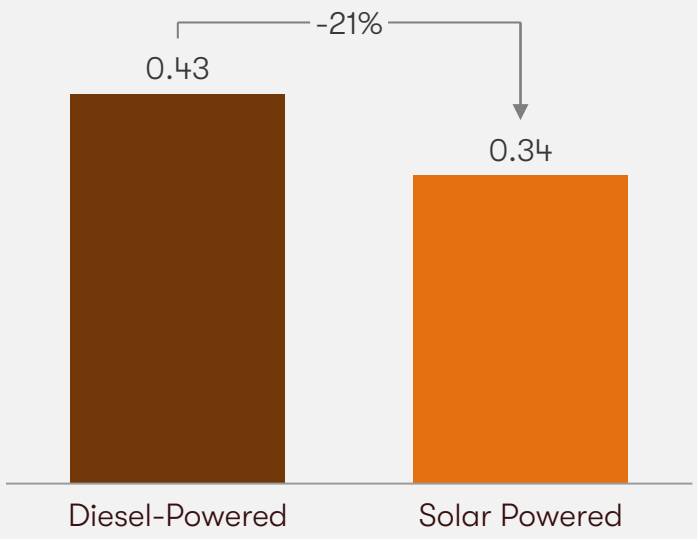
1 Cheaper rental charges

Average daily cold storage rental charge per crate[1,2] (USD)



2 Lower cost of electricity

LCOE of different cold storage technologies (USD)



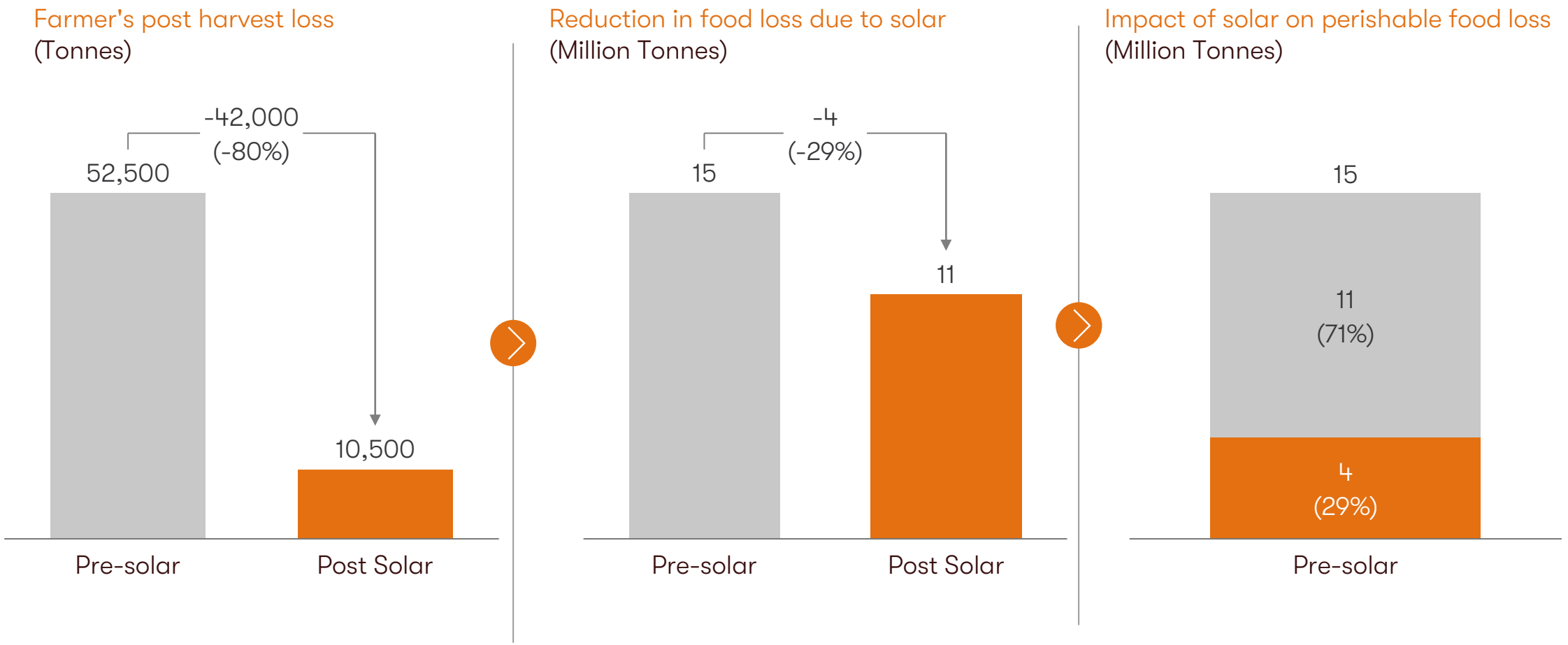
3 Reduced CO_2 emissions

~21K tons

of CO_2 emissions from a typical 18m^3 diesel powered cold room annually

1. A crate of produce equals 20kg, 2. 3. Diesel fuel consumption for a 10kVA generator run at 0.75 load, running for 12 hours a day
Source: Expert Interviews, GIZ, Consultant Analysis

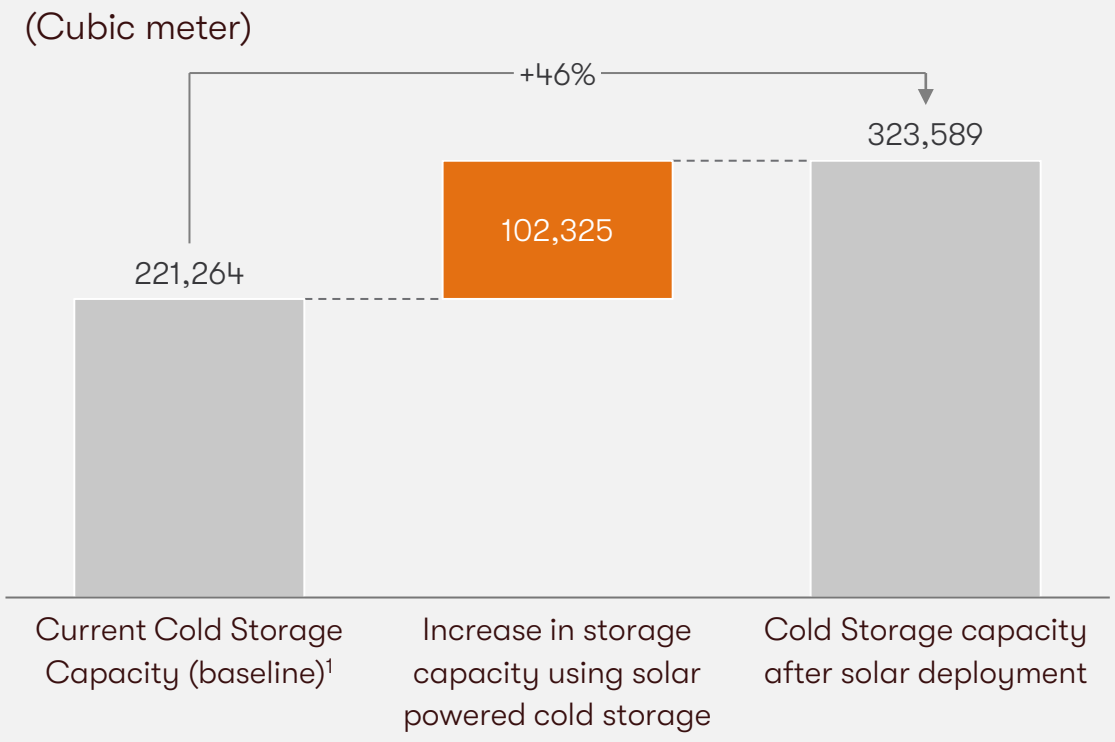
Farmers with solar-powered cold storage experience up to 80% reduction in food loss and if deployed across the country, can save up to 4.4 million tonnes of food, ~30% of perishable food loss



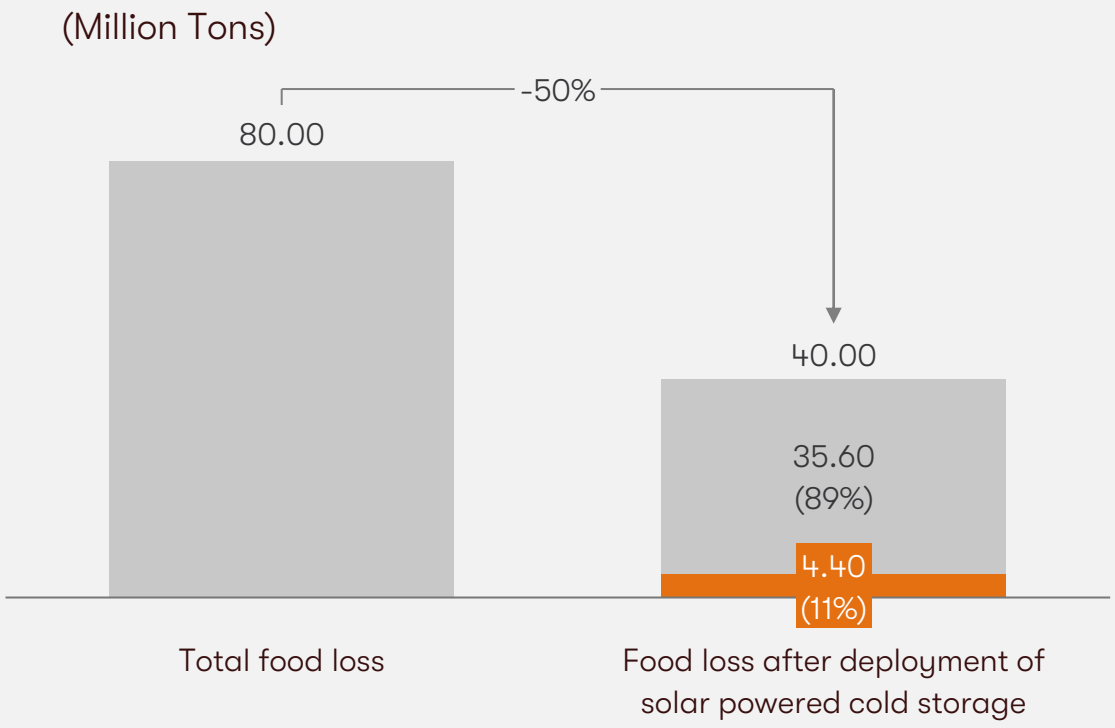
Source: ColdHubs' website, Consultant Analysis

Wider deployment of solar powered cold storage can bridge existing deficit and enable FGN achieve 11% of its post harvest reduction target

Impact of solar on cold storage capacity



Impact of solar on total food loss



Source: Consultant Analysis

Besides cold storage, solar also powers a range of other processes in the agricultural sector

Non-exhaustive

Segment	Use case	Description	Developmental Impact
 Crop production	• Deployment of solar powered water pumps for farmland irrigation by crop farmers	• Utilizes solar water pumps to provide water for farmlands in off grid locations	• Improved farmers income from increase in crops produced
	• Deployment of solar electric fences for security by crop farmers	• Utilizes solar electric fences to provide security to protect farms against unauthorized entry of humans and animals	• Increased farmers profits from reduction in loss of farm produce
	• Deployment of solar bubble dryers for crop drying by crop farmers	• Leverages solar bubble dryers to provide an alternative to the use of sunlight in drying agriculture produce which improves the shelf life of perishable agriculture products	• Improved farmers income from reduction in agriculture produce wastage
 Livestock & fishery	• Deployment of solar poultry lights for egg production	• Employs solar poultry lights to illuminate poultry farms in order to stimulate egg production during seasons of high rainfall and low sunlight	• Improved farmers income from increase in poultry production
	• Deployment of solar powered incubators for egg hatching	• Utilizes solar incubators to develop fertilized eggs into life chicks by providing the prerequisite levels of electric and heat energy through sun power	• Improved farmers income from increase in poultry production
 Agro-processing	• Deployment of solar powered grain mills by crop farmers	• Utilizes solar grain mills to convert cereal crops (e.g., barley, maize, sorghum) into processed flour thereby replacing expensive modes of milling using fossil fuel	• Improved agro-processor profits from increased savings on grain milling

Source: BCG Desktop Research

Socio-economic dimension

Environment

1

Use case

1. Increased solar penetration in Households with fuel generators

2

Rationale for use-case selection

- Under the Paris Agreement, the FGN set an ambition to reduce GHG emissions by up to 45% by 2030
- However, Nigeria depends on fuel generators for ~40% of energy needs due to inadequate grid power supply; with households constituting ~60% of capacity & 20% emissions
- Consequently, reducing generator usage among household is critical to achieving FGN emission target
- Increased solar penetration among households could reduce dependence on fuel generators and lead to a reduction in GHG emissions

3

Impact Measure

1. Improved electricity access
2. Reduction in GHG emissions due to increased solar penetration
3. Increase in GDP due to reduction in GHG emissions

Environment | Increased solar adoption in the residential segment could avoid 5M tons of CO_2e

Developmental Benefits

Indicator

GHG Emissions

Current state indicator in Nigeria & role of solar

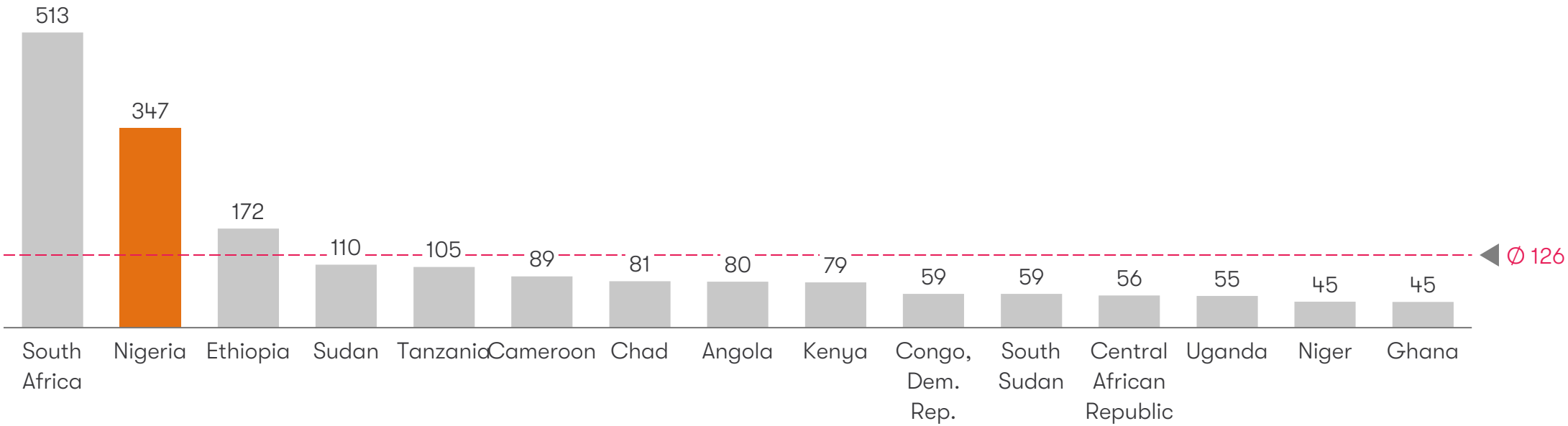
- Nigeria has one of the highest GHG emissions in Sub-Saharan Africa, at ~375 Million tonnes of CO_2e
- The energy sector accounts for ~60% total GHG emission, with fuel generators used by households contributing ~5% to energy sector emission
- … mainly because 40% of electricity demand are met through generators given limited grid supply
- Based on current trajectory, total GHG emissions from generator usage by households expected to increase by 45% in 2030 from 11.9 to 17.1 million tons of CO_2e
- FGN has set an ambition to reduce GHG emissions by 45% by 2030, with reductions from electricity generation expected to contribute 57%
- Peer countries with high fuel generator emissions have opted for solar as it produces approximately zero GHG emissions, serving as a more environment-friendly alternative to generators
- Assuming solar penetration among households in Nigeria reaches peer average of ~30% by 2030, 5 million tonnes of CO_2e can be avoided thereby contributing to FGN emission reduction target
- Replacing fuel generators with solar has additional benefits including reduction in noise pollution and lower fire accidents linked to generators

Benefit from solar adoption

~5 Million	Potential tons of CO_2e emissions to be avoided
~470K	Additional jobs created from increased solar penetration
0.05%	Potential GDP Uplift (USD 225M) from reduced GHG emissions

Nigeria has one of the highest greenhouse gas emissions in Sub-Saharan Africa

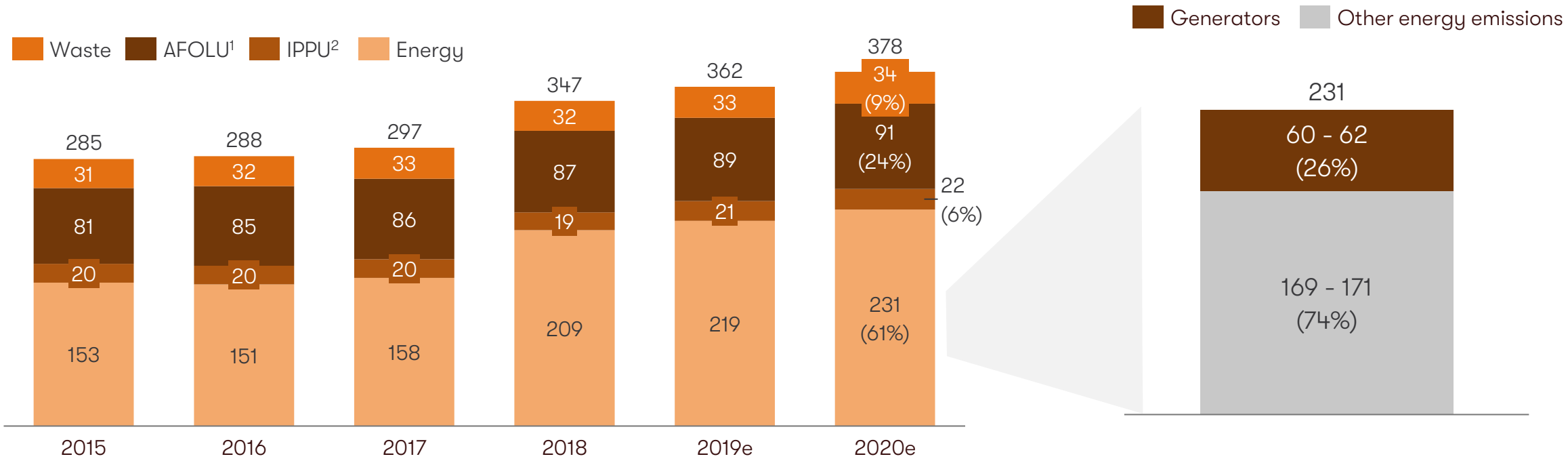
Total greenhouse gas emissions by Country
Million Tonnes of CO_2 equivalent



Note: 1. 2018 Nigeria figure obtained from Nigeria's official document on Nationally Determined Contribution to UNFCCC 2. Total greenhouse gas emissions in kt of CO2 equivalent are composed of CO2 totals excluding short-cycle biomass burning (such as agricultural waste burning and savanna burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), all anthropogenic CH4 sources, N2O sources and F-gases (HFCs, PFCs and SF6).
Source: World Bank Development Indicators

The Energy Sector is the largest source of GHG emissions contributing ~60% to total emissions; with a sizeable share from fuel generators…

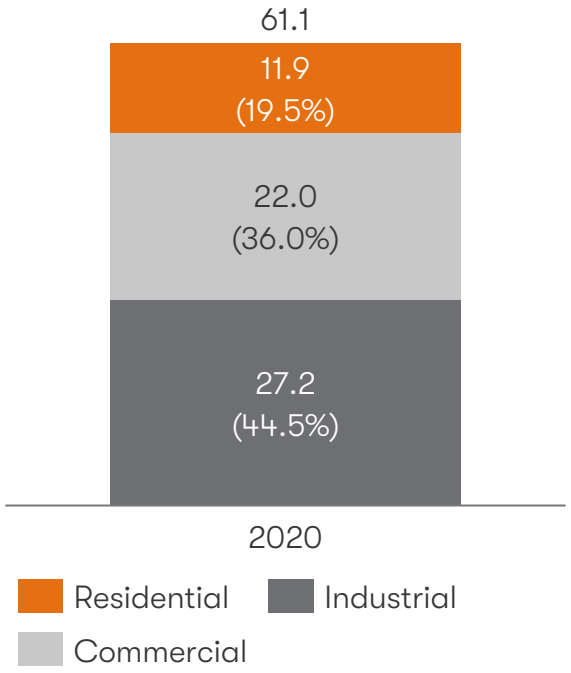
Total GHG emissions in Nigeria between 2015 and 2021
(Mt CO_2e)



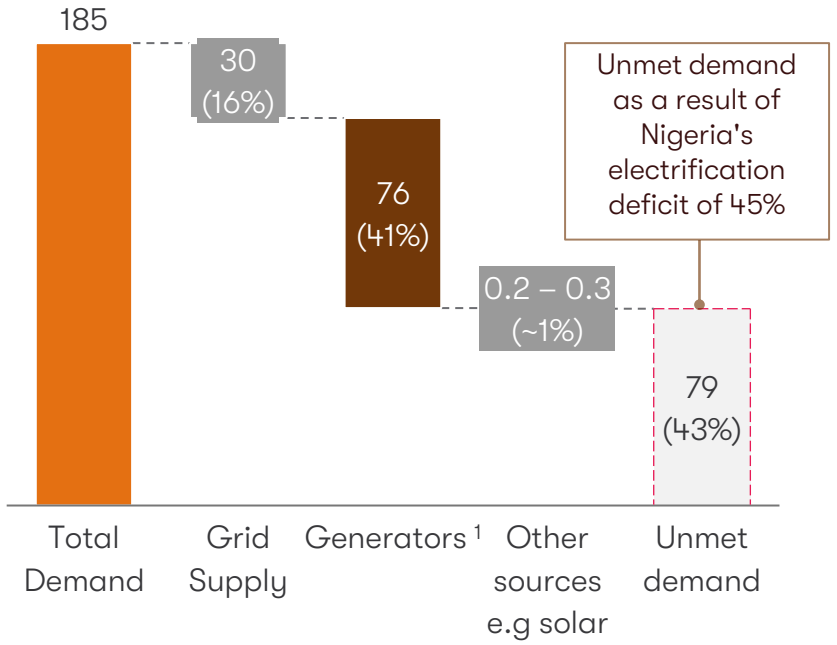
1. Agriculture, Forestry and Other Land Use 2. Industrial Processes and Other Products Use
Note: 1. 2019 and 2020 values estimated using CAGR of 2010 to 2018 values (4.3%) 2. Waste includes emissions from wastewater handling, solid waste disposal and open burning. 3. AFOLU includes emissions from livestock, land, removals for harvested wood products. 4. IPPU includes emissions as by-products from manufacturing new products (cement, ammonia and iron & steel production). 5. Energy includes emissions from oil and gas, transport, electricity generation (grid and off-grid).
Source: Update on Nigeria's Nationally Determined Contribution (United Nations Framework Convention on Climate Change, 2021), Consultant Analysis

… and households contributing ~20% to total fuel generator emissions because 40% of electricity demand is met through fuel generators due to limited grid supply

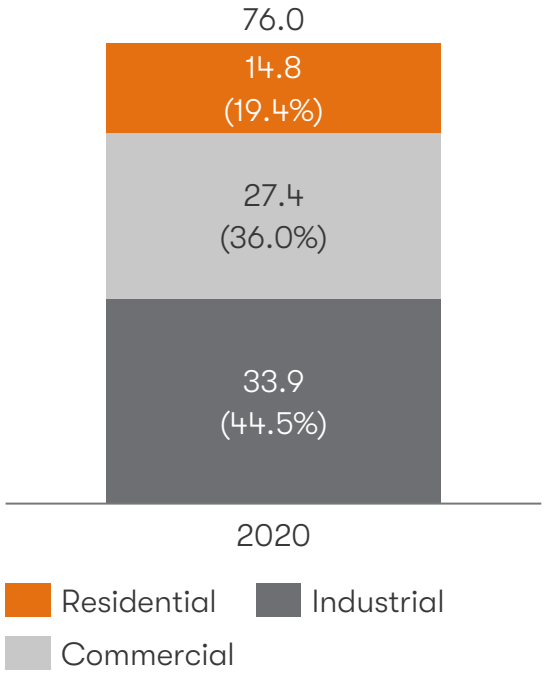
GHG emissions from generators[2] by segment
(Million Tons CO_2e)



Electricity Generation in Nigeria
(TWh)



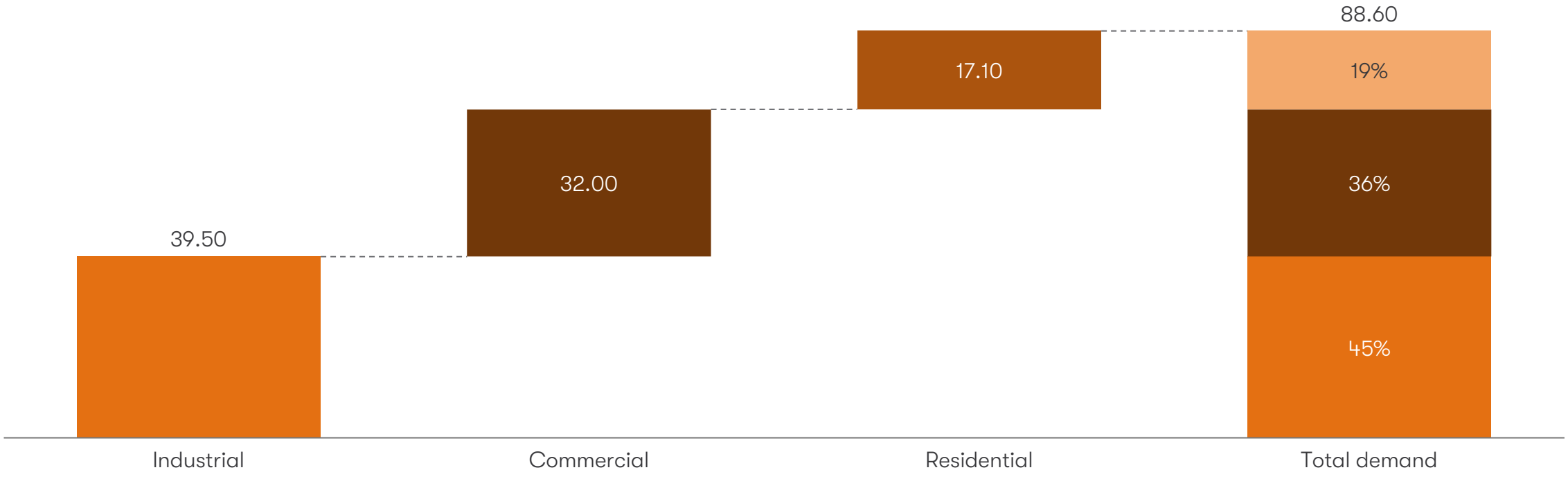
Electricity Generation from Generators by segment
(TWh)



1. Refers to both diesel and petrol generators. 2. Split of electricity consumption by sector used to estimate annual installed capacity of generators by segment
Note: For Electricity Generation Chart, Total Demand based on BCG Electricity Demand Estimation; Grid Supply value gotten from NERC as total energy received by all DisCos in the country; Other sources assumes only off-grid solar.
Source: Nigeria Power Africa Fact Sheet, IFC report 'The Dirty Footprint of the Broken Grid' (2019), BCG Electricity Demand Estimation 2020, NERC Financial Report 2020, Consultant Analysis

Based on current trajectory, total GHG emissions from generator is expected to increase by 45% in 2030, with residential segment contributing 19%

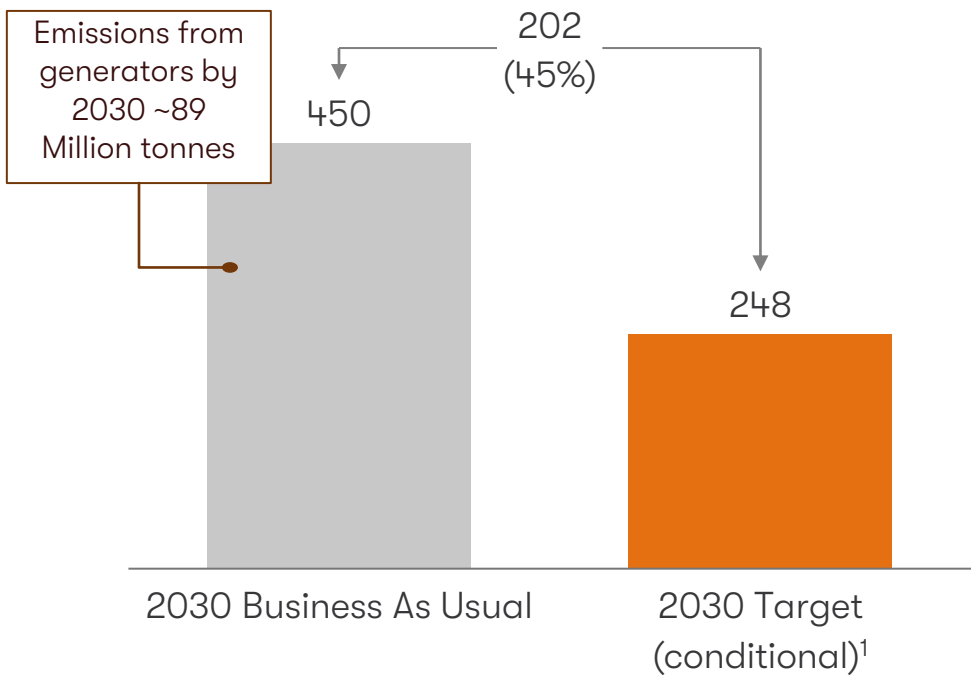
GHG emissions by segment by 2030
(Million Tons CO_2e)



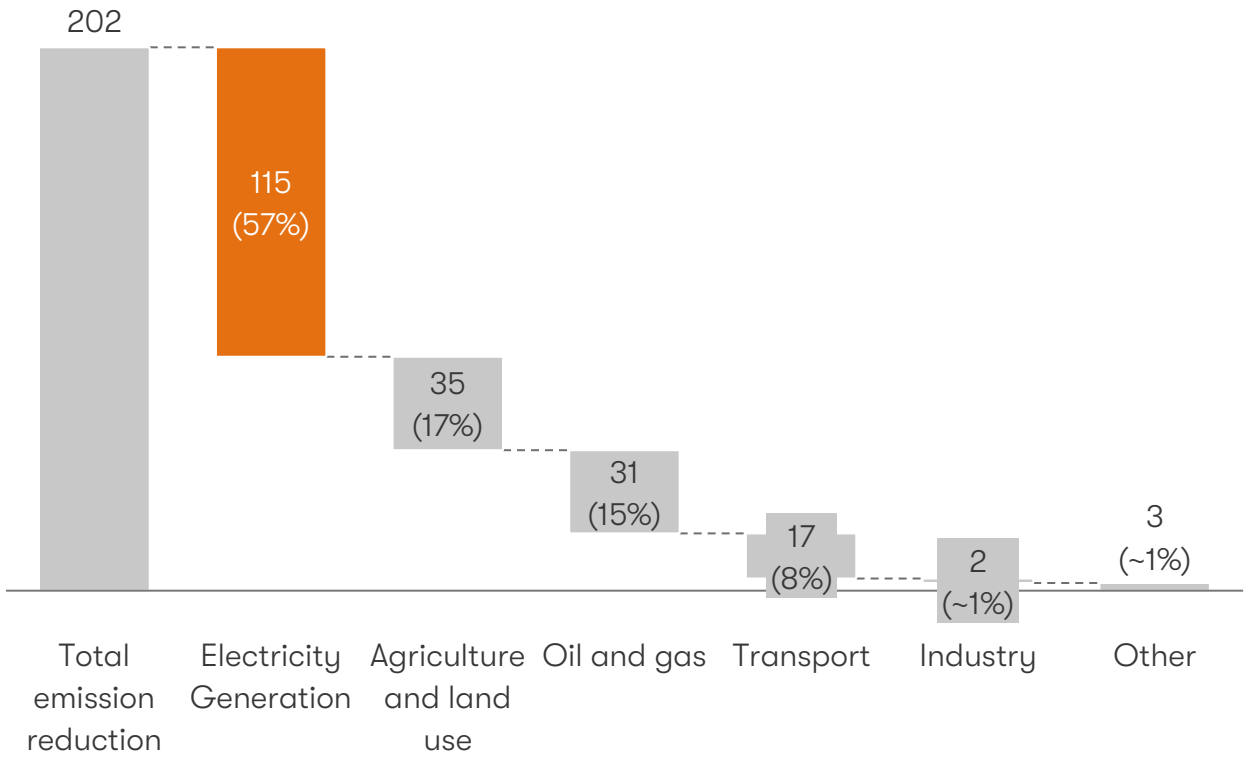
Note: 1. Split of electricity consumption by sector used to estimate annual installed capacity of generators by segment
Source: Consultant Analysis

FGN has set an ambition to reduce GHG emissions by 45% in 2030 with electricity generation identified as a major source of reduction

Projected emissions in Nigeria in 2030
(Million Tonnes CO_2e)



Projected emissions reduction by sector in 2030
(Million Tonnes CO_2e)



1. Conditional target are target emissions Nigeria aims to achieve with international support in the form of "finance and investment, technology and capacity building"
Source: World Bank Indicators, Update on Nigeria's Nationally Determined Contribution (United Nations Framework Convention on Climate Change, 2021), Consultant Analysis

Peer countries with high fuel generator emissions have opted for solar PV systems

India

Government wants to replace 26 million groundwater pumps for irrigation with more efficient pumps that run on solar power, in an effort to relieve farmers of high costs of diesel fuel

Bangladesh

The government has initiated a move to declare a roadmap for replacing diesel-run irrigation pumps with solar-powered ones across the country. Under the roadmap, some 100,000 diesel-operated irrigation pumps will be replaced with solar-powered ones

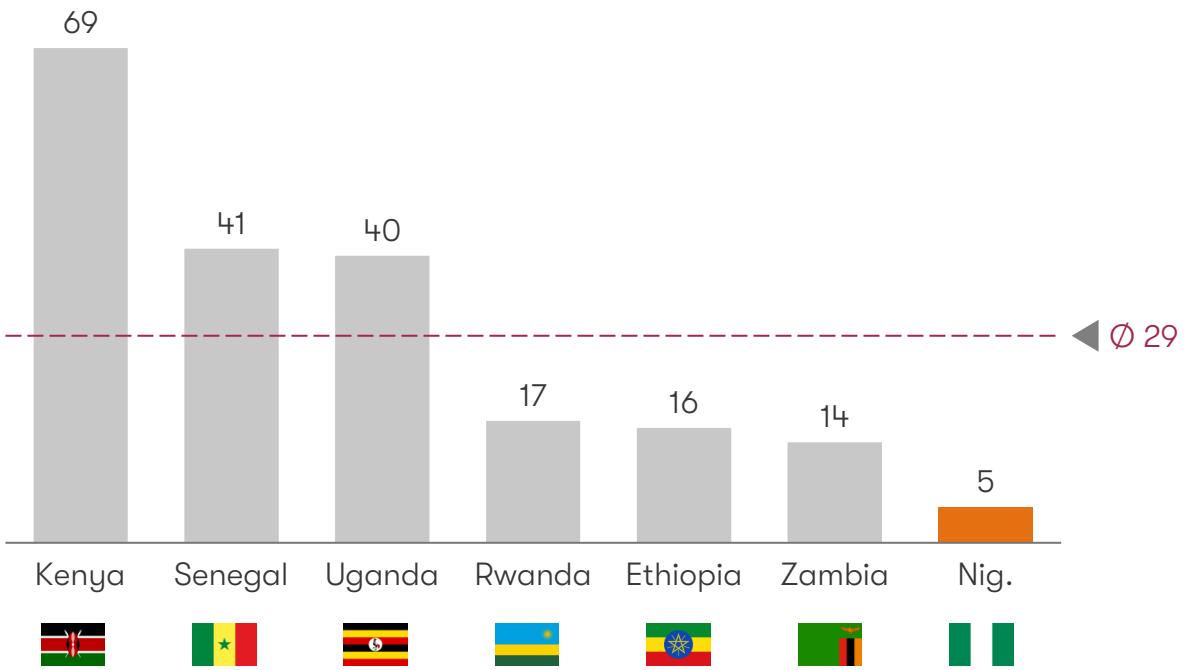
Iraq

Iraq has a plan to gradually replace fossil energy with solar energy, which has a much lower cost...it aims for a national solar energy production of 20%

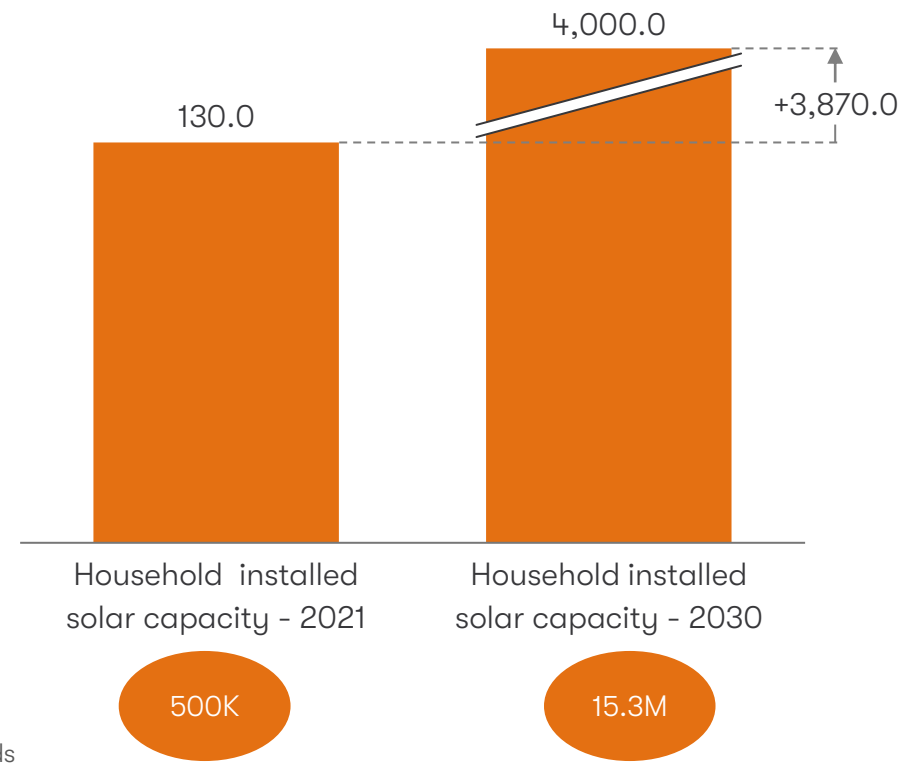
Source: Press Search, Consultant Analysis

Assuming households' solar penetration reaches peer average of ~30% by 2030, installed solar capacity could grow to 4 GW...

Household Solar penetration by Country
(%)



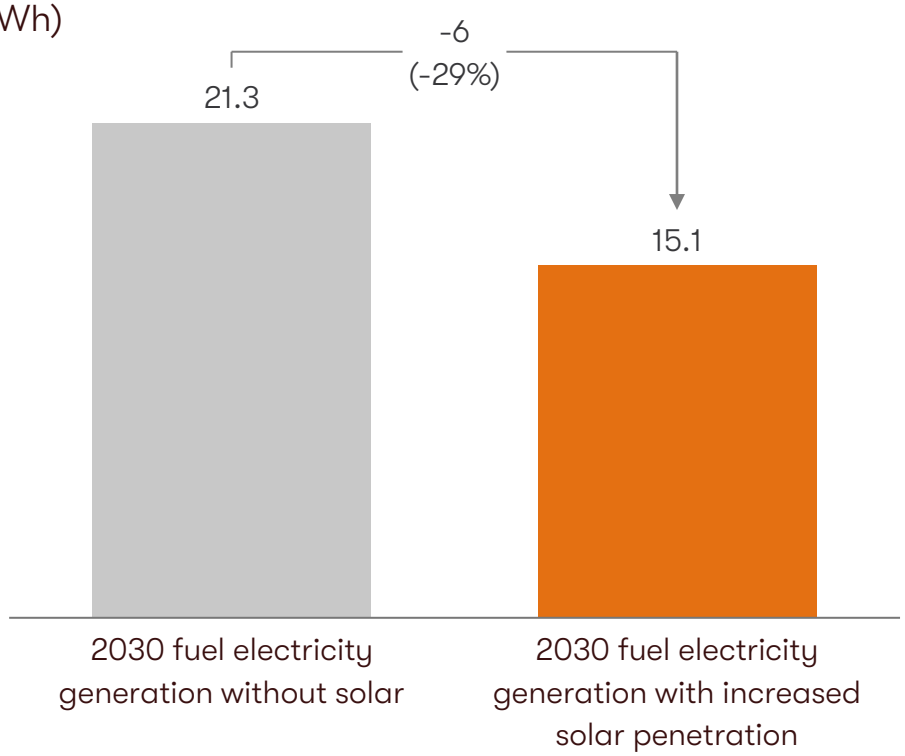
Increase in Installed Solar capacity
(MW)



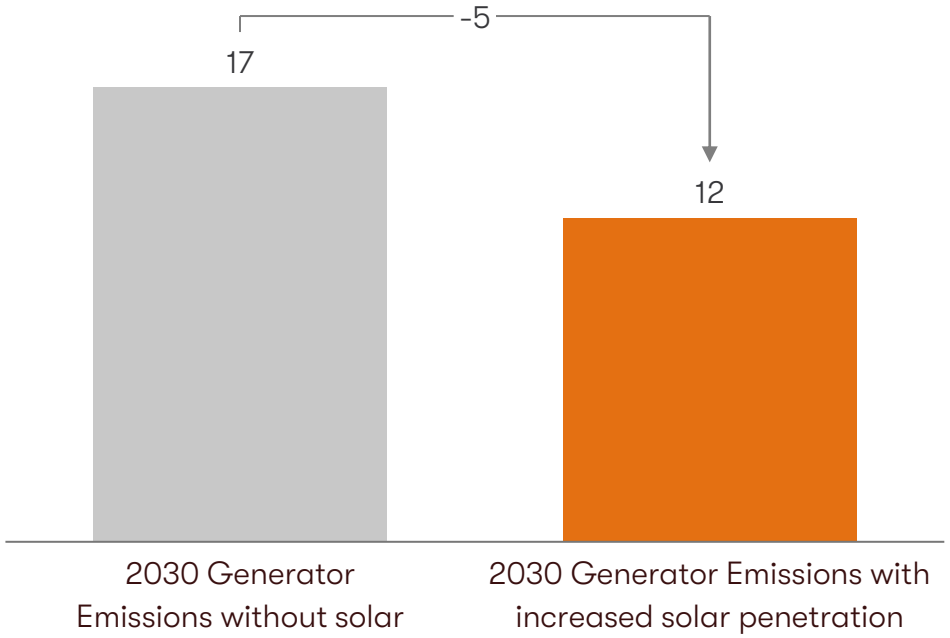
Source: GOGLA Off-Grid Market Report 2020, Consultant Analysis

...thereby reducing generator usage and cutting emissions by up to 5 Million tonnes

Impact of solar penetration on Electricity generation from household fuel generators
(TWh)



Impact of solar penetration on GHG Emissions by household fuel generators
(Million Tonnes CO_2e)



1. 2030 Emissions with increased solar penetration assumes a scenario where all installed solar capacity replaces generators
Source: BCG Estimation, Consultant Analysis

Increased adoption of solar has additional benefits as generators have harmful effects

Air pollution

- Air pollutants from generator fumes cause respiratory diseases[1] & premature deaths
- >10,000 deaths from generator fumes between 2008 and 2014

Noise Pollution

- Long-term noise exposure are linked to stress & illnesses[2]
- Average noise levels of common generators in Nigeria are >90dB, beyond WHO limits

Other threats

- Fuel generators are more likely to cause fire incidents

1. Higher risk of lung cancer 2. Hearing loss, mental stress, anxiety, hypertension, sleep disturbance
Source: World Health Organization, Press Search, African Journal of Science, Technology, Innovation and Development *'Assessment of noise-levels of generator-sets in seven cities of South-Southern Nigeria'* Consultant Analysis

Socio-economic dimension

Trade

1

Use case

1. MSME's in markets w/o access to reliable power supply

2

Rationale for use-case selection

- MSME's in markets are critical to the Nigerian economy; contributing ~90% to total retail trade volumes
- However, most MSMEs in markets do not have reliable grid electricity with >50% identifying inadequate power as the biggest constraint to their business
- Consequently, >60% of these MSME's rely on generators as their main source of electricity
- Given the high running cost of generators, most MSMEs reduce their operating hours to minimize their energy spend; resulting in lost sales
- Also, fire incidents linked to generators are prevalent leading to lost revenues
- Solar deployment creates opportunities to improve MSME operating hours, and reduce fire incidents linked to generators in markets

3

Impact measures

1. Improved electricity access to MSME's
2. Increased operating hours, and reduced fire incidents
3. Increase in GDP due to enhanced MSME income

Trade: Solar deployment across markets in Nigeria could increase Micro, Small and Medium Enterprises (MSME) income by ~30-40% through improved operating hours and reduced fire incidents

MSME income

Current state of indicator in Nigeria & role of solar

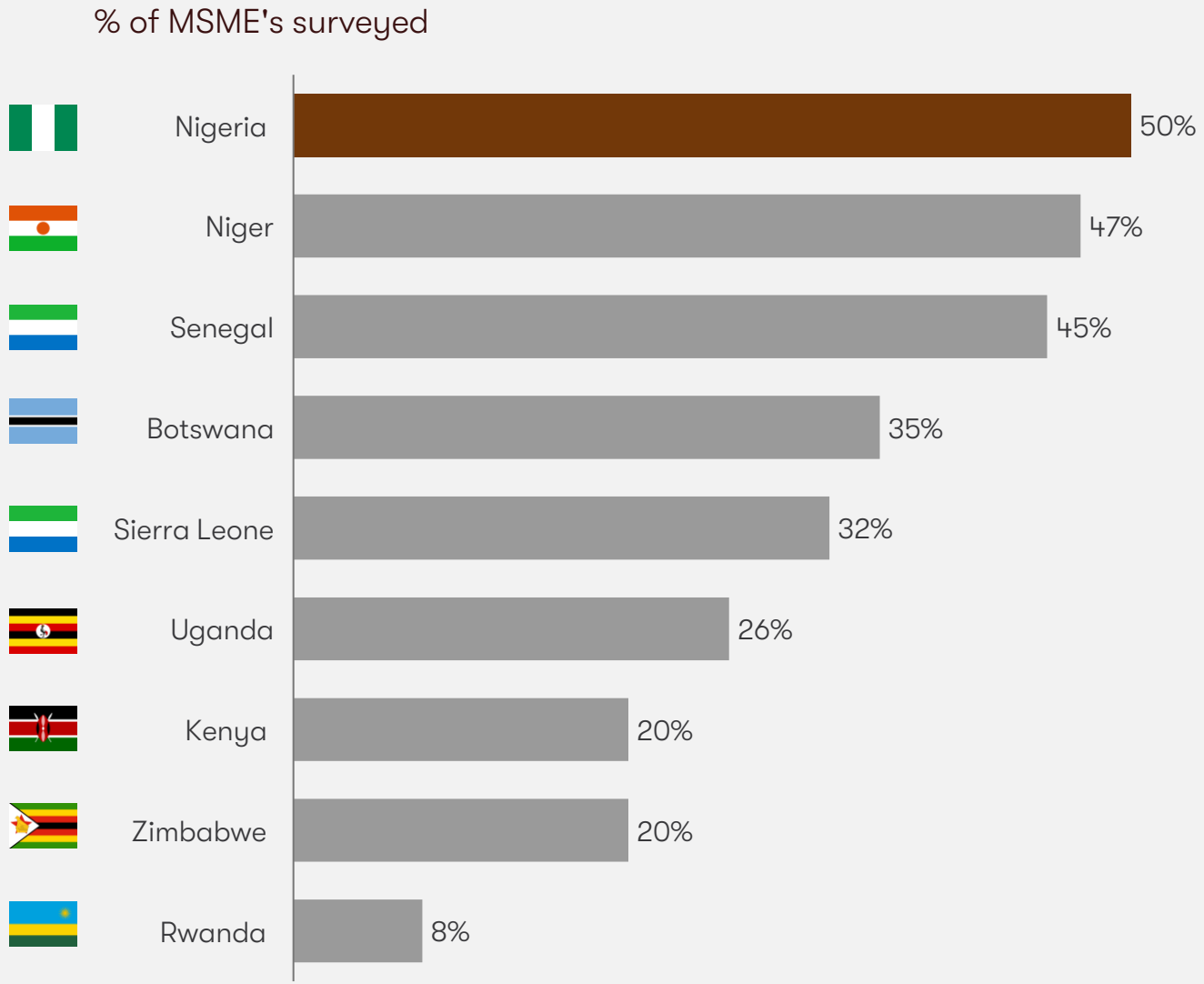
- ~50% of MSME's identify power outage as a major challenge to doing business in Nigeria
- Consequently, most MSME's (>60%) rely on generators as their primary source of power supply; typically for store lighting and ventilation
- However, reliance on generators pose two main challenges to MSME's; they are expensive to operate (generator LCOE is ~2-4x higher than other power sources), and they are also prone to fire incidents (accounting for ~10% of fire incidents in markets)
- Due to the high operating costs of generators, MSME's w/o reliable grid reduce their daily operating hours by ~1-4hrs, in order to cut down amount spent on generators, resulting in ~15-20% loss of sales annually
- Also, inadequate generator safety measures in most markets result in prevalence of fire incidents, leading to annual sales losses of ~USD100-300m (from damaged goods, and lost sales from market closure)
- MSME's in markets with solar mini-grids however witness improved operating hrs. (~1-5 extra hrs of ops.), and reduced fire incidents from generators
- Wider deployment of solar across markets in Nigeria, could result in increased MSME operating hours, reduced fire incidents from gen sets, and increase GDP through higher MSME income

Benefit from solar adoption

~30-40%	Increase in MSME sales from enhanced operating hours and reduced fire incidents
~$15-20bn	Uplift in MSME sales from enhanced operating hours and reduced fire incidents
$1-2b	Uplift in GDP (~0.3% increase) from higher MSME sales

~50% of MSME's identify electricity as a key constraint to doing business in Nigeria...

Survey of MSME's in Nigeria reveal electricity as a key constraint to doing business



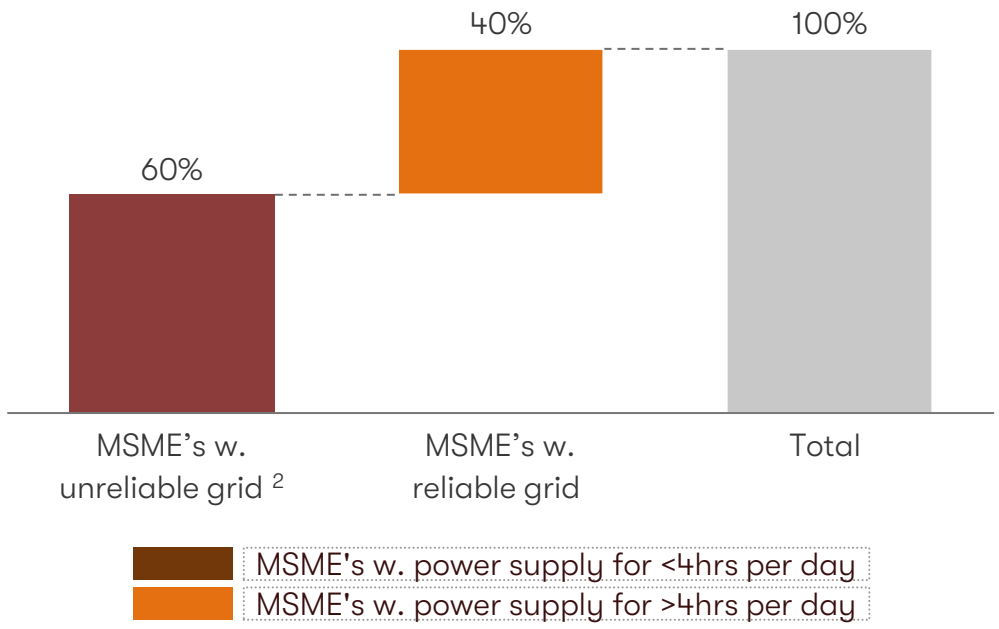
NOTE: 1. Data across countries span 2013-2017 depending on data availability; 2. In Nigeria, ~2,500 SMEs were surveyed across ~19 states Source: World Bank Enterprise Survey; Consultants Analysis

Draft

As a result of inadequate grid power supply, most MSMEs rely on generators as their main source of power

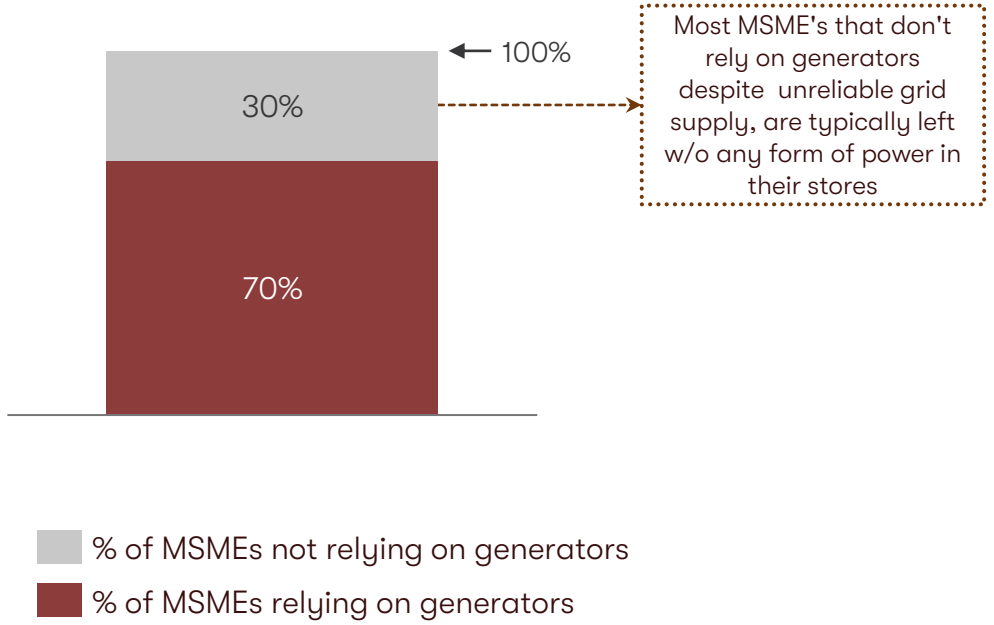
Only ~40% of MSME's have access to reliable power supply...

(% of SME's reporting grid availability)[1]



... and ~70% of MSME's w/o reliable grid supply rely on generators as a primary source of power

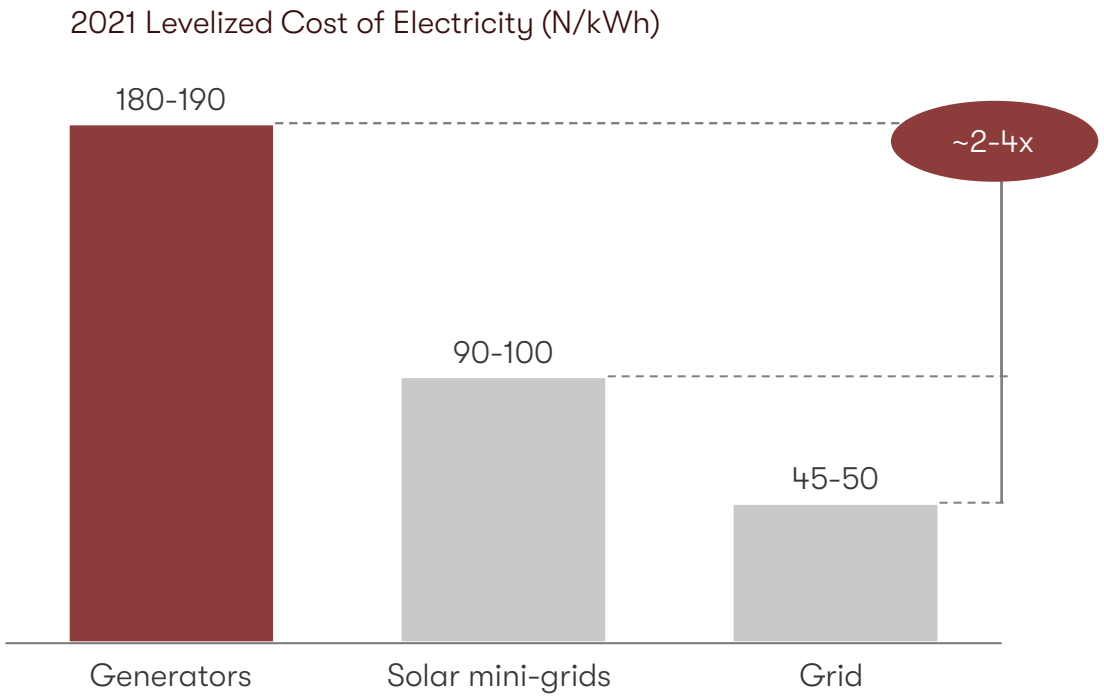
MSME's relying on generators (%)[3]



NOTE: 1. Leveraged All-on's energy need assessment survey of ~1.5m SMEs in three states , to determine avg. hours of reliable power supply received by market traders; 2. Already accounts for ~21% of market traders estimated to be off-grid; 3. Data from World Bank Enterprise Survey, 2014
Source: Nigeria Energy Needs Assessment and Value Chain Analysis; Consultant Analysis

However, reliance on generators pose two main challenges to MSME's; they are expensive, and are prone to fire incidents

Generators cost ~2-4x more than other sources of energy



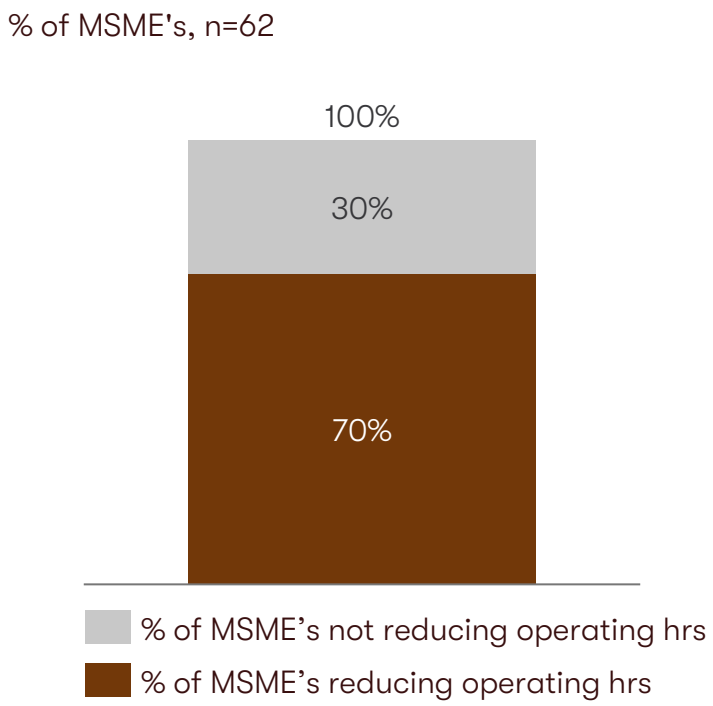
Generators cause ~10% of fire incidents in markets across Nigeria

~10% of market fires are caused by generators

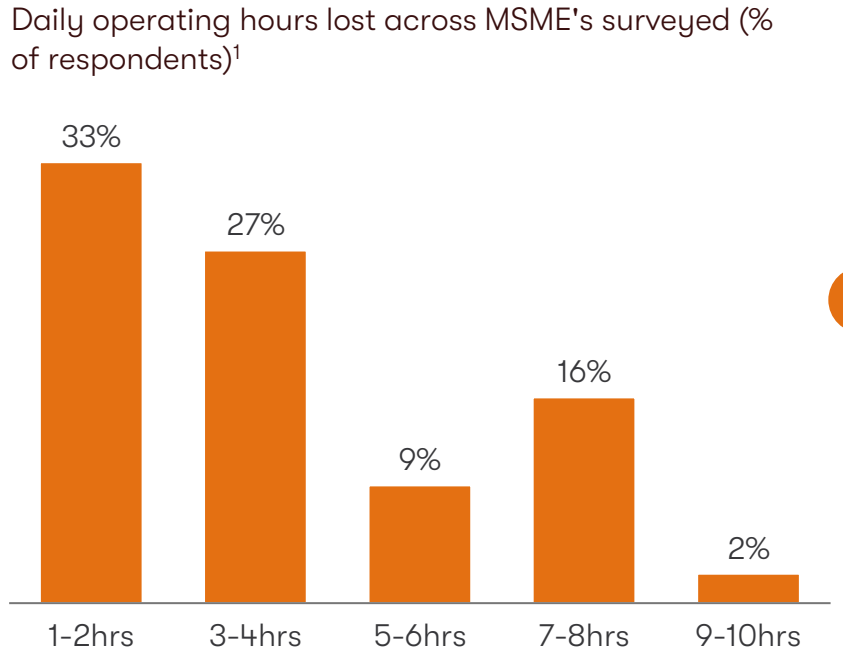
1. Includes both LCOE for petrol and diesel generators; 2. Assumes current LCOE for mini-grids reduce based on current global hardware cost trajectory and cost-savings documented and modelled by RMI (which depend on remote monitoring and payment, automated software, clustering, and other measures), to reach $0.25/kWh 3. Grid refers to tariff alone; 4. Exchange rate used was NGN400/$, to reflect prevailing rate in 2019. Source: Rural Electrification Agency, 2017; Power For All Fact Sheet , 2019; National Fire Statistics, 2015; Consultants Analysis; BCG Experience

Given high running cost, MSME's relying on generators reduce their operating hours to minimise energy spend, resulting in ~USD4-5bn in sales, lost annually

~70% of MSMEs typically reduce their operating hrs. to minimize generator running costs...



...with 60% of the MSMEs affected losing ~1 - 4 hours per day



~USD4-5bn in sales lost by MSME's in Nigeria annually from limited operating hours[2,3]

Question: 1. Did the high cost of running your generator limit your operating hours?; 2. On average, how many hours of operations did you loose daily because of inadequate power supply? NOTE: 1. n=45 – representing number of respondents with limited operating hours due to high cost of operating generators; 2. Calculation was done assuming that ~49% of the 14-17mn MSME's in Nigeria w/o reliable power supply and relying on generators have limited operating hours due to high cost of running generators. Total income calculated to be ~USD23-28bn with ~15-20% of the annual sales lost; 3. On weighted average basis, ~15-20% of annual sales was lost across all MSME's surveyed, due to reduced operating hours
Source: SMEDAN Report 2017; Consultants Analysis; BCG Market Survey, 2020 (n=62)

Beyond reduced operation hours, generator usage is also a major cause of fire incidents in markets where MSMEs operate

Non-exhaustive

Generators cause fire incidents in markets in various ways ...

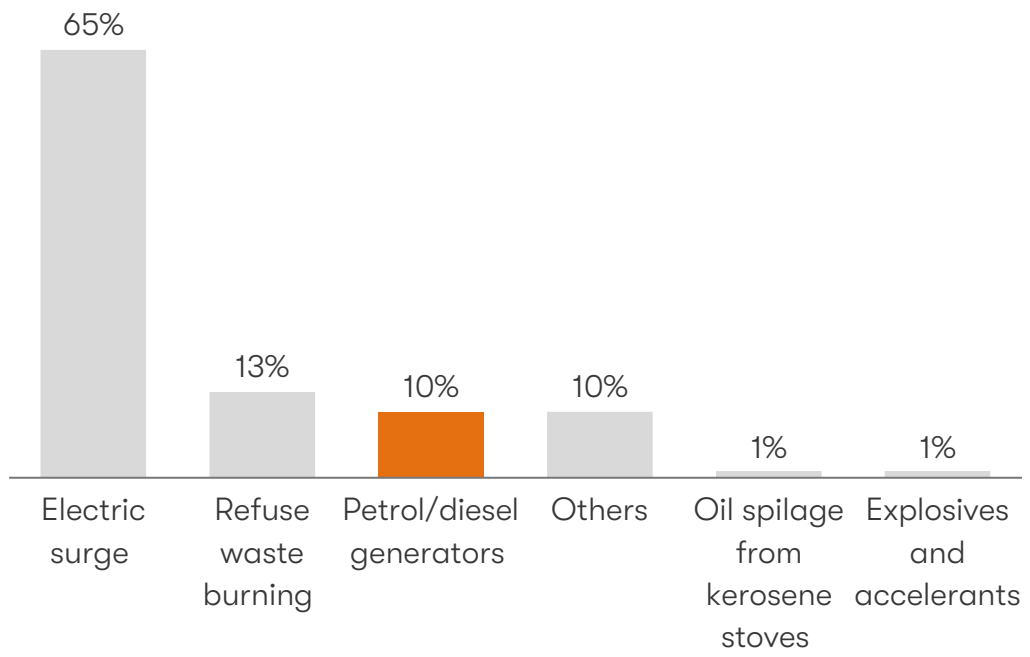
Most markets have no central generator stand, limiting space available for MSME's to safely locate their generator sets, and resulting in inappropriate storage of generator fuels inside stores

Most MSME's in markets refuel running generators, in order to prevent power outage as they engage in their economic activities, resulting in fuel spillage on hot engine parts, which triggers explosions

MSME's in markets connect their gen sets directly to the stores, w. no circuit breaker in place to control voltage fluctuations in the event of generator overloading

...and contributes to ~10% of market fires in Nigeria

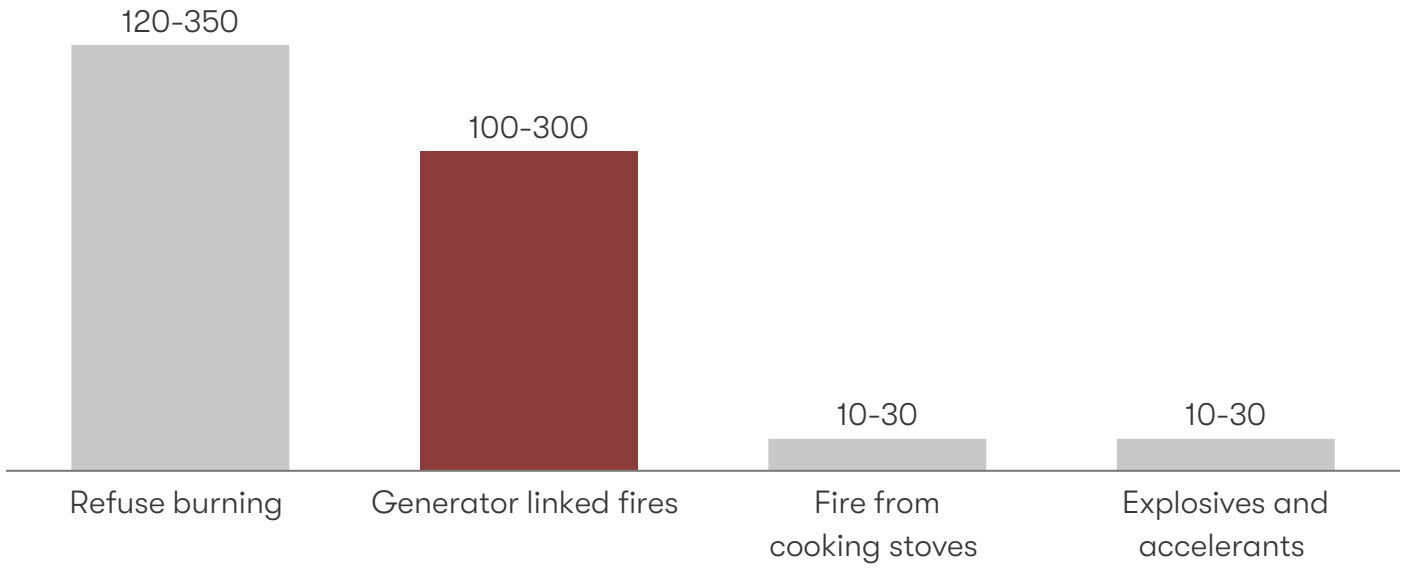
Distribution of market fire outbreaks in Nigeria by source of fire (%)



1. Distribution of fire outbreak by source was determined using avg. # of commercial fires as disclosed in the National Fire Statistics Report (i.e., avg. of 20 p.a.), and assuming ~50% of this was in open markets; 2. Share of open market fires was estimated using the # of fires recorded in Lagos state for 2013 (~26) and assuming the same pattern was seen across Ibadan, Port Harcourt, Kano, Abuja
Source: National Fire Statistics of Nigeria, 2015; Consultants Analysis; Press Release

MSMEs in markets lose ~USD100-300m annually (~1% of their gross sales) to fire incidents caused by generator sets

Annual sales lost by MSME's, by source of market fire (USD'M)



Losses from fire incidents include sales lost from damaged goods and lost sales from market closure. Market closure represents >50% of total sales lost, as markets are closed for ~2-5months following fire outbreak, resulting in significant monthly losses in market revenue of ~USD2-4m

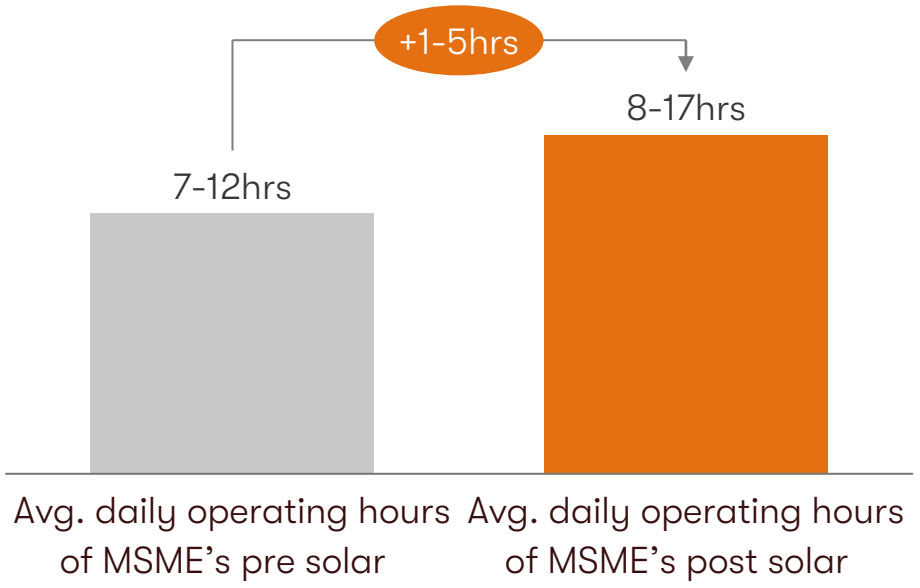
MSME's in markets loose ~1% of their sales annually from generator linked fire incidents[1]

1. Sales of MSME in markets is calculated to be ~USD23-28bn. Assumes MSME's make ~$3.5k annually in sales; 2. Estimated sales lost across each fire type includes both loss of goods due to damages as well as market closure loss 3. Market assumed to be closed for ~2-5 months after fire outbreak; 4. Exchange rate used is NGN400/$
Source: SMEDAN Report, 2017; Economist Intelligence Unit; Africa Consumer sentiments; Planet Retail; Euromonitor; Consultant's analysis

However, findings show that MSMEs in markets with solar witness 30 – 40% uplift in revenue due to longer operating hours enabled by improved power supply…

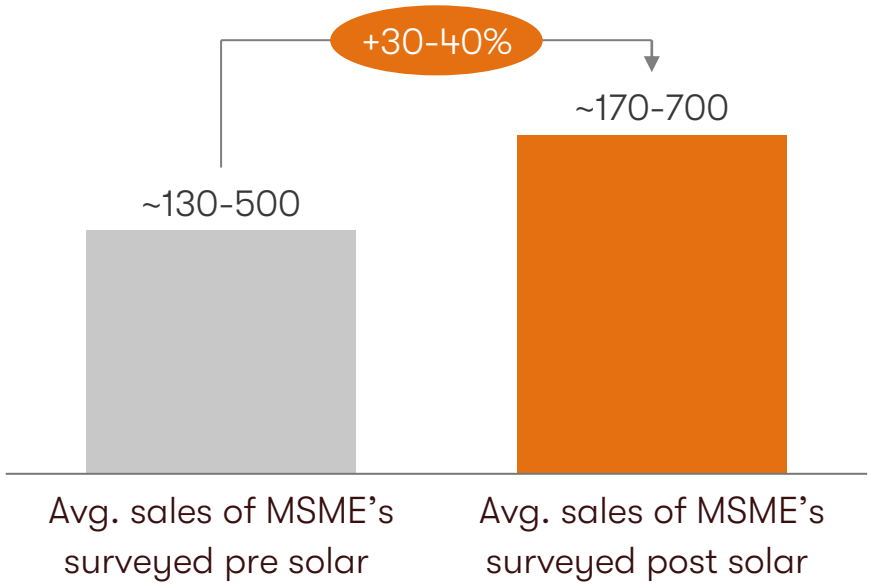
On avg, MSME's in Iponri markets operate for ~1-5 extra hours daily, due to enhanced access to reliable power supply

Avg daily operating hours of MSME's in markets



Consequently, MSME's report ~30-40% increase in monthly sales

Avg. monthly sales of MSME's in Iponri market (USD)

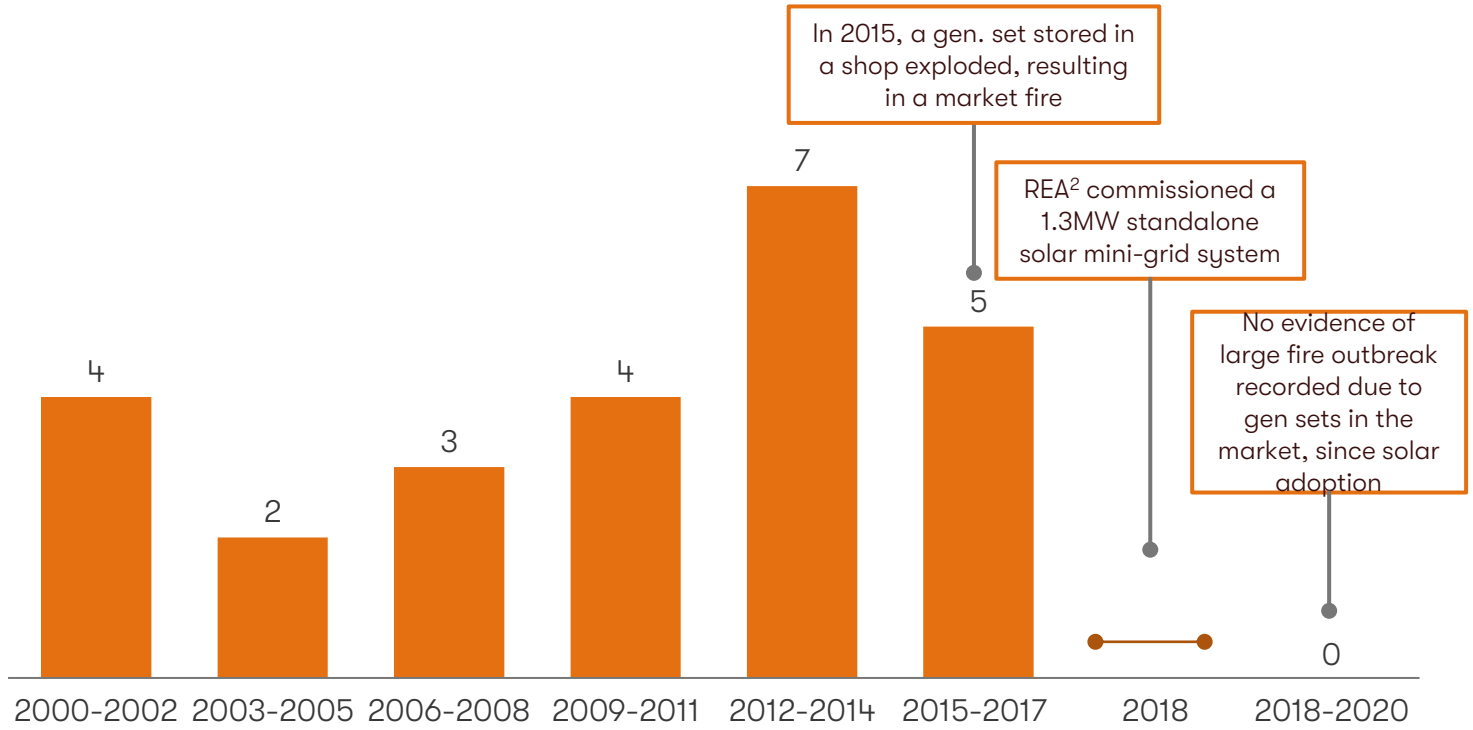


Question: 1. On average, how many hours did you operate your business daily? (before solar adoption); 2. On average, how many hours do you operate daily? (after solar adoption); 3. On average, how much was your monthly sales before solar adoption?; 4. What percentage increase in sales did you witness after solar adoption?; 5. Exchange rate used is NGN400/$

Source: World Bank Open Data; BCG Market Survey (n=62, 45 valid responses)

....and save ~USD2-7mn annually in sales, due to fewer fire incidents post solar deployment

Fire incidents at Sabon Gari Market pre and post solar adoption



Value of goods lost per fire[1] incident (USD'M)	0.36	2.14	2.48	2.95	2.24	4.01	0	0

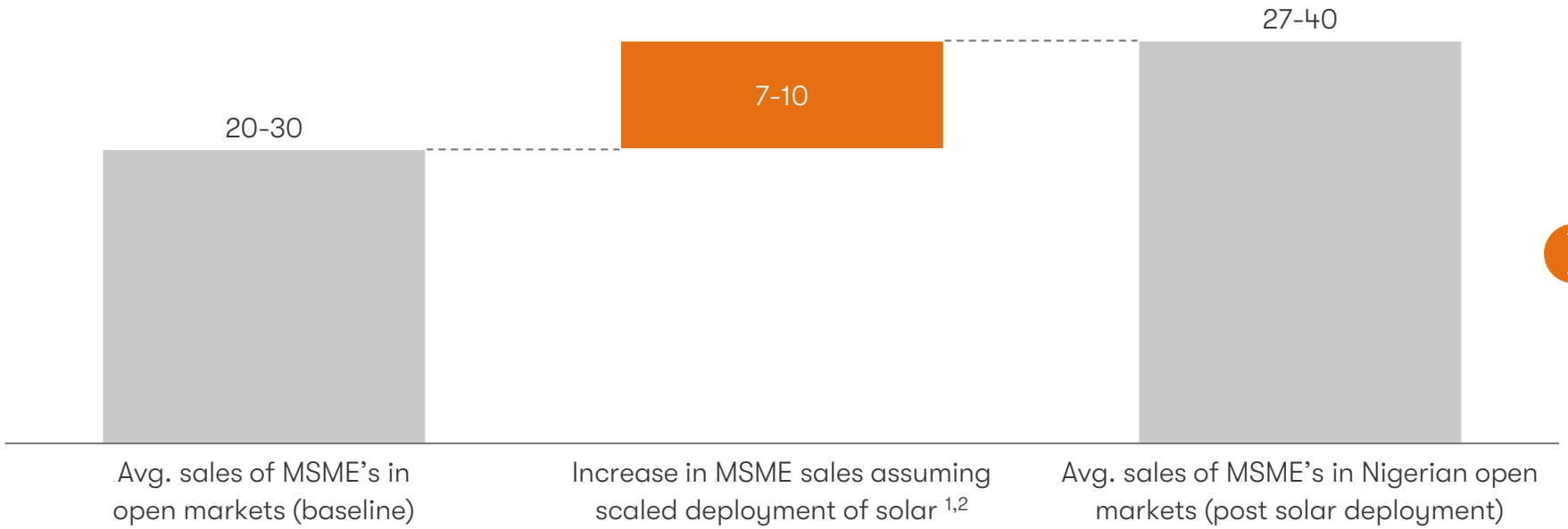
~2-7m

million dollars saved annually from averted damages of goods, and averted sales lost from market closure

1. Includes damaged goods; 2. Rural Electrification Agency; 3. Assuming Sabon Gari witnesses ~4 market fires every 3 years, with 1 fire due to generator linked factors; 4. Amount saved from generator fires calculated for both goods saved and averted market closure. On avg. $2.36m is assumed to be saved on prevented damages to goods. Also, ~$2-4m on avg. is assumed to be saved for every month the market is opened for. Months of market closure averted was calculated to be # of fire outbreak * # of months market will be closed for following outbreak (i.e., 2-5months). Sources: National Fire Statistics; Federal Fire Service Report, 2000-2017; Nigerian Building and Road Research Institute (NBRRI), (Federal Ministry of Science and Technology, Abuja, NigeriaWorld Bank Enterprise Survey; Consultant Analysis

Wider deployment of solar across markets in Nigeria, could result in ~USD7-10bn increase in MSME income leading to ~USD1-2bn uplift in GDP

Increase in MSME sales post solar deployment
(USD'Bn)



USD 1-2bn uplift in GDP obtainable from increased MSME sales[3]

1. Calculated by multiplying Avg. income generated by MSME's in markets (i.e., 20-30bn) with % increase in income due to enhanced power supply (i.e., 30-40%); 2. Calculated by assuming total # of generator related fires in Nigeria is eliminated (i.e., 13 = 10% of 11 total market fires p.a. on avg) , and ~$100-300bn would be saved across damaged goods prevented, and market closure avoided; 3. GDP uplift calculated by applying avg. MSME margins to potential increase in revenue (i.e., 5-20% margin on $7-10bn)
Source: World Bank Enterprise Survey; SMEDAN SME Report 2017; Consultants Analysis; BCG Market Survey 2021 n=62

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Content Summary

Several challenges inhibiting solar PV market penetration identified

Financing

- Quantity: Insufficient availability of low-cost financing
- Process: Difficulty in accessing and delays in disbursement of concessional funds
- Participation: Limited involvement of local FI's[1] due to data availability & market understanding issues

Commercial

- Lack of centralized demand aggregation to create scale (to reduce acquisition cost) for viable use cases, and ownership to drive adoption
- Limited consumer awareness on benefits/ potential of solar products

Operational

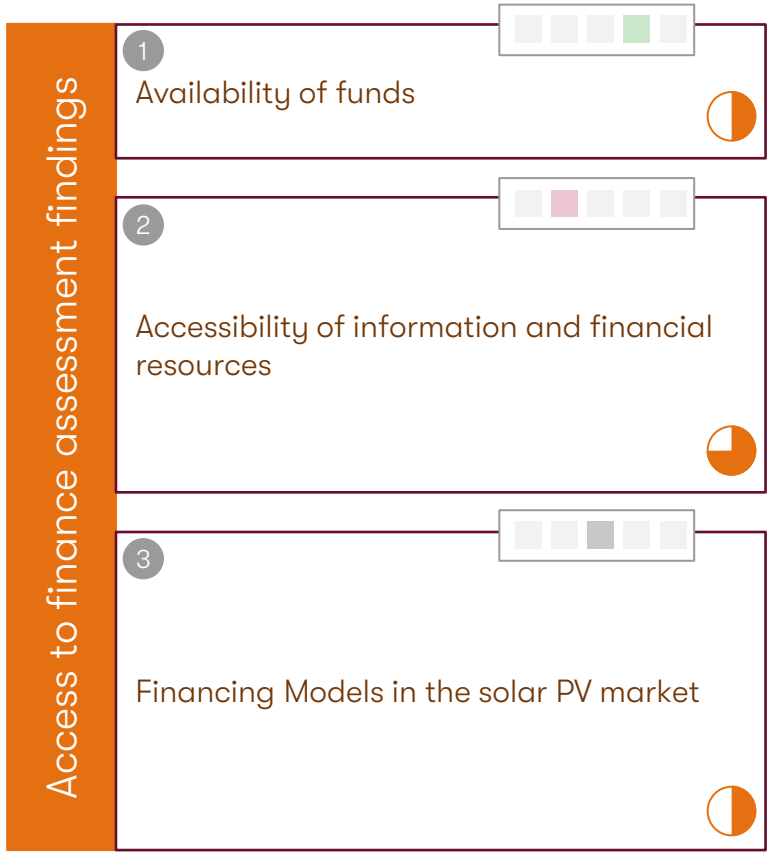
- Insufficient availability of skilled human resources and data
- Complex importation process driving costs up
- Payment collection inefficiencies
- Underdeveloped segments of value chain (e.g., manufacturing, end of life)

Enabling environment

- Insufficient enforcement
  - Quality standards resulting in presence of low-quality products in the market
  - Fiscal policies (e.g., duty and tax exemptions)

1. Financial Institutions
Source: Stakeholder consultations, Consultant Analysis

Financial: Significant financing gaps, unfavorable terms and stringent requirements to access available financing (I/II)



The sector is estimated to need ~$3.1B in financing, of which ~$1.4B in funds are available and investments worth ~$227m[1] made between 2015 and 2020 by DFIs, Dev. Partners and FGN (~55% of total), commercial banks (<1%) and other investors, leaving a financing gap of ~$1.5B. Of the investments made, only ~7% were directed towards local SAS companies

Investors: Limited knowledge of/exposure to the DPV market and its financing needs and are unable to access historical consumer data in order to make informed investment decisions.
Consumers: Low credit uptake because consumers not fully aware of the benefits of using credit to purchase solar products

Stringent eligibility criteria to access funds especially for local companies who are unable to meet the criteria or don't have the know-how to evaluate investment needs and prepare for a capital raise process.

- E.g., the NEP (exclusively focused on rural areas in Nigeria) have only been able to disburse ~$2m of the $500m available in the last 18 months and this has gone mostly to International companies

Slow fund deployment from government/dev. partners vs commercial investors, but commercial investors are out priced from the market (e.g., BOI pricing at 5-8% vs. commercial investor >9%)

Significant supplier financing exists in the DPV market, but there are issues with accessing current

- Majority of companies (esp. local companies) are in the early stage of development (new entrants) and patient capital (grants and equity) is required to achieve scale
- Most common type of financing offered by investors is debt (~55% of investments between 2020-25)
- Developers find it hard to access loans because of the high interest rates, short loan periods and high collateral requirements etc.

There are two prevalent types of financing models available to increase affordability for consumers

- One Stop shop model: Supplier provides financing directly to consumers via lease-to-own structure
- FI Partnership model: Supplier partners with Financial Institutions to provide loans to the consumers

1. 2015–2020
Source: Ace-Taf; Consultant Analysis

Favorability for market entry
Bad  Good
Consultant Confidence level

Financial: Significant financing gaps, unfavorable terms and stringent requirements to access available financing (II/II)

Access to finance assessment findings

4

Level of Involvement of local financial institutions in the solar PV market

Four commercial banks (Sterling, FCMB, UBA and Access Bank) providing financing to DPV developers

Sterling Bank and FCMB have introduced lending facilities accessible by PV developers, while UBA and Access Bank are provide funds to developers through on-lending via facilities provided by development partners

There are only 5 MFIs providing consumer financing for DPV products.

- These are typically provided via partnerships in with Solar PV companies and development partners. There are no commercial banks currently providing consumer financing.

Commercial Banks (such as Union Bank) have installed solar in 142 of 250 branches through a partnership with a PV developer – Reported energy savings of approximately ~20%. Other Banks (such as Sterling and FCMB) have indicated immediate plans to install solar in several of their branches

There 3 main challenges that impede the involvement of commercial banks in the DPV market

- Concessional financing available but loan tenures are too short: Commercial banks typically give short term (<2 years) loans at high interests to maintain profit margins. Interest rates (>15%) are sometimes too high for DPV developers.
- Limited commercial bank awareness on how to assess risks related DPV projects: Most commercial banks struggle to understand the structure and operating model of a solar PV investment
- Lack of data transparency and availability: Commercial banks typically give loans to people who have assessable and available records. PV developers lack accurate and transparent records so fail to build trust with commercial banks for better loan application assessment

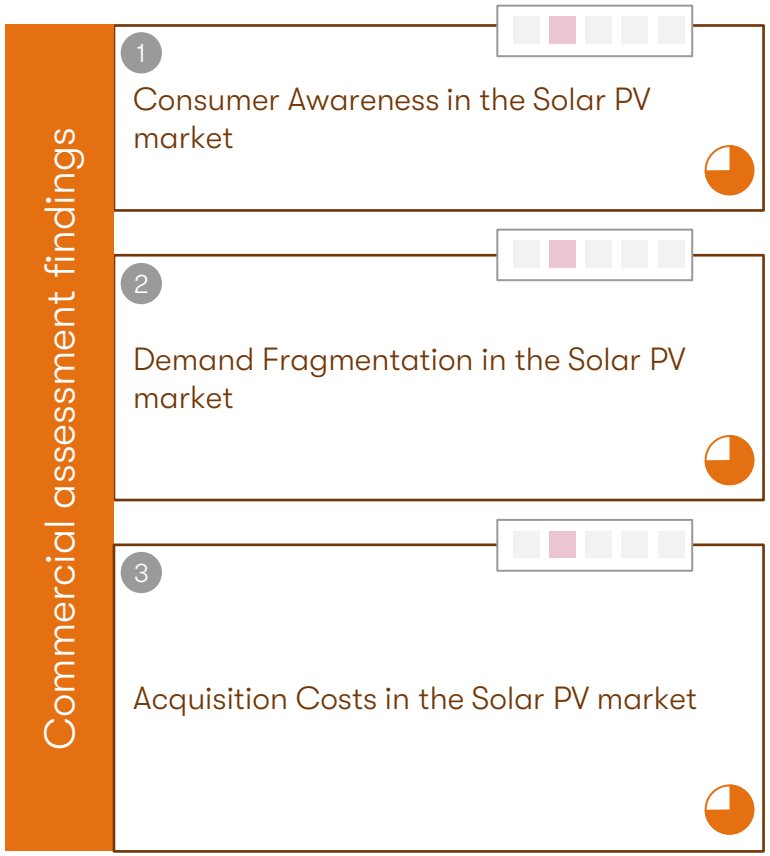
1. 2015–2020
Source: Ace-Taf; Consultant Analysis

Favorability for market entry

Bad  Good

Consultant Confidence level

Commercial: Demand is highly fragmented with early-stage PV developers unable to offer more competitive prices, hence impacting affordability



There is limited consumer awareness regarding solar and its benefits, which results in PV developers bearing the financial and operational burden of educating customers; this limits impact and attainment of scale in increased adoption of DPV products

The PV market has a highly fragmented demand, with a need for demand aggregation

- Financiers find it difficult to invest in small, fragmented projects from individual customers
- Conversely, this makes it difficult for companies to benefit from economies of scale and lowers profit margins

Pricing pressures from high inflationary environment and high dependence on FX due to high importation levels impact affordability

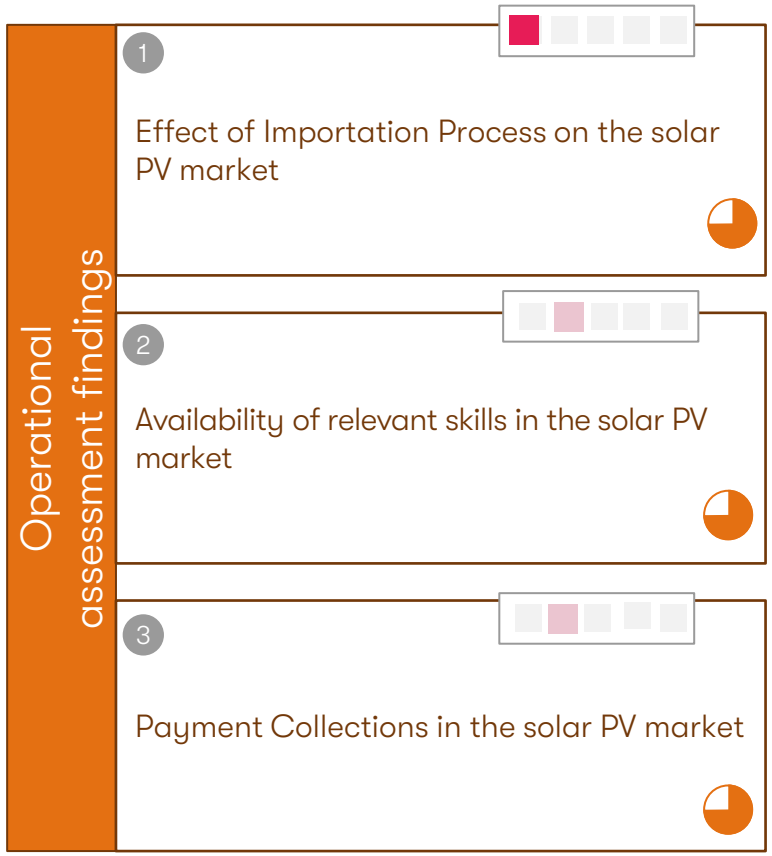
- Volatile foreign exchange regime (increased by ~110% over the last 5 years),
- ~50% increase in Value Added Tax (from 5% to 7.5%)
- high import duties on solar components (ranging from 5% to 20% on various DPV system components)

Current prices are not affordable for customers due to increase in prices as a result of increased acquisition cost for PV developers

Favorability for market entry

Bad  Good  Consultant Confidence level

Operational: Arduous importation process, low mobile money penetration and skill shortages across value chain cause inefficiencies in the DPV market



Unclear and cumbersome importation process in Nigeria causes delays in the business operations of PV developers:

- Long wait times (63% more time than SSA average) and high costs (68% more money spent in Nigeria than SSA average)
- Inefficiency in customs administration e.g., lack of performance standards for customs officers
- Lack of distinct and appropriate standards e.g., lack of coordination among customs officers, SON around HS codes, exemptions and quality standards

Skills shortages across value chain limit the ability of PV developers to scale and vertically integrate across value chain

- Limited number of qualified installers in the market reduces efficiency of solar PV projects
- Nigeria's low human capital index and low quality of education system contribute to the lack of relevant skills in the market

Development of training curriculums specific to solar or incorporating solar PV training into existing curriculum can address current problems

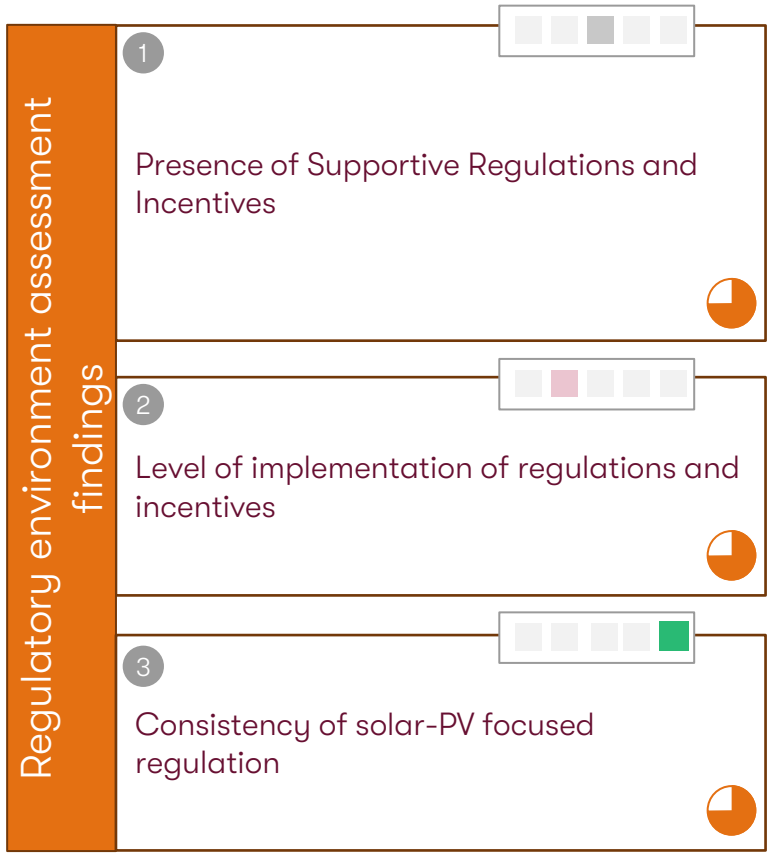
Given identity issues in-country, limited credit information and low penetration of mobile financing, collection is mostly manual and people intensive

- PV developers say that their agents are sometimes unable to reach or identify customers to physically collect cash
- Although technology-based models eliminate the need for agent networks for payment collections, there is still low penetration of mobile money (15M mobile money accounts vs ~190M cell. Subscriptions)

Favorability for market entry

Bad  Good  Consultant Confidence level

Enabling Environment: Good regulatory framework in place but implementation challenges (bureaucratic processes) limiting impact



The Nigerian government has introduced several regulations that support the growth of the RE/DPV market…

- Examples include: 5-year tax holiday for manufacturing companies in RE sector, 0% import duty on solar components; regulations for FIT for RE sourced electricity;, SONCAP standards to ensure customers have access to high quality products

However, there are regulations that limit growth and there are regulatory gaps that need to be addressed:

- Examples of regulation limiting growth: Increase in import duty on solar products (except panels) from 0% - 5%; increase in VAT (5% - 7.5%); High duty on batteries (~20%); Low licensing threshold (1MW) for power generation
- Examples of gaps for which regulations need to be introduced: Lack of net and gross metering policies; No specific DPV regulatory framework that includes clearly defined guidelines to support growth of the market

Insufficient enforcement, limited understanding of and clarity on regulations:

- E.g., Suppliers reporting the need to pay duty on solar components contrary to regulations that exempt them; Consumer complaint on low quality products sold in the marketplace, Poor implementation of existing quality standards for DPV equipment, etc.,

Lengthy review and approval times for regulations - E.g.,:

- Metering programme since 2015
- FIT under review since 2016

Government regulations and actions are consistent with the ambition for increased share of solar in power generation mix. Over the last 5 years, the government has introduced several policies and regulation to support activities and growth of the DPV market in Nigeria. Examples include:

- The National Renewable Energy And Energy Efficiency Policy (NREEEP) & National Renewable Energy Action Plan (NREAP 2015 – 2030) - Develops renewable energy and energy efficiency (RE & EE) targets and action plans
- Power Sector Recovery Programme - Increases electricity access by implementing off-grid renewable solutions
- NERC Minigrid Regulation - Provides definition, registration and grant of permit for minigrid systems

Favorability for market entry

Bad  Good  Consultant Confidence level

Content Summary

Leveraging stakeholder consultations and learnings from benchmark countries, 12 interventions identified; structured into 4 pillars

1 Access to finance enablement

2 Institutional strengthening & capacity development

3 Customer awareness & acquisition

4 Technical and regulatory reforms

Interventions

- Develop solar developer focused financing programs to increase availability of low-cost financing
- One-stop shop to support developers around access to funding issues in current financing programs
- Refine funding processes of existing solar focused programs
- Channel consumer debt financing through local Fis and improve local FI involvement

- Develop and provide standardized training programs focused on key skills required across the value chain
- Improve efficiency during payment collections by:
  - creating partnerships with existing agent net.
  - developing payment platforms
- Simplify importation process to reduce importation costs

- Create a mechanism to aggregate demand from various customer segments to create scale, hence reducing acquisition cost of solar products
- Launch awareness campaign on :
  - benefits of solar systems
  - how to identify quality solar systems
  - credit instruments available for solar products

- Introduce fiscal incentives to attract investment into the sector
- Enforce quality standards and ensure stricter monitoring of quality solar products to reduce the presence of low-quality products in the market
- Introduce regulations to drive solar PV demand to contribute to solar DPV policy framework

Source: Consultant Analysis

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