Nigeria Integrated Energy Plan

Executive summary

January 2022

Powered by

SUSTAINABLE ENERGY FOR ALL

In partnership with

The Rockefeller Foundation

Global Energy Alliance for People and Planet

Context & Objectives

Key findings: least-cost access to electricity

Key findings: productive use demand

Key findings: expansion opportunity for clean cooking

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Context and objectives

Context

- **In 2019**, the Federal Government of Nigeria (FGN), through the **Rural Electrification Agency (REA), developed a geospatial model to determine the least-cost solution** to achieving 100% electrification by 2024 and 2030
- The model revealed that 100% electrification by 2024 would result in 60% of new connections from solar home systems (SHS), 29% from grid extension and 11% of new connections from mini-grids
- **SEforALL has prioritized the development of Integrated Energy Plan towards the achievement of Sustainable Development Goal 7** to 'Ensure access to affordable, reliable, sustainable and modern energy for all'
- **Nigeria's IEP goes a long way towards being an exemplar of an Integrated Energy Plan, but has key limitations** that the FGN, in collaboration with SEforALL, now seeks to address:
  - Some of its data and analysis is outdated;
  - It is not yet a fully open-access tool usable by public and private sector actors;
  - It does not incorporate clean cooking.
- Thus, an **updated Nigerian Integrated Energy Plan** incorporating electrification, clean cooking and productive use will **play a vital role in assisting the FGN in determining the tactical implementation approach for the relevant interventions**

Objectives of this project

- **To develop an updated and enhanced Integrated Energy Plan (IEP)** for Nigeria, by
  - **Updating** the existing geospatial analysis, incorporating more recent data-sets
  - **Overlaying a clean-cooking layer** into the model
  - Overlaying the **energy requirement for productive uses**
  - Ensuring the new IEP, including and their underlying **tools and data are well understood**
  - **Ensuring that the model is accessible** and usable by external stakeholders

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Context & Objectives

Key findings: least-cost access to electricity

Key findings: productive use demand

Key findings: expansion opportunity for clean cooking

Overview of the least-cost electrification analysis

Objectives

Estimate the energy demand of the unelectrified population in Nigeria

- Model identifies area without access to electricity and projects required energy demand based on household characteristics

Determine the least-cost technology mix and required investment to achieve universal electrification

- Least-cost analysis determines the least-cost electrification method for each settlement between grid connection, mini-grid construction and Solar Home System deployment based on an estimation of the lifetime connection cost for each technology

Understand implications of expanding clean cooking

- Some settlements may require an upgrade from SHS to mini-grid connections based on aggregated clean cooking demand

What it will inform

Support the Solar Naija project objective to deploy 5m SHS and Mini-grid connections by identifying prospective locations

Inform the Nigeria Electrification Project (NEP) driven by REA in collaboration with World Bank and AfDB[1] by identifying priority areas for Mini-grid development

Help REA and Discos identify priority areas for grid extension

Key stakeholders

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REA

FEDERAL MINISTRY OF POWER

Other stakeholders: Discos, TCN[2], donors and private sector players

1. African Development Bank
2. Transmission Company Nigeria

The overall electrification picture for Nigeria in 2030

5 Mn

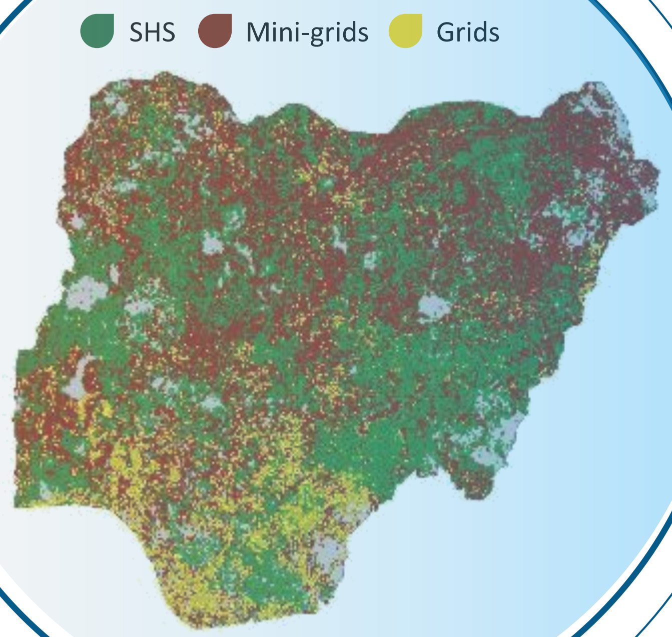
Solar home systems connections, mostly in sparsely populated areas

5.4 Mn

Grid connections in densely populated areas within close proximity of existing grid infrastructure

8.9 Mn

Mini-grid connections (104.8k mini-grids) in densely populated areas further from existing grid infrastructure



USD 25.8 Bn

Total nominal investment needed for universal access

8400 GWh p.a. & 3.6 GW

Total electricity supplied to unelectrified residential households

106 Mn & 19.3 Mn

Additional people and residential households reached respectively

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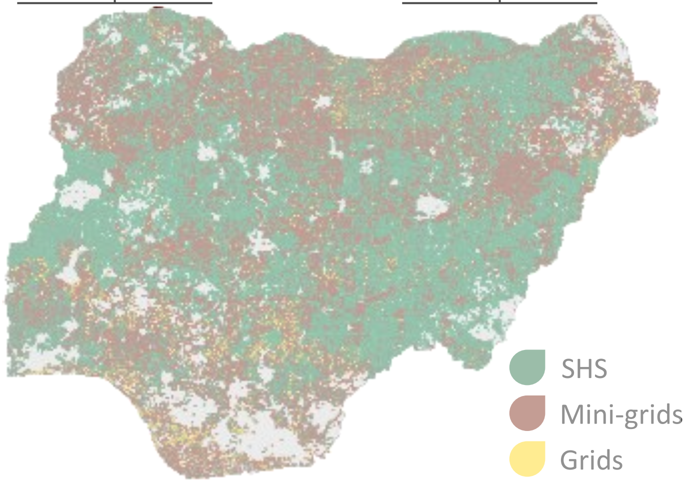
The least-cost approach to universal electrification in Nigeria will cost USD 25.8 Bn, and will result in 5Mn SHS and 8.9Mn mini-grid connections

Snapshot of universal electrification (2030)

USD 25.8 Bn	5 Mn	8.9 Mn	5.4 Mn
Total investment needed for universal access	Solar home system connections, mostly in sparsely populated areas	Mini-grid connect-ions in densely populated areas far from the grid	Grid connections in densely populated areas in close proximity to the grid



Key implications of this work

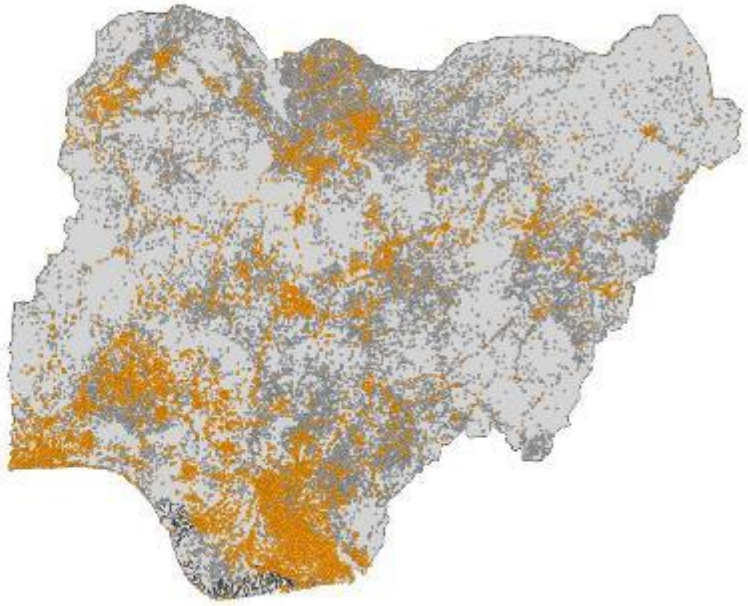
- **A** **The total cost to achieve universal access in 2030 is USD 25.8 Bn, of which USD 20 Bn will be an upfront investment** to which multiple stakeholders must contribute
- **B** **A policy driven choice to drive more mini-grids** would need to be **weighed against default risk and underutilization risk**
- **C** **Productive-use has the potential to improve economic viability of mini-grid** development in agricultural settlements
- **D** **We have identified ~5m SHS sites, in line with the Solar Power Naija program** aim to deploy 5m SHS connections
- **E** **We predict there will be an affordability gap for 92%** of SHS connections and **53%** mini-grids connections

We overlaid the institution location data with the electrification settlement layer to identify unelectrified settlements with institutions

Electrification status of healthcare facilities

Electrified healthcare facilities

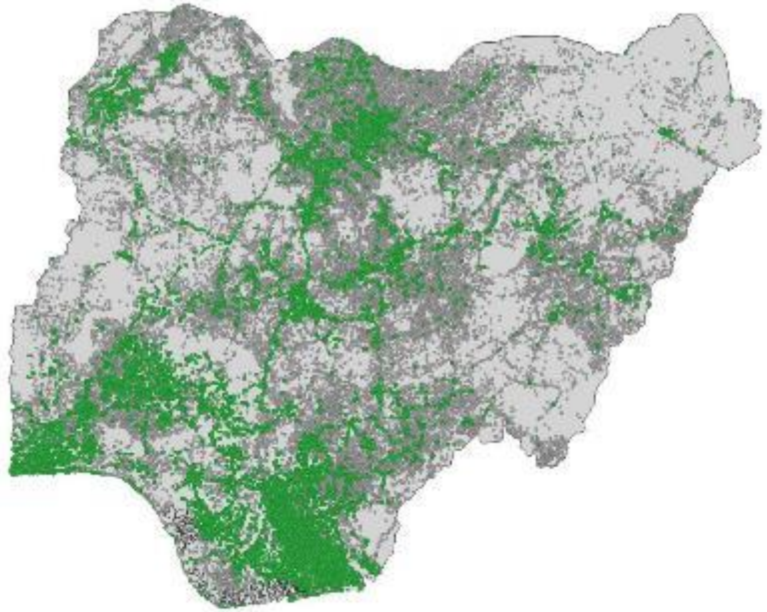
Unelectrified healthcare facilities



Electrification status of schools

Electrified schools

Unelectrified schools



Key insights:

- ~40% of healthcare facilities in Nigeria are unelectrified (18.6k out of 46k)
- ~48% of schools in Nigeria are unelectrified (36.8k out of 76k)
- These unelectrified institutions are located within the 630k unelectrified settlements
- It is possible that facilities designated as electrified are only partially or under – electrified

Source: eHealth Africa (2021) https://data.ehealthafrica.org/datasets, Fraym (2018)

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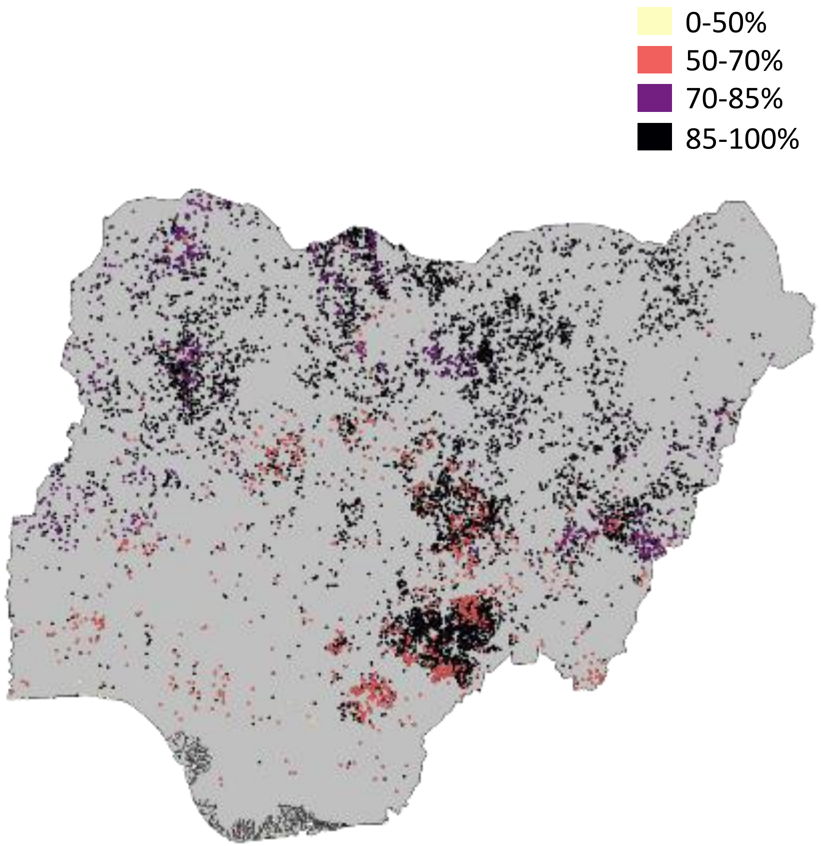
The SHS affordability gap is estimated at USD 1.3Bn which could be addressed through a subsidy of USD 266-370/connection

Households that cannot pay for SHS, %

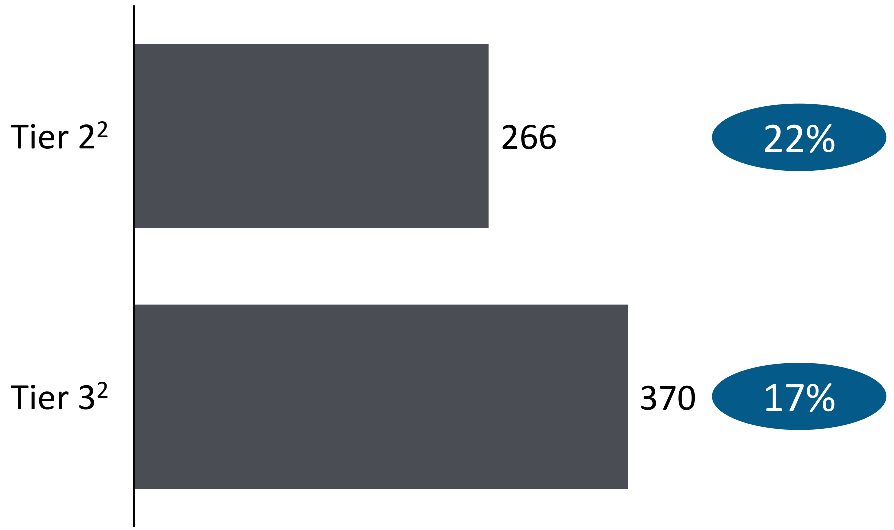


Investment required to close affordability gap, USD

USD 1.3Bn

Investment to close gap

Affordability gap per connection, USD



X% — % of SHS costs

Key Insights:

Settlements in the North have a large number of households that cannot afford SHS

An investment of ~USD 1.3Bn is required to make SHS affordable to consumers

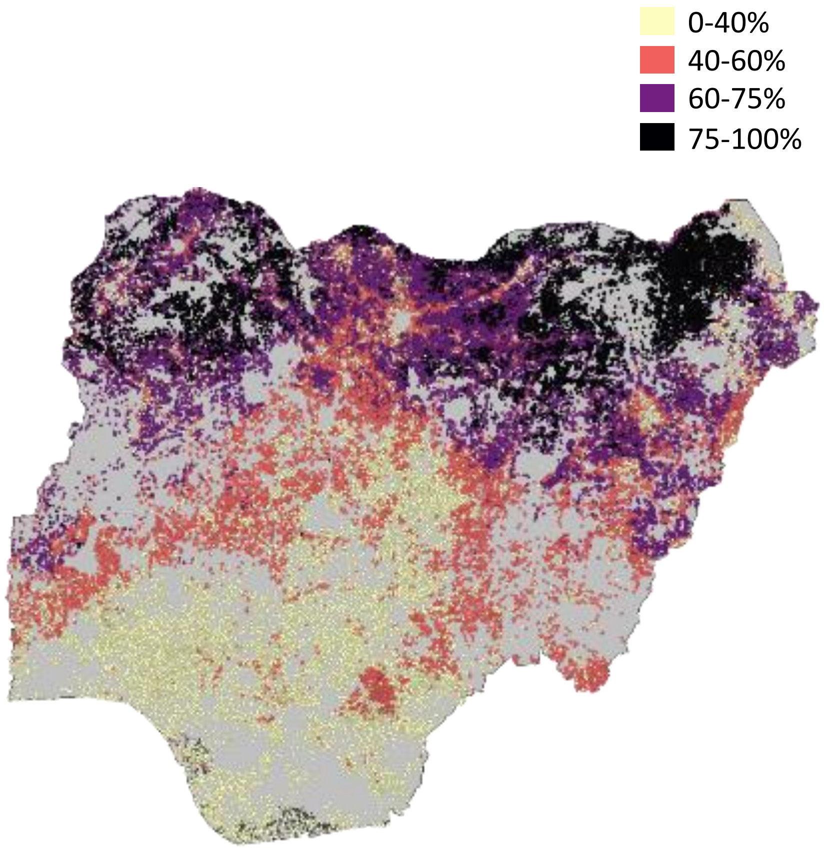
This translated to an average investment of ~USD 268 per connection[1]

1. Weighted average. Tier 2 SHS cost is USD 1202. Tier 3 SHS cost is USD 2151 (includes 3 replacements)
2. Tier 2 systems sizes are assumed at 120kW and Tier 3 systems are assumed at 200kW

Source: REA, Team Analysis

The mini-grid affordability gap is estimated at USD 681Mn which could be addressed through a subsidy of USD 145/connection

Households that cannot pay for mini-grids, %



Investment required to close affordability gap

USD 681Mn

Affordability gap per connection[1]

USD 50 - 485

Key Insights:

Settlements in the North have many households that cannot afford mini-grids

An investment of ~USD 681Mn is required to make mini-grids affordable to consumers

This translated to an average investment of ~USD 145 per connection in 2030

The NEP Government grant is currently USD 350/connection

1. Calculated as the affordability gap on the lifetime cost per connection

Source: REA, Team Analysis

Context & Objectives

Key findings: least-cost access to electricity

Key findings: productive use demand

Key findings: expansion opportunity for clean cooking

Our approach to estimating the impact of productive-use energy requirements in the least cost mix

I. Define productive-uses of energy

Identify productive-use cases for analysis within unelectrified settlements (i.e., agriculture, commercial and industrial energy uses) based on examples from other countries, discussions with experts and availability of data

II. Estimate electricity demand of productive-uses

For each of the prioritized productive-use, we:

- Map areas of productive-use activity to unelectrified settlements
- Estimate productive-use activity output per settlement
- Select electric equipment to satisfy required output per settlement
- Calculate energy demand based on activity output per settlement
- Identify SHS settlements that switch to mini-grid at least-cost based on additional productive-use demand

III. Determine impact on proposed least-cost technology mix

Aggregate additional energy requirement for productive-use and integrate in least-cost electrification model

Estimate impact on least-cost mix and required investment

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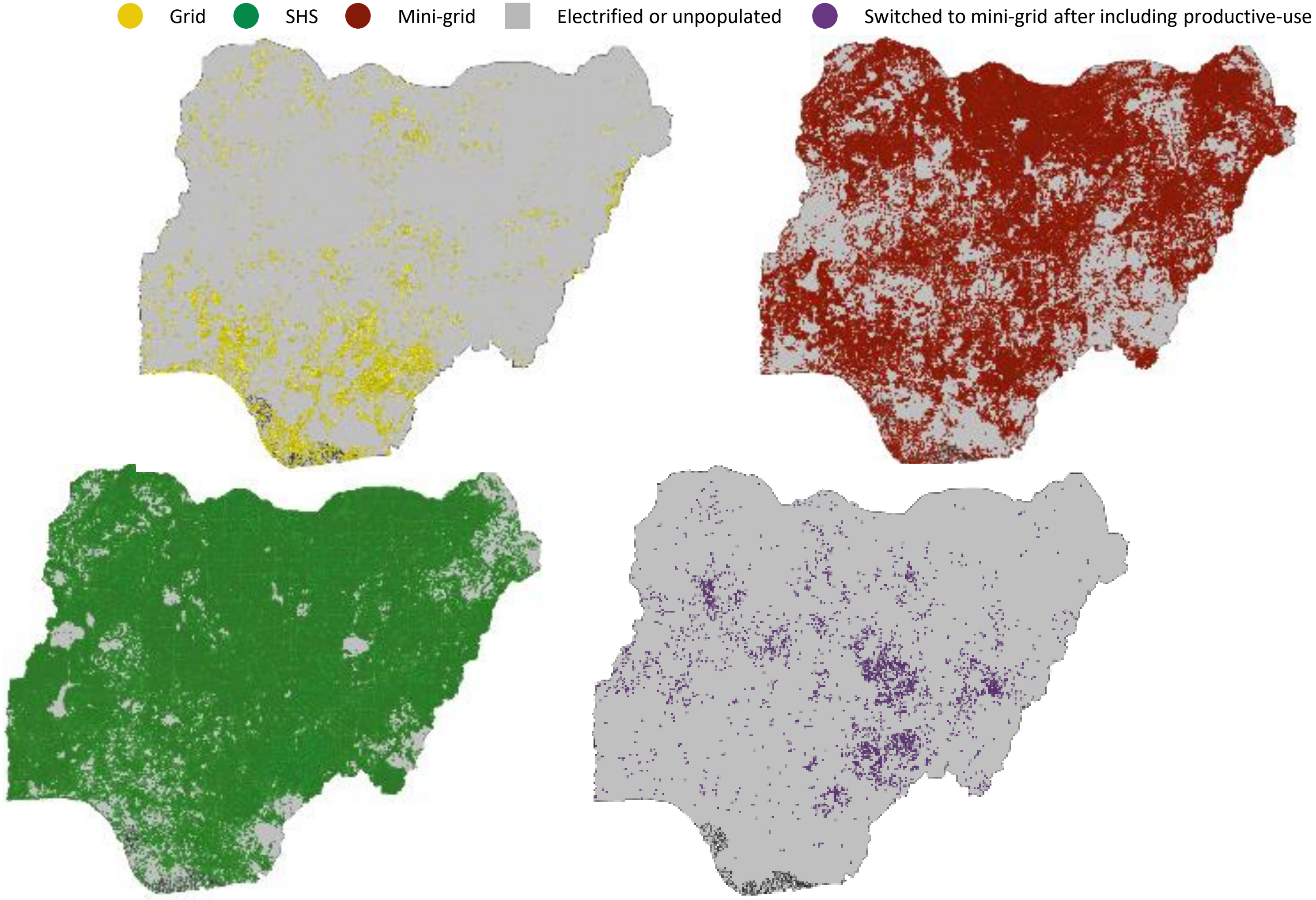
When productive-use demand is considered, the number of mini-grid connections increases by ~200k in 2030

2030 least-cost technology mix including milling productive-use



Number of settlements that can switch to mini-grid	**3,389**
Number of new mini-grid connections	**194,870**
Average reduction in least cost per connection for new mini-grids (%)[1]	**9%**
Average mini-grid cost reduction per connection for new mini-grids (%)	**12%**
Total productive-use energy demand (GWh)	**~106**

1. Cost reduction compared to mini-grid cost considering only residential demand

Source: Geospatial model (2021)

Context & Objectives

Key findings: least-cost access to electricity

Key findings: productive use demand

Key findings: expansion opportunity for clean cooking

Overview of the clean cooking analysis

Objectives

- Determine the opportunity for the expansion of clean cooking solutions, in areas with low clean cooking penetration
- Assess the potential health, climate and environmental co-benefits of clean cooking adoption
- Estimate the investment required to expand access to clean cooking in order to drive clean cooking adoption

What it will inform

Inform targeted support measures from the government for the expansion of clean cooking (e.g., subsidies to enable affordability of LPG)

Identification of potential target markets for private sector players for clean cooking equipment (e.g., Stove appliances, Gas cylinders etc.)

Key stakeholders

FEDERAL MINISTRY OF ENVIRONMENT

MINISTRY OF PETROLEUM RESOURCES

DLPGOVP
Domestic LPG of the Vice President

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LPG, e-cooking and biogas have been prioritized for analysis based on three criteria

Prioritized | ✓ Yes | ✗ No

	Local fuel availability/production potential	Compatibility with government priorities	Equipment/appliance availability
Biogas (prioritized)	Yes	Yes	Yes
Improved cook stoves[1]	Yes	No	No
Electricity (prioritized)	Yes	Yes	Yes
Ethanol[2]	Yes	Yes	No
LPG (prioritized)	Yes	Yes	Yes
Solar cookers[3]	Yes	Yes	No

1. ICS is not considered a clean cooking solution by the WHO, and RMI notes that stoves remain relatively expensive & domestically manufactured stoves have not achieved volumes to benefit from economies of scale
2. In contrast to LPG, electricity, and traditional fuels, effective distribution channels for ethanol are not yet as widespread in the country (RMI, 2021)
3. According to Solar Cookers International, the production of solar cookers in Nigeria have only been at a small scale, organizations such as the Solar Energy Association of Nigeria have plans for the mass production of solar cookers in the country, however, it is yet to be realized

Source: WHO Guidelines for indoor air quality: household fuel combustion (2014), PEDUCCT: Results Brief (Berkley Air Monitoring Group, 2018), Ministry of Environment, Department of Petroleum Resources (DPR, 2021), Nexleaf Analytics – Scaling clean cooking responsibly (2019) , Scaling e-cooking in Nigeria (RMI, 2021), Solar Cookers International

Rationale

Local fuel availability/production potential: Considers if the fuel is either available locally or can be produced in-country based on associated resource for fuel generation

Compatibility with government priorities: Considers three key energy-access priorities:

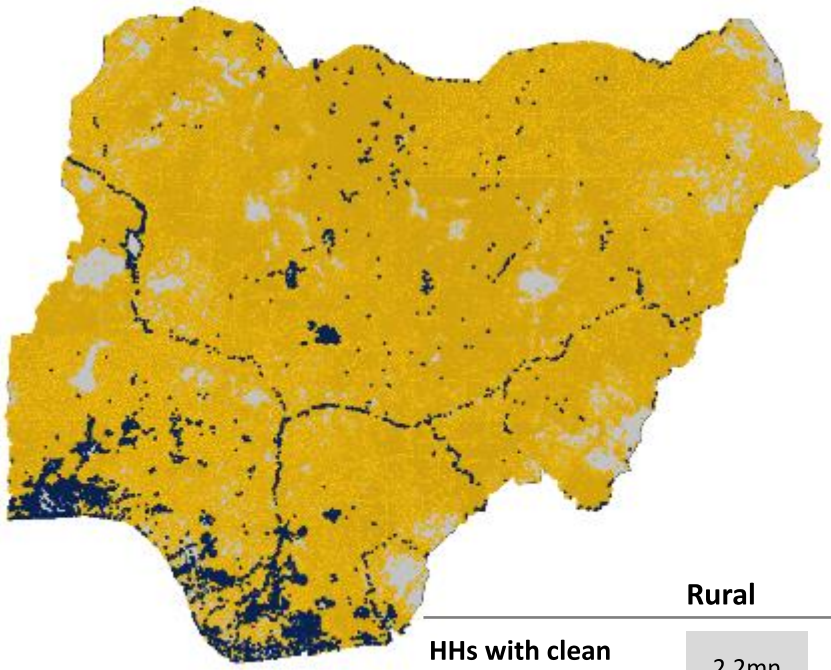
- National LPG Expansion Program (NLEP)
- Universal electrification
- Nationally Determined contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) aimed at the reduction of GHG emissions

Equipment/appliance availability: Accounts for the availability of required cooking appliance in the Nigerian market

The model identifies households with emissions-intensive cooking to determine the opportunity for clean cooking solutions

BAU scenario: Distribution of cooking fuel use (2030)

Emissions-intensive cooking   Clean cooking   Unpopulated



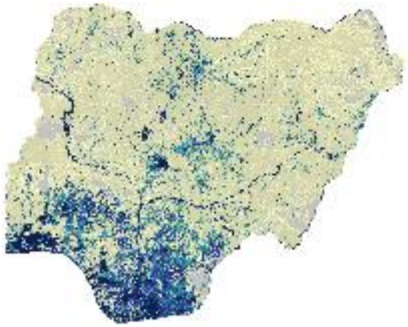
	Rural	Urban	Total
HHs with clean cooking	2.2mn	12.5mn	14.8mn
HHs with emissions-intensive cooking	23.8mn	16.3mn	40.1mn

Geospatial model output: Clean cooking opportunity (2030)

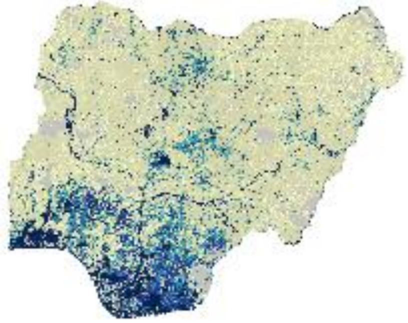
% of HHs in settlement

0-25   25-50   50-100   >100   Clean cooking   Unpopulated

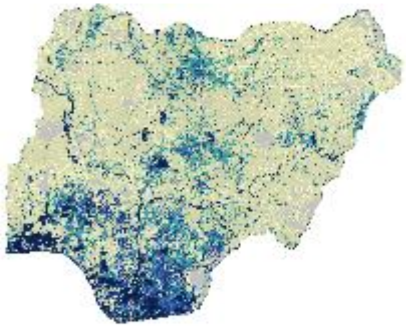
LPG



E-cooking



Biogas



	Rural	Urban	Total
HHs access-constrained from CC[1]	23.6mn	13.1mn	36.6mn
HHs with LPG opportunity	1.5mn	2.2mn	3.7mn
HHs with e-cooking opportunity	1.3mn	2.1mn	3.5mn
HHs with biogas opportunity	2.0mn	2.3mn	4.3mn

1. Defined as households located in settlements where >/=51% of its population cooks with emissions-intensive fuels

3.7mn, 3.5mn and 4.3mn households have the potential to adopt LPG, e-cooking, and biogas, respectively

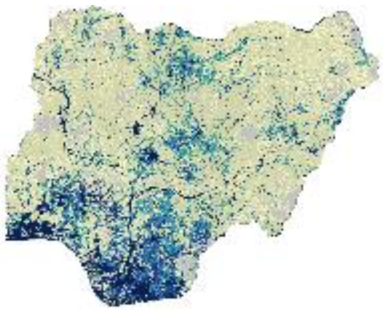
Expansion opportunity for clean cooking solutions in Nigeria in 2030, No. of households

0-25 | 25-50 | 50-100 | >100 | Clean cooking | Unpopulated

LPG

E-cooking

Biogas



	Rural	Urban	Total
HHs access-constrained from CC[1]	23.6mn	13.1mn	36.6mn
HHs with LPG opportunity	1.5mn	2.2mn	3.7mn
HHs with e-cooking opportunity	1.3mn	2.1mn	3.5mn
HHs with biogas opportunity	2.0mn	2.3mn	4.3mn

		LPG	E-cooking	Biogas
# households	**Rural**	1.5mn	1.3mn	2.0mn
	Urban	2.2mn	2.1mn	2.3mn
	Total	**3.7mn**	**3.5mn**	**4.3mn**
% of households access-constrained from clean cooking[1]		10%	10%	12%
Incremental fuel demand p.a. (MT/kWh/L)		76k MT	0.9bn kWh	190bnL
Incremental fuel value p.a., (NGN)		40bn	67bn	N/A[2]

Note:

A settlement may be attractive for multiple clean cooking solutions based on HH characteristics. For instance, a HH may be able to afford all 3 cooking solutions, have an educated adult female (indicating likelihood of clean cooking adoption), and be located in a settlement with sufficient crop waste generation for biogas, as well as either grid or mini-grid connection to enable e-cooking.

Thus, the results of the analysis are considered independently for each of the solutions to avoid double-count.

1. Defined as households located in settlements where >/=51% of its population cooks with emissions-intensive fuels
2. Biogas fuel is zero-cost, as it is generated from agricultural residue

The clean cooking opportunity could drive climate, health and time savings benefits at the national and household level

	LPG	E-cooking[3]	Biogas
Climate[1]	**6.9bn** kg Forest loss avoided from renewable & non-renewable biomass collection; **29.9%** Emissions reduction, compared to BAU[2]	**6.6bn** kg Forest loss avoided from renewable & non-renewable biomass collection; **30%** Emissions reduction, compared to BAU	**8.2bn** kg Forest loss avoided from renewable & non-renewable biomass collection; **30%** Emissions reduction, compared to BAU
Health[4]	**12.1k** Illnesses avoided annually & **551** Deaths avoided annually	**11.5k** Illnesses avoided annually & **524** Deaths avoided annually	**14.3k** Illnesses avoided annually & **649** Deaths avoided annually

Time savings (hr./HH)[5]

107 hrs.
Of cooking and fuel preparation time saved[7] annually per HH

Time savings is same across each of the solutions as a standard clean cooking use rate is applied (30%), which results in same reduction of firewood collection and clean fuels have same time efficiency parameter (85%) according to the BAR-HAP[6]

In addition to these benefits, clean cooking adoption will drive socio-economic development through its contribution to the formal economy (tax revenues), value added to GDP, employment

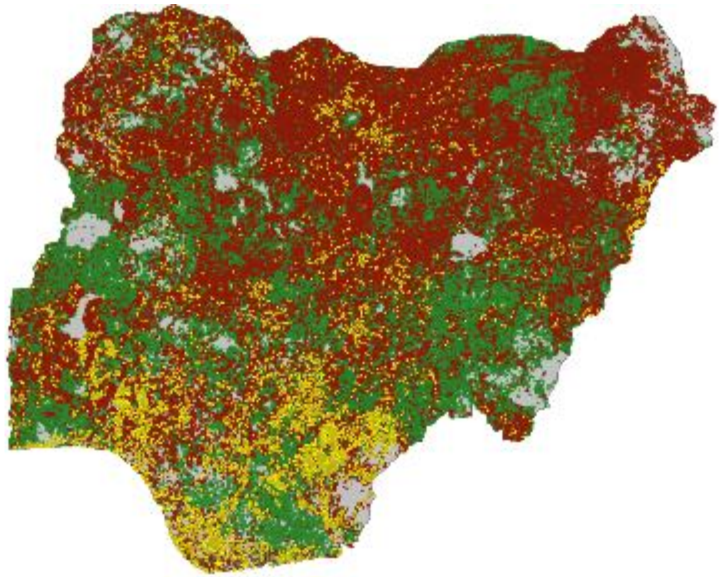
1. Forest loss calculated based on no. of HHs cooking with biomass from the baseline; differing based on the no. of HHs with high opportunity for each solution
2. Assuming sustained use of emissions-intensive fuels by HHs
3. Includes grid and mini-grid connected households
4. Annual illnesses and deaths from Acute lower respiratory infections (ALRI) , Chronic obstructive pulmonary disease (COPD), Ischemic Heart Disease (IHD), lung cancer and stroke
5. Fuel prep time saved only calculated for HHs with clean cooking opportunity that are transitioning from biomass, assuming that collection and preparation time for other fuels is minimal
6. Benefits of Action to Reduce Household Air Pollution (BAR-HAP)
7. Fuel prep. for biogas may have time costs to the HHs, however minimal as HHs have existing uses of crop waste, thus gathering residue will not be a new activity and relative proximity of digesters to users (3km catchment area) will minimize transportation time. Additionally, there is a lack of rigorous research to determine exact time costs

Source: TNC (March 2020) – Pg. 142, WHO BAR-HAP Tool, Benefits and Costs of Improved Cookstoves (Jeuland, Pattanayak – 2012), The carbon footprint of traditional wood fuels (Bailis et al, 2015), EU NILES (2021), Expert input, Team analysis

The least cost electrification pathway of 112k settlements is impacted by the inclusion of e-cooking demand

LCE[1] output, no e-cooking demand

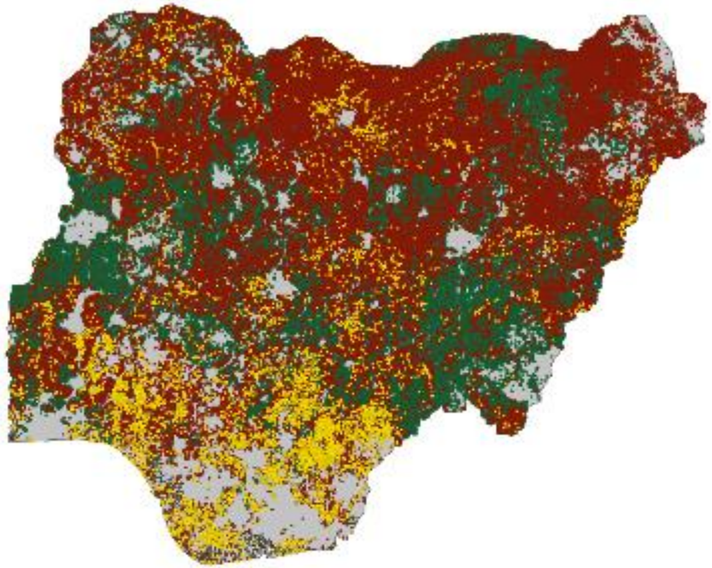
Solar Home System | Mini-grids | Grids



LC Tech	No. of HHs	% of HHs
Grid	5.4mn	27%
Mini-grid	8.9mn	44.5%
SHS	5.7mn	28.5%

LCE output, e-cooking demand included

Solar Home System | Mini-grids | Grids



LC Tech	No. of HHs	% of HHs
Grid	5.5mn	27.6%
Mini-grid	8.7mn	43.9%
SHS	5.74mn	28.5%

Insights

The overlay of e-cooking demand to the least cost electrification analysis impacts:

- Settlement electricity demand
- Settlement electricity cost

As a result, the least cost mix is impacted for settlements where additional electricity supply is required to enable e-cooking – switching from mini-grids to grid connection (0.6k settlements) or requiring bigger mini-grids sizes (112k settlements)

This also impacts the total investment required for universal electrification, from 23.6bn NGN to 23.9bn NGN

Including e-cooking demand, the least-cost mix is only impacted slightly, resulting in 27% grid, 44% mini-grid, and 29% SHS connections

Source: McKinsey analysis

[1] Least-cost electrification

Annex

Our approach to modelling the least-cost technology mix in Nigeria

Steps will be conducted iteratively

1 Define unelectrified households

- a) Define and categorize settlements
- b) Identify unelectrified settlements
- c) Project future population growth

2 Calculate household electricity demand

- a) Define level of energy consumption in tiers
- b) Map settlements to consumption tiers
- c) Project future demand growth

3 Determine energy generation potential

- Define sources of energy generation mapped to consumption tiers and settlement attributes

4 Estimate least-cost technology per settlement

- a) Define bottom-up cost of each technology per connection
- b) Select least-cost technology per settlement
- c) Aggregate results to define least cost mix

5 Include non-residential energy requirements

- a) Factor in electricity requirements in public institutions
- b) Factor in productive energy use
- c) Factor in electric cooking energy requirement

Settlements with rice or maize milling activity are assessed to determine the potential to switch to mini-grids

Methodology to calculate milling electrification need per settlement

1.

Estimate crop output milled locally in small scale mills

Maize and rice account for ~50% of grains milled in Nigeria

On average, an annual ~6 Mn tons of rice and 10 Mn tons of maize were farmed between 2010-19

~50% of domestic rice production and ~65% of maize production are ground locally by small-scale mills

2.

Map crop output milled per settlement

Rice and maize are farmed in most states in the country

+120,000 unelectrified settlements, produce either rice and/or maize. Milling operations generally occur within settlements

In a state, the assumption is made that all farms have a similar rice or maize annual output

3.

Select grinding equipment per crop use case

There is a large range of milling equipment at various capacities. Equipment is selected based on the capacity required to support average settlement level output

- A 7.5 kW mill with capacity to grind 150 kg of rice or maize per hour can be considered selected

4.

Estimate impact of milling electricity demand on least cost technology[1]

The switch to mini-grid occurs in non standalone settlements with rice and/or maize milling activity:

- With a total demand[1] greater than 17,250 kWh p.a. (because mini-grid in the region have a minimum of 10kW in capacity)
- Where milling activity help reduce the residential cost per connection for mini-grid, making it the least-cost technology

1. Includes residential and productive-use demand
2. Soybean, millet, sorghum and cow peas make up remaining share of grains and cereals production

Source: FAO, Fraym (2018), Power Africa, expert interviews

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Approach to modelling the opportunity for expansion of clean cooking solutions in Nigeria

1 Define base layer for analysis

Identify settlements with limited access to clean cooking

2 Estimate HH cooking energy consumption

Estimate cooking intensity of households and associated energy consumption[1]

3 Estimate the opportunity for expansion of clean cooking solutions

a) Determine no. of households that can afford clean cooking solutions in each settlement

b) Determine no. of households likely to adopt clean cooking solutions in each settlement - using female adult education as a proxy

c) Identify settlements with sufficient crop waste for biogas production

4 Define infrastructure required to realize opportunity

a) Determine no. and placement of LPG distribution infrastructure – bottling plants, skids, MDCs - to serve associated demand

b) Determine electricity access gap for e-cooking

c) Determine no. and placement of biodigesters to serve demand

1. Number and size of meals cooked daily in each household/health center

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