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Unlocking Climate Finance to Accelerate Energy Access in Nigeria

November 2, 2021

Developed in partnership with:

Shell Foundation

The Rockefeller Foundation

Sustainable Energy for All

UN Climate Change Conference UK 2021
In partnership with Italy

Research Context

This research is part of a series of reports from Catalyst Off-Grid Advisors and partners

They demonstrate the business opportunity to unlock billions in climate finance and deliver on multiple SDG goals.

> Our 2018 research demonstrated the financing opportunity to achieve universal household electrification in Africa (SDG 7) via off-grid solutions.

> First launched on **Earth Day 2021**, and covering all of Sub-Saharan Africa, this research shows off-grid solar's social dividends, which cut across numerous SDGs1

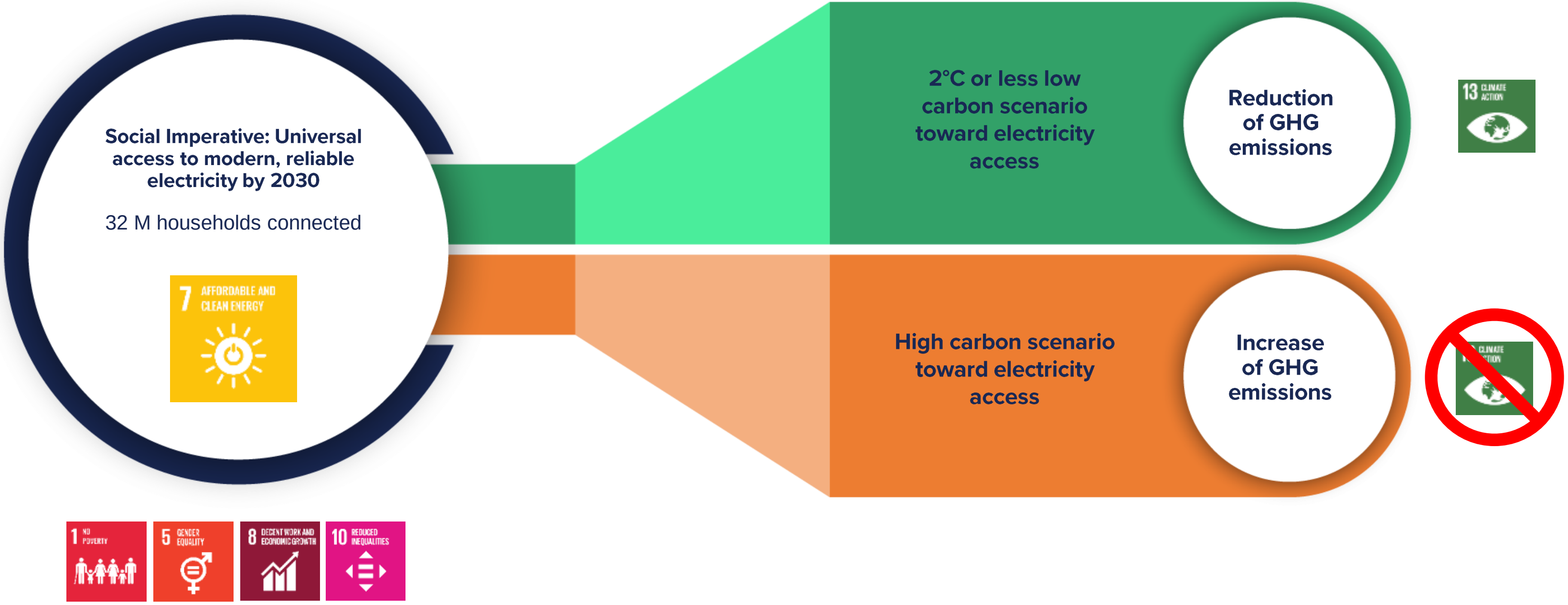
> Alongside the **climate dividends** attributable to low-carbon SDG 7 scenarios

> It forecasts the **climate finance opportunity** associated with these low-carbon SDG 7 scenarios

> Illustrating the **multi-billion-dollar climate finance opportunity** associated with the low-carbon scenarios

Modeling illustrates Nigeria’s low-carbon scenarios and the impact they will have on SDG 13

SDG 7 – Ensure access to affordable, reliable, sustainable and modern energy for all.
SDG 13 – Take urgent action to combat climate change and its impacts.



Low-carbon scenarios accelerate Nigeria's achievement of SDG 7 and SDG 13 via 3 pillars

Predictive modeling forecasts three scenarios for each thematic pillar: business-as-usual, high-carbon, and low-carbon, shows the avoided emissions between the latter two, and then provides the investment costs associated with the low-carbon scenario.

Electricity Access

Electricity access
Providing first-time electricity access

What will it take to provide first time electricity access in Nigeria via a low-carbon trajectory that avoids millions of tons of CO_2 emissions?

+

Unreliable grid

Greening back-up generation
Solving the unreliable grid challenge

What's required to get enterprises and households to transition off back-up generators and onto distributed renewable sources of power?

+

Cleaner cooking

Modern cooking access
Moving households onto modern cooking solutions

What is a credible scenario to move a portion of Nigeria's households onto modern cooking solutions?

=

Nigeria's Climate Finance Opportunity

Improving access and reducing emissions across the continent

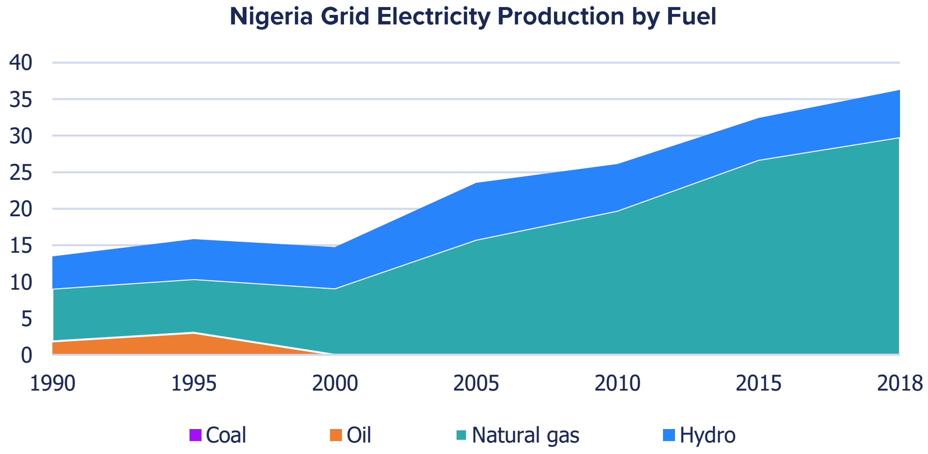
What level of CO_2 emissions are avoided via each pillars' low-carbon scenario? What is the associated climate finance opportunity?

Setting the Scene

Nigeria's grid generation is dominated by fossil fuels

This reliance on fossil fuel generation presents a significant climate challenge

- **38 percent increase** in total generation since 2010, averaging 4.8% increase per annum
- **50 percent increase** in natural gas generation since 2010
- **18 percent** of generation from hydropower in 2018, down from 24 percent in 2010
- **~511 gCO_2/kWh** grid emissions intensity (including losses), 12th highest in Sub-Saharan Africa

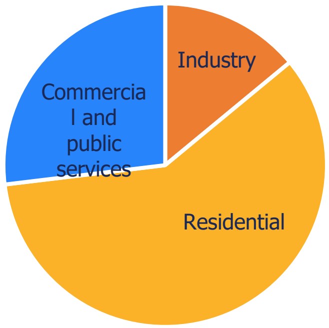


Source: International Energy Agency *Country Analysis and Electricity Statistics*

Nigeria's residential sector accounts for the majority of electricity demand

- **69%** of global electricity demand driven by industrial and commercial off-takers
- **41%** of Nigeria's electricity demand driven by industrial and commercial off-takers. Commercial tariffs average $0.096 / kWh which are low compared to global averages
- **27%** percent of global electricity demand originates from households
- **59%** of Nigeria's electricity demand originates from households
  - > **818 kWh per year residential demand** per customer which is comparatively high. This can be partly explained by the low residential tariffs of **$0.01 / kWh to $0.094 / kWh.**

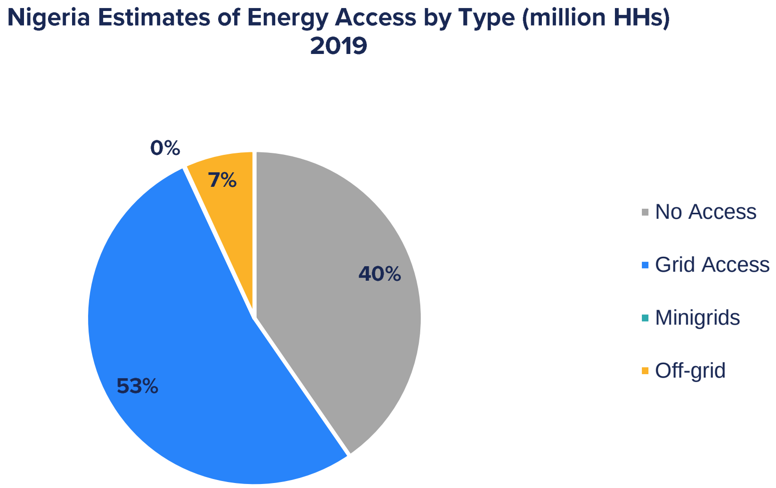
Nigeria Electricity Consumption by Sector (2018)



* All "$" in the report are United Stated Dollars (USD)

Source: International Energy Agency *World Energy Balances 2020*

Nigeria's grid electrification highlights a significant urban vs. rural divide in energy access



- **40%** of households had no source of electrification (About 83 million people)
- **53%** of households in Nigeria had electricity access from the national grid (About 108 million people)
- **About 19.4 million households** will still be without access by 2030 under business as usual

Source: *Nigeria Living Standards Survey 2019*; Catalyst estimates

Nigeria's electrification strategy leverages the private sector

By mobilizing the private sector, Nigeria can deliver access to more underserved communities

Rural Electrification Strategy and Implementation Plan (RESIP)

- The 2016 Rural Electrification Strategy and Implementation Plan (RESIP) and 2017 Regulatory Framework for Mini-Grids underscore the importance the Government of Nigeria places on decentralized renewables as part of the country's energy mix.

Private Sector Mobilization

- Private sector participation also prioritized, with electricity distribution entrusted to eleven private distribution companies (DISCOs). The RESIP and associated Nigerian Rural Electrification Policy foresee a prominent role for the private sector in enhancing energy access.

Rural Electrification Fund

- The Rural Electrification Agency's Rural Electrification Fund looks to expand access through a blend of grid, mini-grid and off-grid electrification solutions.

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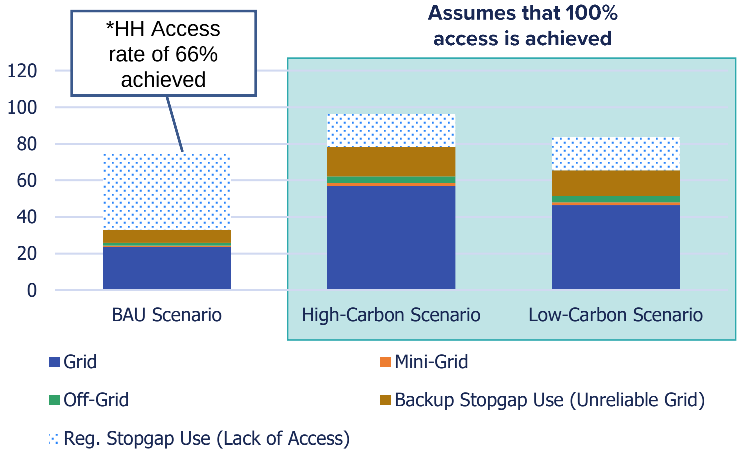
Electricity Access: Pathways and Gamechangers

Tier 1 Pathway: Nigeria's low-carbon scenario for Tier 1* access avoids 13 million tons CO_2 through scaled up mini-grid and off-grid solutions, and greener grid generation

And grid unreliability contributes significant additional emissions of 13.9 MT CO2 from backup stopgap usage



Impact 32 million households get first-time access

Financing opportunity $4.3 B (Low-Carbon)

Scenario		Connections	Climate Finance Opportunity
BAU		**Total Access Rate: 66%** • No Access: 19.4M HH (34%) • Grid: 29M HH (51%) • Mini-grid: 0.5M HH (1%) • Off-grid: 7.7M HH (14%)	**Total: $1.4 Billion** • Mini-grid: 313M • Off-grid Solar: 1.1B
High Carbon		**Total Access Rate: 100%** • Grid: 41M HH (72%) • Mini-grid: 1M HH (2%) • Off-grid: 14.5M HH (26%)	**Total: $3.1 Billion** • Mini-grid: 635M • Off-grid Solar: 2.46B
Low Carbon[1]		**Total Access Rate: 100%** • Grid: 36M HH (64%) • Mini-grid: 2M HH (3%) • Off-grid: 18.5M HH (33%)	**Total: $4.3 Billion** • Mini-grid: 1.46B • Off-grid Solar: 2.87B

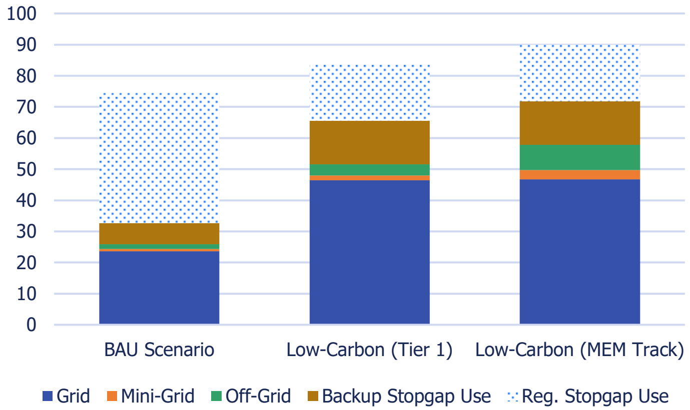
No Access | Grid | Off-grid | Mini-grid

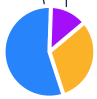
*Tier 1 access is the minimum threshold for these scenarios and is defined as at least 4.3 kWh of electricity consumption per household per year – supporting basic lighting and device charging

[1]The low-carbon scenario has lower estimated emissions than the BAU scenario since emissions from electrification activities are more than offset by reductions in stopgap emissions.

Achieving the Modern Energy Minimum (MEM)* generates an additional 7 million tons CO_2, though it unlocks higher levels of household consumption

To achieve the MEM (300 kWh/capita/year) by 2040, per person consumption exceed to 141 kWh by 2030



Scenario		Connections	Climate Finance Opportunity
Low Carbon (Tier 1)		**Average consumption: 76.5 kWh/pp/yr** Connection mix: • Grid: 6.8M HH • Mini-grid: 0.9M HH • Off-grid: 7.0M HH	**Total: $4.3 Billion** • Mini-grid: 1.46B • Off-grid Solar: 2.87B
MEM		**Average consumption: 141 kWh/pp/yr** Change in connections compared to Tier 1: • Grid: Same • Mini-grid: 2 million additional • Off-grid: 2 million fewer	**Total: $9.05 Billion** • Mini-grid: 2.99B • Off-grid Solar: 6.1B
OGS Mix[1]		**MEM, OGS mix of system sizes** • Tier 1: 2.14 million HHs • Tier 2: 8.91 million HHs • Tier 3: 4.99 million HHs • In LC Tier 1 scenario, 62% of HHs had Tier 1, 33% Tier 2, and 5% Tier 3	**OGS financing mix:** Tier 1: 115 million Tier 2: 2 billion Tier 3: 3.9 billion

No Access | Grid | Off-grid | Mini-grid

Sources: Catalyst estimates
[1]The MEM calls for a higher, more inclusive level of electricity consumption as a better access metric to raise global energy ambitions; Energy for Growth Hub, 2020.

Gamechanger 1: Grid-connected DREs to improve reliability and expand first time access

The Challenge

- **Extreme grid unreliability:** 33 outages/month = ~50% downtime
- **82% of generation** comes from emission intensive natural gas
- Low carbon universal access scenario envisages **14.2 million new grid connections**, spurring 69 TWh of new consumption by 2030
- If 82% of new demand is met by gas power, this would lead to **39 MT CO_2 of additional emissions**

The Opportunity

- **Meet 25% of new grid generation demand via grid-connected DREs** (e.g. Konexa) or potentially under-grid microgrids (e.g. Interconnected Mini-Grid Acceleration Scheme, Mokoloki)
- DRE generation **would reduce emissions** compared to a natural gas counterfactual
- **DREs improve power reliability and quality**, reducing transmission and distribution congestion, supporting power quality and regulation services, grid flexibility, islanding critical loads, etc.
- **Support local manufacturing** (e.g. Solar Connection Facility, Nigeria Borno Manufacturing Plant, etc.), via increased demand for DRE components

Sources: Power for All / Rockefeller Foundation; Catalyst estimates

Gamechanger 1: Impact and key design considerations

Contributing 25% of additional supply needed via DREs requires **$2.5 billion** in climate finance and avoids nearly **10 million tons of CO_2** emissions

Key Design Considerations

- Implementation Arrangements: DRE ownership models or franchise models (i.e. Konexa) need to be considered
- Develop **bankable power purchase agreement** (PPA) framework for GenCos, IPPs, and mini-grid developers to sell to DISCOS or direct to customers
- **Competitive tendering approach** (or feed-in-tariff) to help ensure competition and value for money for the deployed DREs
- Joint Planning: **Ensure DREs are built into integrated resource** and service network planning at DISCO levels
- **Targets and Incentives**: Fiscal incentives and/or generation mix targets would help foster buy-in on both buy and sell side of DRE generation
- **Climate Finance**: If avoided emissions were monetized, this could unlock nearly **$300 million in climate finance** at a price of $30 / ton

Gamechanger 2 Impact

- **1.7 GW** of new DRE capacity
- **3.55 million connections** served with DRE power
- **9.7 MT of avoided CO_2** from new generation
- Grid-tied DREs and under-grid microgrids can improve grid reliability for end users by reducing outage time and improving power quality

Sources: Catalyst estimates

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Unreliable Grid: Pathways and Gamechangers

An unreliable grid and subsidized fuels leads to massive use of fossil fuel-powered gensets in Nigeria

Growing electricity demand will further stress grid reliability, while massive fuel subsidies distort the economic realities of using backup gensets

Unreliable grid connections

- In developing countries, unreliable grids are the primary driver for genset use:
- About **75% of sites** using fossil-fuel powered gensets are "grid connected"

In Nigeria alone:

- **78% of firms experience outages**
- **33 outages in a typical month** for total downtime of 380 hours (About **51 percent downtime**)
- Unreliable grid connections result in an **average 15.6 percent** loss in business revenues

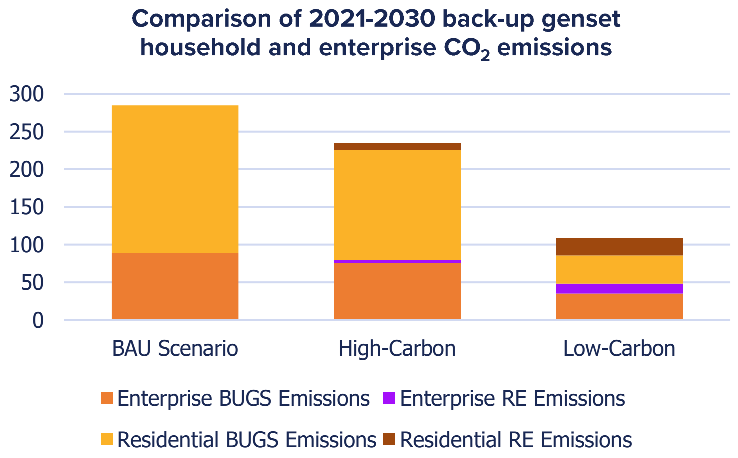
Use of backup gensets

- Backup fossil-fueled generators are used by households and enterprises
- Powered with fossil fuels, typically diesel or gasoline which is a significant source of air pollutants
- Off-grid enterprises often resort to using gensets for power, particularly for productive use applications
- In Nigeria, **173k gensets are deployed** for commercial use (98% are on-grid businesses), while **3.2 million gensets** are deployed for residential use (83% are grid connected residences); Overall 17 GW of capacity
- Diesel and petrol fuels have historically been subsidized and the current regulatory environment for subsidies is uncertain

[1] An unreliable grid is defined as one in which local enterprises, on average, report 12 or more hours of electrical outages in a typical month;
Source: World Bank Enterprise Surveys; IFC *Dirty Footprint of Broken Grid*; SERC estimates; Catalyst estimates

**Based on $1.046 / liter*

Replacing Nigeria's genset fleet with DREs would reduce emissions by 126 million tons of CO_2



- Emissions reductions are driven by the growth rate in back-up genset fleets and the rate at which back-up gensets are replaced by renewables; replacement rates are varied across scenarios[1]
- In the low-carbon scenario displacing over **4.8 million assets** with a total generation capacity of **24.5 gigawatts by 2030** would yield a **$60.2 billion** climate finance opportunity.
- Generator displacement in later years is forecasted to be considerably cheaper thanks to ongoing reductions in RE technology costs, particularly lithium-ion batteries

[1]The modeling assumes that average capacity factors of back-up generators remain fixed over time, in line with historical averages (i.e., assumes no improvement or deterioration in grid reliability).
Sources: IFC *Dirty Footprint of Broken Grid*; SERC estimates; Catalyst estimates

Gamechanger 2: Leverage genset density to aggregate demand for "community solar" schemes

The Challenge

- **78% of Nigerian enterprises experience outages**, leading to over 15% loss in business revenue
- **Over 70% of enterprises** have gensets on site
- **98% of these gensets** are grid-connected and used as back-up.
- Fuel subsidies, unfavorable policies and regulations, and a nascent commercial solar sector make the economics genset replacement challenging

The Opportunity

- **Aggregate clusters of demand** from existing grid-tied commercial gensets, bundling into for multi-customer "community solar" clusters
- **Programmatic approach to identifying and clustering demand centers**, leveraging existing platforms (e.g. REA GIS, Odyssey, Konexa, etc.) for this purpose
- Develop modality for private sector to build, finance, and operate these assets, via a competitive selection process
- **Mobilize guarantee and subordinated capital** to help de-risk early transactions and prove out business model

Sources: Power for All / Rockefeller Foundation; Catalyst estimates

Gamechanger 2: Impact and key design considerations

$300 million in climate finance would cover investment for costs for community solar and storage systems at 100 aggregated commercial demand sites

Key Design Considerations

- Surveying, regulatory reporting, or other methods (e.g. satellite imagery) to map existing genset assets in Nigeria
- **Structure PPAs** and other commercial agreements to make demand aggregation & brokering bankable
- Ensure community solar **planning is embedded into integrated resources planning** for local service areas.
- **Clarify regulatory considerations**, e.g. licensing requirements, feed-in-tariffs, net metering, etc.
- **Leverage economies of scale** on system design as well as climate finance to support uptake and ensure cost competitiveness

Gamechanger 2 Impact

- **100 community solar installations** supporting aggregated demand sites (average of 1.5 MW per site)
- **Replacing 2,000 commercial gensets** (1% of the total) with a total capacity of 163 MW
- Cumulatively reduces emissions by **1.3 MT**
- Cumulative **reduction in fuel costs by an estimated $396 million** (fuel use reduced by 596 million liters) by 2030
- **$40 million** in climate financing could be mobilized (assuming $30/ton carbon price)

Sources: Catalyst estimates; Global petrol prices; Based on $0.619 liter on October 7th, 2021

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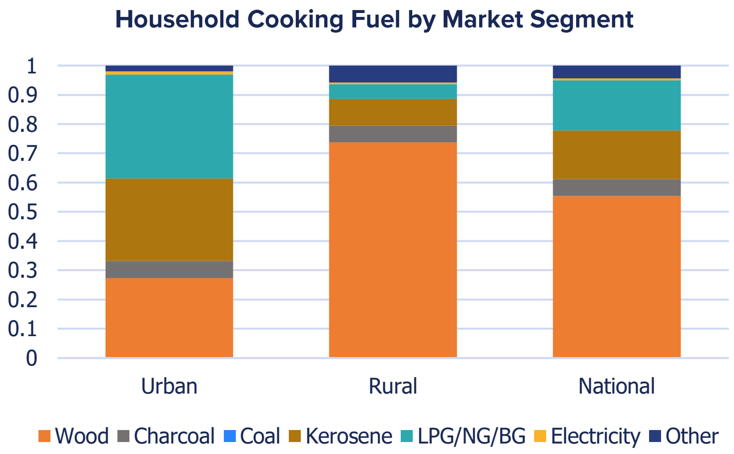
Cleaner Cooking: Pathways and Gamechangers

Firewood, charcoal, and kerosene cooking dominate in Nigeria, with notable LPG cooking penetration in urban areas

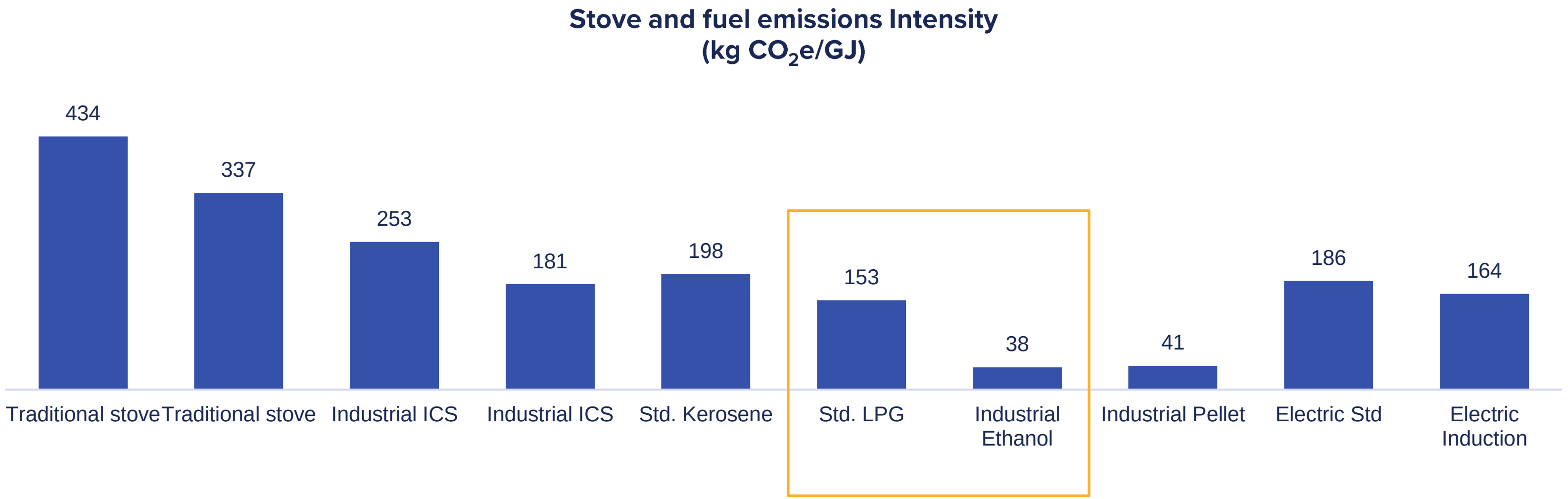


- **28.1 million households (78.6% of total)** in Nigeria use firewood, briquettes, kerosene, or charcoal as their main fuel for cooking
- **218,000 people killed annually** from household air pollution
- **18 percent of households** (35% in urban areas) cook primarily with LPG stoves
- **34 percent of households** utilize multiple types of stoves

Source: *Nigeria Living Standards Survey 2019*; WHO *Global Health Observatory*

With high domestic supply, existing penetration, and existing policy targets the most likely modern cooking transition would be via LPG

However, LPG cooking itself is emission intensive, with only 22% lower emissions than cooking with kerosene

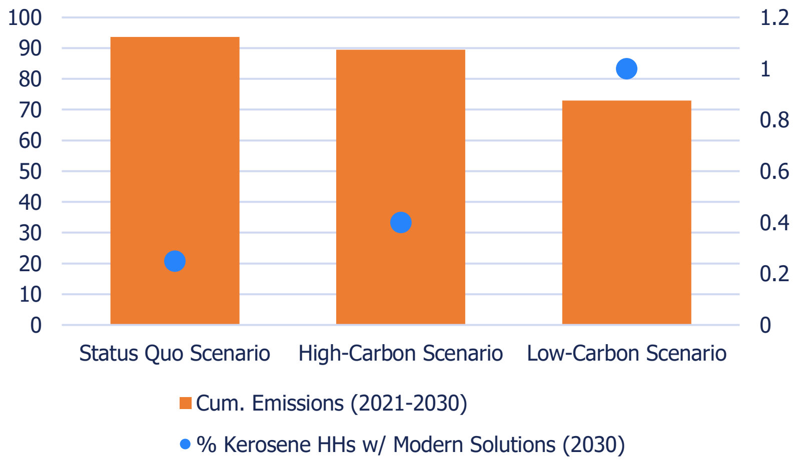


*Each fuel has a GHG emissions intensity factor (kgCO2e per gigajoule of fuel burned) which illustrates the carbon-intensity of the fuel when burned. When used in a particular stove, only a percentage of the burned fuel is converted into useful energy, resulting in a higher GHG emissions intensity in practice.

Source: Authors' analysis based on multiple sources including Penisse et al, Bailis et al; Clean Cooking Alliance's Clean Cooking Catalog, inter alia.

Moving kerosene households onto LPG cooking can help avoid 17 million tons of CO_2 compared to a high-carbon scenario

In the low-carbon scenario, **6.7 million** kerosene households would cook with modern fuels, primarily LPG



- Kerosene customers are likely candidates to switch to LPG given similar products, existing customer awareness and marketing, and urban supply chains
- **$1.51 billion investment** required to primarily produce and distribute LPG stoves (~4% of costs) as well as to support infrastructure development for LPG (~96% of costs)
- However, this is **still a comparatively high emissions pathway** given the marginal savings of LPG compared to kerosene

[1]In a household, the primary fuel is the one which accounts for the majority of cooking needs
Sources: Catalyst estimates

Gamechanger 3: Convert some of customers targeted for LPG to ethanol-based fuels

The Challenge

- About 6.7 million households cook with kerosene, producing **an estimated 5.5 $MTCO_2$ in annual emissions**
- LPG usage levels set to grow dramatically, with National LPG Expansion Plan targeting **90% LPG cooking**, despite marginal emissions savings compared to kerosene
- Uncertain regulations and currency/market fluctuations, have caused price volatility
  - **LPG:** Average price for a 5kg LPG cylinder increased 12% to $5.39 from August 2020 to August 2021
  - **Kerosene:** Average price per liter increased 15% to $0.97 in the same period

The Opportunity

- Tap **ethanol's 75% lower emissions** compared to LPG cooking, to help support Nigeria's low carbon pathway
- **Support 25% of households** that cook with kerosene to transition to ethanol
- **Leverage climate finance** to support adoption and cost competitiveness for ethanol fuels

Sources: Nigeria Bureau of Statistics *LPG/Kerosene Price Watch*, MECS; Catalyst estimates, based on 410.85 Naira/USD October 6th, 2021

Gamechanger 3: Impact and key design considerations

$180 million in climate finance to cover investment costs and support 1.7 million households that cook with kerosene to transition to ethanol instead of LPG

Key Design Considerations

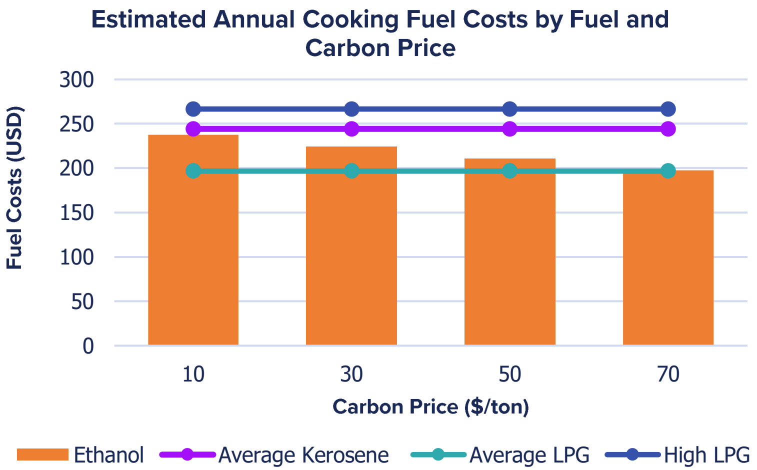
- **Developing a domestic market for ethanol cooking fuels** including fuel imports as well as building domestic production over time
- Consumer awareness and behavioral change key barriers for adoption, though ethanol fuels/stoves are similar in operation and appearance to kerosene stoves
- **Affordability of fuels is a critical factor for consumers switching** cooking fuels (see next page)
- **Carbon finance** could be used to reduce stove and fuel costs

Gamechanger 4 Impact

- **Avoid 3.7 MT CO_2** compared to the LPG use
- **~$200 million savings** for infrastructure and stoves compared to the full LPG scenario
- At $30 / ton, approximately **~$110 million** could be mobilized

Sources: Modern Energy Cooking Services (MECS); Catalyst estimates

Gamechanger 3: Ethanol is cheaper than kerosene and monetizing avoided CO_2 emissions can boost cost-competitiveness



Average kerosene costs are **$0.97 / liter and LPG are $0.55 / liter**

Established ethanol cooking markets like Kenya have prices at **$0.70 / liter**

With stove efficiencies and cooking needs total annual cooking costs are estimated at:

- **Kerosene:** $244
- **LPG:** $197
- **Ethanol:** $244 (assumes $0.80/liter to account for nascent market)

Monetizing avoided CO_2 emissions could make ethanol cost competitive, though this depends on carbon pricing on voluntary markets

Ethanol costs likely to come down as demand increases, further boosting competitiveness

Source: Nigeria Bureau of Statistics *LPG/Kerosene Price Watch*; MECS; KOKO fuels; Catalyst estimates; KOKO Fuels estimates for Kenya based on 410.85 Naira/USD October 6th, 2021

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Summary

Nigeria's energy sector: setting the scene

Key energy trends and their climate impacts illustrate the scope of the SDG 7 and SDG 13 challenges

Electricity access

- **40% of Nigerians** lack access to electricity, **16.9 million households**
- Natural gas accounts for **82%** of electricity generation, a **50% increase** since 2010
- Nigeria's energy sector reforms emphasize private sector participation
- Nigeria also sees a prominent role for DREs in meeting their SDG7 ambitions

Unreliable grid

- Nigeria's grid, where available, is often unreliable, with enterprises experiencing an average of **51% downtime**, and **15.6% revenue losses**
- Consequently, there is an estimated **3.6 million backup gensets (17 GW)** deployed in the country today.
- These gensets consume **9.9 billion liters** of fossil fuels each year

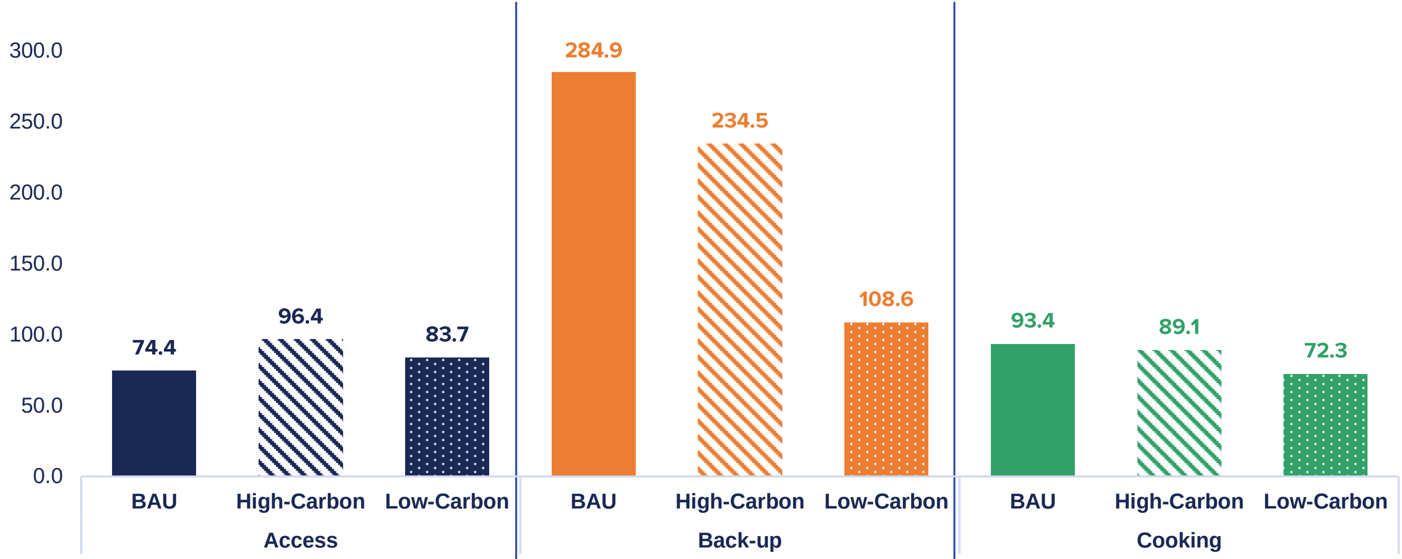
Cleaner cooking

- **82%** of Nigeria's population use solid fuels for primary cooking needs
- **218,000 people** in Nigeria die annually from household air pollution
- **>17% of all households** have already transitioned to LPG cooking, offering a pathway to more modern, clean cooking

Source: *Nigeria Living Conditions Survey*; IFC *Dirty Footprint of Broken Grid*; SERC estimates; Catalyst estimates

The low-carbon scenarios avoid 153 million tons of CO_2, deliver SDG 7 impacts, and unlock a substantial climate finance opportunity

Emissions from Nigeria's low-carbon scenarios are benchmarked against high-carbon counterfactuals; the difference between the two constitutes the avoided emissions



	Access	Back-up	Cooking
Avoided CO_2	12.7 MT CO_2 Avoided	125.9 MT CO_2 Avoided	16.8 MT CO_2 Avoided
Impact	32 million households get first-time access	4.8 million gensets retired	6.2 million households using clean fuels
Financing opportunity	$4.3B	$60.2B	$1.4B

Summing up: Nigeria's low-carbon path

Nigeria's low-carbon universal access path unlocks a **US $65.9 billion-dollar climate finance** imperative

A low-carbon scenario contributes massively toward universal access

32 million new connections from off-grid technologies delivered

More than **4.8 million gensets** used by enterprises and households replaced

More than 6.2 million households cooking with kerosene now utilizing LPG

A low-carbon scenario benchmarked vs. a high-carbon scenario yields

153 million tons of avoided CO_2 emissions over the next decade

A low-carbon scenario requires substantial volumes of new capital

$4.3 billion climate finance opportunity for first time access

$60.2 billion climate finance opportunity to green back-up generation for enterprises and households

$1.4 billion climate finance opportunity for clean cooking

Potential gamechangers to accelerate energy access and development in Nigeria

Grid-connected DREs	> Meet 25% of new grid generation via grid-connected DREs or undergrid renewable mini-grids instead of new natural gas power plants, reduce emissions by **9.7 MT** > Will also improve power reliability and quality, reducing transmission and distribution congestion, and supporting new energy access
Community Solar to Displace Backup Gensets	> Aggregate demand clusters from existing grid-tied commercial gensets and bundle them for multi-customer "community solar" clusters > Develop 100 community solar installations to replace over **2,000 commercial gensets and avoid 1.3 MT of emissions**
Clean Cooking with Ethanol	> Develop a small but meaningful domestic market for ethanol cooking; support 25% of kerosene households to convert to ethanol cooking instead of LPG > Avoid an additional **3.7 MT CO_2 and save ~$200 million** on infrastructure and stoves; carbon finance could play a critical role

Commissioned by

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