NIGERIA

BEYOND GENSETS:
ADVANCING THE ENERGY TRANSITION IN LAGOS STATE

OCTOBER 2024

Global Energy Alliance for People and Planet
GEAPP

CONFIDENTIAL AND PROPRIETARY

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GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning
Back-checks	Verification procedures conducted to ensure the accuracy and reliability of data collected during the survey process.
C&I	Commercial and Industrial
Centroid	The geometric centre point of a cluster or sampling area, often used as a reference point for spatial analysis or mapping.
Cluster	A group of sampling units, such as households or businesses, which are selected collectively as part of a sampling strategy. Clusters are often used in survey sampling to facilitate efficient data collection.
CO	Carbon Monoxide
CO2	Carbon Dioxide
Community Head	A recognized leader or authority figure within a community, typically responsible for representing the interests of community members and facilitating communication with external parties.
DPV	Distributed Solar Photovoltaics
Enumeration	The process of systematically counting and listing all units within a defined population or sampling frame, such as households or individuals, to create a comprehensive inventory for sampling purposes.
ETO	Energy Transition Office
ETP	Energy Transition Plan
GDP	Gross Domestic Product
GENSET	Generator Set
GRID3	Geo-Referenced Infrastructure and Demographic Data for Development
GW	Gigawatts
Household Head/ Head of Household	A person who is acknowledged as such by members of the household and who is usually responsible for the upkeep and maintenance of the household.
Household	A person or a group of related or unrelated persons, who live together in the same dwelling unit, who acknowledge one adult male or female 15 years old or older as the head of the household, who share the same housekeeping arrangements, and are considered as one unit.
IEP	Integrated Energy Plan
Interval adherence	The degree to which sampling intervals are followed consistently during the selection of sampling units

GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning
Interval Sampling	A sampling method where sampling units are selected at regular intervals from a predefined list or sampling frame.
kVA	Kilo-Volt-Amperes
LBS	Lagos State Bureau of Statistics
LCDA	Local Council Development Areas
LCOE	Levelized Cost Of Energy
LGA	Local Government Area
Market	A geographic concentration of interconnected businesses and other related establishments.
MCQ	Multiple Choice Questions
MSME	Micro, Small and Medium-Sized Enterprise
MtCO2e	Metric tons of carbon dioxide equivalent
MW	Megawatts
NBS	National Bureau of Statistics
NDC	Nationally Determined Contributions
NOx	Nitrogen Oxide
NVMOC	Non-methane Volatile Organic Compounds
Primary Sampling Unit	A sampling approach where data collectors move through a sampling area in a systematic but random manner, selecting households or individuals for inclusion in the sample based on predefined criteria.
RE	Renewable Energy
REA	Rural Electrification Agency
Sample	The subset of the population selected for participation in a survey or study, intended to provide representative data for analysis and inference.
Sampling approach	The overall strategy or methodological framework used to select sampling units and collect data for a survey or study, including decisions related to sample size, sampling design and data collection methods
Sampling errors	The representative errors due to the sampling of a small number of eligible units from the target population instead of including every eligible unit in the survey.

GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning
Sampling frame	Complete list of all sampling units that covers the entire target population.
Sampling methodology	The systematic process of selecting a representative sample from a target population, including decisions regarding sampling design, sample size determination and data collection procedures.
Sampling unit	The unit of selection at each stage of the sampling process.
Sampling weight	The design weight corrected for non-response or other calibrations.
SDG	Sustainable Development Goal
Self-Generation	The production of electricity or energy for personal or local use, typically using decentralized or off-grid generation technologies such as diesel gensets or solar panels.
SME	Small and Medium-Sized Enterprise
SO2	Sulphur Dioxide
Stratification	The process by which the survey population is divided into subgroups or strata that are as homogeneous as possible based on certain criteria. The principal objective of stratification is to reduce sampling errors.
Stratified cluster strategy	A sampling approach that combines stratification and clustering techniques to achieve a representative sample from a large and diverse population.
Target sample size	The predetermined number of sampling units or observations required to achieve the desired level of precision and reliability in survey estimates. The target sample size is determined based on factors such as population size, variability and sampling design.
tCO2e	Tons of carbon equivalent
TWh	Terawatt hours
Ward	A local administrative division within a city or municipality and the third administrative division in Nigeria, representing subsets of local government areas (LGAs).
Weighted average	A statistical measure calculated by summing the products of each observation and its associated weight, then dividing by the total sum of weights.
Weighted distribution	The proportional allocation of sample weights to survey data, ensuring that each observation contributes appropriately to population estimates and statistical analyses.

The Beyond Gensets: Advancing the Energy Transition in Lagos State report is more than just a study—it's a catalyst for action.

The study offers insights that systemically should drive Distributed Solar PV (DPV) initiatives such as rooftop solar with backup storage that reduce our reliance on fossil fuels, starting here in Lagos and scaling across the nation. By understanding and working to mitigate the impacts of diesel and petrol generator sets, we are taking decisive steps toward a cleaner, more sustainable energy future for Lagos and Nigeria as a Nation.

Together, we can transform these findings into tangible progress, setting the standard for genset displacement nationwide.

BIODUN OGUNLEYE

Commissioner of Energy and Mineral Resources, Lagos State

01 | EXECUTIVE SUMMARY

EXECUTIVE SUMMARY (1/6)

Context & Objectives

Nigeria’s ambitious energy transition targets universal access by 2030 and net-zero emissions by 2060. Diesel and petrol generator sets (hereafter “gensets”) pose a significant challenge, contributing 70% of power sector emissions in Nigeria and necessitating urgent displacement. However, transitioning to cleaner alternatives, in line with the nation’s climate and development goals, requires precise data collection around the number of gensets.

In 2023, SEforALL provided support to the Lagos State Government through the Lagos State Ministry of Energy and Mineral Resources to conduct a state-wide fossil fuel genset study. This study, with spatial data accessible on the Nigeria Integrated Energy Planning (IEP) tool, aims to guide the design, development and delivery of a state-wide fossil fuel displacement programme to replace fossil fuel-based self-generation of power. The project also intends to test and develop a data collection methodology to create a cost-effective, replicable and scalable pathway that serves as a blueprint for similar initiatives nationwide. Ultimately, this study marks a crucial step towards sustainable and scalable renewable energy solutions, aligning with broader national energy transition objectives.

Rationale for the study

The lack of adequate actionable data and understanding regarding the capacity, usage and impacts of gensets currently impedes the development of targeted and effective solutions. To address genset usage in Nigeria, a more precise and comprehensive examination of usage patterns was imperative. As Nigeria’s largest economic hub, Lagos State was an ideal pilot state to undertake such a study. In addition, the interest of the Lagos State Government in a distributed solar PV programme, its high electricity demand and prevalent genset usage made it the ideal starting point.

Lagos is home to a significant portion of Nigeria's population and contributes approximately 27% of its GDP. It faces critical energy challenges, and has the highest electricity demand in Nigeria, yet only about 20% of this demand is met by the grid, leading to a reliance on gensets for the deficit. Consequently, Lagos has the highest expenditure on fossil fuel purchases nationwide. This reliance on backup generation together with the removal of fuel subsidies puts a lot of pressure on both households and businesses. In response to these challenges, the Lagos State Government expressed interest in implementing a distributed solar PV programme to replace gensets, indicating a clear need for comprehensive energy studies and potential interventions. Studying energy dynamics and potential interventions in Lagos State presents a strategic opportunity to address critical energy challenges and facilitates sustainable development in Nigeria's economic and demographic epicentre.

The study can inform decisions such as the development of targeted energy policies and interventions, the design of tailored solutions to customer segments determined by specific energy needs, and consumption patterns.

EXECUTIVE SUMMARY (2/6)

Study Approach

SEforALL carried out surveys utilizing both traditional methodologies and advanced geospatial analytics to establish baseline estimates on various indicators relevant to replacing fossil fuel-based gensets such as: household/industry characteristics, grid connectivity and use, genset ownership and use, etc.

Primary data collection involved **household field surveys across 20 local government areas (LGAs) in Lagos and enumeration of the commercial sector** (using a list **sourced from the Lagos State Ministry of Commerce and the GRID3 database). Secondary data collection** involved reviewing previous studies, with a focus on markets. Impact analysis was conducted on collected baseline data across five key indicators: economics, health, environmental impact, interest in solar backup systems and financing.

The resulting data will be available on the Nigeria Integrated Energy Planning (IEP) tool for visualization. Residential data are aggregated and presented at the ward, LGA and state levels, while results for the commercial sector as well as markets are aggregated at the state level. Moreover, commercial sites were also added as interactive points of interest within the tool.

Methodology & Assumptions

Residential Survey: A stratified cluster strategy was employed, with a target sample size of 6,000 respondents across Lagos State's 20 LGAs. Wards served as primary sampling units, with 200 clusters of 30 households each selected proportional to LGA household population. For example: Agege LGA contains an estimated 5% of households in Lagos, therefore, 5% of the 200 survey clusters were selected from Agege. The method employed was simple random sampling within each ward using the “random walk” methodology, starting from each ward’s centroid and continuing until the necessary household quota for that cluster had been reached.

To extrapolate residential genset capacity for Lagos State, raw survey responses were used to determine the most reported size per genset class, multiplied by the household count, and summed to compute the total capacity and other metrics.

Commercial Survey: The commercial category, as defined in this study, encompassed micro, small and medium-sized enterprises (MSMEs). Although the survey did not exclude large commercial and industrial (C&I) sites, they were not considered in the inference of the survey results to the entire universe of commercial entities in Lagos State because of their extreme variability in terms of energy needs and the lack of reliable statistics on the total number of commercial entities in the state. A total of 240 commercial entities participated in the survey, comprising 123 from the Lagos Ministry of Commerce and 117 from the GRID3 database. Counted enterprises were first classified into three mutually exclusive categories (micro, small and medium-sized enterprises) based on the number of employees and estimated monthly revenue. Selected metrics from the survey results were calculated for each category first, and then extrapolated and aggregated to the total 80,072 MSMEs in Lagos State[1] using the number of MSMEs in each category.

[1] The number of MSMEs in Lagos State reported in the National Bureau of Statistics (NBS) 2021 MSME Survey Report was used.

Sources: Lagos State Government Official Website, Lagos Bureau of Statistics, Lagos State Electricity Policy, Edomah and Ndulue (2020), World Bank Genset Study (2014), LBS Household Survey (2020), World Bank DPV Study (2021)

EXECUTIVE SUMMARY (3/6)

Methodology & Assumptions

Economic Clusters: In this study, economic clusters (hereafter "markets") are specifically defined as MSMEs situated within markets. This delineation allowed for a focused analysis of MSMEs operating within market environments. **A total of nine markets were evaluated through secondary data review.** Estimations for all 276 markets within Lagos State were derived by extrapolating findings from the nine surveyed markets and scaling them.

Results & Implications

Data Visualization: The data is openly accessible through an online geospatial visualization platform, the Nigeria Integrated Energy Planning (IEP) tool (https://nigeria-iep.sdg7energyplanning.org/). This geospatial tool enables a detailed examination of key metrics at different geographical aggregation levels, including baseline genset ownership and usage, carbon emissions, electricity grid access and usage, and other relevant indicators. The IEP tool can help determine areas where renewable energy (RE) solutions can have significant impact, leading to an informed and strategic deployment of private sector-led initiatives while playing a pivotal role in informing policy decisions and attracting essential financing for fossil fuel genset displacement programmes within the state.

Financial Implications: To displace diesel and petrol gensets and replace with solar systems, across residential, commercial and market sectors, there is a significant capital expenditure gap. Addressing this barrier is crucial to promote solar adoption and displace gensets. Implementing a lease-to-own model funded by concessional funding can make solar systems immediately affordable.

Highlighting two cases from the residential category, insights reveal significant cost disparities between petrol gensets and equivalent solar PV systems. The households were grouped into two main archetypes based on genset ownership: small households and medium-sized households. For small households (0.1–1.2kVA), the equivalent solar system was sized to produce and store the energy supplied by the genset, even during the rainy season, with specific PV modules, battery storage and inverter specifications. Similarly, the equivalent solar systems for medium-sized households (1.3–5kVA) were tailored to meet their energy needs, with specific PV modules, battery storage and inverter specifications. Initially, gensets appear 10 to 15 times more economical, but over a 10-year period, solar PV proves only 20% pricier. These insights underscore the challenge for backup PV systems, struggling due to high fixed costs and limited usage. The primary barrier to solar adoption is the significant upfront investment. Bridging this gap and devising viable financing mechanisms are essential for successful displacement of gensets. Leveraging standardized PV designs tailored to the small to medium-sized gensets presents a promising solution.

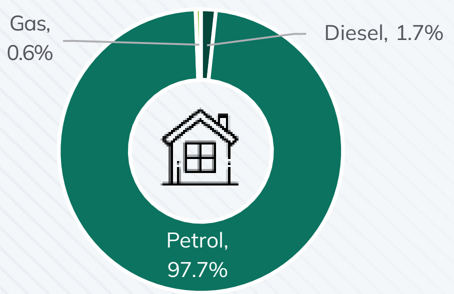
EXECUTIVE SUMMARY (5/6) Summary of Results

RESIDENTIAL

8.8 GW
Total Estimated Genset Capacity

4,323,000
Estimated No. of Gensets

Share of Gensets by Fuel Type



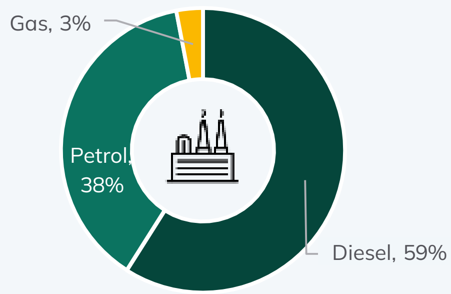
Annual Fuel Consumption (Litres)	**9 billion**
Estimated Number of HHs	**5,703,437**
Total Estimated Annual Emissions (tCO_2e)	**21 million tons**
Share of Genset Capacity 0.1-5kVA	**96%**
% of HHs that own at least one genset	**72%**

COMMERCIAL[1]

10.4 GW
Total Estimated Genset Capacity

113,642
Estimated No. of Gensets

Share of Gensets by Fuel Type



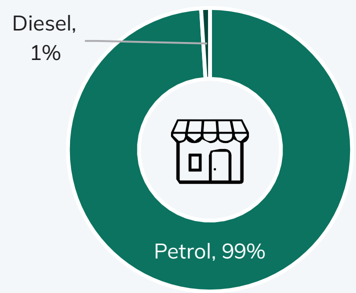
Annual Fuel Consumption (Litres)	**6.6 billion**
Estimated Number of MSMEs	**80,072**
Total Estimated Annual Emissions (tCO_2e)	**17.8 million tons**
Share of Genset Capacity 0.1-5kVA	**33%**
% MSMEs that own at least one genset	**94%**

MARKETS

192 MW
Total Estimated Genset Capacity

13,704
Estimated No. of Gensets

Share of Gensets by Fuel Type



Annual Fuel Consumption (Litres)	**61 million**
Estimated Number of Markets	**276**
Total Estimated Annual Emissions (tCO_2e)	**141,125 tons**
Share of Genset Capacity 0.1-5kVA	**76%**

[1] The number of MSMEs in Lagos State reported in the National Bureau of Statistics (NBS) 2021 MSME Survey Report was used.

EXECUTIVE SUMMARY (5/6)

For Context →

Contextualizing Lagos State's Genset Capacity and Emissions Impact: Our findings estimate that Lagos State has ~ 19 GW of genset capacity. To put this in perspective, Nigeria's entire national grid has an installed capacity of 12.2 GW. However, due to various operational inefficiencies, the peak available capacity is often around 5.4 GW, with the average available generation capacity being 4.2 GW as reported in the Nigerian Electricity Regulatory Commission's Electricity on Demand Quarterly Report in Q3 2023.

The environmental impact of this reliance is profound. The total estimated annual emissions from gensets in Lagos are around 39 million tons of CO_2 equivalent (tCO_2e).

To contextualize this impact, it is useful to compare Lagos' genset emissions with those of entire countries:

- **Togo:** ~ 9.8 million tons of CO_2
- **Rwanda:** ~ 10.6 million tons of CO_2
- **Gabon:** ~ 10.2 million tons of CO_2

The estimated annual emissions from gensets in Lagos amount to approximately 39 million tons, which is nearly four times the emissions of these entire countries. This comparison highlights the substantial environmental burden that genset usage in Lagos imposes, not just locally but also globally.

What it means →

Homogeneity in genset usage across micro, small and medium-sized enterprises (MSMEs) suggests a prime opportunity for solar and storage interventions in this sector. Given that MSMEs form the backbone of Nigeria's economy, tailoring solutions to their energy demands could yield significant impact. In contrast, the diverse energy requirement and genset usage in larger enterprises requires more efforts in developing suitable decarbonisation strategies.

The study underscores the usefulness of its data, analysis and geospatial visualization, and delineates how it can be effectively leveraged by various stakeholders, including the private sector, donors and governmental entities alike.

Sources: NERC Operational Performance of Power Plants (January 2024): https://nerc.gov.ng/media/factsheet-operational-performance-of-power-plants/
NERC Third Quarter 2023 Report: https://nerc.gov.ng/wp-content/uploads/2024/02/NERCThirdQuarter2023Report.pdf
2020 Country Emissions Data: https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE

EXECUTIVE SUMMARY (6/6)

What it means

The outcomes of this study are crucial for designing programmes, particularly regarding the displacement of fossil fuel generators and the deployment of targeted RE solutions. These data can be used as a strategic tool for both the private sector and donors, leveraging the functionalities of the IEP tool. The private sector can leverage this information to enhance operational strategies and identify suitable markets for genset displacement, while donors can use it to better align their support with energy transition initiatives. Governments can utilize these insights to refine energy policies, particularly for reducing reliance on diesel and promoting cleaner, more sustainable solutions.

The IEP serves as a robust tool for designing projects and initiatives. This study can enhance its usefulness by providing additional data for refining business cases and gaining deeper market insights. For instance, the IEP facilitated the design of the and with updated data, it can better support project implementation.

The study's robust data and analysis can be leveraged as the baseline to design tailored programmes and interventions that consider incentives, subsidies and results- based financing (RBF) mechanisms. Moreover, it can support the Lagos State Government to address policy gaps and regulatory adjustments, and provide specific, actionable recommendations for replacing gensets with cleaner alternatives, as well as to collaborate with partners to garner the support required to address financing challenges that will aid the prioritizing of initiatives based on factors such as feasibility, impact and stakeholder support.

This study provides a blueprint that can be adapted to diverse regional contexts, allowing for the strategic planning and execution of interventions aimed at removing fossil fuel genset usage. By detailing methodologies for collecting robust data on genset emissions and alternative energy solutions, the study equips stakeholders with the necessary information to assess the viability and impact of sustainable interventions in various environments.

The study underscores the importance of improving grid reliability to reduce genset dependence and highlights challenges hindering residential solar adoption, such as high upfront costs. It suggests that standardized bulk procurement for deploying solar systems in households and market shops would be effective, while centralized solar solutions may offer cost-effective options for markets. Additionally, insights reveal that tailored incentives are necessary for MSMEs due to their diverse energy needs. Understanding genset utilization factors is also crucial for effective transition strategies, with residential and commercial sectors requiring distinct approaches.

To guide future studies on genset enumeration, it is vital to first establish clear goals and metrics. This lays the foundation for well-formulated survey questions that are relevant and effective. Additionally, defining accurate calculation methods for desired metrics and employing statistical inference for population extrapolation are essential aspects of survey design. When crafting survey questions, it is necessary to prioritize open responses for numeric data to facilitate analysis. Lastly, when dealing with enterprises owning multiple generators, recording the capacity of the most utilized or suitable unit helps avoid overestimation.

Note: Some solar system components last for 25 years e.g. solar panels, while others like inverter and batteries and charge controllers may have shorter lifespans . The comparative analysis in this study used the assumptions the that total asset useful life is 10 years.

02 | INTRODUCTION

BEYOND THEIR NEGATIVE CLIMATE/ENVIRONMENTAL IMPACTS, GENSETS POSE SIGNIFICANT HEALTH AND ECONOMIC BURDENS

1,500+ DEATHS

~ 1,500 deaths per year from inhaling genset smoke and carbon monoxide

2 OUT OF EVERY 3

>2/3 of users report impaired hearing

70% RISK

70% increased risk of lung cancer

~ N20K-40K/MONTH

The average small business spends ~ N20,000 - 40,000 per month just on fuel. This is the largest cost to many small and medium enterprises (SMEs) in their operations.

$10BN

Nigerians reportedly spend $10 billion (~ N7.6 trillion) annually on fuel and maintenance for small petrol gensets

HIGH COST

The cost of electricity for petrol gensets is ~ 83% higher than the cost of electricity from the grid[2]

Gensets directly or indirectly affect at least 8 SDGs

[2] Cost estimates are from before petrol subsidy removal. Current costs are likely much higher.
Sources: Preliminary energy study of Nigerian MSMEs/markets (REA/Vista/UMass Amherst) 2022, Access to Energy Institute and Dalberg 2019 Study, UN SDGs.

EXISTING DATASETS/STUDIES ARE FRAGMENTED, SPARSE AND OUTDATED

RATIONALE

Urgent action to displace gensets is needed but constrained by a lack of comprehensive data.

- Insufficient actionable data and understanding of the capacity, use and impacts of gensets currently hinder the development of targeted and effective solutions.
- Existing studies, though useful, are limited in breadth and scope.
- Addressing genset use in Nigeria calls for a more precise and comprehensive examination of usage patterns.

PROJECT OBJECTIVES

- To begin resolving the existing data gaps and lay the foundation for effective fossil fuel genset displacement programmes, SEforALL and the Lagos State Government (the Lagos State Ministry of Energy and Mineral Resources) developed the Lagos State Fossil Fuel Genset Study.
- The project also aims to test and develop data collection methodology, which can be replicated cost effectively to conduct similar surveys nationwide.

STUDY	DALBERG AND ACCESS TO ENERGY INSTITUTE (A2EI), 2019	WORLD BANK, 2014	LAGOS STATE ELECTRICITY BOARD, 2014	WORLD BANK DPV STUDY 2021, LAGOS STATE GOVERNMENT (LASG), 2016
KEY TAKEAWAY (GENSET COUNT/ CAPACITY)	22 million small gensets (0 – 4 kVA) powering Nigerian households and SMEs. Total capacity: ~42GW	Diesel genset capacity: 0.855 – 3.3 GW Diesel self-generation: 5.24TWh – 20.38TWh	15GW of the ~45GW of off-grid gensets in Nigeria in Lagos State	Residential – 18GW Commercial – 2.28 GW Industrial – 1.435 GW
FOCUS SECTORS	Households, SMEs	Manufacturing, Telecommunications, Oil & Gas, Residential, Commercial	Cross cutting	Residential, Commercial and Industrial
FOCUS REGION	Bayelsa, Delta and Rivers	Nigeria	Lagos	Lagos
STUDY PARAMETERS	n = 910 households, 165 SMEs	Estimated from existing datasets across different vintages and quality levels	Extensive door-to-door survey (e.g. 13,000 locations across 11 areas)	Estimated largely based on benchmarking and demand-supply gap (relies on baseline data from 2014)
LIMITATIONS	• Limited scope; estimates for the whole nation based on data from 3 states • Covers only petrol gensets	• Outdated • Applies secondary data with different quality levels • Focuses on only diesel gensets • Report advises not to aggregate estimates for different sectors	• Limited outdated research rigor and sampling methodology, impeding extrapolation to state- level statistics	• Draws on outdated data • Largely built on estimations and not empirical evidence (especially in commercial and industrial sectors)

LAGOS STATE SERVED AS THE IDEAL PILOT LOCATION FOR SEVERAL REASONS

27% OF NIGERIA'S GDP

The Lagos GDP accounts for ~27% of Nigeria's total GDP and more than 50% of non-oil GDP

~ 30-40 TWH

Unconstrained annual electricity demand is ~ 30- 40 TWh. Current supply gap is about 80% (23 – 33 TWh or about 3 – 4 GW).

POPULATION: 24 MILLION

Estimated population of 24 million, which is larger than any other economy in the ECOWAS subregion (~4.8 million households)

DPV MARKET OPPORTUNITY

$1.5 – 3 billion market opportunity for DPV in the state. DPV potential of ~ 12GW

1000MW

1000MW dispatched from the grid for an average of 12 hours daily (~ 4TWh per year). Average operational capacity on the Nigerian grid is ~ 4000MW

Sources: Lagos State Government Official Website, Lagos State Electricity Policy, Edomah and Ndulue (2020), World Bank Genset Study (2014), LBS Household Survey (2020), World Bank DPV Study (2021).

LAGOS STATE AT A GLANCE

- The Lagos State Government (LSG) has a strong interest in facilitating a state-wide distributed solar PV (DPV) programme to replace fossil fuel gensets.
- Lagos State is considered Nigeria's economic and commercial capital, and home to the largest share of the nation's population.
- Given its population and economic activity, Lagos State has the highest electricity demand in Nigeria. Two of the eleven distribution companies in Nigeria solely serve Lagos State.
- Energy supply is currently the single biggest infrastructure and developmental challenge in the state. Only ~ 20% of electricity demand is being supplied by the grid, with a significant share of the deficit being met via gensets.
- The 2014 World Bank report on diesel gensets notes that Lagos State has the highest number of diesel gensets in the residential sector and the highest expenditure on diesel purchases of all states in Nigeria.

Sources: Lagos State Government Official Website, Lagos State Electricity Policy, Edomah and Ndulue (2020), World Bank Genset Study (2014), LBS Household Survey (2020), World Bank DPV Study (2021)

LAGOS STATE SERVED AS THE IDEAL PILOT LOCATION FOR SEVERAL REASONS

The Lagos State Fossil Fuel Genset study was undertaken to generate detailed data on the **quantity, usage patterns and environmental impacts of fossil fuel gensets** in Lagos State to inform the design and implementation of targeted initiatives and policies aimed at replacing existing generator sets.

STUDY SCOPE

PRIMARY DATA COLLECTION

Gathering data on genset number, types, sizes, fuel consumption, maintenance costs, performance characteristics, demand patterns, cost details, demographic data of asset owners and perceptions on self-generation alternatives.

SECONDARY DATA REVIEW

Analyzing current fossil fuel self-generated electricity, across markets, leveraging data from previous audits.

IMPACT ANALYSIS

Estimating climate, cost and health implications of genset use, as well as predisposition of citizens to DPV and associated considerations.

GEOSPATIAL DATABASE DEVELOPMENT

Creating a geospatial database integrating data and analytics.

03 | STUDY APPROACH

PROJECT APPROACH

- Crafting the study to meet predefined objectives demanded meticulous attention to various factors and the application of robust methodologies.
- Evidence-backed strategies were employed throughout the study, encompassing the sampling technique, field collection approach, questionnaire development and piloting, quality assurance and control, as well as stakeholder engagement and collaboration.
- When challenges surfaced, adjustments were implemented and valuable lessons were documented.
- Throughout the project duration, more than 7,400 distinct observations were recorded across Lagos State's residential, industrial and commercial sectors.

KEY RESPONSIBILITIES

Two consultants – Vista Advisory Partners (VAP) and FRAYM – were engaged to establish a consortium to carry out the comprehensive diesel/petrol genset audit for Lagos State.

The audit employed traditional survey methodologies and advanced geospatial analytic tools to establish baseline estimates on a wide range of indicators relevant to the replacement of gensets.

VAP	FRAYM
On-the-ground data collection and preparation: enumeration across the state (residential & C&I)	Stratification of Lagos State using traditional and geospatial methods
Secondary data research: review and assessment from existing data sources and studies	Data analysis and visualization of collected data on geospatially enabled platforms

*Georeferenced Infrastructure and Demographic Data for Development (GRID3)

PROJECT APPROACH

PRIMARY DATA COLLECTION

1 — **RESIDENTIAL SECTOR SURVEY**
Household surveys (representative across 20 LGAs in Lagos)

2 — **COMMERCIAL & INDUSTRIAL SECTOR SURVEY**
(information from Ministry of Commerce + *GRID3 database)

SECONDARY DATA COLLECTION

3 — **MARKET ANALYSIS**
(prioritizing markets, drawing from previous audits)

↓

4 — **IMPACT ANALYSIS ON COLLECTED BASELINE DATA**
(financing, economics, health and environment impacts, interest in DPV)

↓

5 — **MAPPING/VISUALIZATION**
(host resulting data and analytics on geospatial database - Nigeria Integrated Energy Planning (IEP) tool)

*Georeferenced Infrastructure and Demographic Data for Development (GRID3)

PRIMARY DATA COLLECTION

RESIDENTIAL

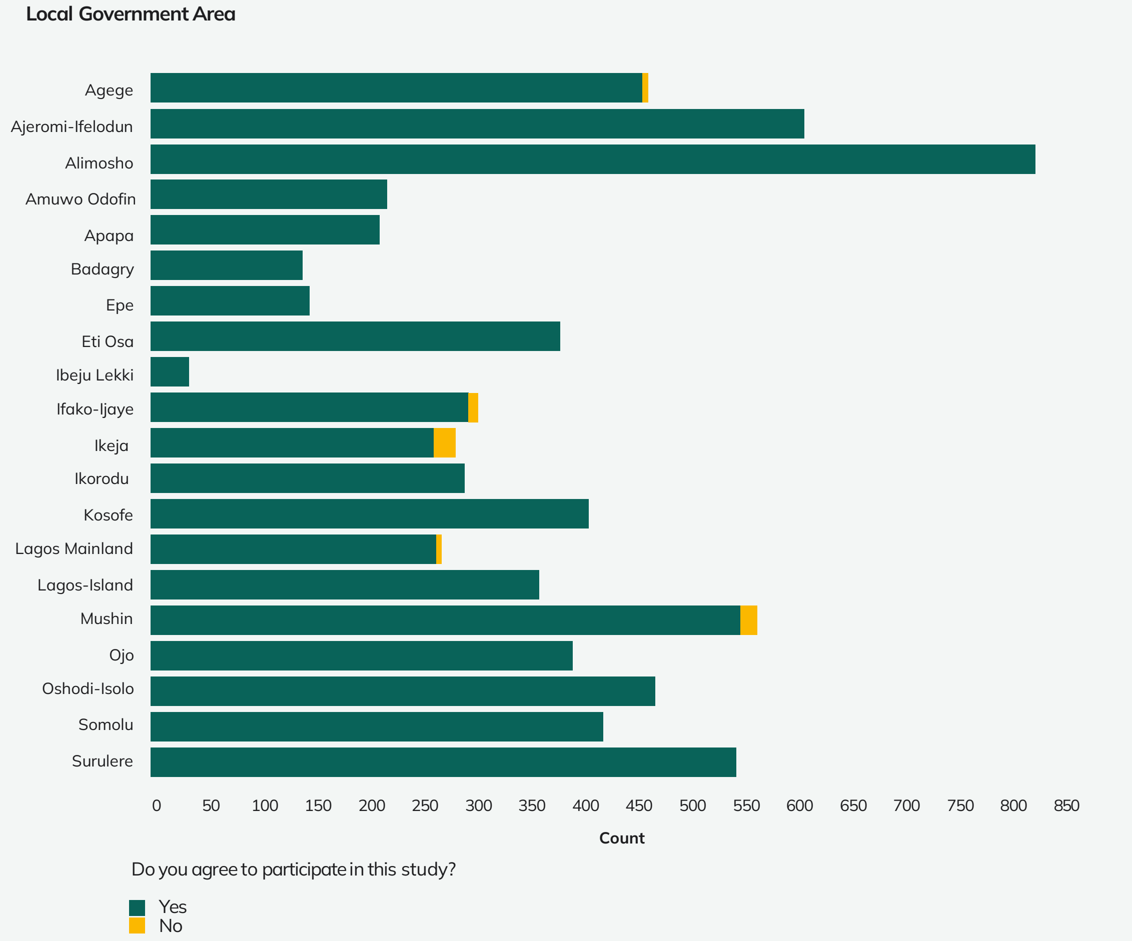
Sampling Technique

- The sample for the study was designed to provide estimates that are representative for each of the state's 20 local government areas (LGAs).
- A target sample size of 6,000 respondents was selected. This surpasses previous studies.
- While the geospatial analysis may not have required such a robust sample to produce adequate spatial outputs, the consortium chose to mirror the sample size required for a national-level engagement to maximize the chances of producing quality results.
- Wards served as the primary sampling units in a single-stage stratified cluster strategy. The sample frame was stratified by LGA, and then 200 ward clusters of 30 households each were randomly selected with probability proportional to the LGA household population. For example:
- Agege LGA contains an estimated 5% of households in Lagos, therefore, 5% of the 200 survey clusters were selected from Agege.

A comprehensive total of **7,232 data points were acquired.** Of these, 7,186 respondents willingly provided their consent to participate in the survey (~20% greater than the target value).

Collection Period: 12th October – 21st November 2023

Number of Enumerators Deployed: 99



PRIMARY DATA COLLECTION

FIELD APPROACH

Following the selection of the 200 wards, a random walk methodology, starting from each ward's centroid, was systematically adopted by field teams to survey the stipulated 30 households per ward.

- The centroid coordinates[3] within each selected ward were calculated using boundary data from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) database
- Using this point as guidance, enumerators executed a random walk starting from the nearest viable street and covering the entire area through various interconnected paths. Local administrative bodies also deployed locally staffed mapping assistants to support the project.
- Based on this interval sampling approach, the field teams surveyed approximately 1 out of every 5 residences.

The enforcement of interval adherence was managed through the counting of households by field supervisors and the implementation of random back-checks, affirming the integrity and accuracy of the survey process.

WARD SELECTION: 200 wards were chosen.

SURVEY METHODOLOGY: Field teams used random walks from ward centroids to survey 30 households per ward.

CENTROID CALCULATION: Centroid coordinates were determined using the GRID3 database.

RANDOM WALK EXECUTION: Enumerators walked from the nearest street, covering the area guided by centroids.

MAPPING ASSISTANTS: Local bodies deployed assistants.

SAMPLING APPROACH: Approximately 1 in 5 residences were surveyed.

ENFORCEMENT: Supervisors counted households and implemented random back-checks for accuracy.

[3] Using randomly generated coordinates for randomization within wards seemed beneficial. However, combining random walks with these coordinates was considered impractical because enumerators couldn't easily avoid crossing ward boundary lines during their wdks.

PRIMARY DATA COLLECTION

COMMERCIAL ENTITIES

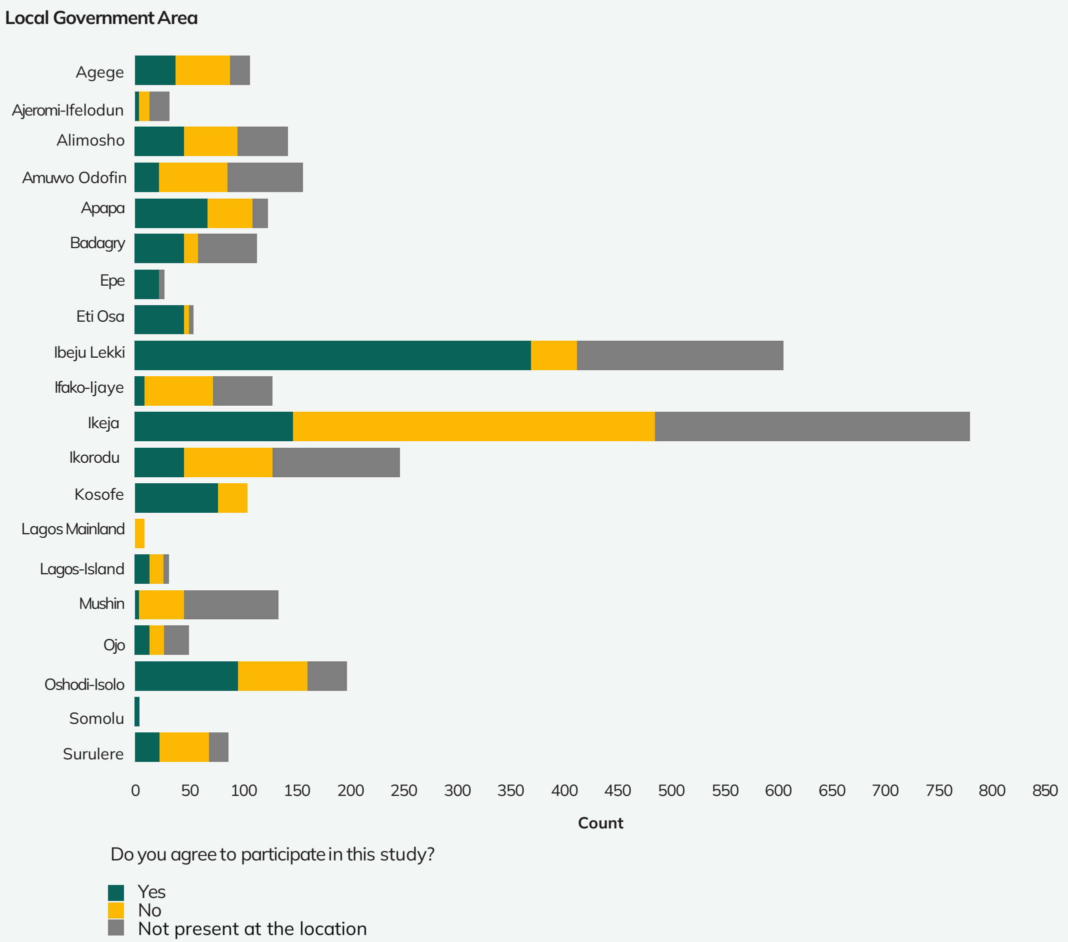
Sampling Technique

- To assess indicators on electrical grid connectivity, genset ownership and attitudes towards alternative energy across the Commercial sector, a sampling frame of known commercial and industrial sites was constructed. This sampling frame was based on points of interest (POI) data from GRID3, which was cross-referenced with a registry provided by the Lagos State Ministry of Commerce, Industry and Cooperatives.
- This yielded a list of 470 Commercial entities within Lagos State.
- Given this manageable number of commercial entities, random sampling was not required; rather, the consortium sought to count the entire known "universe" of commercial entities.
- As an unknown proportion of the commercial entities in the sampling frame were no longer operational, a baseline threshold of counted commercial entities was established. By enumerating the threshold number of commercial entities at minimum, a representative sample of the population of commercial entities in Lagos State could be achieved. The threshold was determined by referencing methodology from the World Bank Enterprise Survey, which calculates that given a population of 800 enterprises and a desired precision of 5% at 90% confidence, a sample size of 202 enterprises constitutes a representative sample.

240 respondents granted consent to participate in the survey.

Collection Period: 11th October – 30th November 2023

Number of Enumerators Deployed: 24



PRIMARY DATA COLLECTION

COMMERCIAL ENTITIES

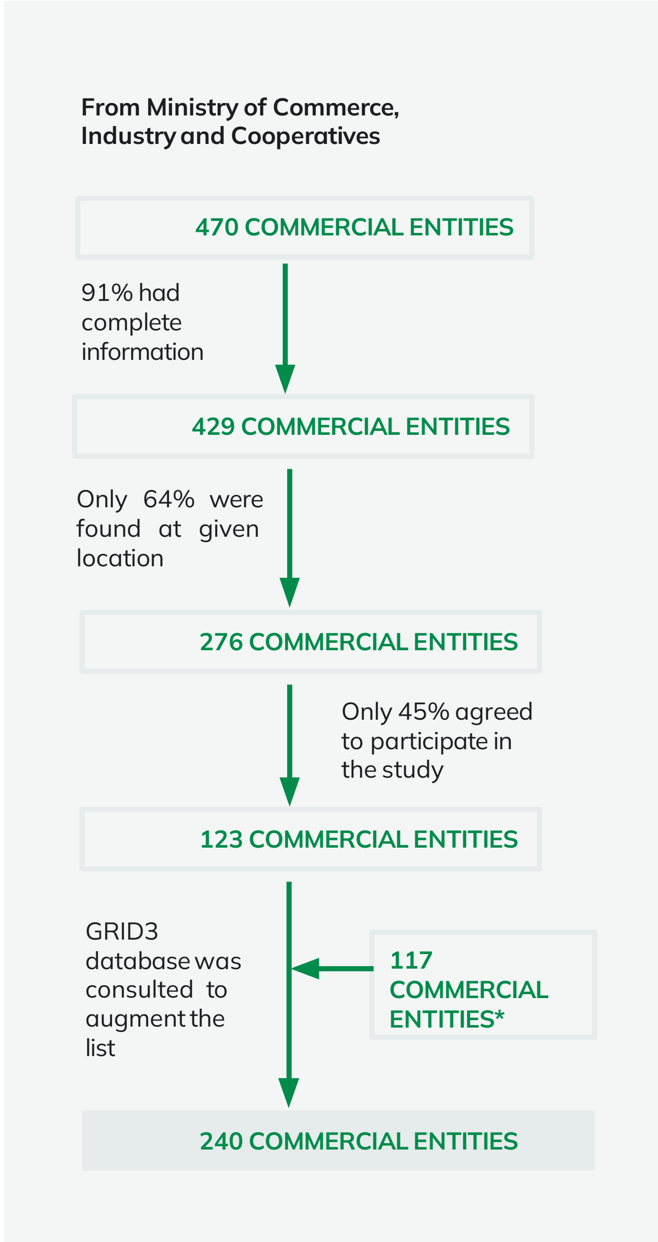
No hyperlocal estimation was envisaged for the commercial and industrial sector. The survey aimed to count all known commercial entities in Lagos based on a list of 470 commercial entities obtained from the Lagos State Ministry of Commerce, Industry and Cooperatives.

Although the intention was to establish state-level statistics by aggregating collected data, this proved challenging due to field collection limitations:

- 429 commercial entities from the list of 470 had complete information for a field visit
- 36% of these 429 commercial entities were no longer available at the given address, reducing the list to 276
- Only 123 commercial entities in the reduced list of 276 agreed to participate in the study (about45%)
- 102 commercial entities (37% of the 276 industries) expressed a general lack of interest in the study
- Other reasons cited for non-participation included unsuitable time and place, and some industries claimed lack of notification from the LGA/LCDA, despite individually addressed letters from the Ministry of Energy and Mineral Resources.

To supplement the list of participating commercial entities, the consortium consulted the GRID3 record of industries in Lagos:

- Over 300 commercial entities were randomly selected from this list
- Similar to the list from the ministry, 48% of these commercial entities were not found at the given locations, reducing the list to 173
- 117 of these 173 commercial entities (68%) accepted to participate.
- Thus, the study successfully counted 240 commercial entities in Lagos.
- This experience underscores the importance of undertaking a robust enumeration of key commercial entities in Lagos State, as well as **updating/consolidating existing lists** to **create a comprehensive database.**



* From GRID3

QUESTIONNAIRE DEVELOPMENT

To ensure the effectiveness and reliability of the study, careful consideration was given to the design of the questionnaire.

The questionnaire, designed for both quantitative and qualitative insights, was configured into a user-friendly dynamic app, covering the following sections:

- **Geolocation of household/business**
- **Organization/household information:** including household size/employee count, source of income/nature of business, estimated monthly income/monthly revenue, indications of any business activity within the household, etc.
- **Electricity usage and consumption patterns:** including grid connection, hours of grid usage, expenditure on grid, grid supply reliability, presence of meter, etc.
- **Genset usage and fossil fuel consumption pattern:** genset capacity, maintenance patterns, fuel type, consumption and purchase patterns, etc.
- **Genset impact:** including perceptions of air quality and pollution, noise contribution, complaints and mitigation, etc.
- **Alternate energy source (focus on solar):** including interest in transitioning, post-subsidy reflection, awareness, current solar use, etc.
- **Socioeconomics:** including banking habits, mobile phone ownership and perceptions of local infrastructure.

PILOT EXERCISE

- The data collection approach underwent validation through a robust pilot exercise across three LGAs – Alimosho, Eti Osa, and Somolu – comprising 1,610 households.
- This exercise ensured methodological suitability and alignment of survey question responses with expectations and provided insights into the time required for each LGA survey.
- Completed within a three-week time frame, the pilot exercise provided valuable lessons that were applied to enhance the efficiency of the subsequent data-gathering process and field protocols.

QUALITY CONTROL MECHANISMS

To guarantee the quality and consistency of collected data, the consortium prioritized comprehensive classroom and field training for all supervisors and enumerators before the commencement of the survey exercise.

Survey Questionnaire and App Design: Multiple choice questions (MCQs) were largely designed to restrict raw data entry and limit the likelihood of misinterpretation/ inaccuracies.

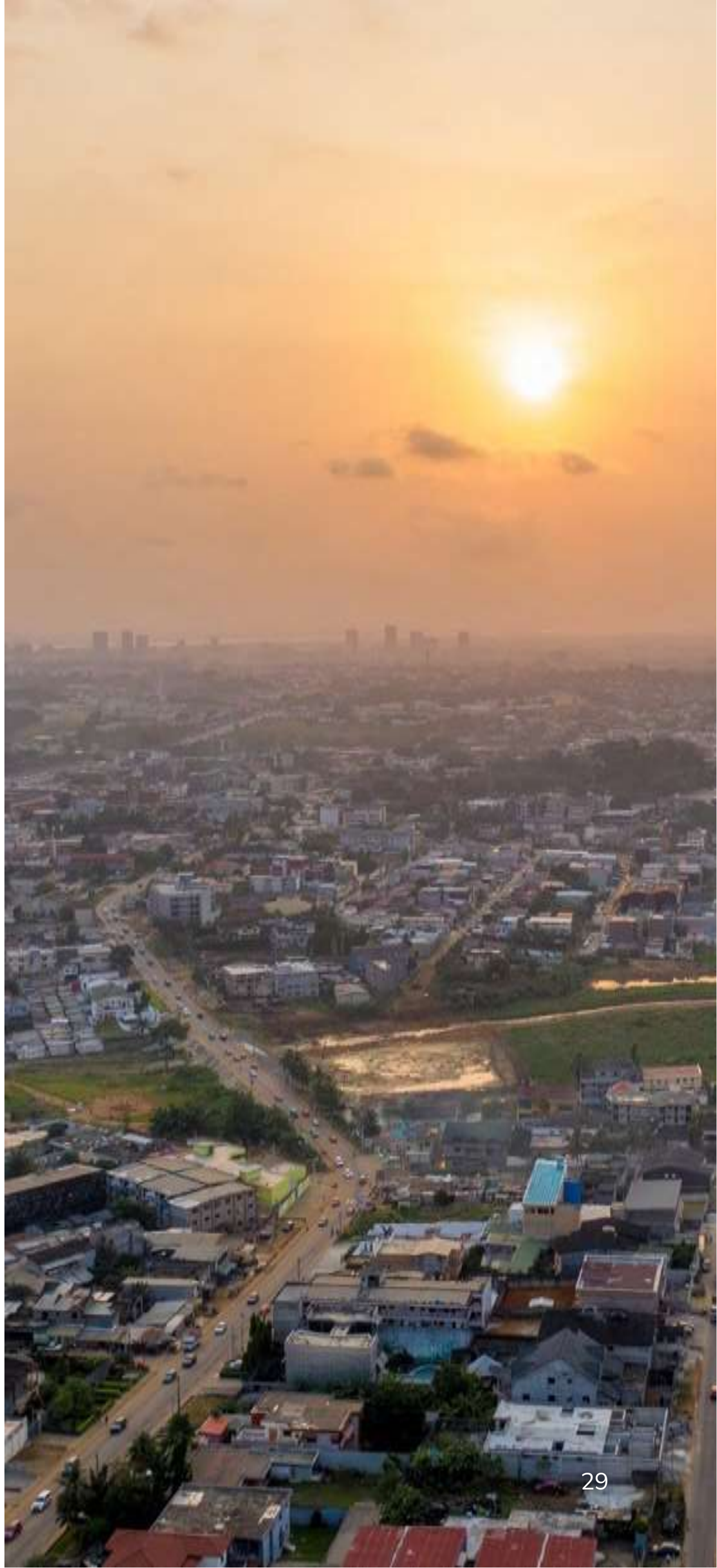
Enumerators' self-assessment of accuracy in data collection: Instances where enumerators expressed low confidence in the honesty/accuracy of respondent answers (e.g. when 0–25% accuracy was selected) were flagged and addressed.

Concurrent Validation: Near real-time reviews flagged select forms for prompt re-verification through respondent revisits or phone calls. Over 10% of completed surveys underwent independent re-verification through back-checks.

Protocol Adherence: Automated triggers and clear escalation protocols notified managers of any methodology deviations, facilitating swift corrective action and one- on-one mentoring.

Field Audits: Unannounced site visits and remote form reviews assessed operational facets like spatial adherence, data capture diligence and interview etiquette, with improvement recommendations shared within 24 hours.

Error and Outlier Check Algorithm: Automated algorithm were developed to meticulously classify each data point as either "clean" or "outlier," contributing to the quality of the overall data lifecycle.



STAKEHOLDER ENGAGEMENT

Alignment of key stakeholders was achieved through formal communications (letters and meetings), interactive forums, mass/social media campaigns and the strategic leveraging of community partnerships. These efforts played a pivotal role in fostering acceptance and active participation in the study.

STAKEHOLDERS

LAGOS STATE

LAGOS STATE Ministry of Information and Strategy

LAGOS STATE Ministry of Energy and Mineral Resources

LAGOS STATE Ministry of Local Government, Chieftaincy Affairs and Rural Development

Lagos State Ministry of Budget and Economic Planning

LASEPA

Global Energy Alliance for People and Planet GEAPP

All On

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

REA RURAL ELECTRIFICATION AGENCY ENERGY • EMPOWERMENT • EFFICIENCY

THE WORLD BANK IBRD • IDA

POWER AFRICA

COMMUNICATION STRATEGIES FOR IMPROVED SURVEY PARTICIPATION

Letters: The Lagos State Government (LASG) drafted introductory letters that were sent to local government areas (LGAs), local council development areas (LCDAs), and community heads, providing comprehensive information about the study. Separate notifications were also disseminated to industry associations and operators.

Town Hall Meetings: Interactive town hall orientation meetings were organized across the 20 LGAs to directly brief representatives and community leaders.

Radio Jingle: A 60-second audio jingle was broadcast on prime radio channels at key intervals during the survey.

Social Media Engagement: The Nigeria Energy Transition Office's X, formerly Twitter, and Facebook platforms were used to release infographics on the survey.

COMMUNITY PARTNERSHIPS

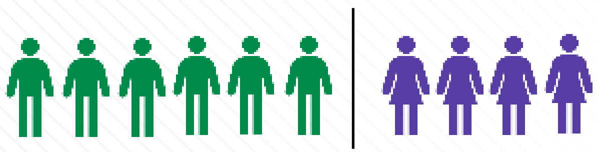
The establishment of partnerships with community stakeholders (local governing bodies and grassroots associations) played a crucial role in gaining community trust and enhancing participation rates for the household genset survey.

Local opinion leaders and community heads actively mobilized participation by **conducting peer outreach within their communities**

Local governing bodies provided valuable support by **deploying locally staffed mapping assistants with geographic familiarity of wards.** These "area guides" assisted field teams in navigating boundaries where potential enumeration uncertainties may have arisen.

Their participation also lent a level of localized trust that facilitated resident participation.

In each local government, about 5 local guides (3 males and 2 females) supported the team, depending on their availability. **In total, 100 local guides were engaged in the project, comprising 60 males and 40 females.**



CHALLENGES AND ADAPTATIONS

CHALLENGES	ADAPTATIONS
Access Constraints: Initial resistance/unavailability was recorded in conservative and gated areas	The challenge was resolved through targeted local community partnerships, aligning with cultural norms. • For example, in Ibeju ward, scepticism towards participation was addressed by conducting a localized sensitization exercise including the LCDA chairman and influential residents. Timings were adjusted based on occupant availability patterns. • For example, the commercial and industrial enumerators were deployed on weekdays from Mondays to Fridays, while the residential teams were deployed from Thursdays to Sundays.
Language Barriers: Vernacular communication gaps were observed	Multilingual capabilities were incorporated within field teams. The reassignment of enumerators to linguistic zones was observed to enhance receptivity. • For instance, in the Shomolu LGA cluster, an enumerator proficient in the interviewee's native language was promptly deployed to resolve language comprehension issues.
Non-cooperation: Instances of non-cooperation, arising from resident distrust or hostilities were recorded, especially in the commercial and industrial sector (~ 40% of industries that were visited refused to participate in the study)	• Localized sensitization efforts were undertaken. Clear communication of project goals and transparent dialogue helped mitigate respondents' concerns. • In cases of persistent non-cooperation, alternative willing respondents were engaged.

INSIGHTS FROM DATA COLLECTION PROCESS

Scope of Pilot Survey: Conducting the pilot survey within a subset of a local government area (LGA) rather than the entire LGA would have been more effective. Corrections and refinements identified during the pilot were primarily applied to subsequent LGAs, bypassing the pilot LGAs. This adjustment would ensure that lessons learned from the pilot are promptly implemented across all LGAs as relevant.

Communication Strategy: The use of generic letters of introduction, lacking addressee details, resulted in site access rejections and data gathering delays, especially in the commercial and industrial sector. To address this, addressed letters should be provided for the intended recipients.

Project Lead Time and Stakeholder Engagement: Unforeseen delays in engagements with government stakeholders at different levels prolonged the project duration. Early and comprehensive engagements should be prioritized with sufficient time allocated in the project timeline.

Survey Length: Stakeholders expressed concerns about the survey's length potentially deterring community enthusiasm. Efforts to continuously improve question articulation and brevity should be explored.

Sensitive Question Scrutiny: LGAs advised caution regarding certain vocabulary that could be culturally inappropriate. Alternate standard terms were suggested and incorporated.

For example, enumerators were advised to avoid directly questioning residents about reasons for electricity non-provision in communities like Ilase and Tarkwa Bay with limited grid power access. Given that government bodies sponsored the survey, it was noted that such questions could evoke frustration and agitation. Hence, enumerators were counselled to frame questions objectively, focusing on current costs, reliability issues and cleaner energy aspirations.

SECONDARY DATA REVIEW

MARKETS

Evaluation Approach

The secondary data collection approach for this study involved leveraging existing data gathered during a survey conducted by the E-guide, Rural Electrification Agency (REA) and Vista Advisory Partners in 2022. The research concentrated on nine markets spread across seven local government areas (LGAs) within Lagos. The markets include Oniru and Saka Tinubu in Eti-Osa, Ketu and Ketu Shopping in Kosofe, Alade in Ikeja, Oyingbo in Lagos-Mainland, Ilupeju in Mushin, Abraham Adesanya in Somolu and Lawanson in Surulere.

Key information such as market distribution across LGAs, market occupancy and the types of businesses present in each market were reviewed and analyzed based on the available data. This secondary data collection approach provided valuable insights into electrification status and self-generation across the markets.

04 | STUDY METHODOLOGY

PRIMARY DATA COLLECTION

The selected methodology[4] used data from scientifically sampled, geo-tagged household surveys, along with satellite imagery layers[5], to predict given characteristics/indicators within each 1 km^2 grid cell.

After data collection, post-hoc sampling weights were created to account for oversampling and ensure representativeness.

Each household was assigned a survey weight using iterative proportional fitting (ranking) based on the household population data provided by Lagos State Bureau of Statistics (LBS) to ensure that the weighted distribution of households in the sample aligned with the distribution of households according to the LBS data. This addressed potential over- and underrepresentation in the sample.

Following this, a model was created that identifies correlations between the collected data at enumeration clusters and the satellite imagery and remotely sensed layers from the same location (model-stacking machine learning approach)[6]. The resulting model was then used to predict the desired characteristics for all non-counted areas[7].

The data layers at a 1 km^2 resolution were then aggregated at the required geographic levels (primarily LGA and state).

FOR EXAMPLE:

For indicators with continuous values greater than 1, such as fuel consumption, the hyperlocal estimates produce mean values at the 1 km^2 resolution. To generalize from mean estimates to total estimates, the mean values were applied to household population figures from WorldPop and LBS.

[4] This methodology is encapsulated in Fraym's Artificial Intelligence/Machine Learning (AI/ML) software. In the development of this methodology, Fraym has collected/assessed, cleaned and harmonized over 1,000 surveys from around the world.

[5] The methodology (Fraym's AI/ML software) uses only high-quality imagery and derivative inputs. The satellite imagery and related derived data products include earth observation data, gridded population information (e.g., human settlement mapping), proximity to physical locations (e.g., health clinics, ports, roads, etc.) and biophysical surfaces like soil characteristics.

[6] Fraym's machine learning process involves generating predictions from a set of base-learner models upon which a super learner model is trained. By leveraging multiple base models, the software can improve the final predictions across large geographies. Models are tuned and evaluated using industry-standard cross-validation techniques, and as needed, the predictive power of datasets is improved through systems of boosting, bagging and k-fold cross-validation.

[7] A similar approach was pioneered by USAID's Demographic and Health Surveys programme in 2015 and has since been improved upon by Fraym and others.

* scaling from survey responses to all of Lagos State

PRIMARY DATA ANALYSIS: COMMERCIAL

To calculate commercial metrics, enterprises that were counted were first classified into three mutually exclusive categories based on the number of employees and estimated monthly revenue for each enterprise:

- Micro Enterprises: < 10 employees
- Small Enterprises: 10–50 employees
- Medium Enterprises: 51–100 employees, or 101–500 employees and estimated monthly revenue N500,000-N100,000,000.

Enterprises that fell out of this range, or did not report the number of employees, were not included in the analysis. Based on data limitations, these definitions of micro, small and medium-sized enterprises (MSMEs) do not perfectly align with the definitions of MSMEs from the National Bureau of Statistics (NBS) 2021 MSME Survey Report.[8]

Based on the NBS classification, micro enterprises in this report would also include Nano/Homestead enterprises, while medium enterprises would not have more than 199 employees.

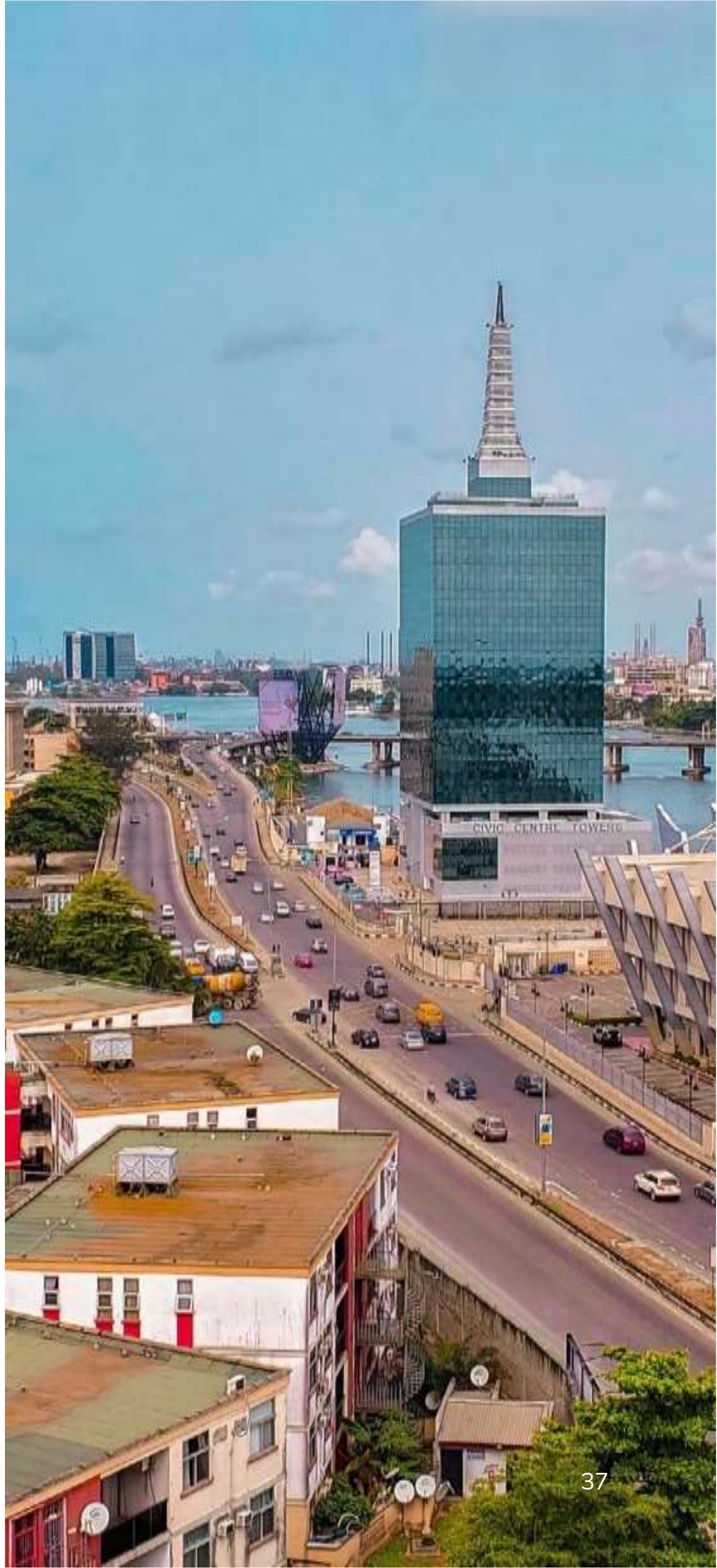
The classification and calculations used in this report assume that counted enterprises did not include any Nano/Homestead enterprises, and that estimates for these are captured in the residential demand sections.

To calculate metrics across MSMEs, the number of MSMEs in Lagos State reported in the National Bureau of Statistics (NBS) 2021 MSME Survey Report was used.[9]

Enterprise population estimates by enterprise size were extrapolated by multiplying average metrics from the survey by the number of enterprises in each category. These estimates were then aggregated to extrapolate total population (of MSMEs) values and divided by the total number of relevant enterprises to produce total population (MSME) weighted averages per metric.

These calculations assume that the survey provided a representative sample of MSMEs across Lagos State, and that the number of enterprises by size in the 2021 NBS report are accurate.

[8, 9] https://smedan.gov.ng/wp-content/uploads/2022/03/2021-MSME-Survey-Report_1.pdf



PRIMARY DATA IMPACT ANALYSIS: CLIMATE AND ENVIRONMENT

To provide insight into how the use of fossil fuel gensets affects climate change, environmental conditions and health, emissions of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as well as air pollutants including nitrogen oxides (NOx), carbon monoxide (CO), sulfur oxide (SO_2) and non-methane volatile organic compounds (NMVOC) were estimated.

Measures of annual fuel consumption from the survey data served as the basis of the estimation according to the following formula:

$$E = F \times emFact \times \{conFact\}$$

Where:
E = Emissions (kg/year)
F = Annual fuel consumption (litres)
emFact = Emissions factor (kilogram/litre)
conFact = Carbon equivalent conversion factor

Annual fuel consumption was converted into annual emissions using, for each fuel type, emission factors provided by the Greenhouse Gas Protocol[10], while greenhouse gases were converted to carbon equivalents using conversion factors from the U.S. Environmental Protection Agency[11].

[10] Greenhouse Gas Protocol, Emissions Factors from Cross-Sector Tools, https://ghgprotocol.org/calculation-tools-and-guidance
[11] Environmental Protection Agency, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

PRIMARY DATA IMPACT ANALYSIS: COST / ECONOMICS

To assess the cost implications of genset use, survey responses were used to estimate the associated capital, operational and maintenance costs as well as cashflow for different sizes of gensets and corresponding solar PV replacement systems.

Specific questions in the survey addressed genset purchase costs, maintenance costs and frequency, and fuel consumption and frequency. The fuel consumption data were paired with price information from the National Bureau of Statistics (NBS) to calculate fuel costs[12]. The operational (fuel and maintenance) costs were then grouped into expenditure bands, revealing the proportion of Lagos households and industries (counted sites) spending certain amounts on genset operation. The genset purchase costs were directly obtained in bands during the survey.

Using the proportion of households in each cost band, the average expenditure within each band, and the total number of households with gensets in Lagos, the overall purchase and operational costs of gensets were computed.

A similar approach was adopted to determine the total genset purchase costs for the commercial and industrial sites that were counted. In contrast, for operational costs, a direct summation was performed across collected data for the individual industries.

Sample Calculation:

Total Genset Maintenance Cost =

$$\sum_{i=1}^{n} (AvgGenMaintCost \cdot BrandPop \cdot GenPop)$$

Where:

n = number of identified expenditure bands

i = Each band (e.g., "< N1,500", "N1,500 – N2,499", "N2,500 – N4,999", etc.)

AvgGenMaintCost = Midpoint of the band/Average genset maintenance cost in the band

BandProp = Proportion of genset-owning households in the band

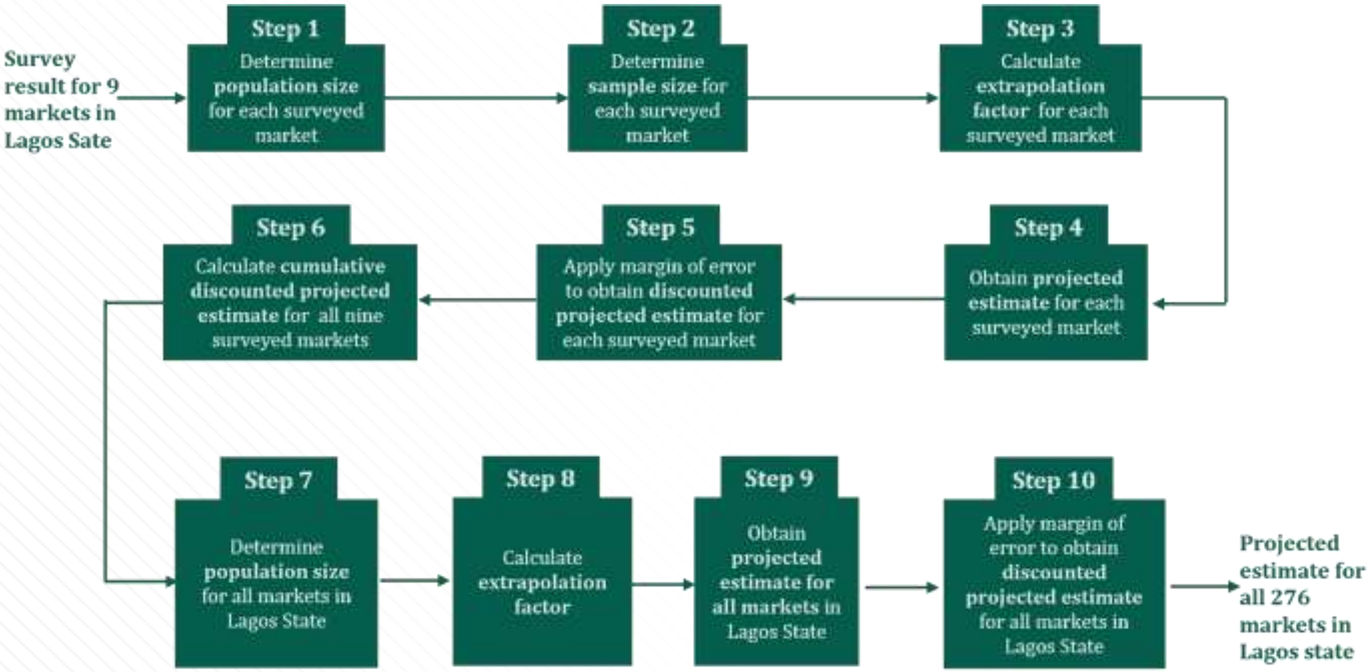
GenPop = Number of households in Lagos that own at least one genset

Additionally, genset costs were compared to grid costs for grid-connected households and industries, using information collected from the grid electricity bill.

[12] NBS: Automotive Gas Oil (Diesel) Price Watch (January – November 2023)- Average price for Lagos (N874.75 per litre), Premium Motor Spirit (Petrol) Price Watch (January - November 2023) - Average price for Lagos (N436.21 per litre), Gas (LPG) Price Watch (January - November 2023)- Average price for Lagos (N508.69 per litre).

SECONDARY DATA ANALYSIS: MARKETS

Due to the novelty of this study, the limited data available on the nine markets were scaled up with reasonable assumptions to obtain estimates for all 276[13] markets in Lagos State. To calculate these projections, a 10-step approach was employed.



NOTES ON SECONDARY DATA ANALYSIS

Population size (i.e. number of shops) for all markets in Lagos State was assumed to be 42,037 as of 2019, as per the official National Bureau of Statistics (NBS) statistics.

Population growth rate between 2019 and 2024 was assumed to be 18.93%.

An extrapolation factor of 19.93 was used in obtaining projected estimates from the survey results[14].

Margins of error of 10% and 30% were adopted to account for variabilities and uncertainties due to limited data available on Lagos State markets across the surveyed 9 markets and the total 276 markets respectively.

[13] While there are 299 markets from the report published by the Lagos State Ministry of Economic Planning and Budgeting, only 276 markets provided information on the number of shops available across all markets per LGA. Source: LAGOS BUREAU OF STATISTICS, Local Government Statistics 2020, page 70. https://mepb.lagosstate.gov.ng/wp-content/uploads/sites/29/2022/02/LGA-Statistics-ver-2020.pdf

[14] Calculated as the ratio between the population size in 2024 (total number of shops within markets in Lagos State) and the total number of occupied and unoccupied shops in the nine audited markets reported by E-GUIDE.

METRICS AND INDICATORS

The resulting data have been integrated into the Nigeria Integrated Energy Planning (IEP) tool. Residential data at the 1- km^2 resolution will allow users to conduct analysis at the ward level. Data for each commercial and industrial site have been added as an interactive point of interest and the markets are at state level.

GENERAL RESIDENTIAL	• Household size • Household head occupation, education, gender • Monthly income • Business ownership • Cooking fuel
GENERAL COMMERCIAL	• Sector • Employees (number, gender) • Monthly revenue
GENERAL MARKETS	• Shop count • Business type
ELECTRICITY CONSUMPTION	• Grid connectivity, reliability • Alternative energy sources • Usage (days per week, hours per day), tariff band
GENSETS	• Ownership (brand, number, capacity, cost) • Usage (fuel type, purpose, hours per day, times of day, days per week) • Maintenance (frequency, cost, issues) • Income-generating activities • Social/environmental impact
CLEAN ENERGY	• Awareness (Energy Transition Plan, solar energy) • Solar systems usage (number, capacity, cost)

DATABASE AND VISUALIZATION:

INTEGRATED ENERGY PLANNING TOOL

The Nigeria Integrated Energy Plan (IEP) consists of an enhanced least-cost electrification plan and a clean cooking plan, which are accessible through an online, interactive geospatial visualization tool (IEP tool). The IEP tool enables users to select their own parameters and download the results of the IEP model.

The tool is free and publicly accessible at https:// nigeria-iep.sdg7energyplanning.org/

To maximize the existing platform and make the generated data publicly accessible to a wide range of stakeholders, the analytical outputs from the project will be incorporated into the Nigeria IEP, including:

- Key metrics from the residential survey data, extrapolated to the whole population and aggregated at the state, LGA and ward levels.
- "Point" data of all counted commercial and industrial sites
- Selected metrics for the extrapolated commercial results, aggregated at the state level
- Selected metrics for the market results, aggregated at the state level
- Auxiliary spatial data such as population counts and ground-level air pollution

While spatial outputs from the hyperlocal estimation have a 1 km^2 resolution, integration to the IEP tool is aligned to the *ward*, *LGA*, and *state* geographic scopes. The aggregation occurred in one of three ways:

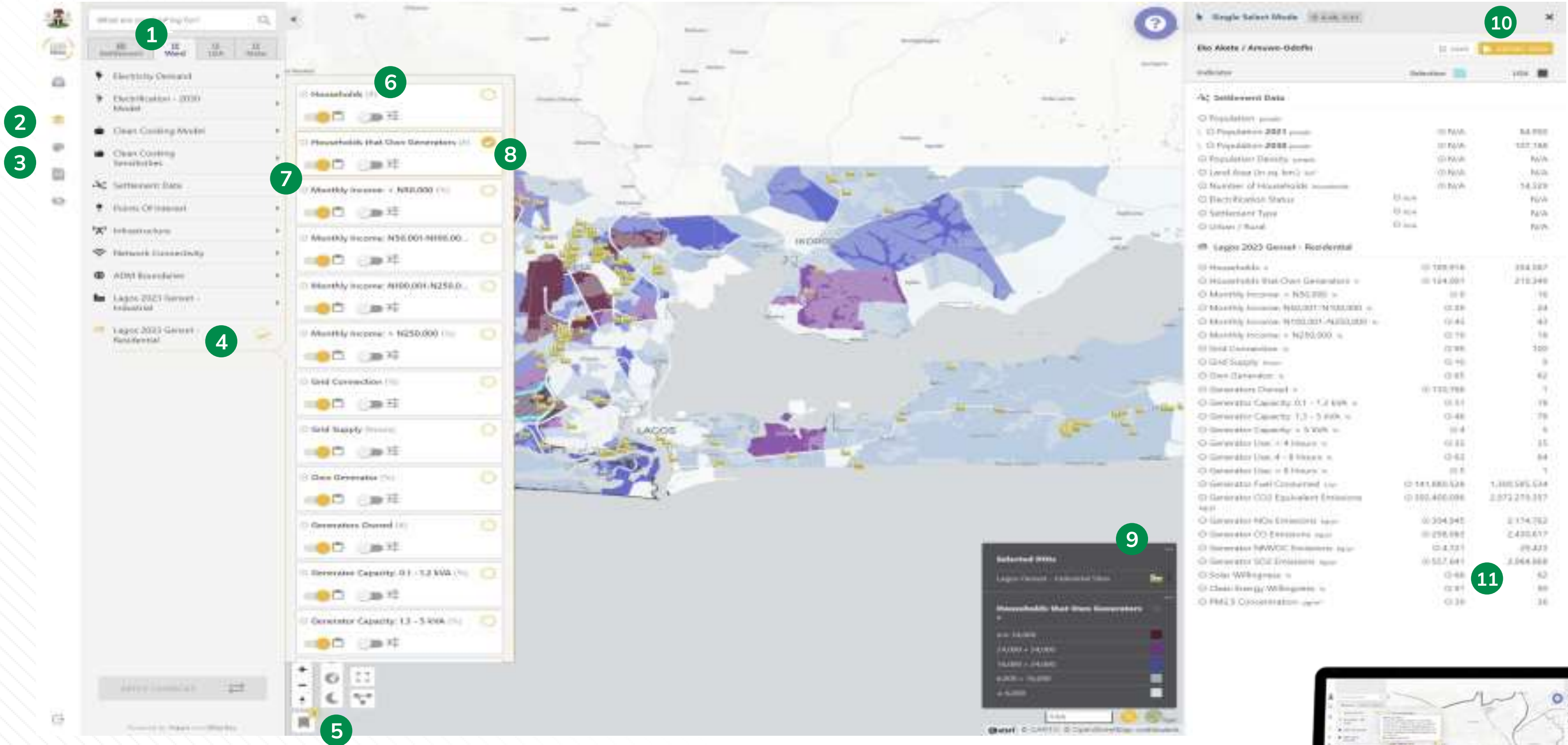
- Administrative-level population proportions, such as "the proportion of households that own at least one genset", were produced via a weighted average. Grid cells were weighted by a population layer, such as the number of households per 1 km^2.
- Mean values such as "average annual estimated ground-level concentration of fine particulate matter" were simply averaged across the administrative division
- Continuous indicators greater than 1, such as "total fuel consumed by gensets per year by households", were summed.

Through the IEP tool, users will be able to intuitively explore the data from the project, conduct simple analyses such as correlations, and export administrative-level summaries and reports.

Further documentation will also be available on the tool's "Metadata" section:

- Guidance documents
- Raw survey data
- Cleaned version of the survey results extrapolated to the Lagos State.

NIGERIA INTEGRATED ENERGY PLANNING TOOL



1. Geographical Scope Selection
2. Map Styling
3. Metadata section
4. Indicator Menu
5. Selection Tools
6. Indicator Description

7 8 Buttons to enable and filter indicators in the report and map

9. Indicator Legend
10. Data Export
11. Indicator Report

https://nigeria-iep.sdg7energyplanning.org/

05 | RESULTS

SUMMARY OF RESULTS

The robust methodology employed in the study resulted in it meeting the predefined objective of producing high-quality data regarding the quantity, usage patterns and impacts of diesel/ petrol gensets in Lagos State.
The residential and commercial surveys and the evaluation of markets yielded four categories of data through their respective modules:

- general characteristics
- electrical grid access and usage
- genset ownership and usage
- attitudes towards alternative energy.

The estimated results[15] for each category are highlighted below:

RESIDENTIAL	COMMERCIAL	MARKETS
~8.8 GW of genset capacity in Lagos households[16]	**~10.4 GW** of genset capacity across 80,072 MSMEs	**~192 MW** of genset across 276 markets
4,323,000 Generators owned by HHs	**113,642** Generators owned by MSMEs	**13,704** Generators owned by markets
9 billion litres of fuel Consumed by HHs annually	**6.6 billion litres of fuel** Consumed by MSMEs annually	**61 million litres of fuel** Consumed by markets annually

[15] Results scaled up for each category
[16] Converted from kVA using power factor of 0.8

CONTEXTUALIZING THE RESULTS

Our findings estimate that Lagos State has ~ 19 GW of genset capacity. To put this in perspective, Nigeria's entire national grid has an installed capacity of 12.2 GW. However, due to various operational inefficiencies, the peak available capacity is often around 5.4 GW, with the average available generation capacity being

4.2 GW as reported in the Nigerian Electricity Regulatory Commission's Electricity on Demand Quarterly Report in Q3 2023.

The environmental impact of this reliance is profound. The total estimated annual emissions from gensets in Lagos are around 39 million tons of CO_2 equivalent (tCO_2e).

To contextualize this impact, it is useful to compare Lagos' genset emissions with those of entire countries:

- **Togo:** ~ 9.8 million tons of CO_2
- **Rwanda:** ~ 10.6 million tons of CO_2
- **Gabon:** ~ 10.2 million tons of CO_2

The estimated annual emissions from gensets in Lagos amount to approximately 39 million tons, which is nearly four times the emissions of these entire countries. This comparison highlights the substantial environmental burden that genset usage in Lagos imposes, not just locally but also globally. It also highlights the opportunities that adopting cleaner energy as backup power solution presents, and the contributions that the state can make towards improving energy access, climate and socio-economic development through job creation.

~19GW
Lagos State
Genset Capacity

~4.2 GW
Nigeria's average
Generation Capacity

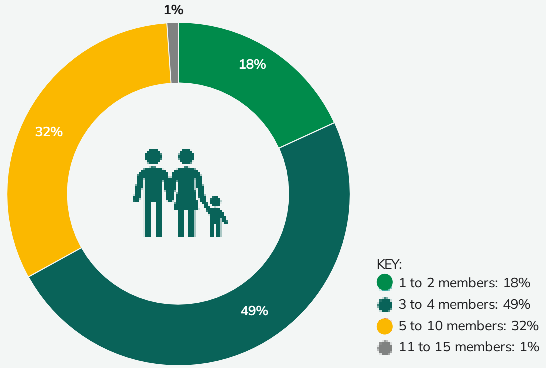
~39 $MtCO_2e$
Annual Emissions

145,440
Operation and maintenance jobs
across all sectors

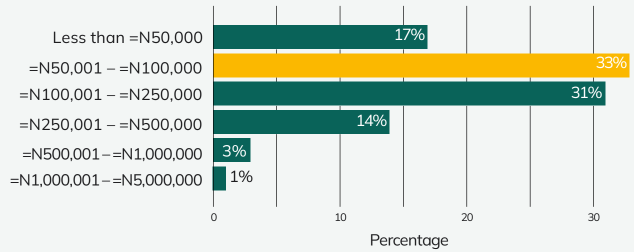
Note: 19.39GW × 7500 jobs/GW = 145,440 Jobs. The job multiplier is applied to estimate the number of jobs created in operation and maintenance for decentralized solar solutions
Sources: Nigeria ETP Just Transition Financing and Roadmap. NERC Operational Performance of Power Plants (January 2024): https://nerc.gov.ng/media/factsheet-operational-performance-of-power-plants/ NERC Third Quarter 2023 Report: https://nerc.gov.ng/wp-content/uploads/2024/02/NERCThirdQuarter2023Report.pdf 2020 Country Emissions Data: https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE

RESIDENTIAL: GENERAL CHARACTERISTICS

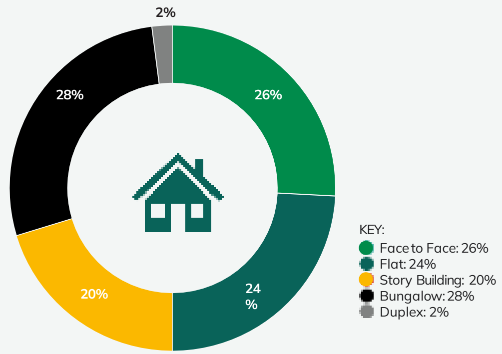
Household Size



Household Monthly Income

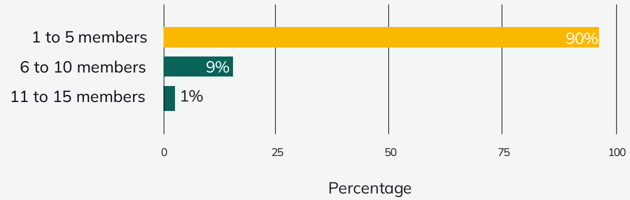


Residential Building Type



Household Business

24% of Lagos households operate household businesses

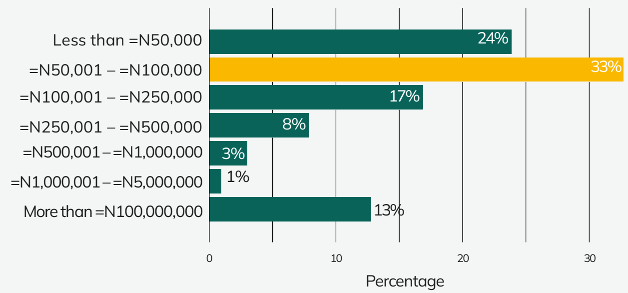


Socioeconomic Access

97% of Lagos households have access to a bank account

99% of Lagos households have access to a mobile phone

Household Business Monthly Income



Key Takeaway(s): Household income levels play a crucial role in determining the affordability of backup power and associated costs. The fact that almost a quarter of households operate household businesses indicates the potential for increased affordability, as stable and reliable electricity can contribute to higher earnings and business sustainability. Almost all households having access to bank accounts and mobile phones allows for considerations of payment methods or incentives for the consumer.

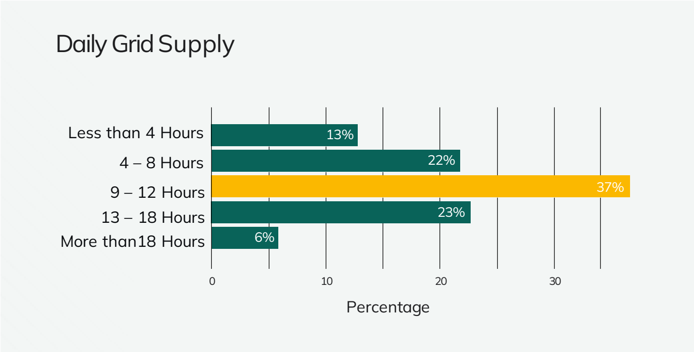
RESIDENTIAL: ELECTRICAL GRID ACCESS AND USAGE

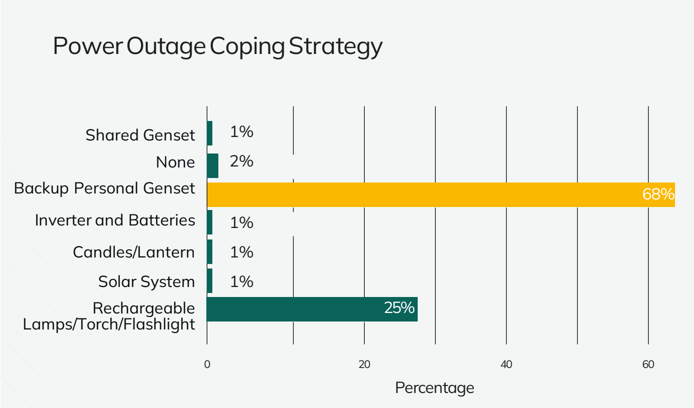
98%
of households are connected to the grid. However, power supply is unreliable and varies considerably.

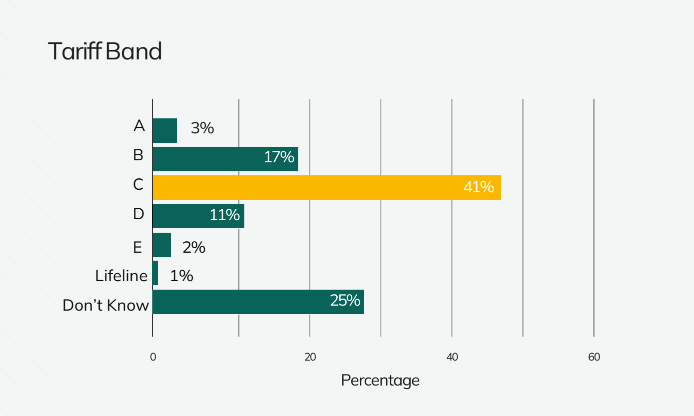
74%
of households are willing to pay a higher tariff for reliable power.

25%
of households do not know their tariff bands, suggesting a lack of general awareness of energy policy issues.

68%
of households cope with power outages using backup gensets, followed by portable lighting methods (25%).







RESIDENTIAL: GENSET OWNERSHIP AND USAGE

~72%

of households own at least one genset, obtained primarily for backup power. On average, most households own just one genset. Some however have more than one.

Majority of gensets used in the residential sector are less than 5kVA and use petrol as the principal fuel.

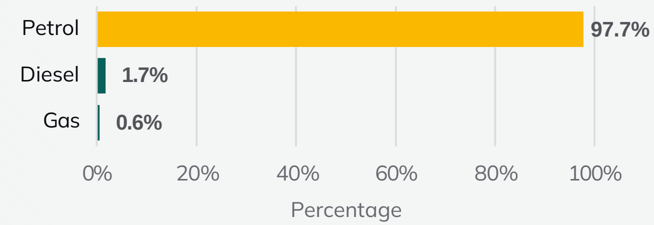
~8.8GW

Genset capacity in Lagos households

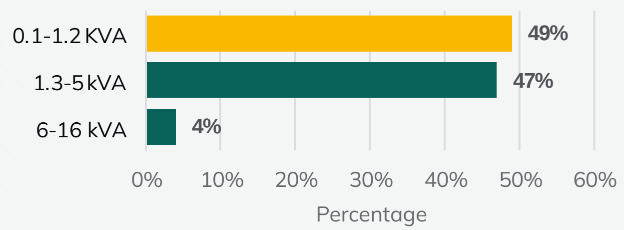
13%

of households use their gensets for income generation

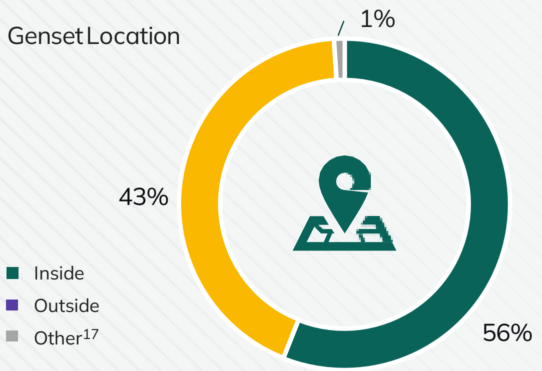
Genset Fuel



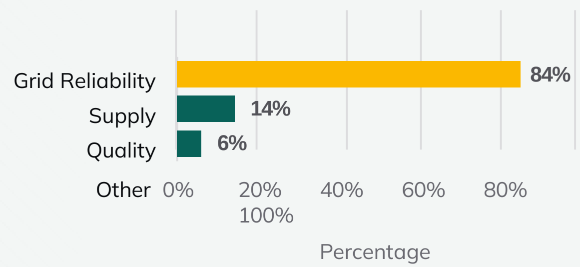
Genset Capacity



Genset Location



Genset Purchase Motivation



NOTES ON SCALING METHODOLOGY

Modelled hyperlocal outputs for the proportion of households that own each genset size-class[18] were translated into household counts.

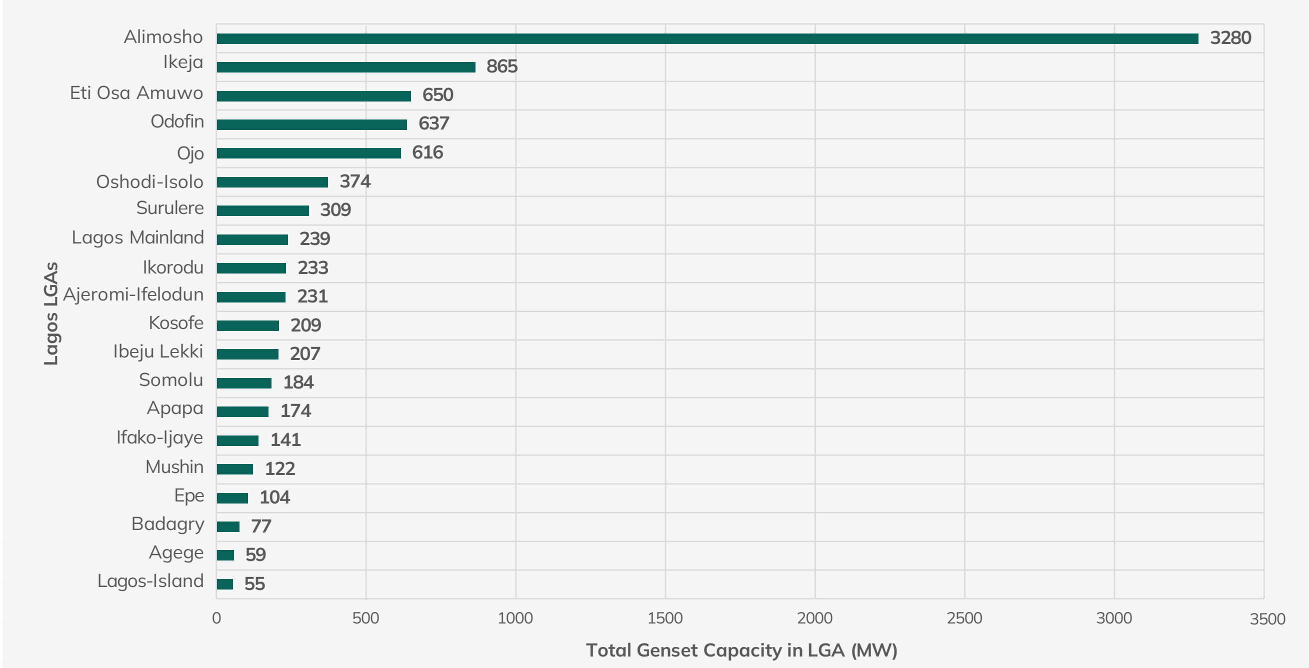
In the raw residential survey data, respondents were specifically asked for their exact genset size. Based on this information, the most reported size (mode) and median size per genset size class were obtained.

Using household counts per genset size-class and the modal and median genset capacities per size-class, the total genset capacity per genset size-class in Lagos State was obtained. These values were then summed to estimate the total residential genset capacity in Lagos.

Using the modal capacity yielded a total residential genset capacity in Lagos of 10,956,600 kVA (11 GVA/8.8 GW) while employing the median capacity yielded a total capacity of 9,107,220 kVA (9.1 GVA/7.3 GW). This implies that the Lagos State residential category has a capacity range between 7.3GW and 8.8GW

[17] Other responses included "backyard", "at the shop", "home at night", "in my room" and "at the farm".
[18] Using the lower and upper bounds of the genset size-classes gives a range of 2.9 GW - 11.6 GW (3.6 - 14.5 GVA). A power factor of 0.8 is used for the conversion from volt-amperes to watts

RESIDENTIAL: TOTAL GENSET CAPACITY BY LAGOS LOCAL GOVERNMENT AREA (LGA)



Number of households' genset ownership per 1 km²

Proportion of households that own at least one genset per 1 km²

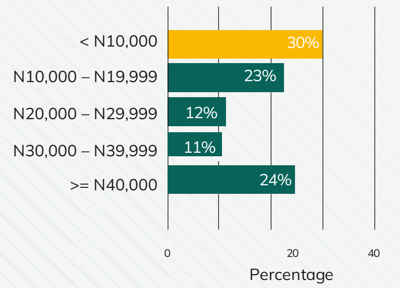
Key Takeaway(s): At 72%, nearly seven in ten households report owning at least one genset. According to the study findings, Alimosho has the highest genset capacity, which aligns with its status as the most populous LGA in Lagos.

Source: Nigeria IEP tool. Ward shapefiles GRID 3 (2022)

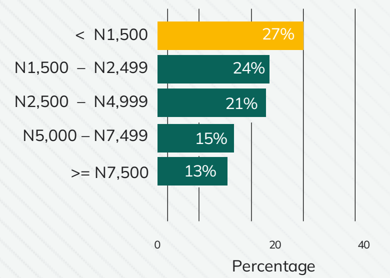
RESIDENTIAL: GENSET OWNERSHIP AND USAGE

COST IMPLICATIONS

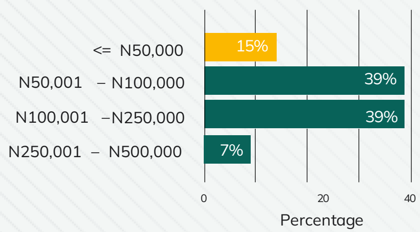
Average Monthly Expenditure (Fuel)



Average Monthly Expenditure (Maintenance)

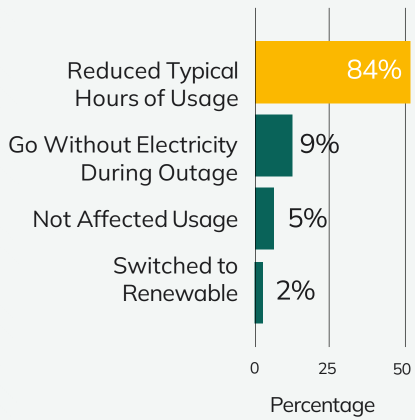


Genset Purchase Cost



- Households in Lagos have spent about N532 billion[19] to acquire current gensets.
- Annually, households with gensets in Lagos collectively spend ~ N1.43 trillion on fuel and ~ N192 billion on maintenance.
- The average cost of operating gensets exceeds that of using grid supply by over N2,000 per hour

Impact of Subsidy Removal



[19] Using the lower and upper bounds of the genset purchase costs gives a range of ~ N338 billion – N725 billion World Bank reports GNI per capita to be N900,761

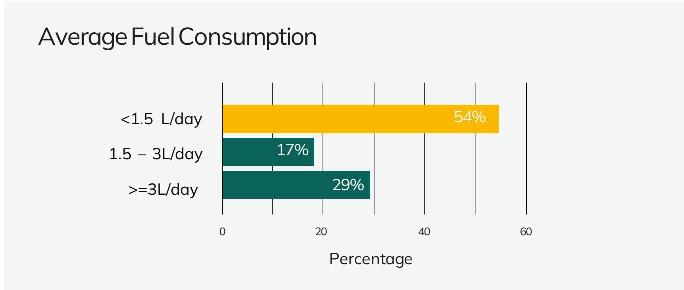
RESIDENTIAL: CLIMATE AND ENVIRONMENTAL IMPLICATIONS

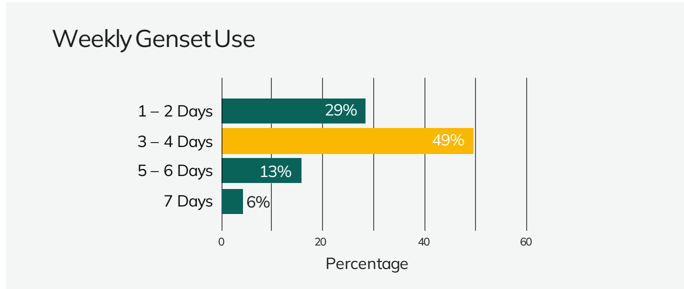
9 billion litres of fuel

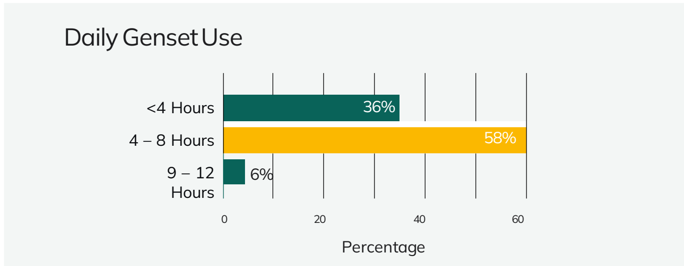
Lagos households consume about 9 billion litres of fuel per year.

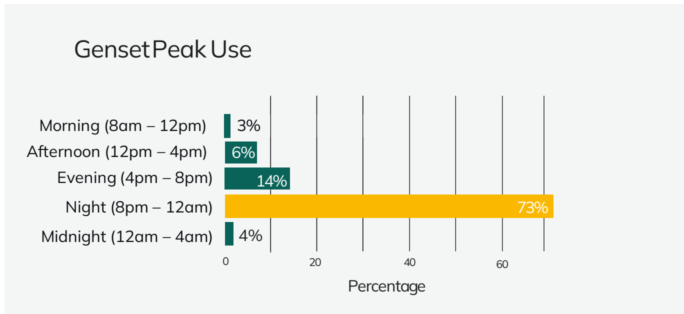
This translates to:

- ~ 21 million tons of carbon equivalents (tCO_2e)/21 $MtCO_2$ emissions annually
- ~ 15,000 tons of annual NOx emissions
- ~ 17,000 tons of annual CO emissions
- ~ 205 tons of annual NMVOC emissions
- ~ 21,000 tons of annual SO_2 emissions



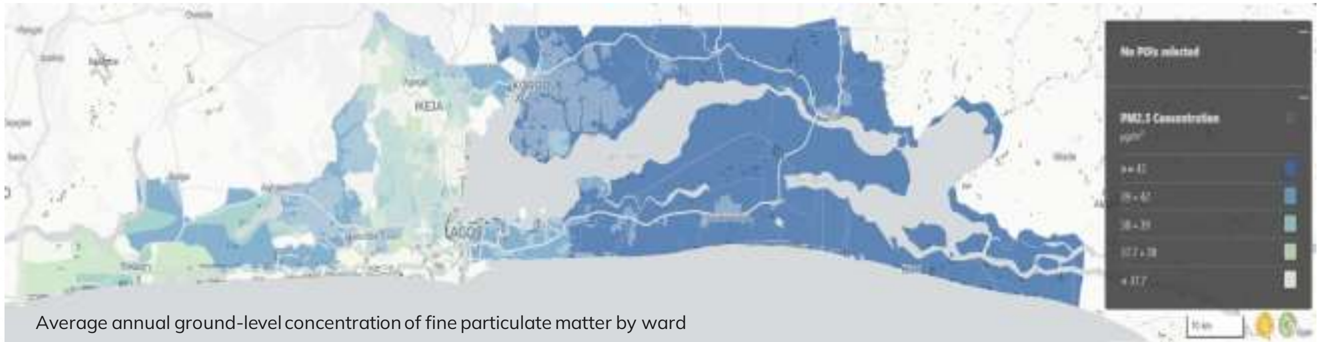






RESIDENTIAL: FUEL CONSUMPTION AND LOCAL AIR POLLUTION BY WARD

Households' annual genset fuel consumption by ward



Average annual ground-level concentration of fine particulate matter by ward

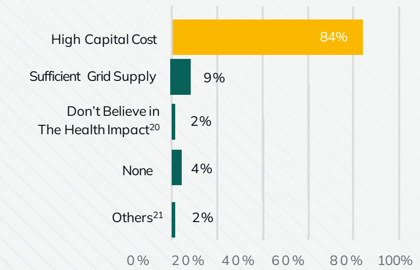
Key Takeaway(s):

- The average estimated fuel consumption per household in Lagos is about 2000L resulting in almost 45,000 kg of carbon equivalent emissions per year.
- While there is a correlation between annual fuel consumption and ground-level concentrations of fine particulate matter (PM2.5), this is influenced by multiple factors, including other emission sources, and regional environmental variables. Genset usage contributes to this dynamic, though the specific proportion of its impact on PM2.5 levels was not quantified in this study. Areas with higher fuel consumption, including from gensets, generally experience elevated levels of air pollution. This correlation highlights the need to explore targeted interventions to reduce fuel consumption and mitigate air pollution to improve public health outcomes.

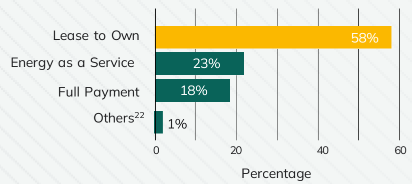
Source: Nigeria IEP tool. Ward shapefiles GRID 3 (2022)

RESIDENTIAL: ATTITUDES TOWARDS ALTERNATIVE ENERGY

Reason Why Solar Has Not Been Adopted



Solar Ownership Model of Interest



- 88% of Lagos households would consider alternative energy sources if available
- 70% of Lagos households are aware of solar power
- 75% are interested in solar
- However, only 2% currently use solar power
- 28% of households have specifically considered alternative energy since the removal of the petrol subsidy

RESIDENTIAL: ATTITUDES TOWARDS ALTERNATIVE ENERGY

55%

of households believe gensets contribute to air pollution.

60%

of households believe gensets significantly contribute to noise pollution.

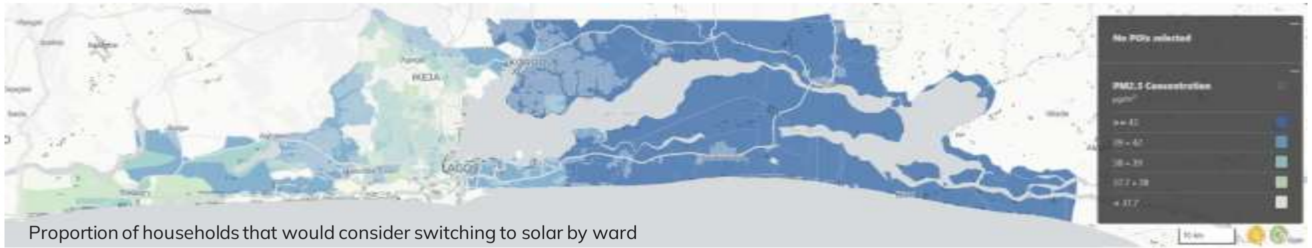
[20] Environmental/Health Benefits.

[21] Other responses included lack of sufficient knowledge about solar or where to purchase it, intention to purchase a solar system soon, inability to use solar in a rental, satisfaction with current genset, inadequate consumption, lack of space, security concerns and current use of an inverter.

[22] Other responses included the lack of sufficient information on the price of such systems and the desire for government subsidy.

RESIDENTIAL: CO_2 EMISSIONS AND WILLINGNESS TO ADOPT ALTERNATIVE ENERGY BY WARD

Annual CO_2 equivalent emissions from household gensets by ward



Proportion of households that would consider switching to solar by ward

Key Takeaway(s):

While almost all homes are willing to consider alternative energy and have a general awareness of solar power as an option, only about 2 percent of households report the use of solar home systems, with the majority citing the high capital cost as a barrier to the adoption of solar.

Source: Nigeria IEP tool. Ward shapefiles GRID 3 (2022)

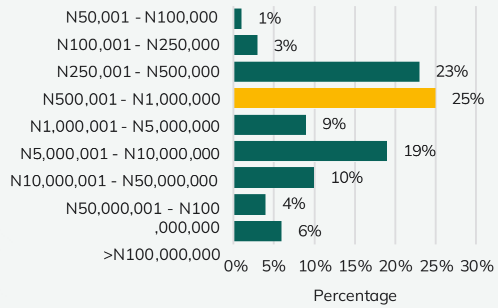
COMMERCIAL : GENERAL CHARACTERISTICS

240

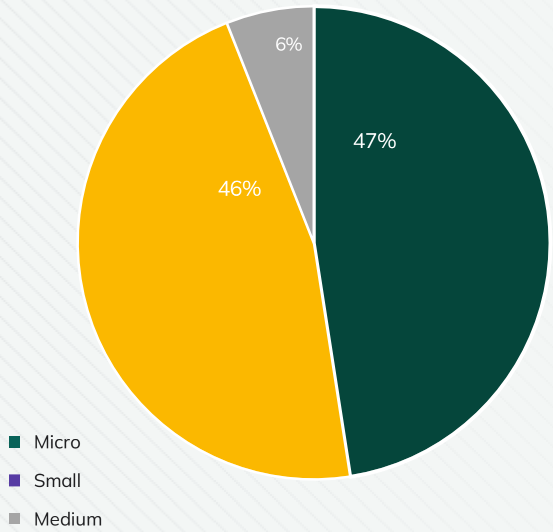
businesses were counted across Lagos State.

Only 8% of the surveyed businesses are led by females, and only 10% have a workforce that is more than half female.

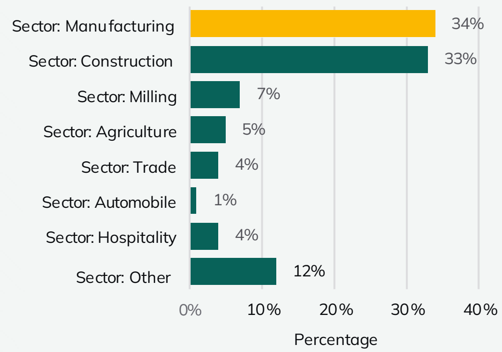
Monthly Revenue



Business Size

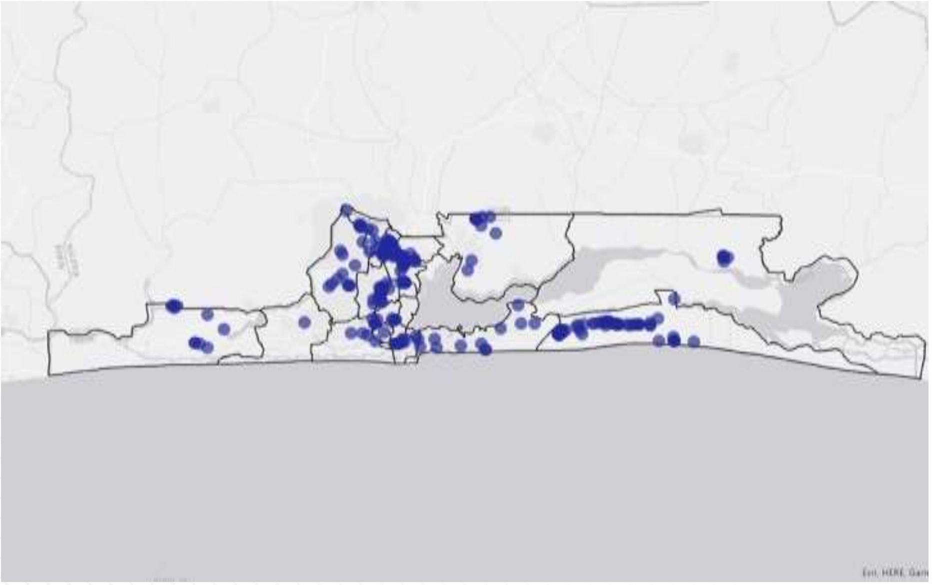


Sector



COMMERCIAL : GENERAL CHARACTERISTICS – BUSINESS TYPE

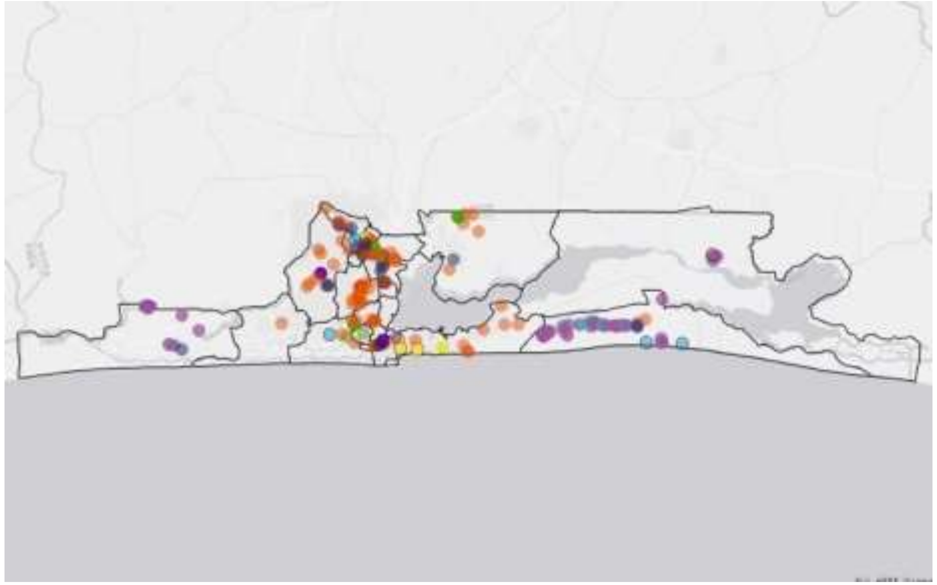
TOTAL NUMBER OF GENSETS PER 1KM²



KEY

- Commercial and Industrial Site
- LGA Boundary

TOTAL NUMBER OF GENSETS PER 1KM²



KEY

Agriculture	Healthcare	Milling
Real Estate	Automobile	Hospitality
Oil & Gas	Trade	Construction
Manufacturing	Other	NA

Point Data from Fraym Analysis

COMMERCIAL: ELECTRICAL GRID ACCESS AND USAGE

~ 94%

of MSMEs own at least one genset, obtained primarily for backup power.

90% rely on grid supply

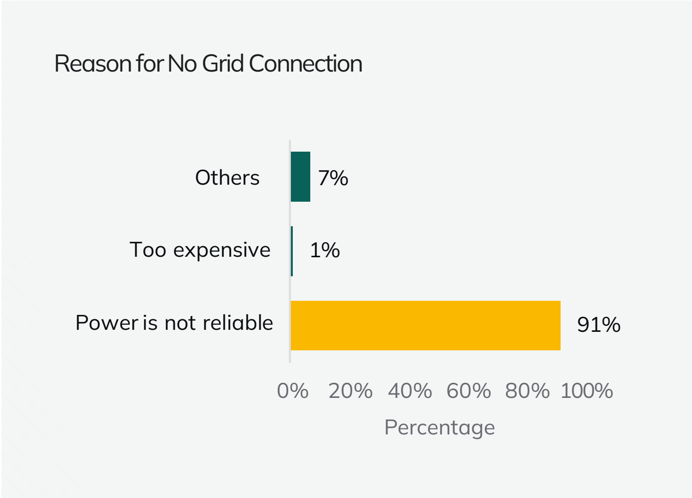
59% of MSMEs are connected to the grid, and within this group, 90% rely on grid supply for their operations.

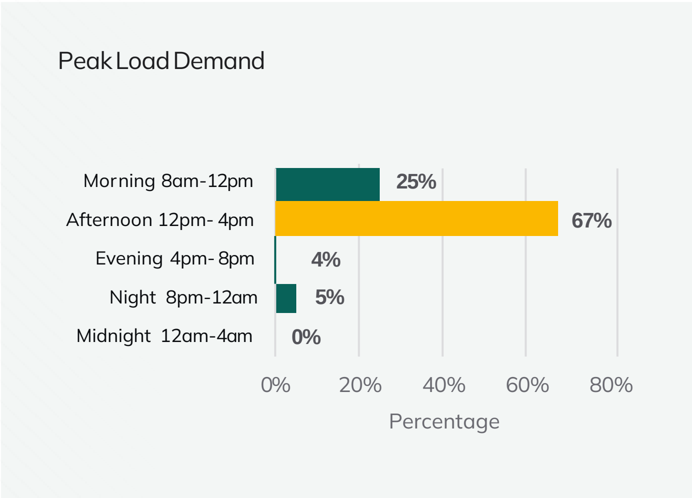
~ 41% not connected to grid

MSMEs that are not connected to the grid cite unreliability as the main reason.

67%

of MSMEs experience peak load demand in the afternoon between 12 pm and 4 pm.

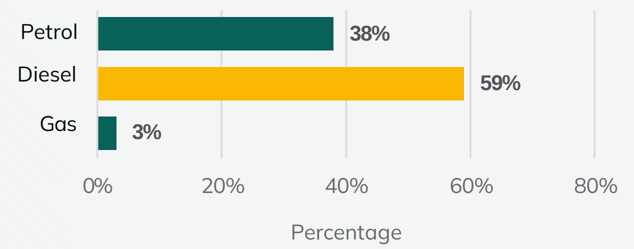




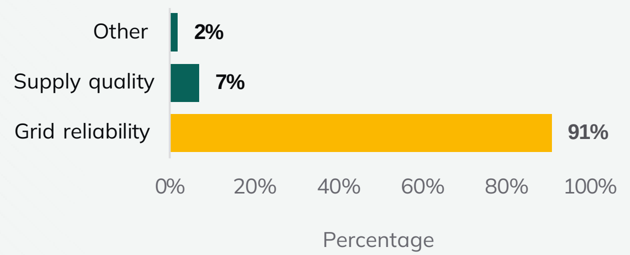
COMMERCIAL: GENSET OWNERSHIP AND USAGE

- Diesel is the most used fuel (59%), followed by petrol (38%)
- The predominant genset size is under 5kVA (33%). However 20% of gensets are larger – between 34 and 275kVA, and 19% are between 276 and 500kVA. These findings suggest that a range of solutions may be needed for solar PV adoption
- Unreliability and power quality of the grid service together make up 91% of genset purchase motivation.

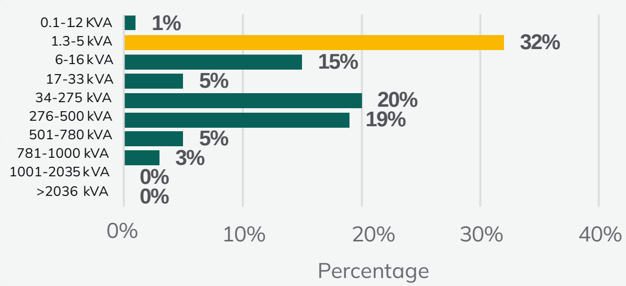
Genset Fuel Type



Genset Purchase Motivation



Genset Capacity



NOTES ON THE COMMERCIAL CATEGORY

In the context of this study, defining the commercial and industrial (C&I) category is essential to outline the study scope. The C&I sector encompasses a diverse array of businesses, ranging from micro, small and medium-sized enterprises (MSMEs) to large C&I entities.

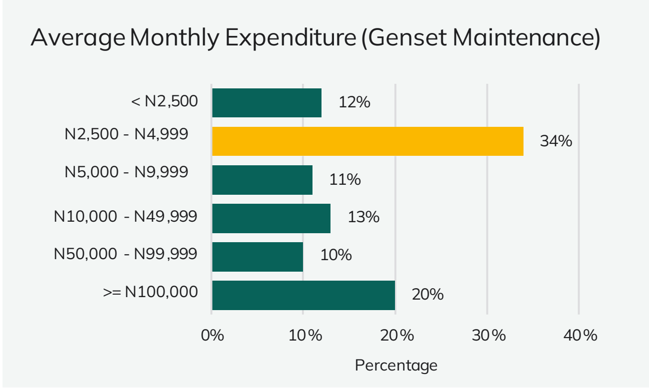
During data collection, MSMEs and large C&I entities were counted. However, the approach applied to analyze these sub-categories differed due to differences in scale and the requirements for decarbonisation strategies.

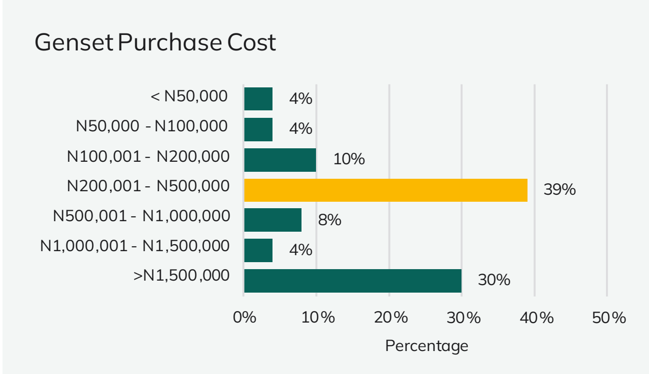
While some large industries were counted, it is important to note that only the MSMEs were extrapolated. Large commercial entities typically possess the financial means and infrastructure to explore and implement tailored decarbonisation strategies. The solutions for the larger C&I entities require more tailored planning and the unique operational challenges and energy demands of each entity need to be considered. Therefore, a blanket solution is seldom applicable across this diverse group, necessitating a case-by-case approach to displacing their gensets.

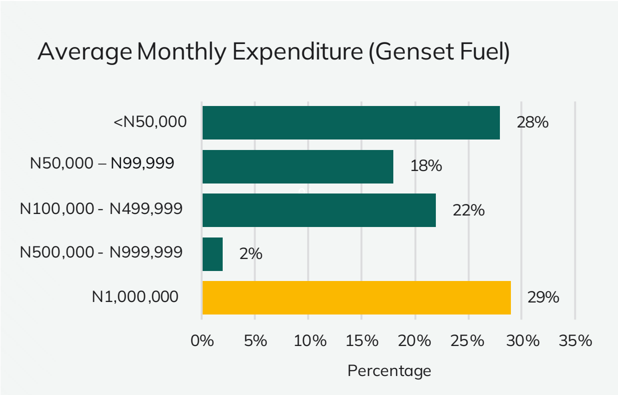
COMMERCIAL : ELECTRICAL GRID ACCESS AND USAGE

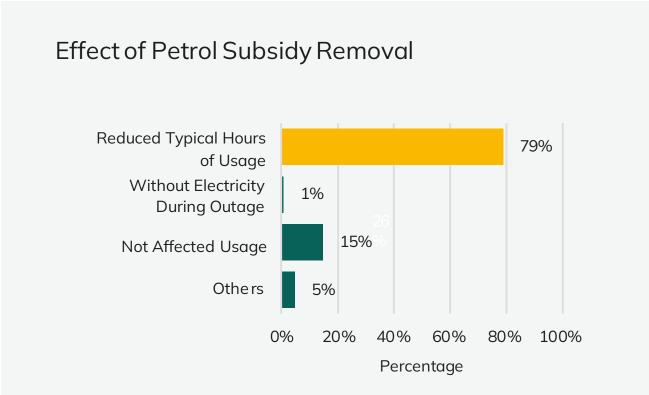
COST IMPLICATIONS

- Diesel and petrol users collectively spend ~ N5.3 trillion on fuel annually.
- Subsidy removal has had significant impacts on usage patterns; 79% of the industries counted have reduced their typical hours of usage.

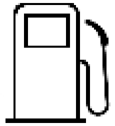








COMMERCIAL: CLIMATE AND ENVIRONMENTAL IMPLICATIONS

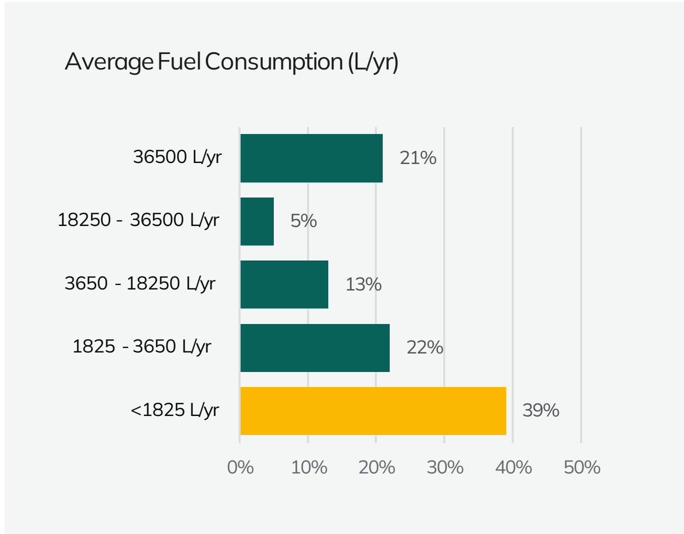


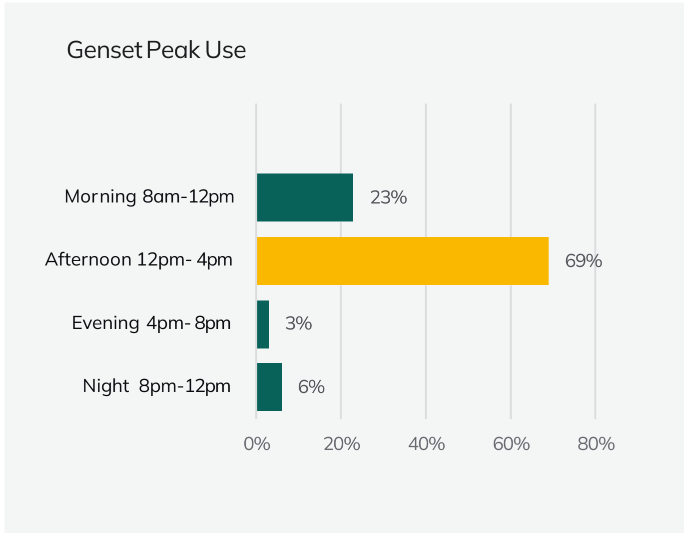
6.6 billion litres of fuel

are consumed by MSMEs annually.

This translates to:

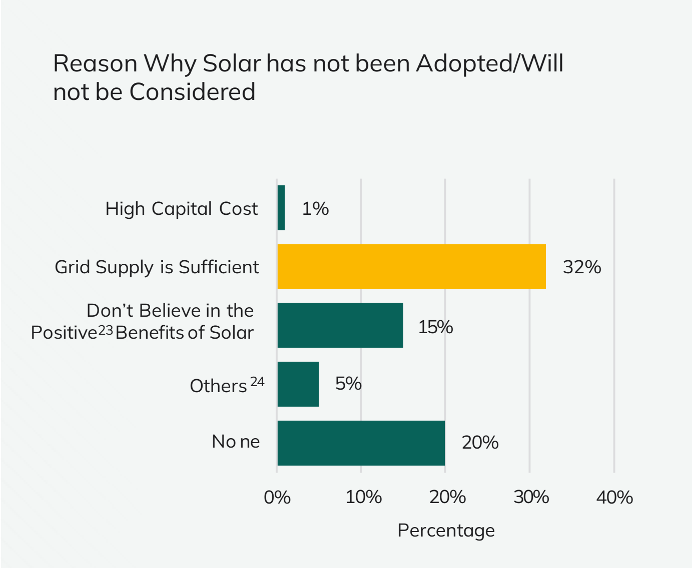
- ~ 17.8 million tons of carbon equivalents (tCO_2e) annually
- ~ 12,000 tons of annual NOx emissions
- ~ 14,000 tons tons of annual CO emissions
- ~ 166 tons of annual NMVOC emissions
- ~ 16,700 tons of annual SO_2 emissions



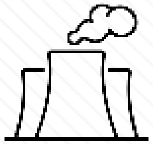


COMMERCIAL: ATTITUDE TOWARDS ALTERNATIVE ENERGY

- 52% of MSMEs report willingness to consider alternative energy sources
- 26% of MSMEs have specifically considered alternative energy since the petrol subsidy removal
- 80% are aware of solar power
- 64% are interested in solar
- However, only 3% currently use solar power

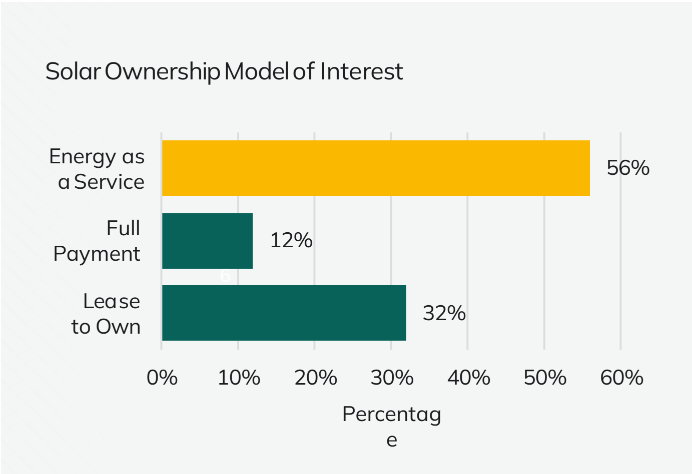


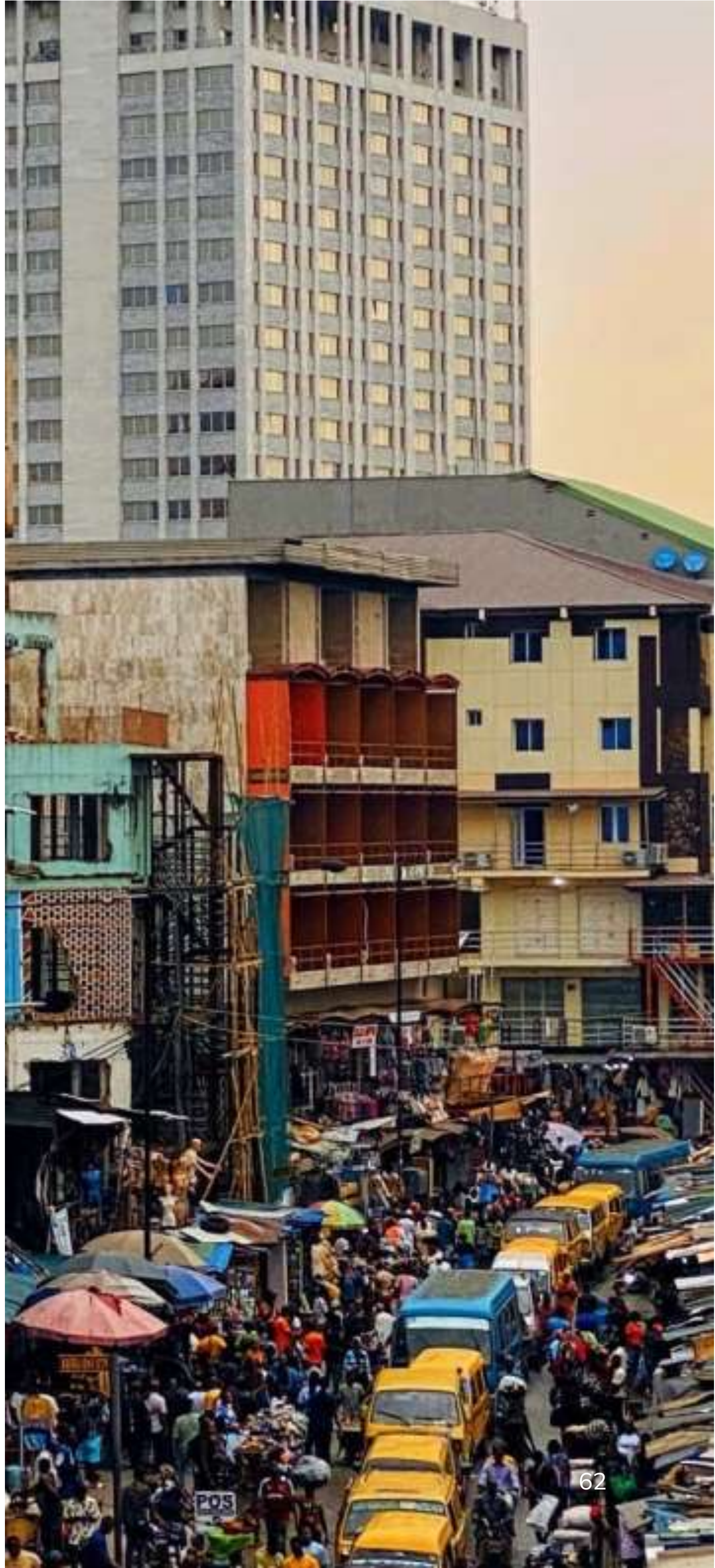
COMMERCIAL: HEALTH PERCEPTIONS



44%
of MSMEs believe that gensets significantly impact air quality in their area.

36%
state that gensets contribute significantly to noise in their local surroundings.

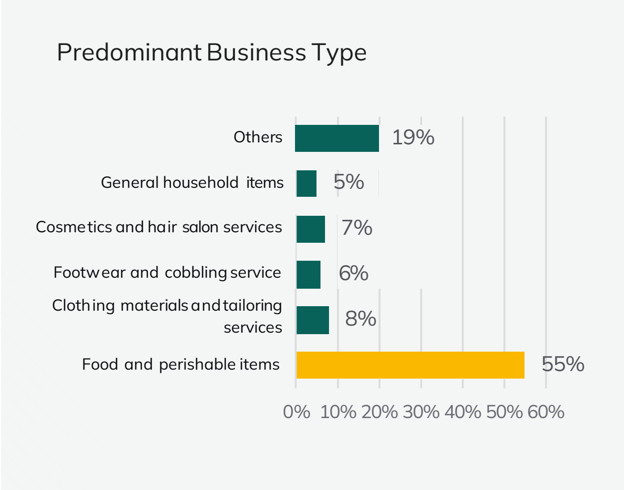


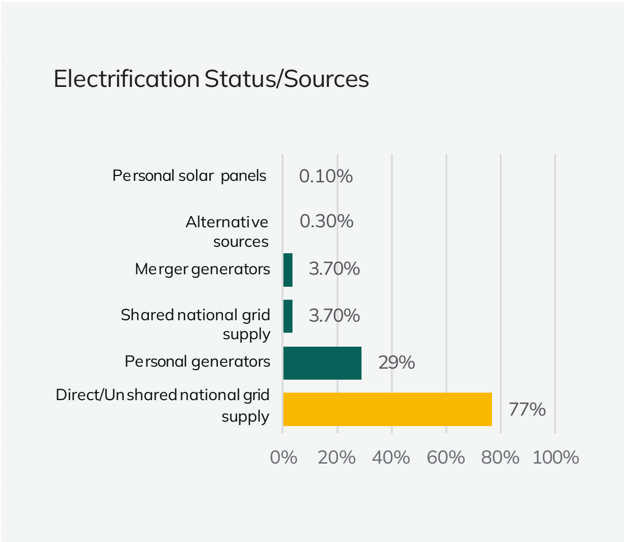


[23] Environmental/Health Benefits of Renewable Power
[24] Other responses included "planning to get one," "undecided," "it's up to the government," "currently use gas," "deciding which one to get," and "still studying the issue".

MARKETS: GENERAL CHARACTERISTICS

- Available data cover nine markets across Lagos State; These markets include Abraham Adesanya, Alade, Ilupeju, Ketu, Ketu shopping, Lawanson, Oniru, Oyingbo and Saka-Tnubu.
- There are **4,680 shops** across these nine markets, with a total of **340 generators** in use.
- The majority of the shops sell food and perishable items.

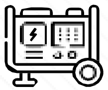




MARKETS: GENSET OWNERSHIP AND USAGE

192 MW

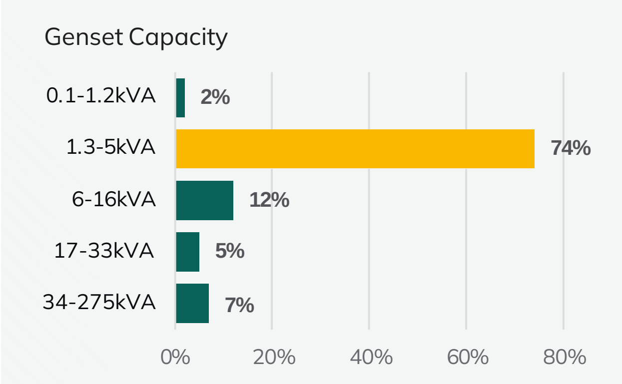
Genset capacity in Lagos households

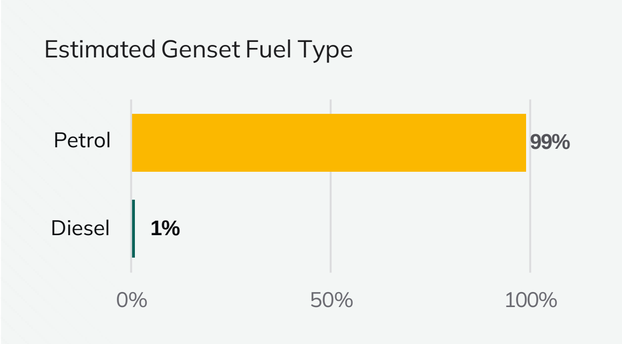


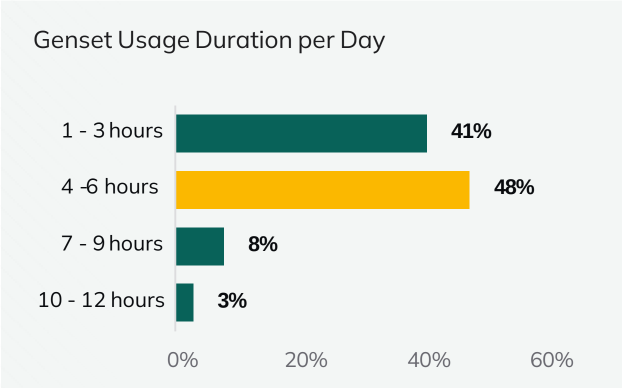
13,704

Generators across Lagos markets

- 78% of the gensets used are predominantly under 5kVA
- They are largely fuelled by petrol, with only 1% using diesel
- The most common genset usage duration is between four to six hours daily







NOTES ON MARKETS SCALING METHODOLOGY

The total generator installed capacity from the survey carried out by E-GUIDE (2022) for nine markets is 6.02MW This figure represents the generator installed capacity of audited shops, serving as a sample from the broader universe of shops within the surveyed markets. This figure was scaled up to 7.42MW by multiplying the number of generators counted in each market during the survey by the extrapolation factor.

The extrapolation factor for each market was obtained using the formula below:

$$\frac{Population\ \ Size}{Sample\ \ Size}$$

$$= \frac{Total\ number\ of\ occupied\ and\ unoccupied\ shops}{Total\ number\ of\ audited\ shops}$$

A margin of error of 7.42±10% was adopted to account for uncertainty or variability, resulting in a range of 6.68 to 8.162.

The total generator installed capacity across all 276 markets was obtained by multiplying the results obtained by an extrapolation factor of 19.93. This extrapolation factor[25] was obtained by dividing the total number of shops in Lagos State by the total number of occupied and unoccupied shops in the nine audited markets reported by E-GUIDE (2022) resulting in 49,9942,509 = 19.93

Therefore, the total generator installed capacity across all 276 markets (with a 30% margin of error) is 147.88±30% equivalent to 103.52 to 192.24 MW.

25 $\frac{Population\ \ Size}{Sample\ \ Size} = \frac{Total\ number\ of\ shops\ across\ all\ 277\ markets\ in\ Lagos\ State}{Total\ number\ of\ occupied\ and\ unoccupied\ shops\ in\ the < audited\ markets}$

Note: Estimated results from the Genset Ownership and Usage for the Markets were Extrapolated for 276 markets across Lagos State.

MARKETS: COST, CLIMATE AND ENVIRONMENTAL IMPLICATIONS

~ 33%

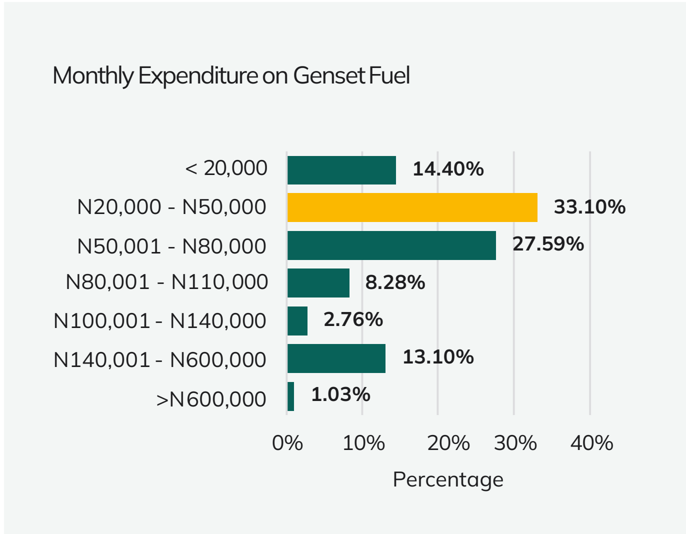
of MSMEs spend between N20,000 and N50,000 on fuel per month.

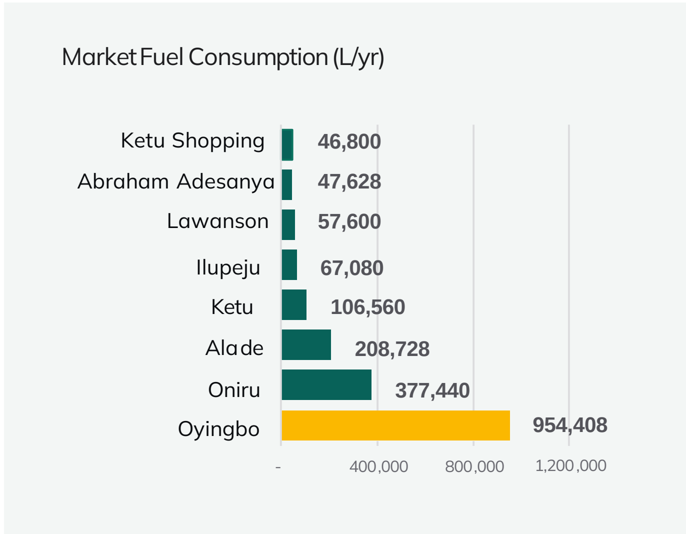
~ 61 million litres of fuel

are consumed by Lagos markets annually.

This translates to:

141,125 tons of carbon equivalents (tCO_2e)





FINANCIAL IMPLICATIONS OF DISPLACING GENSETS

Initial Investment:

- **Higher upfront costs**: Solar systems require a significant initial investment for solar panels, inverters and installation. However, financing options and subsidies can help mitigate these costs.

Operational Costs:

- **Reduced fuel and maintenance expenses**: Solar systems eliminate the need for purchasing fuel and have lower ongoing maintenance costs compared to diesel generators.
- **Long-term savings**: The operating cost of solar systems is substantially lower, leading to considerable savings over the system's lifespan.

Return on Investment (ROI):

- **Break-even point**: Typically reached within a few years, depending on the size of the installation and initial costs.
- **Long-term profitability**: Post break-even, the cost savings become net gains, enhancing financial returns over time.

Incentives and Support:

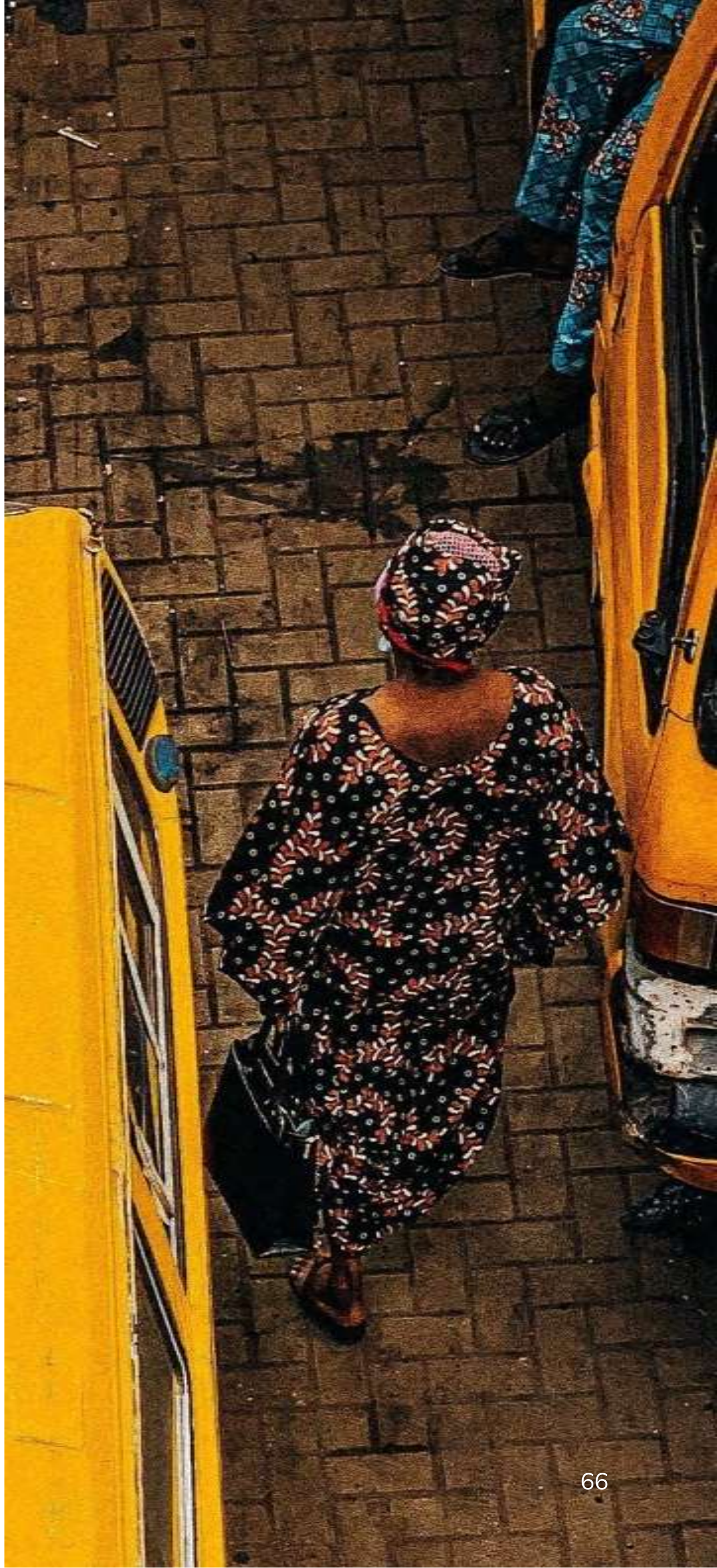
- **Government and international grants**: Availability of financial incentives to support the adoption of solar energy.
- **Tax benefits**: Potential tax deductions or credits for renewable energy installations.

Risk and Market Variability:

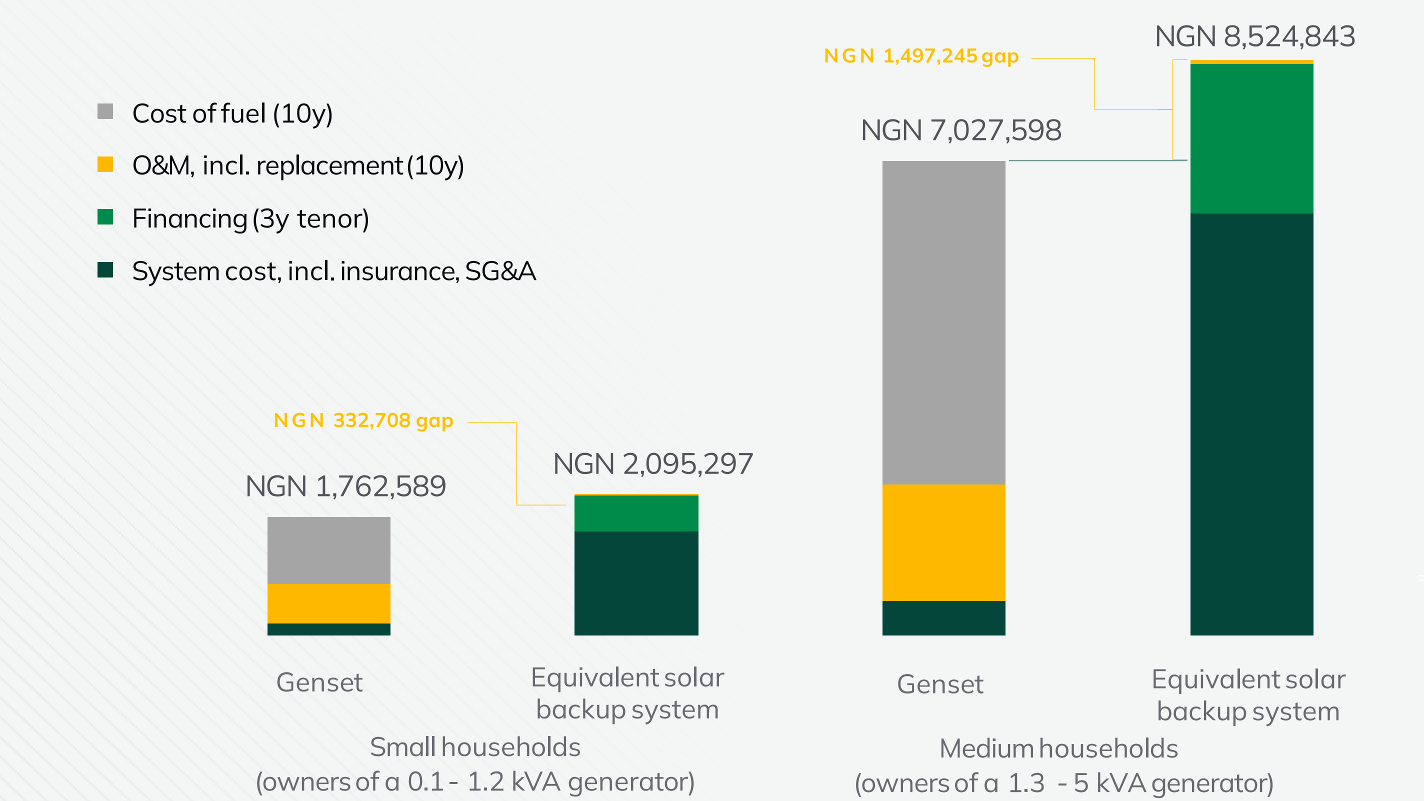
- **Less fuel price volatility**: Solar energy provides protection against the unpredictability of fuel prices.
- **Dependency on sunlight**: While generally reliable, solar output can be affected by climatic variations.

Economic Impact:

- **Job creation**: The solar industry can create jobs in installation, maintenance and manufacturing sectors.
- **Boost to local economies**: Investment in local solar projects can stimulate local economic growth.



FINANCIAL IMPLICATIONS OF DISPLACING FOSSIL FUEL GENSETS



	Small households: Genset	Small households: Equivalent solar backup system	Medium households: Genset	Medium households: Equivalent solar backup system
LCOE (NGN/kWh)	**774**	**920**	**637**	**772**
LCOE (USD/kWh)	**0.59**	**0.71**	**0.49**	**0.59**

Assumptions:

The households were grouped into two main archetypes based on genset ownership:

1. **Small households**: The equivalent solar system was sized in such a way that it can produce and store the energy supplied by the genset (currently 0.62 kWh/day on average) when the grid supply is not available, even in the rainy season (PV modules: 545 Wp; battery storage: 1.2 kWh Li-ion; inverter: 800 VA).
2. **Medium-sized households**: The equivalent solar system was sized in such a way that it can produce and store the energy supplied by the genset (currently 3 kWh/day on average) when the grid supply is not available, even in the rainy season (PV modules: 2000 Wp; battery storage: 5 kWh Li-ion; inverter: 3.5 kVA).
3. Operation and Maintenance cost calculated based on tariff projection by Vista.
4. Cost of fuel was based on the following assumptions: specific fuel consumption of existing gensets: 1.5 kWh/L; cost of petrol: 650 N/L (no future price increase).
5. Operational Expenses (OPEX) are calculated over the lifecycle period of 10 years; high-quality batteries have been modelled, and therefore no battery replacement costs have been assumed.
6. Financial assumptions: Assuming 32.5% tax rate, cost of petrol at N 650, cost of diesel at N 1500, O & M charge at N 25/KWh.

NOTES ON FINANCIAL IMPLICATIONS

Two cases have been highlighted to reflect the cost difference between gensets and equivalent backup solar systems over their lifecycles.

Petrol gensets are 10 to 15 times cheaper than equivalent solar PV systems when considering only installed system costs and financing costs.

This gap is reduced if considering the total cost of ownership: in this case solar PV is “only” 20% more expensive than gensets over a 10- year period.

Because backup PV systems have high fixed costs and are only used during power outages, they struggle to compete with gensets.

The major reason given for not adopting solar in the survey was the high upfront adoption cost.

Plugging the initial CAPEX gap and designing effective financing mechanisms will be necessary for successful displacement of diesel and petrol gensets.

The two standardized designs of DPV can be used for “small” and “medium” households, representing 49% and 47% of the total, respectively.

06 | INSIGHTS

KEY STUDY INSIGHTS

The insights from the study highlight several critical factors to address for the design of a fossil fuel genset displacement programme:

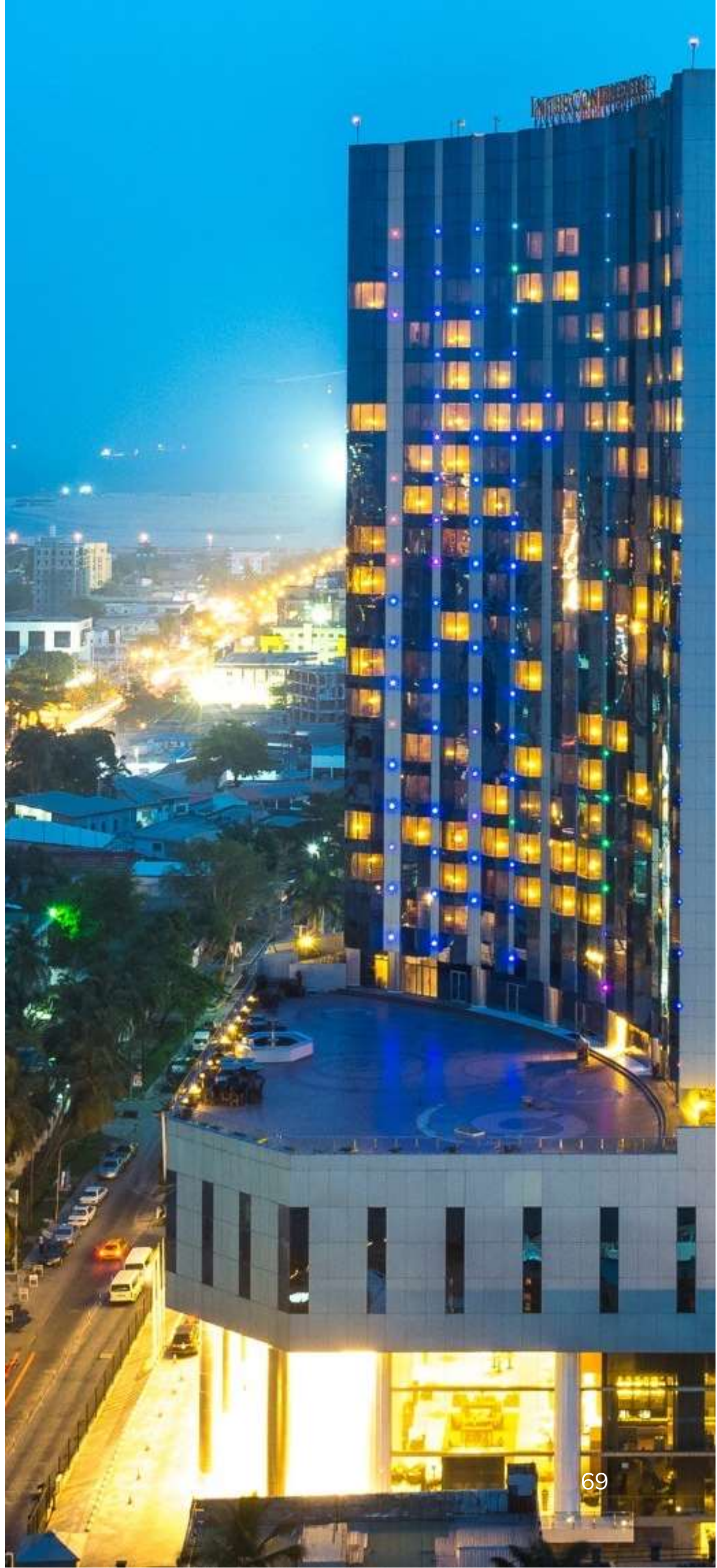
Grid reliability and genset use: The prevalence of gensets due to grid unreliability suggests that improving grid reliability is essential. Doing so could significantly reduce reliance on gensets, benefitting both consumers and the environment.

Addressing capital cost barrier for households: High upfront capital costs of solar backup systems hinder the adoption of this technology among residential respondents. To promote solar adoption and displace gensets, addressing this barrier is crucial. Implementing a lease-to-own model supported by concessional funding could make solar systems immediately affordable, facilitating their adoption.

Strategy for replacement of gensets with solar:

- The prevalent use of smaller capacity gensets by **households** and market shops, primarily fueled by petrol, suggests the possibility of adopting standardized designs in bulk procurements to deploy high-quality equipment, which would also reduce procurement and financing costs.
- However, delivering a centralized solar PV backup system for the **shops in markets** instead of small individual systems for each shop might be a more efficient, cost-effective and sustainable solution.
- **MSMEs,** on the other hand, have a wide range of energy needs that require detailed energy audits to determine the required design for solar PV backup systems. Therefore, a different type of incentive is required to promote the adoption of solar, such as an RBF linked to the size of the main components (i.e. battery capacity and solar PV capacity), tax exemptions or financing mechanisms to reduce financing costs.

Genset utilization factor: Although the residential sector has a much larger number of gensets, the commercial sector exhibits nearly equal emissions. This is largely due to the higher utilization and capacity of commercial gensets, which often operate as primary power sources, running for longer hours and closer to their full capacity. In contrast, residential gensets are typically used only during power outages, often at lower load factors. Additionally, from the results, the fuel mix plays a role, with petrol being more common in residential gensets, while commercial gensets predominantly rely on diesel, further influencing the emission levels.



KEY STUDY TAKEAWAYS

The study presents a transformative opportunity for the sector and the country at large:

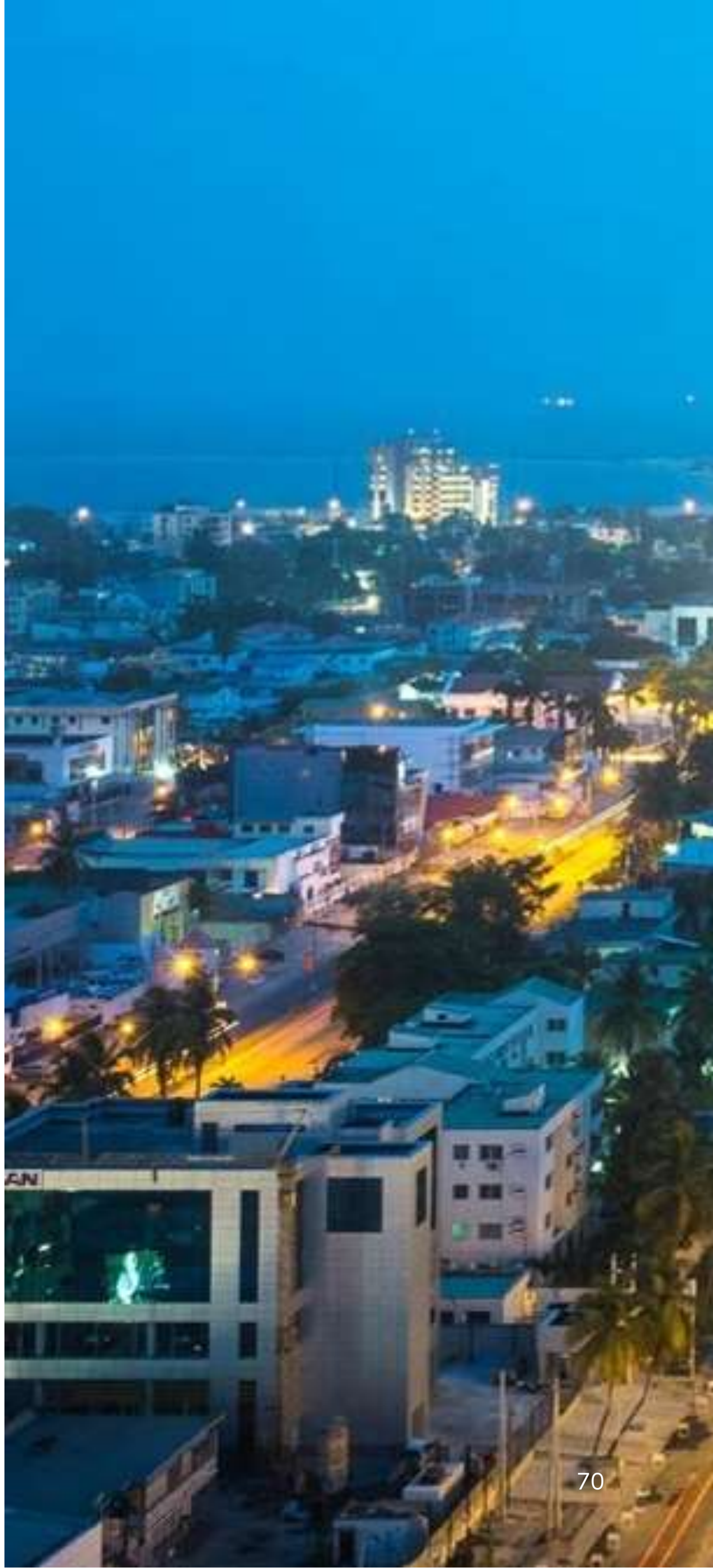
Focus on MSMEs: A government-backed intervention will have limited control over the gensets with a higher capacity used by larger commercial sites. This is primarily because understanding their energy demands and peak loads, and subsequently designing a system to replace their current genset requires extensive planning. The usage of these gensets whether as a primary or backup power source also varies significantly, making it difficult to develop standardized solutions for larger industries.

Programme incorporation: The study can provide data-driven insights on design and implementation opportunities for ongoing and upcoming projects like the Nigeria Distributed Access through the Nigeria Distributed Access through Renewable Energy Scale-up (DARES) project, approved by the World Bank with the aim of providing over 17.5 million Nigerians with new or improved access to power through distributed renewable energy solutions.

Ground-breaking study: This study encompasses the most comprehensive data on genset purchase, maintenance and usage across homes, businesses and markets in Lagos State. It incorporates machine learning and data analysis techniques, including the extrapolation of collected data, to derive crucial insights.

Additionally, the spatial extent of the data from this study can be accessed via the Nigeria Integrated Energy Planning (IEP) tool, which is designed to support energy planners, policymakers, donors and implementing agencies to design tailored policies and programmes at different geographic levels.

Extensiveness of the study: This is the most rigorous and comprehensive study on baseline gensets energy generation to be carried out in Nigeria to date. The use of machine learning also allowed for effective extrapolation of residential data to Lagos State, while extensive secondary data analysis complemented the study by including insights on markets.



LESSONS LEARNED FROM THE STUDY

Valuable lessons were recorded to provide recommendations for future studies on genset enumeration, including its reproduction in other Nigerian states or other countries:

- Prior to creating and conducting the survey, ensure that the goal of the investigation and the metrics to be derived are well established. This will assist in properly defining the questions, ensuring that only the relevant ones are included and that they are well formulated.
- Establish an accurate method for calculating the desired metrics before defining the survey questions, not the other way around.
- Similarly, establish a clear method for extrapolating the selected metrics to the whole population using statistical inference before the survey is designed. For example, use the same classification of enterprises as those adopted by the official census of enterprises to make the inference process easier.
- When creating the survey, pay close attention to the response type for numeric responses. For key information like fuel consumption, genset capacity, expenditure levels and other numeric responses, use open responses over pre-determined bands or ranges, since this makes it easier to perform analytics, which is challenging with ranges.
- Some enterprises own more than one generator, typically for redundancy or to cover extended periods off the grid running them in shifts. In these cases, it is not advisable to record the cumulated capacity of all the generators altogether, because this overestimates the required capacity. Instead, record the capacity of the unit that is used the most or the one that is most suitable for the load.
- To ensure adequate data for analysis, in areas where there are significant data gaps, the study scope should prioritize primary data collection. The secondary data used for this study provided valuable insights into self-generated electricity from fossil fuels. However, their scope was limited, covering only nine out of 299 markets in Lagos State. It would be useful to include the remaining markets across the state and collect additional metrics for a more detailed understanding.

COLLABORATIVE ACTIONS TOWARDS ENERGY TRANSITION

STAKEHOLDER GROUP	STUDY SIGNIFICANCE TO GROUP
LAGOS STATE & SUBNATIONAL LEVEL GOVERNMENTS	Aid data-driven decision-making; identify the most effective strategies for reducing reliance on fossil fuel gensets; influence regulatory frameworks and energy policies; advocate for energy transition, funding opportunities and support from DFIs committed to climate change mitigation and sustainable development.
FEDERAL GOVERNMENT	Nationwide policy formulation; foster enabling environment for sector development, education and public awareness campaigns; provide infrastructure development and support; introduce tax incentives and subsidies for renewable energy investments; foster innovation and technology transfer; attract international investments.
PRIVATE SECTOR RENEWABLE ENERGY UTILITIES	Deepen understanding of the market opportunities and customer base to tailor its renewable energy solutions to better meet the needs of beneficiaries; attract investors looking to fund green initiatives; facilitate strategic partnerships with technology providers.
DFIs & DEVELOPMENT PARTNERS	Provide targeted concessionary financing; influence policy development; drive private sector-led initiatives, market development and capacity building.

Interdependence of relevant stakeholders in shaping a fossil fuel displacement programme is key. The coordinated efforts of the Lagos State Government, federal agencies, renewable energy utilities, DFIs and industry groups are essential for the successful implementation of fossil fuel genset displacement interventions. This collaborative approach, grounded in expertise, financial acumen and strategic partnerships, lays the foundation for a future where DPV supplants traditional gensets, contributing to a cleaner and more sustainable energy ecosystem in Lagos and beyond.

07 APPENDIX

IMPACT METHODOLOGY – Gas Emissions

GREENHOUSE GASES & AIR POLLUTANTS

Emissions (kg / year) = Annual fuel consumption (L) * Emissions factor (kg / L) * {Carbon equivalent conversion factor}

GREENHOUSE GAS	DIESEL EMISSIONS FACTOR[26] (KG / L)	PETROL EMISSIONS FACTOR[26] (KG / L)	GAS EMISSIONS FACTOR[26] (KG / L)	CARBON EQUIVALENT[27]
Carbon dioxide (CO_2)	2.68	2.27	1.61	1
Methane (CH_4)	3.612e-4	3.278e-4	1.277e-4	28.5
Nitrous Oxide (N_20)	2.167e-5	1.967e-5	2.554e-6	273

AIR POLLUTANT	DIESEL EMISSIONS FACTOR[26] (KG / L)	PETROL EMISSIONS FACTOR[26] (KG / L)	GAS EMISSIONS FACTOR[26] (KG / L)
Nitrogen Oxide (NO_x)	1.184e-3	1.671e-3	1.302e-3
Carbon Monoxide (CO)	2.058e-3	1.869e-3	6.641e-4
Sulfur Oxide (SO_2)	2.528e-3	2.295e-3	7.663e-6
NMVOC	2.492e-5	2.262e-5	4.853e-5

[26] Greenhouse Gas Protocol, Emissions Factors from Cross-Sector Tools https://ghgprotocol.org/calculation-tools-and-guidance
[27] Environmental Protection Agency https://www.epa.gov/ghgemissions/understanding-global-warming_potentials#:~:text=Chlorofluorocarbons%20(CFCs)%2C%20hydrofluorocarbons%20(,more%20heat%20than%20CO2.

IMPACT METHODOLOGY – Gas Emissions

GENERALIZING SURVEY RESULTS – FUEL CONSUMPTION

1. Survey Response

Method:
Fuel purchased per "period" * number of fuel purchases per year

Output:
Annual fuel consumption (L / year)

2. Gridded Map

Method:
Run residential survey inputs through Fraym machine learning software

Output:
Average annual household fuel consumption (L / year) per 1 km^2

3. Population Weighted Gridded Map

Method:
Average annual household fuel consumption (L / year) per 1 km^2 * number of households per 1 km^2

Output:
Total annual household fuel consumption (L / year) per 1 km^2

4. Aggregated Estimates

Method:
Sum of total household fuel consumption AND industrial fuel consumption per boundary

Output:
Total annual fuel consumption per boundary

Source: Fraym

IMPACT METHODOLOGY – Health & Environment

SUBJECTIVE POLLUTION RATING

About **50 percent** of residential respondents answered both the subjective measures of pollution questions. To avoid dropping responses with missing observations, Fraym suggests creating a composite measure of pollution from its gridded 1 km^2 maps.

SUBJECTIVE MEASURE OF POLLUTION – RESIDENTIAL PILOT		Air Pollution	
		Non-missing	Missing
Noise Pollution	Non-missing	713 (50%)	178 (12%)
	Missing	132 (9%)	409 (29%)

Following this methodology, industries would not receive a health and environment score (similar non-response rate as residential).

1. Survey Responses

Method:
None

Output:
Air and noise pollution ratings (1-5 discrete)

2. Gridded Maps

Method:
Run survey inputs through Fraym ML software

Output:
Average pollution ratings (1-5 continuous) per 1 km^2

3. Composite Gridded Map

Method:
Sum noise and air pollution gridded maps

Output:
Total pollution rating (2-10 continuous) per 1 km^2

4. Reclassified Composite

Method:
Reclassify composite map into 5 classes

Output:
Total subjective pollution rating (1-5 discrete) per 1 km^2

Source: Fraym

IMPACT METHODOLOGY – Economics

NET PRESENT VALUE OF PV SYSTEM

Fraym will calculate NPV (IRR, payback period) using the assumptions below in the survey data and estimate these values at the 1 km^2 level. These estimates can be aggregated to the administrative level using the same approach as emissions.

Net Present Value: $\sum_{t=0}^{n} \frac{R_t}{(1+i)^t}$ - initial investment

VARIABLE	DESCRIPTION	ASSUMPTIONS
R_t	Net cash inflow-outflows during month t	Monthly savings on fuel – monthly OpEx of PV system
i	Discount rate	5%
n	Number of time periods	Assuming a return period of 7 years, estimated lifespan of PV battery[28]
Initial investment	CapEx	

[28] Solar Depot Nigeria https://www.solardepotng.com/faq
Source: SEforAll, Fraym

RESIDENTIAL SECTOR RESULTS BREAKDOWN BY LGA

AGEGE

73,170

Total residential genset capacity (kVA)

Households counted	451
Total estimated households	139,960
Total gensets owned	67,000
Total annual fuel consumption (L)	45,137,000
Solar interest (%)	70

AJEROMI IFELODUN

289,122

Total residential genset capacity (kVA)

Households counted	600
Total estimated households	203,353
Total gensets owned	102,000
Total annual fuel consumption (L)	62,566,000
Solar interest (%)	53

ALIMOSHO

4,100,399

Total residential genset capacity (kVA)

Households counted	811
Total estimated households	1,120,776
Total gensets owned	473,000
Total annual fuel consumption (L)	714,381,000
Solar interest (%)	92

AMUWO ODOFIN

796,407

Total residential genset capacity (kVA)

Households counted	218
Total estimated households	354,587
Total gensets owned	236,000
Total annual fuel consumption (L)	1,300,586,000
Solar interest (%)	62

RESIDENTIAL SECTOR RESULTS BREAKDOWN BY LGA

APAPA

217,580

Total residential genset capacity (kVA)

Households counted	210
Total estimated households	83,875
Total gensets owned	68,000
Total annual fuel consumption (L)	79,707,000
Solar interest (%)	92

BADAGRY

96,763

Total residential genset capacity (kVA)

Households counted	140
Total estimated households	143,423
Total gensets owned	97,000
Total annual fuel consumption (L)	40,009,000
Solar interest (%)	56

EPE

130,546

Total residential genset capacity (kVA)

Households counted	146
Total estimated households	122,022
Total gensets owned	98,000
Total annual fuel consumption (L)	68,570,000
Solar interest (%)	70

ETI-OSA

812,687

Total residential genset capacity (kVA)

Households counted	376
Total estimated households	189,266
Total gensets owned	229,000
Total annual fuel consumption (L)	306,770,000
Solar interest (%)	88

RESIDENTIAL SECTOR RESULTS BREAKDOWN BY LGA

IBEJU-LEKKI

258,317

Total residential genset capacity (kVA)

Households counted	35
Total estimated households	71,496
Total gensets owned	67,000
Total annual fuel consumption (L)	138,573,000
Solar interest (%)	74

IFAKO IJAYE

175,917

Total residential genset capacity (kVA)

Households counted	292
Total estimated households	310,924
Total gensets owned	191,00
Total annual fuel consumption (L)	139,091,000
Solar interest (%)	56

IKEJA

1,080,722

Total residential genset capacity (kVA)

Households counted	260
Total estimated households	393,127
Total gensets owned	285,000
Total annual fuel consumption (L)	270,655,000
Solar interest (%)	64

IKORODU

291,161

Total residential genset capacity (kVA)

Households counted	288
Total estimated households	348,822
Total gensets owned	264,000
Total annual fuel consumption (L)	267,689,000
Solar interest (%)	92

RESIDENTIAL SECTOR RESULTS BREAKDOWN BY LGA

KOSOFE

261,463

Total residential genset capacity (kVA)

Households counted	401
Total estimated households	360,958
Total gensets owned	284,000
Total annual fuel consumption (L)	256,253,000
Solar interest (%)	86

LAGOS ISLAND

68,558

Total residential genset capacity (kVA)

Households counted	262
Total estimated households	27,199
Total gensets owned	18,000
Total annual fuel consumption (L)	12,456,000
Solar interest (%)	54

LAGOS MAINLAND

298,838

Total residential genset capacity (kVA)

Households counted	356
Total estimated households	128,142
Total gensets owned	82,000
Total annual fuel consumption (L)	100,151,000
Solar interest (%)	86

MUSHIN

152,881

Total residential genset capacity (kVA)

Households counted	541
Total estimated households	285,743
Total gensets owned	162,000
Total annual fuel consumption (L)	123,451,000
Solar interest (%)	54

RESIDENTIAL SECTOR RESULTS BREAKDOWN BY LGA

OJO

769,601

Total residential genset capacity (kVA)

Households counted	386
Total estimated households	392,107
Total gensets owned	217,000
Total annual fuel consumption (L)	4,415,147,000
Solar interest (%)	81

OSHODI ISOLO

466,991

Total residential genset capacity (kVA)

Households counted	462
Total estimated households	639,866
Total gensets owned	501,000
Total annual fuel consumption (L)	486,423,000
Solar interest (%)	94

SOMOLU

229,566

Total residential genset capacity (kVA)

Households counted	414
Total estimated households	106,529
Total gensets owned	86,000
Total annual fuel consumption (L)	59,684,000
Solar interest (%)	64

SURULERE

385,910

Total residential genset capacity (kVA)

Households counted	537
Total estimated households	281,262
Total gensets owned	201,000
Total annual fuel consumption (L)	192,171,000
Solar interest (%)	89

FORMULAS: FINANCIAL VIABILITY

Capital Recovery	Per kWh system cost = Total Capex/Total estimated units of energy produced
Cost of Fuelling	Per kWh fuel cost = Total estimated cost of fuel over the life of the asset/Total estimated units of energy produced
Operation & Maintenance Cost	Per kWh fuel cost = Total estimated cost of maintenance over the life of the asset/Total estimated units of energy produced
SG&A	Per kWh fuel cost = Total estimated administrative expenses over the life of the asset/Total estimated units of energy produced
Insurance	Per kWh fuel cost = Total estimated insurance cost over the life of the asset/Total estimated units of energy produced
Cost of Funding	Per kWh fuel cost = Total estimated finance cost over the life of the asset/Total estimated units of energy produced
Total Energy Produced	Total Energy Produced = Production Capacity * Daily Hourly Usage * Number of Days in a Year * Expected Useful Life of the Asset
Viability Gap	Viability Gap is the difference between the solar tariff and the grid tariff

ABOUT SEforALL

Sustainable Energy for All (SEforALL) is an independent international organization that works in partnership with the United Nations and leaders in government, the private sector, financial institutions, civil society and philanthropies to drive faster action on Sustainable Development Goal 7 (SDG7) – access to affordable, reliable, sustainable and modern energy for all by 2030 – in line with the Paris Agreement on climate change.

SEforALL works to ensure a clean energy transition that leaves no one behind and brings new opportunities for everyone to fulfil their potential. Learn more about our work at www.SEforALL.org