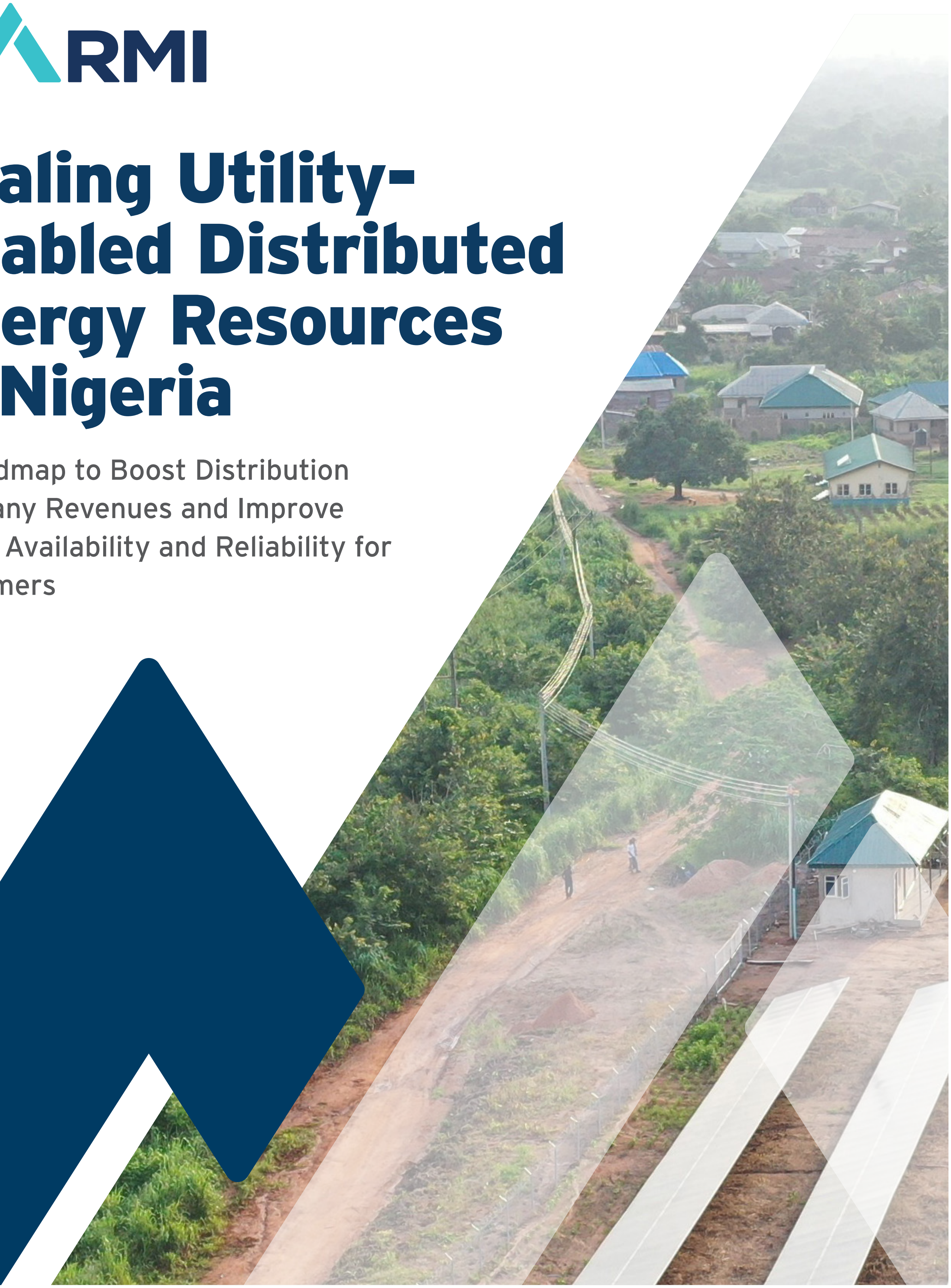
Scaling Utility-Enabled Distributed Energy Resources in Nigeria

A Roadmap to Boost Distribution Company Revenues and Improve Power Availability and Reliability for Customers



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Wuse interconnected minigrid, aerial view © RMI

ABOUT RMI

RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut climate pollution at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; Abuja, Nigeria; and Beijing.

ABOUT RMI'S GLOBAL SOUTH PROGRAM

RMI's Global South Program works across three core geographies — Africa, Southeast Asia, and island nations — to address barriers to the energy transition and achieve radical implementation at scale. RMI tackles these challenges using upstream, midstream, downstream, and cross-cutting interventions.

In the upstream, we demonstrate inclusive energy planning and policy processes that create the enabling environment for investment. In the midstream, we test and pilot projects to address a wide range of energy needs. Downstream, we provide climate finance access support to countries that have not received their fair share of funding. Cross-cutting all of this is our unique approach to capacity building and workforce development.

In Africa, RMI partners with governments, development partners, utilities, and the private sector in sub-Saharan Africa to drive deployment of affordable, efficient, reliable, and resilient energy systems that incorporate distributed energy resources to rapidly provide energy access and support economic development.

ABOUT GEAPP

The Global Energy Alliance for People and Planet (GEAPP) is an alliance of philanthropy, governments in emerging and developed economies, and technology, policy, and financing partners. GEAPP's common mission is to enable LMIC's shift to a clean energy, pro-growth model that accelerates universal energy access and inclusive economic growth, while supporting the global community to meet critical climate goals during the next decade. As an alliance GEAPP aims to reduce 4 gigatons of future carbon emissions, expand clean energy access to one billion people, and enable 150 million new jobs. With philanthropic partners, IKEA Foundation, The Rockefeller Foundation, and Bezos Earth Fund, GEAPP works to build the enabling environment, capacity, and market conditions for private sector solutions, catalyze new business models through innovation and entrepreneurship, and deploy high-risk capital to encourage private sector solutions, and assist just transition solutions.

This roadmap is accompanied by a *DER Toolkit* that equips DisCos and developers to accelerate the identification, preparation, and execution of utility-enabled DER projects by providing templates of key documents used in DER implementation.

Templates in the *DER Toolkit* are referenced in **Appendix C** of this roadmap and include:

- Financial models,
- Project implementation plans,
- Project procurement documents, and
- Term sheets and contract agreement templates.

The *DER Toolkit* was developed to ensure an effective, sustainable, and timely implementation of utility-enabled DER projects.

TABLE OF CONTENTS

Definitions of key terms used

Embedded generation as defined in Nigerian Electricity Regulatory Commission's regulation means the generation of electricity that is directly connected to and evacuated through a distribution system that is connected to Nigeria's transmission network.

First wave of projects refers to utility-enabled distributed energy resource pilot projects that have been recently commissioned or are under construction and that are testing the technical and commercial feasibility of distributed energy resource models in Nigeria.

Self-generation refers to the private production of electricity by grid-connected electricity consumers, using small, expensive fossil-fueled generators as an alternative to or to augment power supply from the grid.

Undergrid minigrids are minigrids that utilize existing electricity distribution infrastructure and incorporate distributed energy resources to better serve customers who live within a distribution company's territory. Unlike interconnected minigrids, undergrid minigrids do not receive electricity supply from the regional distribution company.

Utility-enabled distributed energy resources (DERs) are those that interconnect with the distribution company's network under an arrangement that allows power supply from the DER and the distribution company at varied times. It includes interconnected minigrids, interconnected commercial and industrial DER projects, and renewable embedded generation.

LIST OF ACRONYMS

AEDC	Abuja Electricity Distribution Company
ATC&C	Aggregated Technical, Commercial, and Collection
BEDC	Benin Electricity Distribution Company
Capex	Capital Expenditures
CNG	Compressed Natural Gas
C&I	Commercial and Industrial
DER	Distributed Energy Resource
DisCo	Distribution Company
DUOS	Distribution Use of System
EEDC	Enugu Electricity Distribution Company
EKEDC	Eko Electricity Distribution Company
ETO	Energy Transition Office
ETP	Energy Transition Plan
GEAPP	Global Energy Alliance for People and Planet
GenCo	Generating Company
IBEDC	Ibadan Electricity Distribution Company
IE	Ikeja Electric
IMG	Interconnected Minigrid
IRP	Integrated Resource Plan
JED	Jos Electricity Distribution Company
KE	Kaduna Electric
KEDCO	Kano Electricity Distribution Company
LCOE	Levelized Cost of Electricity
MYTO	Multi-Year Tariff Order
NEMSA	Nigerian Electricity Management Services Agency
NERC	Nigerian Electricity Regulatory Commission
Opex	Operating Expenditures
PHEDC	Port Harcourt Electricity Distribution Company
REA	Rural Electrification Agency
REG	Renewable Embedded Generation
RMI	Rocky Mountain Institute
TCN	Transmission Company of Nigeria
TREP	Transmission Rehabilitation and Expansion Program
UK-NIAF	United Kingdom Nigeria Infrastructure Advisory Facility
PV	Photovoltaic
YEDC	Yola Electricity Distribution Company
WB	World Bank

EXECUTIVE SUMMARY

Utility-enabled distributed energy resources (DERs) provide a unique opportunity to address the persistent challenges of power availability and reliability in Nigeria. Leveraging the momentum generated by initial "first-wave" projects, this strategic roadmap shows that a more than **20 GW market opportunity is possible with the rapid expansion of utility-enabled DERs across Nigeria over the next 10 years**. This roadmap recommends solutions to address challenges encountered by distribution companies (DisCos) and developers in reaching this scale. It suggests a massive investment opportunity for distributed solar photovoltaics (PV), batteries, and gas backup technologies that offer clear and tangible benefits for DisCos, project developers, and customers:

- With new DER assets, **each DisCo can increase its revenue by an average of over ₦70 billion (~$50 million) every year** over the next decade.[i]
- **DisCos can reduce ATC&C losses by up to 20%** across their respective territories if distribution network upgrades are included as part of the DER scope.
- **Customers served by DERs can save up to 25%** on their energy costs by displacing existing fossil-fueled self-generated power, such as from diesel generators.
- **DERs present an investment opportunity of nearly $14 billion across Nigeria in generation assets** over the next ten years.[ii]
- Current regulations support commercial viability by allowing **project developers to charge cost-reflective tariffs**.

Since 2018, RMI, GEAPP, and the Rockefeller Foundation, along with other funding partners (USTDA and UK-PACT), have worked with 5 electricity distribution companies (DisCos) in Nigeria to assess opportunities for strengthening financial performance and delivery of clean, reliable, affordable power.[iii] This DER roadmap (*the Roadmap*) shares insights from that work, highlighting the significant opportunity for utility-enabled DERs to grow DisCo profitability, improve distribution and metering infrastructure, close the supply gap, and reduce losses while presenting a mechanism to reduce customer costs and enable private sector renewable energy project developers encouraged by the federal government. The Roadmap provides a detailed analysis based on the situations of those 5 DisCos, with additional results to show the potential impact across all 11 DisCos in Nigeria.

In Nigeria today, DisCos cannot meet key performance indicators set by the regulatory body, the Nigerian Electricity Regulatory Commission (NERC). High aggregate technical, commercial, and collection (ATC&C) losses and low metering rates compound the challenges of a growing customer base. At the same time, RMI analysis suggests that electricity supply from the Transmission Company of Nigeria (TCN) can meet only 70%–80% of forecasted DisCo electricity demand — even with an 8% increase in TCN supply (see **Exhibit ES-1**).

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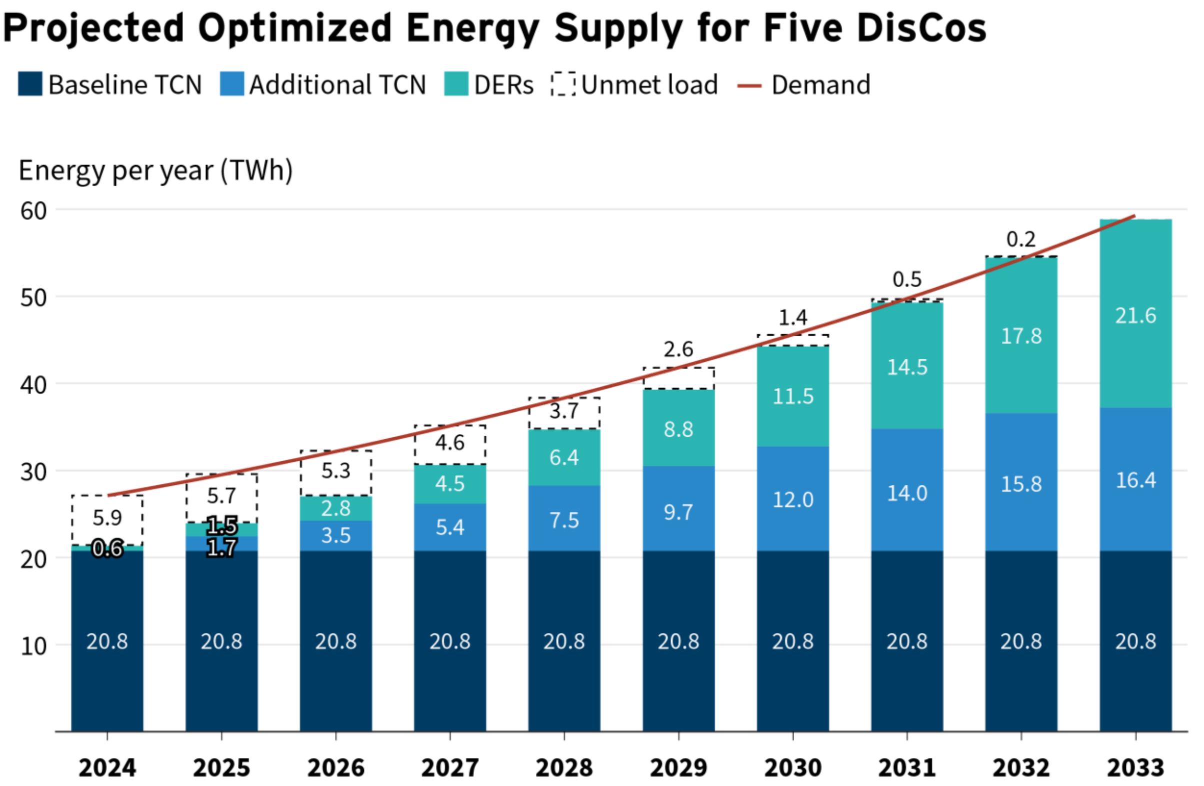
[i] As of the publication of this report, 1 US dollar = 1,400 naira.

[ii] These estimates are based on current prices. **Appendix E** details the cost assumptions and other parameters used to calculate the market opportunity.

[iii] DisCos engaged include Abuja Electricity Distribution Company (AEDC), Benin Electricity Distribution Company (BEDC), Eko Electricity Distribution Company (EKEDC), Kano Electricity Distribution Company (KEDCO), and Ikeja Electric (IE).

Exhibit ES-1: RMI projections for electricity demand and supply across five DisCo territories demonstrate a growing opportunity for DERs to fill a supply gap.



Perspectives across Nigeria's power sector are converging on DERs as a unique, scalable solution that can use multiple tailored business models to address unique customer needs. DisCos were already actively seeking support to grow DER programs (as RMI and GEAPP have seen), but as of March 2024, NERC has also ordered DisCos to meet a minimum of 10% demand allocation through embedded generation resources (one category of DER) by April 2025, with half to come from renewable energy sources.

Current customer electricity demand outpaces supply by at least 20%, and the gap continues to grow. The Roadmap, based on close engagement with 5 out of Nigeria's 11 DisCos, projects how DERs can help close this supply gap by accelerating the deployment of utility-enabled DERs. Accomplishing that requires **1 GW annually across the five DisCo territories** under analysis, or about 2 GW annually across the country, of utility-enabled DERs. The Roadmap demonstrates that a mix of DER resources — including solar PV, battery, and gas — provides a path to increasing supply across a range of customer demand scenarios and projections of national grid supply. These DER projects also provide a "win-win-win" for each party involved, including benefiting broader DisCo operations through improvements in distribution network infrastructure and customer metering (see **Exhibit ES-2**).

Exhibit ES-2: Win-win-win value proposition of utility-enabled DER projects.

DisCo	Customer	Developer
Increased energy sales and revenue	Increased electricity supply availability and reliability	Reasonable returns with predictable revenues
Reduced financial losses and operational constraints	Reduced levelized cost of energy	Access to DisCo customers and opportunity for project expansion and scaling across DisCo territory
Compliance with regulatory targets	Less reliance on polluting and expensive alternatives	
Improved distribution network		

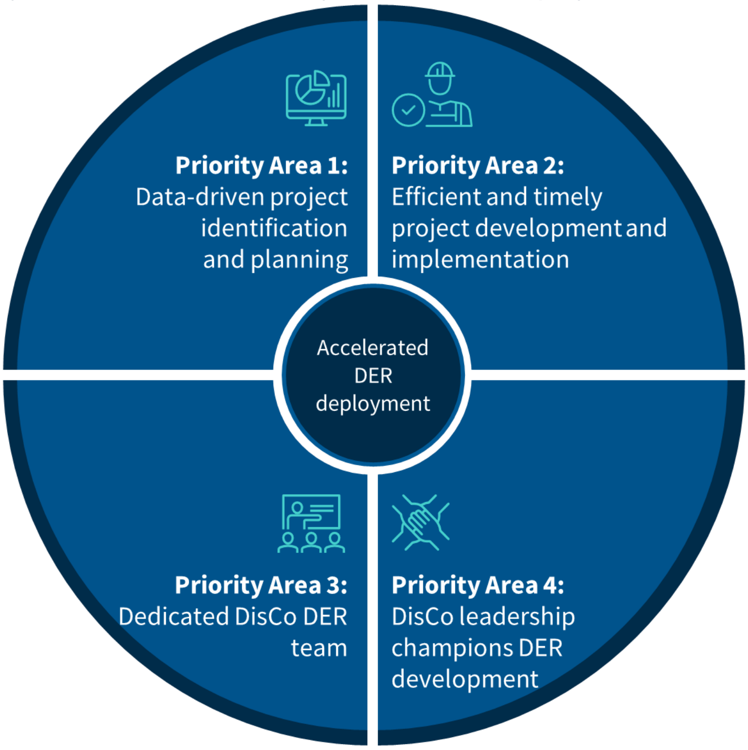
The Roadmap shows that deploying DER capacity to close the supply gap across five DisCos presents an **investment opportunity of over $8 billion over the next 10 years**, which scales to nearly $14 billion nationwide (not including distribution network upgrades). Outside Lagos, space availability results in solar PV being the leading modeled DER technology in capacity and energy by 2033, while in Lagos space constraints increase the role of gas in the energy mix.

DisCos, through planning and close collaboration with developers and other stakeholders, can prioritize where these DER solutions are deployed to maximize increased revenue in areas where there is ability and willingness to pay, resulting in improved financial performance. DERs also offer a compelling case for customers, who will save money on energy expenses, and developers, who can charge cost-reflective tariffs through DER regulation and expand their footprint to DisCo territories. DER implementation can **reduce carbon pollution across the five DisCo territories by about 14 million metric tons CO_2e per year**, or about 33 million metric tons CO_2e per year across all DisCos.[iv] This reduction represents approximately 8% of Nigeria's total 2022 emissions.[1]

The Roadmap offers guidance for Nigerian DisCos to meet their strategic goals and calls for stronger collaboration by developers, investors, and stakeholders to accelerate project deployment. The roadmap describes utility-enabled DER business models and outlines key lessons learned from the implementation of the first wave of projects. Based on an assessment of five DisCos, the roadmap quantifies the market potential of utility-enabled DERs over the next decade, including a breakdown of technology needed year by year to close DisCo supply gaps. Finally, the roadmap introduces and describes four priority areas and provides action-oriented recommendations for each priority area to achieve the DER opportunity (depicted in **Exhibit ES-3**).

[iv] CO_2e refers to carbon dioxide equivalent.

Exhibit ES-3: Priority areas to accelerate utility-enabled DER deployment.



In considering the roadmap as part of a collaborative discussion with DisCos, Abba Ibrahim Tarab, Deputy General Manager of NERC, reflected: *In the roadmap, reviewing the feeder levels and the energy supply gaps has been quite revealing. The potential is quite substantial: only from the 5 DisCos alone, there is an investment opportunity exceeding $5 billion — $5 billion!*

To ensure DisCos are ready for DER implementation, DisCo leaders can begin with the checklist below and expanded in **Section 5**. These actions correspond with the detailed documents and templates provided in RMI's accompanying *DER toolkit.*

Checklist of priority action items for DisCos to enable DER deployment.

- ❑ Form a cross-functional DER team and appoint a team leader.
- ❑ Develop a DER strategy that speaks to the DisCo's Performance Improvement Plan (PIP) and incorporate DER targets into key performance indicators.
- ❑ Brief DisCo board members on DER analysis benefits, implementation, and performance.
- ❑ Establish a system to build DER awareness among DisCo staff.
- ❑ Aggregate DER project data in a central platform or database.
- ❑ Create a systemic process flow for developing DER projects, and identify DisCo lead staff.
- ❑ Assess feeder and distribution network capacity and quality.
- ❑ Clarify DisCo and developer roles throughout the project.
- ❑ Engage customers to evaluate their interest in DER solutions.
- ❑ Establish a list of credible vendors and use memoranda of understanding to coordinate with project developers.
- ❑ Implement a competitive procurement framework.
- ❑ Codify customer engagement and conflict resolution mechanisms for full project lifetime.
- ❑ Establish monitoring, evaluation, and learning framework for continuous improvement.
- ❑ Ensure strict adherence to embedded generation and renewable energy targets.

1. INTRODUCTION

Nigeria, West Africa's largest economy and Africa's most populous country, continues to face numerous bottlenecks in its power sector that limit national growth and development. Constrained power transmission capacity accompanies large supply deficits; high aggregate technical, commercial, and collection (ATC&C) losses; non-cost reflective tariffs; and low revenue collections. These factors limit the ability of electricity distribution companies (DisCos) to cover operational costs and prevent them from raising capital for distribution infrastructure upgrades. The vicious cycle of debt and weakening infrastructure inhibits DisCos from adequately serving their customers with the reliable and affordable electricity they need to power their homes and businesses.

RMI and the Global Energy Alliance for People and Planet (GEAPP) work with DisCos, developers, and other stakeholders in Nigeria to explore opportunities for distributed energy resources (DERs) that support DisCo electricity supply, operational efficiency, and profitability. DERs — small to medium energy generation and/or storage units located near a source of consumption[v] — offer a regulated opportunity for external investors to build and operate generation units while backstopping grid supply to improve customer service. DERs are one of a suite of options to improve grid power availability and reliability to reduce DisCo rates of un- and underserved customers.

Through engagement with 5 of Nigeria's 11 DisCos, RMI analyzed the opportunity for DER implementation across Nigeria. Currently available data suggest a DER market opportunity of 1 GW annually for these five DisCos, or about 2 GW per year across the country over the next decade.

In April 2024, RMI and GEAPP convened over 40 participants from five DisCos and NERC to discuss the preliminary findings of this roadmap and explore DER scaling possibilities. Participants unanimously supported and committed to working toward the expansion of utility-enabled DER models in Nigeria. While DisCo leaders underscored the importance of resources like this roadmap and RMI's *DER Toolkit*, they also noted that additional modeling and financial analysis could support more rapid DER deployment. Given the consensus from DisCo leaders that DERs offer a unique and sustainable opportunity to strengthen utility financial metrics, this roadmap offers best practices for DisCos to enable DER growth. Specifically, this roadmap:

(a) Identifies the benefits of implementing utility-enabled DERs for various stakeholders (**Section 2**);
(b) Provides an overview of common utility-enabled DER business models and illustrates case studies (**Section 3**);
(c) Outlines the lessons learned from the implementation of the first wave of utility-enabled DER projects in Nigeria (**Section 3**);
(d) Quantifies the market potential of utility-enabled DER projects and estimates the investment opportunity (**Section 4**);
(e) Assesses the impact of using utility-enabled DERs to meet demand from the five DisCos (**Section 4**); and
(f) Introduces and describes priority areas to accelerate project deployment to achieve scale, including recommended actions and timeline for implementation (**Section 5**).

[v] Authors of this report define small to medium DERs as those with installed capacity from ~100 kW up to 20 MW including solar PV, Li-ion batteries, and/or gas backup technologies hosted anywhere on a distribution network.

The analytical scope of the Roadmap is to quantify the market size for utility-enabled DER resources needed to help close DisCos' supply deficit by 2033 and quantify the revenue increases. The Roadmap is not a detailed capacity expansion modeling, feeder-by-feeder study, and does not include a grid stability analysis.

The Roadmap does not include a detailed characterization of DER technologies, a breakdown of their costs and capabilities, or deep background on policy and regulatory considerations. Existing resources cover these issues well, so the authors choose here to provide references to those resources while focusing the roadmap report on quantifying the opportunity and actionable next steps in the Nigerian DER sector.

RMI and GEAPP hope that this roadmap will clarify the business case for utility-enabled DER implementation by providing facts, exhibits, and actions for DisCos, developers and other partners.

1.1 DER buildout can bolster DisCo efficiency

Utility-enabled DERs present a sizeable, unique opportunity to address power supply challenges, grow private sector developer capacity, and improve service to customers. While DERs hold large potential for strengthening service, DisCos are just beginning to incorporate these resources. A first wave of utility-enabled DER projects (see **Section 3**) demonstrates how several DisCos are already collaborating with developers to deploy utility-enabled DERs to meet strategic goals. However, due to the emerging nature of DER business models and the continuing development of DER regulatory structures, many DisCo leaders continue to seek clarity on how to best scale deployment and manage utility-enabled DER investments.

The need for this roadmap was validated by key stakeholders in Nigeria. RMI engaged DisCos, DER project developers, Nigerian Electricity Regulatory Commission (NERC), Rural Electrification Authority (REA), the U.K. Nigeria Infrastructure Advisory Facility (UK-NIAF), and Nigeria's Energy Transition Office (ETO) through a series of in-person and virtual consultations to align on the need for, evidence to support, and objectives of the roadmap. Informed by these partnerships and building on the momentum created by the first wave of DER projects, this roadmap provides a guide and action-oriented set of recommendations to DisCos and developers in Nigeria to accelerate the deployment of utility-enabled DER projects. RMI based findings on close engagement with 5 out of the 11 DisCos.[vi]

RMI reviewed a wide range of resources, including five Nigerian energy plans, to better place utility-enabled DER opportunities in the context of broader power system development. A brief description of the national-scale plans reviewed is provided in **Appendix A**. Aggregating and building on that existing literature, this roadmap provides a brief overview of Nigeria's DER landscape and available technologies, supporting regulations and policies, DER technology unit installed costs, and business models. The RMI reports *Under the Grid*,[2] *Electrifying the Underserved*,[3] *Improving Electricity Supply for Large Customers in Nigeria*,[4] and *Unlocking Renewable Embedded Generation in Nigeria* provide an in-depth explanation of the business cases for utility-enabled DER models.[5]

[vi] DisCos engaged include Abuja Electricity Distribution Company (AEDC), Benin Electricity Distribution Company (BEDC), Eko Electricity Distribution Company (EKEDC), Kano Electricity Distribution Company (KEDCO), and Ikeja Electric (IE).

1.2 Nigerian power sector prospects indicate the time is right for DER projects

Across Nigeria, efforts are underway to improve power supply across generation, distribution, and transmission constraints.

Transmission is one factor that significantly constrains the ability to move electricity across Nigeria. The Transmission Company of Nigeria (TCN) launched the Transmission Rehabilitation and Expansion Program (TREP) in 2017 to rehabilitate and upgrade the transmission network to improve grid stability and improve power supply, and implementation is currently underway.[6,vii] The Central Bank of Nigeria's Power Intervention Fund is developing 53 ongoing power transmission projects.[7]

The government of Nigeria is also investing in power generation. The Presidential Power Initiative — a partnership between the Nigerian government and Siemens corporation with the support of the German government — will add 2 GW to the national grid.[8] Additionally, stakeholder interviews highlight at least 4 GW of new gas and hydro power plants expected to come online within the next decade.[viii]

At the distribution level, Nigeria's Distribution Sector Recovery Program for Results seeks to improve DisCos' financial and technical performance.[9] Through the program, the World Bank seeks to facilitate access to investment funds for distribution infrastructure upgrades and expansions. To augment power supply from the national grid at the distribution level, NERC has enacted a number of regulations to enable the development of distributed energy resources, which include the following:

(a) *Regulation for Embedded Generation*, 2012: This regulation enables the development of embedded generation projects, large utility-enabled DERs, up to 20 MW. The regulation allows developers to sell power to DisCos and calls for the competitive procurement of embedded generation projects.[10]

(b) *Guidelines on Distribution Franchising in the Nigerian Electricity Supply Industry*, 2020: This guideline permits third parties to sub-franchise certain areas of a DisCo's network, thereby providing for expansion for DER projects that was not previously allowed.[11]

(c) *Mini-Grid Regulation*, 2023: The recently updated *Mini-Grid Regulation* (first published in 2016) continues to recognize the role of isolated and interconnected minigrids (IMGs) and provides for DER development through a tripartite agreement among developers, DisCos, and customers. This regulation supports the submission of a pipeline of projects for approval, fast-tracking the process to speed implementation. Additionally, it introduces a Distribution Use of System (DUOS) charge, which incentivizes DisCos to share existing infrastructure with private developers in exchange for a new source of revenue.[12]

Other regulatory efforts also support DER expansion. Nigeria's Electricity Act 2023 empowers states to create independent electricity markets to reduce reliance on the national grid and improve electricity access and supply.[13] In the 2024 Supplementary Order to the Multi-Year Tariff Order (MYTO), NERC instructed DisCos to target 10% of demand allocation through embedded

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[vii] The TREP has attracted significant interest from the financing community with the African Development Bank (AfDB), which provided $250 million, and the World Bank, which approved $480 million in 2016 and an additional amount of $450 million in 2023.

[viii] New installations expected include 240 MW hydro Kainji expansion, 1,350 MW thermal Gwagwalada IPP, 700 MW hydro Zungeru, and 1,900 MW thermal Egbin Phase II.

generation by April 2025, with half to come from renewable sources.[14] NERC, in its 2024 MYTO tariff order, mandated DisCos to secure bilateral contracts to meet their energy requirements. This allows DisCos to procure supply directly from generating companies (GenCos), thereby reducing their exposure to transmission constraints. Additionally, NERC recently increased tariffs for Band A customers from ₦60/kWh to ₦225/kWh to push end-user tariffs closer to cost-reflective levels.[15] To reflect changes in macroeconomic indices including inflation, exchange rates, and gas prices, NERC will conduct a monthly review of tariffs. Collectively, these recent policy and regulatory changes have attracted new investments from private developers in DERs to help address power supply availability and reliability bottlenecks. In addition, on May 1, 2024, NERC ordered the establishment of a new Independent System Operator.[16]

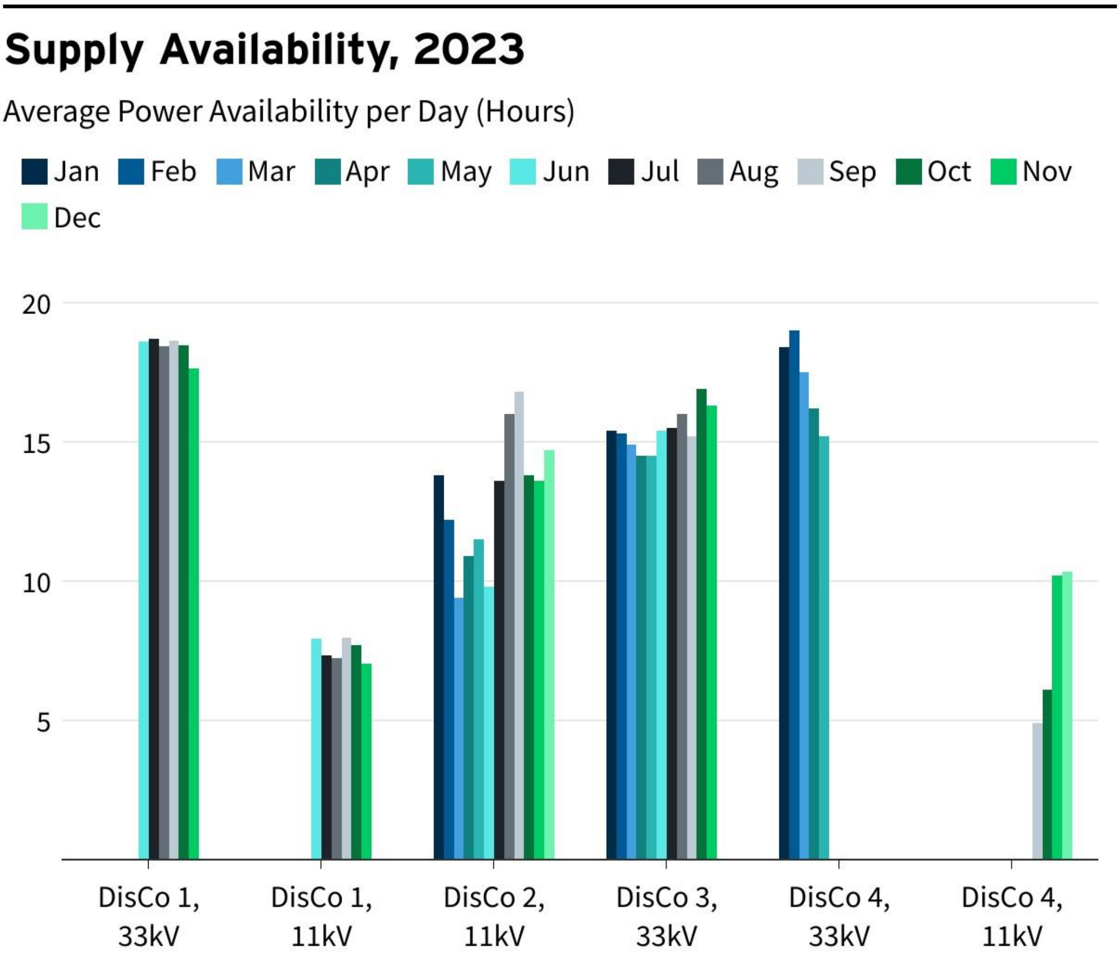
To build on this strong policy foundation and the first wave of operational utility-enabled DER projects, in December 2023, the World Bank approved the Nigeria Distributed Access through Renewable Energy Scale-up (DARES) program. With a credit line of $750 million to the Federal Government of Nigeria, implemented by the Rural Electrification Agency,[17] DARES aims to strengthen the Nigerian energy sector, providing funding and financing opportunities for new DER efforts.

1.3 Despite improvement, DisCo challenges persist

While the national grid has achieved marginal improvements in supply, limitations persist. Constraints on Nigeria's transmission network limit the average energy delivered to about 4 GW, which is about half of the available generation capacity of 7.5 GW.[18,ix] The national electricity grid is therefore only able to provide a very limited supply per day to DisCos. According to DisCo data, the annual average electricity supply on 11 kV feeders ranges from 7 to 13 hours daily, and that of 33 kV feeders ranges from 15 to 18 hours daily.[x] In **Exhibit 1**, 2023 data from hundreds of 33 kV and 11 kV feeders across four DisCos reveal the scarce nature of power supply over time.

[ix] Total installed capacity is about 12.5 GW.
[x] This is based on 2023 feeder data from four DisCos, albeit data was not available across all feeder types for each month.

Exhibit 1: Average availability of supply from DisCo data (each bar represents one month).



Note: Data was not available for all months for some DisCos. Analysis using DisCo data from 230–33 kV feeders and 650–11 kV feeders.

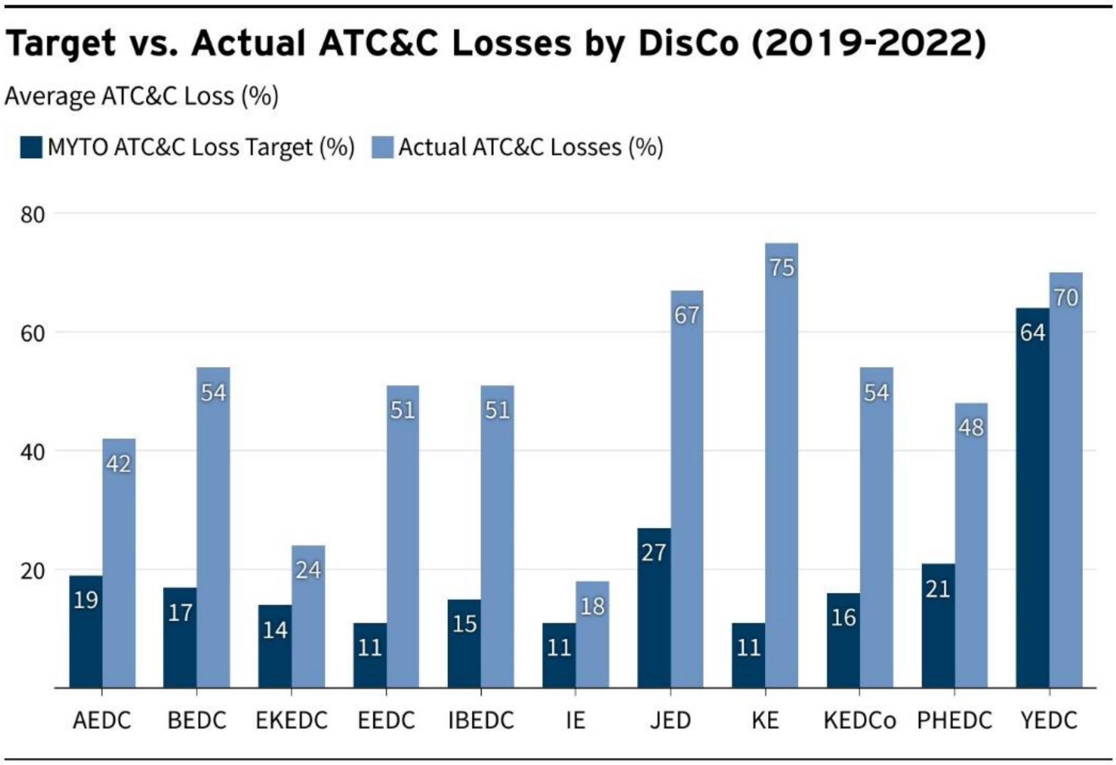
As a result of low grid reliability, Nigerian businesses, individuals, and communities often resort to the use of petrol and diesel gensets as back up supply, with some customers completely defecting from DisCos' distribution network.[xi] Nigeria has a fleet of 22 million petrol generators.[19] RMI analysis suggests that emissions from the use of generators to supplement unreliable grid power alone is as high as 33 million metric tons CO_2e per year nationally, and this does not include off-grid use. For instance, a recent Bloomberg report estimates Lagos State's generator capacity at 15 GW, or about 15 times what TCN supplies to the state.[20]

Nigerian customers who use generators to augment or supplant grid service experience high fossil-fueled self-generation costs. Nigerians reportedly spend ₦553–₦967/kWh ($0.40–$0.69/kWh) on fossil-fueled self-generation.[21] This far exceeds the 2024 Multi-Year Tariff Order (MYTO) average cost-reflective tariff of ₦129/kWh ($0.10/kWh), which is the unsubsidized cost of electricity from the grid.[22] Fossil-fueled self-generated electricity costs are also unstable. For instance, the removal of the fuel subsidy in Nigeria in July 2023 spiked petrol prices by 175%, increasing it from ₦195 to ₦540 per liter ($0.13–$0.36/L).[23]

[xi] Anecdotal evidence suggests that customer defections have been increasing due to poor supply.

Fossil-fueled self-generated electricity is expensive for consumers, but also costly to utilities. Ultimately, Nigerian DisCos are caught in a vicious cycle — an inefficient power sector leads to a high rate of fossil-fueled self-generation, which then reduces revenue and increases ATC&C losses for the DisCos. Power supply unreliability also contributes to high ATC&C and revenue losses. Between 2019 and 2022, average ATC&C losses across all Nigerian DisCos were 30% higher than the average ATC&C loss allowed in the MYTO.[24] **Exhibit 2** indicates the variation in ATC&C losses and its deviation from the MYTO targets for each DisCo within this period.

Exhibit 2: Comparison between average ATC&C losses and average MYTO targets.



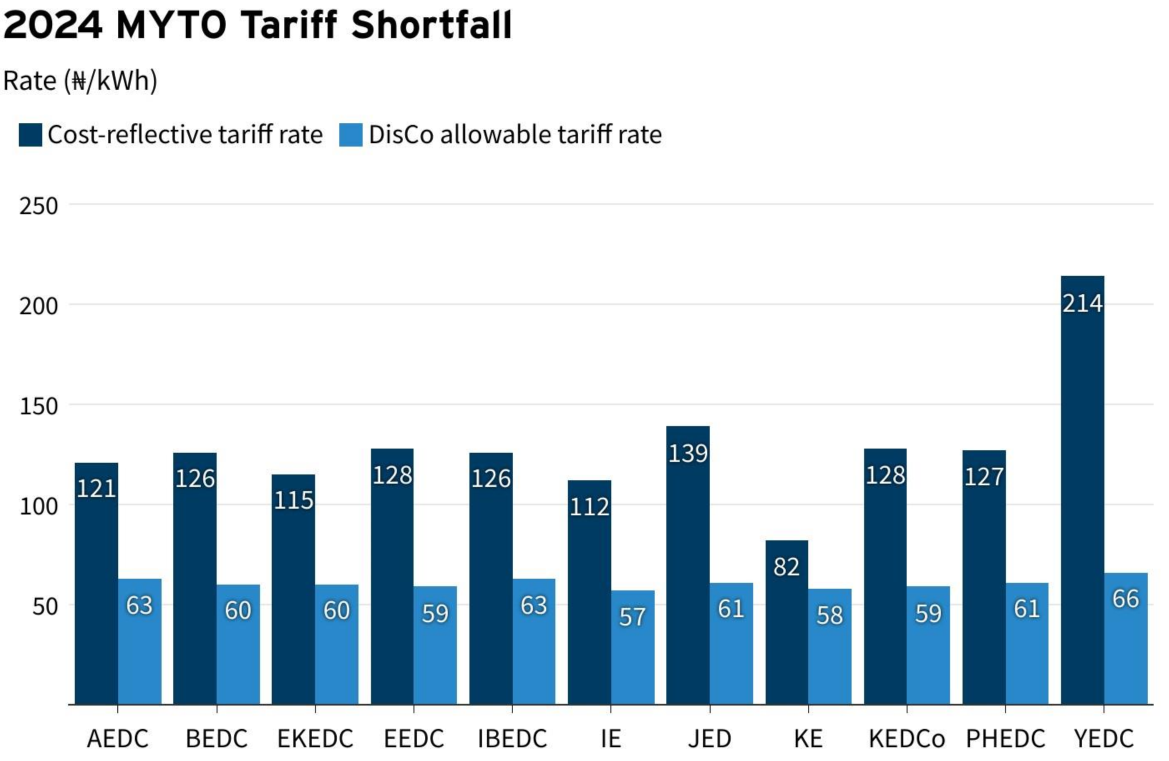
Source: Key Financial and Operational Data of Nigeria DisCos, 2022, NERC

Widespread electricity theft among consumers and persistent metering gaps contribute significantly to high system losses. For instance, 56% of customers across all Nigerian DisCos are not metered as of December 2023, with the highest metering gap at 85% in Yola Electricity Distribution Company.[25] Metering rates for all DisCos are described in **Appendix B**.[26]

Shortfalls in DisCo revenue requirements result from the non-cost-reflective tariffs that DisCos charge their customers, as well as from the unreliable power supply and ensuing high ATC&C losses. Electricity tariffs in Nigeria have historically not been revised to cost-reflective levels, and while reviews periodically account for changing costs, implementation of those changes tends to be slow due to affordability concerns. For instance, NERC's recently published 2024 MYTO tariffs demonstrate large shortfalls in the tariffs DisCos are allowed to charge and their approved cost-reflective counterparts.[27] On average across all DisCos, the allowed tariffs are less than half the approved cost-reflective tariffs.[xii] The shortfall for each DisCo is shown in **Exhibit 3**; aggregated, the nationwide revenue shortfall for 2024 is estimated at ₦1.67 trillion ($1.19 billion) and is expected to be borne by the federal government through DisCo subsidies.[28]

[xii] According to NERC, this is in line with the government's policy of subsidizing electricity due to the cost-of-living crisis.

Exhibit 3: 2024 Projected shortfall in tariff for each DisCo.



Source: 2024 DisCo Multi-Year Tariff Order, NERC

The revenue shortfall not only affects DisCos' ability to cover fixed operational costs, but also makes it difficult for them to finance distribution infrastructure upgrades and expansion. Ultimately, DisCos become less able to collect revenue and they enter a vicious cycle of debt and weakening infrastructure.

2. THE ROLE OF UTILITY-ENABLED DERS

Utility-enabled DERs present a unique and compelling opportunity for DisCos to increase access to electricity, augment power supply, and reduce system losses in their territories. At the same time, DERs reduce dependence on the national grid and transmission infrastructure, increase the share of renewable energy, reduce customer defection, and improve DisCo revenue collection. **DERs offer a *win-win-win* model for developers, utilities, and customers.**

Nigerian DisCos, as part of their PIP submitted to NERC, have proposed a number of measures to increase revenue, reduce ATC&C losses, and increase supply availability and reliability. Measures include investments to improve metering, billing, and collection; to rehabilitate infrastructure; and to reduce the supply deficit. Despite these well-informed measures, lack of access to capital limits DisCo implementation. Utility-enabled DERs, when accompanied by improvements in distribution network infrastructure and customer metering, can help meet DisCo's strategic goals while limiting the up-front investment required on their part.

RMI and other development partners have worked closely with DisCos and energy project developers to develop and test business models for utility-enabled DER solutions and to assess DERs ability to improve power supply, availability, and reliability.

2.1 Utility-enabled-DERs can help DisCos achieve strategic goals

By interconnecting DERs, DisCos can address operational challenges including ATC&C losses, supply reliability and availability, and financial investment constraints. By enabling DER developers to generate electricity and sell directly to customers with supply gaps for an agreed period of time, DisCos can increase generation to match local consumption and address distribution bottlenecks. DER deployment benefits developers and customers as well. A summary of the value proposition to DisCos, developers, and customers is outlined in **Exhibit 4**, and each benefit is further expanded on below.

Exhibit 4: Value proposition of utility-enabled DER projects.

DisCo	Customer	Developer
Increased energy sales and revenue	Increased electricity supply availability and reliability	Reasonable returns with predictable revenues
Reduced financial losses and operational constraints	Reduced levelized cost of energy	Access to DisCo customers and opportunity for project expansion and scaling across DisCo territory
Compliance with regulatory targets	Less reliance on polluting and expensive alternatives	
Improved distribution network		

As indicated in **Exhibit 4**, DisCos benefit from DER implementation through:

1) **Increased energy sales and revenues.** Many utility-enabled DER contracts obligate DisCos to supply power for a given period — in this instance, DisCos guarantee energy sales for those specific hours of grid supply. Through increased energy sales and the DUOS usage fee for sharing distribution infrastructure, the DisCo benefits from increased revenues.

2) **Reduced financial losses and operational constraints.** Utility-enabled DERs can reduce ATC&C losses, increase reliability and resilience from greater local generation supply, and reduce customer defection. Many of these benefits result from the ability to transfer collections responsibility (and risk) to third-party developers.

3) **Compliance with regulatory targets.** In addition to meeting DisCo commercial and technical performance targets, utility-enabled DERs provide a strategic solution to meeting DisCo embedded generation and renewable energy targets recently set by NERC. New renewable embedded generation projects can fulfill the new 10% embedded generation requirement while also supporting distribution infrastructure, billing, metering, and collections, and providing other co-benefits.[xiii]

4) **Improved distribution network through leveraged commercial finance.** New utility-enabled DER development projects can help DisCos modernize their networks by incorporating distribution network upgrades, including metering, as part of the initial capital investment financed by the developer. Through provisions made for many DER models, Nigerian regulation allows third parties to improve or augment DisCo distribution systems that third parties will utilize[29]. Because many MYTO utility tariffs are not comprehensively cost-reflective, this model creates a cost-recovery mechanism for necessary distribution upgrades.

Developers benefit from DER implementation through:

1) **Reasonable rates of return with predictable revenues**. Utility-enabled DERs offer an attractive investment opportunity to developers and investors. Nigeria's minigrid regulation and franchising guidelines allow developers to charge cost-reflective tariffs, which strengthen the business case for project development. DER developers benefit from reasonable internal rates of return with predictable revenues by charging cost-reflective tariffs and premium tariffs for improved service. For instance, RMI analysis suggests that interconnected minigrids could provide up to ₦75 billion (US$50 million) in annual revenue to developers across the country.[30] Utility-enabled DERs also offer an attractive investment opportunity of nearly $14 billion across Nigeria over the next decade.

2) **Access to DisCo customers and project expansion and scaling opportunities across DisCo territory**. The growing DisCo supply gap has encouraged DisCos to sign binding long-term contracts with DER developers. Successful developers might partner with DisCos to expand and scale projects with predictable revenues across utility territories. The size of DisCo-specific DER opportunities is explored in **Section 4**. Access to DisCo customers; as explored in RMI's report *Under the Grid*, the communities, customers, and businesses with the most attractive demand are often already underserved by DisCos.[31] Traditionally, regulations only allow DER developers to access completely *un*served customers. Utility-enabled DER projects offer a unique proposition for developers to access larger, urban, and peri-urban customers already within the DisCo service area.

[xiii] Additional discussion of these renewable embedded generation business models is provided in RMI's report *Unlocking Renewable Embedded Generation in Nigeria: Enabling Energy Developers in Nigeria to Provide Improved Electricity Services through Renewable Embedded Generation*.

Finally, electricity customers benefit from DER implementation through:

1) **Increased electricity supply availability and reliability**. Contracted supply hours, from the DisCo and developer collectively, significantly increase supply reliability to customers. Customers rely less on diesel gensets with associated reductions in noise and air pollution.

2) **Reduced levelized cost of energy**. For customers, reduced energy costs and increased supply hours make utility-enabled DERs a cost-effective and reliable alternative to their current expensive fossil fuel sources. Because tariffs for DERs are lower than fossil-fueled self-generation costs, RMI analysis shows that aggregate customer energy costs drop by 20%–30% compared to customers' current generation mix.

3) **Less reliance on polluting and expensive energy alternatives**. Greater stability and reliability of the energy supply from the DER developer means that customers will not need to rely on expensive fossil fuel alternatives. A recent study shows that in Lagos State alone, electricity customers can save up to ₦1.4 trillion (~US$1 trillion) through avoided fuel costs every year.[32] Nationwide, carbon pollution can be reduced by at least 33 million metric tons of CO_2e per year through the transition from generators to DERs.

By improving service reliability, utility-enabled DERs will reduce DisCo customer reliance on expensive alternatives — such as fossil fuel generators — to supplement their grid supply. At the same time, DERs provide new advantages to support DisCos in meeting their operational and regulatory targets.

DER Toolkit

- This Roadmap is accompanied by a *DER Toolkit* that equips DisCos and developers to accelerate the identification, preparation, and execution of utility-enabled DER projects by providing templates of key documents used in DER implementation.
- Templates in the *DER Toolkit* include financial models, project implementation plans, data collection methodology, and term sheets.
- The *DER Toolkit* was developed to ensure an effective, sustainable, and timely implementation of utility-enabled DER projects.
- **Appendix C** provides a schematic of the various tools intended to guide the implementation of this Roadmap.

3. IMPLEMENTATION OF UTILITY-ENABLED DERS

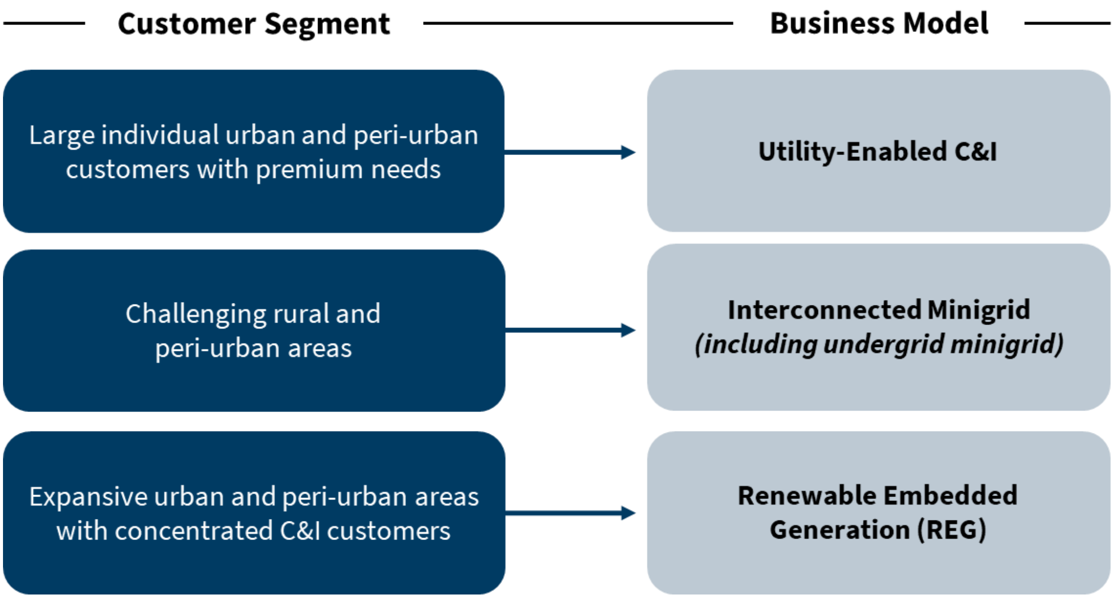
As DisCos increasingly confirm the benefits of utility-enabled DERs, they have begun developing and implementing a first wave of projects. The range of utility-enabled DER business models can be both an opportunity and a barrier, as it can require DisCo leadership to assess, understand, and match a range of customer needs, regulatory guidance, and developer requirements.

Across Nigeria, utility-enabled DER project implementation is currently in the pilot stages. Building on initial DisCo interest and in partnership with GEAPP, USTDA, UK-PACT, and World Bank,[xiv] RMI is supporting the execution of a set of the first wave of utility-enabled DER projects.[xv] This section explores three key DER business models, lessons learned from them, and an AEDC case study.

3.1 Three utility-enabled DER business models meet diverse customer needs

RMI has collaborated with DisCos and other key stakeholders to design and test three business models to meet the needs of unique customer archetypes. **Exhibit 5** maps the business models and the customer segments that they best serve.[xvi]

Exhibit 5: Utility-enabled DER business models offer solutions to some of the most challenging customer segments for DisCos to serve.



The first wave of utility-enabled DER projects in Nigeria supports the business model-customer segment alignment matches indicated in **Exhibit 5**. Although only interconnected minigrids (including undergrid minigrids) are fully operational at the time of this writing, several DisCos are making progress toward implementing renewable embedded generation and large commercial and industrial (C&I) customer projects. **Table 1** identifies projects demonstrating each business model, defines the models, and projects the market opportunity they offer. **Appendix D** offers schematics indicating how each business model operates.

[xiv] World Bank Distributed Access through Renewable Energy Scale-up (DARES) $127 million facility for IMGs.
[xv] This list is not extensive. The Interconnected Minigrid Acceleration Scheme (IMAS) program by GIZ Nigeria Energy Support Programme has also been supporting DER developers, REA, and DisCos in this space.
[xvi] Commercial districts are a common customer base requiring augmented power and are appropriate for DER service; however, commercial districts can be served by any of the three business models and do not represent a separate model.

Table 1: Overview of three utility-enabled DER business models — each of these models leverages existing DisCo infrastructure while allowing an independent developer to build and operate a new facility.

DER Business Model	Description	Market Opportunity	Implementation Example
Utility-enabled C&I	A large commercial or industrial customer receives uninterrupted electricity supply from a DER solution during the day and the DisCo's distribution network at night, with backup for grid outages provided by the DER system.	Governed by NERC's *Mini Grid Regulations 2023* OR *Feed in Tariffs for Renewable Energy Generation*.[33] Estimated to increase DisCo sales to up to 170,000 underserved C&I customers by 150%.[34]	• Under construction: Tripartite agreement signed between AEDC, Daystar Power, and The Wood Factory Limited for a 615kW solar PV generating plant.[xvii] • Under development: An additional 19 projects with a total capacity of 26 MW within the territory EKEDC and IE.[35]
Interconnected Minigrid	A renewable energy interconnected minigrid (IMG) supplies an underserved community already connected to the distribution grid. The IMG can buy energy from and sell energy to the grid, especially at night to reduce the cost of battery and fossil fuel backup.	Governed by NERC's *Mini Grid Regulations 2023*.[36] Estimated at ₦1–₦2 billion (US$3–$6 million) per DisCo or ₦10–₦20 billion across 4,000 communities nationally.[37] World Bank: *Millions of people in sub-Saharan Africa and India who are connected to the main grid suffer from poor grid reliability ("weak grid").*[38]	• Operational: Toto 352 kWp solar-plus-battery IMG in AEDC territory, developed by PowerGen. • Operational: Zawaciki 1 MWp solar IMG in KEDCO territory, developed by Bagaja. • Under commissioning: Wuse 1 MWp solar-plus-battery IMG in AEDC territory, developed by GVE. • Under construction: Robinyo 500 kWp solar-plus-battery IMG in IE territory, developed by Darway Coast. • Operational: Mokoloki 100 kWp solar-plus-battery undergrid minigrid in IBEDC territory, developed by NayoTT.[39]
Renewable Embedded Generation (REG)	A renewable embedded generation plant supplies electricity to the DisCo, increasing supply and reliability for all customers within the customer cluster.	Governed by *NERC Regulation on Embedded Regulation 2012*.[40]	• Under construction: Following a competitive procurement process, a developer is implementing two REG projects for AEDC (2.2 MW) and IE (5.2 MW). • Procurement stage: KEDCO is procuring a REG site along with other utility-enabled DERs.

[xvii] Anticipated benefits include over 40% reduction in customers' energy costs and about 80% reduction in emissions.

The projects highlighted in **Table 1** demonstrate the opportunity for innovation and collaboration between DisCos and developers, supported by government, investors, and development partners to create a cleaner, more reliable energy future for Nigerians. Not only do these projects address DisCo pain points, but the early-stage results point to an average tariff of ₦275/kWh (US$0.18/kWh), which offers savings relative to the average cost of fossil-fueled self-generation in Nigeria of ₦553–₦967/kWh ($0.40–$0.69/kWh).[xviii] Replicating the successful models discussed in this section at scale can unlock the nationwide market opportunity of 22 GW and US$14 billion (see **Section 4**). Since current projects show a commercial case for utility-enabled DERs, it will remain important for the federal government of Nigeria to continue demonstrating investment and support. Government officials, as well as development partners, DisCos, and developers, will need to work with financiers and other investors to ensure financial viability and mitigate risk for the next wave of DER projects.

The scale of current DER project pipelines is insufficient to meet the large market opportunity, which includes commercially viable areas such as commercial streets and clusters across DisCo service territories, as well as residential customers. While the utility-enabled DER market remains largely untapped, operational utility-enabled DERs and the commissioning of near-complete pilot projects provide an occasion to attract new developers and financiers to unlock the market's potential.

Like any new business model, it is important to mitigate key risks

While the three utility-enabled DER business models present a compelling solution for DisCos, they include inherent risks that must be adequately identified and mitigated.

First, current DisCo supply from TCN is unreliable, and there is a risk that the DisCo cannot provide supply during the contracted hours to its DER customer. The successful implementation of many utility-enabled DER projects relies on the DisCo's ability to supply power during a specified time. The DisCo's inability to do so may reduce supply availability to the customer, or increase the customer's energy cost by forcing the DER to backstop with expensive fossil-fuel generation to meet its obligations to customers. To mitigate this, project contracts should incorporate provisions that incentivize the DisCo to ensure a consistent supply of power. Developers should manage this risk from early in the project development phase.

Second, financing and upgrading distribution networks as part of utility-enabled DER projects is new to DER project developers and can result in project delays or substandard execution. In addition to project developers requiring more time to raise additional funding, project implementation may face logistical challenges in managing distribution upgrades. DisCos and project developers should work closely to agree on the required distribution upgrades and align on procurement and construction processes to complete the upgrades. Lastly, distribution network upgrades are an opportunity for DisCos and DER developers to jointly improve underinvested areas. However, that should not be the prime criteria when DisCos identify and shortlist sites for utility-enabled DERs.

[xviii] The average tariff value is informed by the average end-user tariff from interconnected minigrids operational as of May 2024, which feature power supply that varies from 16 to 20 hours per day.

Insights into these and other risks, such as transmission network failure, developer or customer non-payment, and foreign exchange rate — and corresponding mitigation measures — are discussed in greater detail in RMI's reports *Improving Electricity Supply for Large Customers in Nigeria* and *Unlocking Renewable Embedded Generation in Nigeria.*[41]

3.2 Lessons learned from first-wave projects can improve future DER efforts

The successes achieved and challenges encountered in the implementation of the DER projects offer important lessons for future efforts. The first wave of projects offers a set of lessons and best practices for DisCo and developer consideration as they continue to build out DER programs and pipelines. The most important lessons focus on relationship and role clarity, project management, financing, and internal DisCo capacity.

As recommended in RMI's *DER Toolkit*, through a *Project Implementation Plan*, a utility-enabled DER project can be completed within 12 months — from project initiation to project commissioning. Nonetheless, renewable energy projects globally are experiencing delays, with commercial operations being achieved months after the original expected online dates.[42]

In the Roadmap, *project initiation* involves the identification and engagement of potential customers seeking reliable power. *Project preparation* includes technical assessment, DER system design, and developer selection for a DER project. At the *project execution* stage, the developer finalizes and signs all project agreements, including the tripartite agreement, and constructs the DER system along with any distribution network upgrades.

RMI's utility-enabled *DER Project Implementation Plan*, which is part of the *DER Toolkit*, outlines the steps and processes under each phase and details the roles and responsibilities of DisCos and developers.

Collaboration between project developers and DisCos for utility-enabled DERs in Nigeria can be complex as the market is nascent. On average, start-to-finish project execution timelines for four DER projects in Nigeria overran projected completion by over two years (see **Exhibit 6)**.[xix] As illustrated in Exhibit 6, DER projects can be completed within 12 months from initiation to commissioning, albeit most projects are currently facing about 15 months of delay globally. In Nigeria, delay factors include DisCos' internal approval timelines for contract agreement, availability of bridge financing for the construction process, and clarity of roles and responsibilities between stakeholders throughout project implementation. While there is clearly room for improvement, there are also clear examples of how these improvements can be implemented.

[xix] Developer self-reported timelines for interconnected minigrids.

Exhibit 6: Ideal project development timeline and representative case for four projects.

As Exhibit 6 shows, one area for significant improvement is the lead time that past projects have experienced between project initiation and project preparation.

Table 2 outlines lessons learned from RMI and GEAPP's support to DisCos and DER developers and categorizes lessons learned under three main project stages: initiation, preparation, and execution.

Table 2: Lessons learned from first-wave utility-enabled DER projects.

Project Stage	Lessons Learned
Initiation	• DisCos are willing to share data with developers but need to centralize data for ease of project identification and to reduce data collection lead time. • Developers should align project planning and commissioning dates with realistic timelines that account for a broad range of potential delays. • External risk factors such as supply chain delays, political interference, and currency fluctuations should be anticipated and mitigation measures put in place.
Preparation	• Original equipment manufacturers and suppliers must be carefully selected and closely managed to avoid delays. Steps such as pre-ordering equipment can help to reduce supply chain backlogs. • Customers should be regularly updated on project implementation progress to maintain interest and buy-in. • Adequate capital with reasonable allocation for contingencies, at least 15% above initial project budget estimates, should be budgeted to prevent developer cashflow constraints.
Execution	• Dedicated DER teams can help DisCos develop and manage project implementation. DER team members should receive access to professional development on project management, DER models and regulation, and other necessary skills.

- Developers must be competitively procured to achieve technical efficiency and minimum project costs.
- For clarity of roles and expectations, DisCos and developers should align on interconnection roles and responsibilities early in the project implementation phase, ideally outlining their commitments and responsibilities in a tripartite agreement.[xx]
- DisCo-approved developers and suppliers should be engaged for network rehabilitation and upgrades executed by DER developers to ensure compatibility with DisCo systems and criteria from the request for proposal. Capacity building may be required to support an adequate selection of DisCo-approved developers and suppliers.

The first wave of DER projects demonstrated the urgency of obtaining adequate financing before project construction. This financing bridges construction phase costs until long-term financing is obtained to operate the completed project, which customer payments will eventually repay. Financiers can support effective project development by approving construction loan requests at affordable rates that include a buffer to account for contingencies, knowing that these are common in the Nigerian energy sector.

Through a 2022 DER needs assessment, RMI collected perspectives on key requirements for DER adoption. DisCos identified a dedicated DER team as critical. A dedicated DER department can sustain project development momentum amid events that would otherwise threaten project development continuity (such as changes in DisCo executive leadership). In response to a request from DisCos to support the development of DERs, RMI, with funding from GEAPP, supported the creation of DER departments at three DisCos. These departments feature appointed DER team leaders and officers who work closely with DisCo leadership and RMI to drive DERs through measures including a DER strategy, the creation of DER teams, and continuous awareness efforts to demonstrate the benefits of DERs to their colleagues. The lessons from **Table 2** can significantly accelerate DER implementation in the next wave of projects by avoiding unnecessary delays and roadblocks.

[xx] Tripartite agreements are a mechanism introduced through NERC's original *Mini Grid Regulations* and explored in RMI's *Electrifying the Underserved* report.

Case Study: AEDC's Path to Utility-Enabled DERs

Abuja Electricity Distribution Company (AEDC) sought to reduce financial and ATC&C losses, and at the same time noticed the emergence of utility-enabled DER models. Supported by funding from the US Trade and Development Agency (USTDA), AEDC began a partnership with RMI in 2019 to assess the viability of DER models to bolster the DisCo's service offerings and profitability, and to identify, pilot, and test new business models.

Key actions taken by AEDC to advance DER deployment:

- ☑ Dedicate a full-time DER team lead.[xxi]
- ☑ Define AEDC DER strategy and processes.
- ☑ List high-potential DER opportunities across three business models.
- ☑ Form an internal DER team with additional staff.
- ☑ Engage with project developer and potential host communities.
- ☑ Publish request for proposal to competitively procure project developer.
- ☑ Codify monitoring and evaluation framework for DER projects.

While AEDC has undergone major changes in the past several years, including two significant changes in ownership and management, DERs have remained a priority for the company thanks to these actions along with consistent leadership by the DER Team Lead. **Table 3** shows the projects being developed at the company.

Table 3: AEDC's operational and under-development DER projects to date.

Project stage	Interconnected Minigrids	REG	C&I customers
Operational	Toto – 0.35 MW Wuse – 1 MW (commissioning stages)	NA	NA
Under Development	Obi Cluster – 0.25 MW Lambata – 1 MW Maraba Udege – 0.65 MW Gwagwalada – 0.6 MW	Bwari – 2.2 MW	The Wood factory[43] – 0.6 MW
Capacity Subtotal	3.85 MW	2.2 MW	0.6 MW
Total Capacity	~7 MW		

Six months after the completion of the Toto project, Omosede Imohe, AEDC's DER team lead, acknowledged that, "*Communities like Toto are typically loss making for DisCos in Nigeria. However, PowerGen has been able to obtain revenues in the Toto community that are 30 to 40 times larger than similar communities along that feeder, and demonstrate a path to profitability for the Disco.*"

[xxi] The AEDC DER Team Lead was funded by GEAPP.

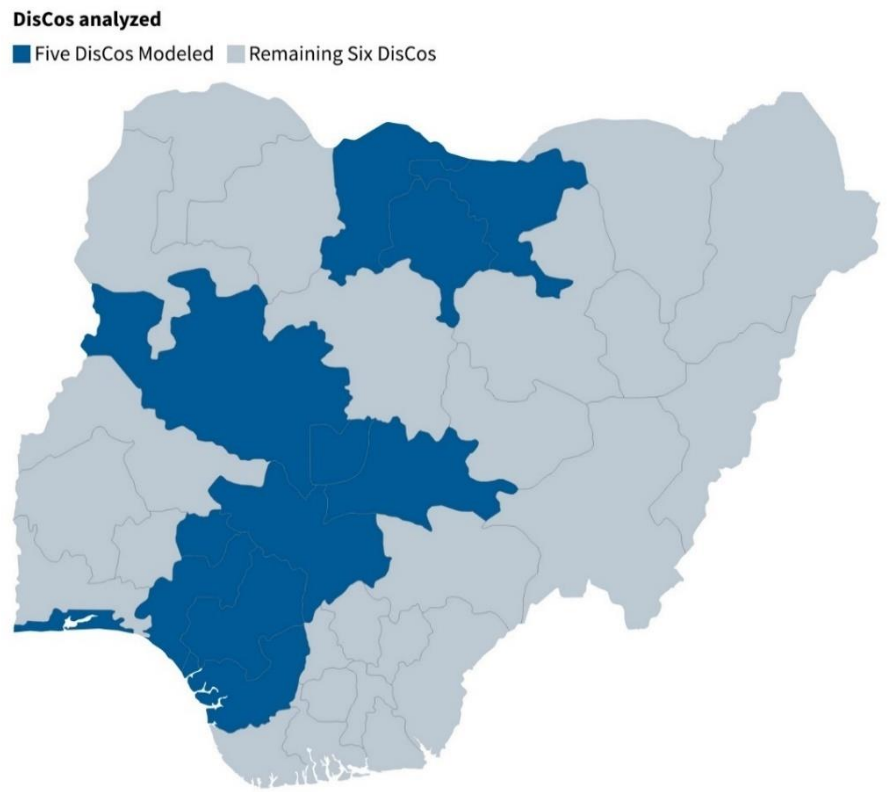
4. DER MARKET POTENTIAL

The large DER market potential in Nigeria is clear. The Energy Transition Plan, for instance, estimates that 10 GW of decentralized generation systems, of which 6.3 GW are renewable, are needed by 2030 to achieve universal electrification.[44]

Building on these studies, this section assesses the DER opportunity through a least-cost analysis of the capacity requirements for five Nigerian DisCos (AEDC, BEDC, EKEDC, IE, and KEDCO) over the next decade (2024–2033) at the distribution network level. The five DisCos were engaged due to existing working relationships with RMI, which tended to correlate with greater interest in DER implementation. The DER market potential for the five DisCos modeled was then scaled up to estimate the potential for the remaining six DisCos (EEDC, IBEDC, JED, KE, PHEDC, and YEDC).[xxii] **Appendix E** provides the methodology used for this analysis.

Between January 2019 and September 2022, the five DisCos received 55% of the total supply from TCN. At this time, they served 45% of the registered customers in Nigeria.[45] Given the geographic spread of these DisCos, variations in electricity distribution coverage, TCN supply offtake, and differences in customer types, they are reasonably representative of the electricity distribution market in Nigeria.[xxiii] **Exhibit 7** visualizes the geographic coverage of the five DisCos analyzed. A map of all DisCos in Nigeria is shown in **Appendix F.**

Exhibit 7: Geographic coverage of the five electricity distribution companies analyzed.



[xxii] The six remaining DisCos are Enugu Electricity Distribution Company (EEDC), Ibadan Electricity Distribution Company (IBEDC), Jos Electricity Distribution Company (JED), Kaduna Electric (KE), Port Harcourt Electricity Distribution Company (PHED), and Yola Electricity Distribution Company (YED).

[xxiii] The coverage areas of these five DisCos are indicated in **Appendix F**

4.1 Using a least-cost methodology to estimate the DER market

RMI's analysis sought to estimate the energy need across Nigeria over the next decade and the appropriate DER resources to meet that need at the lowest possible cost.

First, RMI estimated the supply gap using DisCos' hourly feeder data for recent years. This data was cleaned and edited to estimate full customer demand including during periods of DisCo shut-offs. TCN allocations come from the National Control Centre's Daily Demand Allocation Table. RMI assumed 8% annual growth in TCN supply, which is expected to come from improvements in existing generation and capacity expansion based on DisCo forecasts. The *Base Case* scenario assumes that demand for current customers grows at 9% annually, consistent with DisCo estimates which outpace an 8% annual increase in TCN supply.[xxiv]

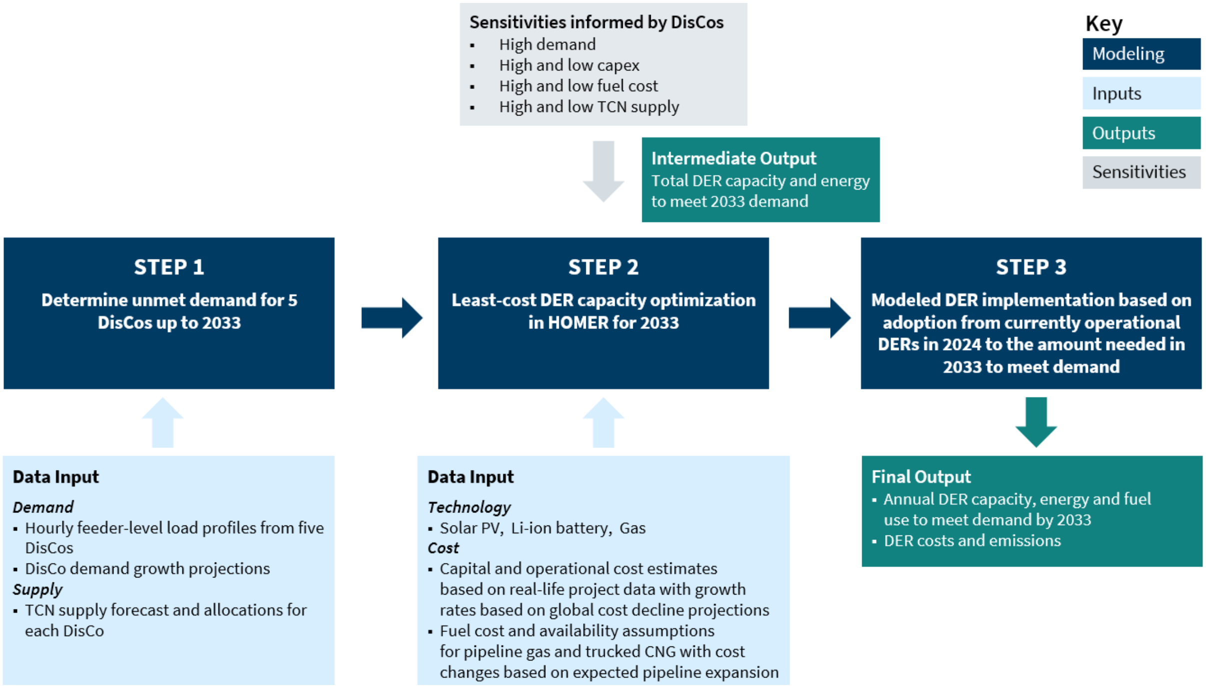
Distributed solar PV, battery, and gas capacity were optimized using HOMER software to meet the total projected demand with the lowest possible cost. The *Base Case* scenario assumes average project costs by adjusting data from pilot interconnected minigrids smaller than 1 MW (which includes C&I projects) to account for a mix that also includes renewable embedded generation projects larger than 1 MW.[xxv]

Finally, the *Base Case* analysis assumes gas pipeline expansion in Nigeria, consistent with the country's plans.[46] This scenario assumes that domestic sources can supply 80% of all DER gas projects in the South and 70% in central and North Nigeria by 2033, projecting that the new Ajaokuta-Kaduna-Kano pipeline will supply the majority of DER gas projects since piped gas is cheaper than compressed natural gas (CNG). **Exhibit 8** provides a schematic of the modeling methodology, and **Appendix G** provides additional details about fuel cost and other modeling assumptions.

[xxiv] The 9% annual demand growth rate was derived from the average growth rate AEDC, BEDC, IE, and EKEDC used in forecasting their energy demand.

[xxv] Project costs assume 60% new capacity from interconnected minigrids and 40% from renewable embedded generation. This mix is assumed based on the pace of development and expected new project numbers. **Appendix E** provides details on the modeled capex cost.

Exhibit 8: DER roadmap modeling methodology.



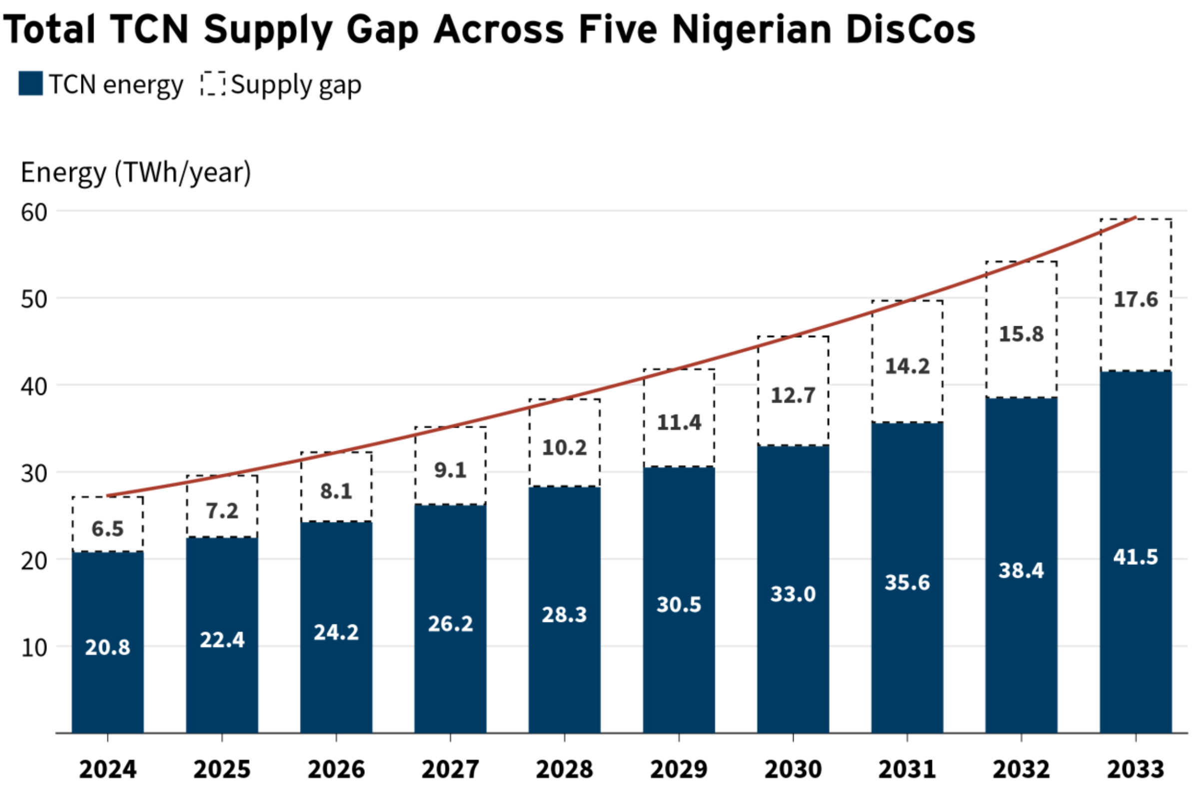
As discussed in Section 4.4 and detailed in Appendix G, RMI conducted sensitivity analyses to assess DER outcomes under different scenarios. Sensitivity analyses were conducted in the same way as the *Base Case* depicted in Exhibit 8, but the input values were varied based on the scenario definition. These analyses were conducted for each DisCo analyzed and used to highlight a representative or archetypical outcome for two regions of Nigeria: DisCos in Lagos, and DisCos outside of Lagos. More than any other factor, this differentiation had the most impact on sensitivity outputs.

4.2 As the DisCo supply gap grows, DERs become increasingly important

With DisCos forecasting electricity demand to grow at 9% per year on average and TCN supply forecasted to grow at 8% annually, the five DisCos analyzed will experience an electricity supply gap ranging from 12% to 38% of demand over the next decade.[47, xxvi] Within this timeframe, RMI analysis suggests that TCN can meet only 70%–80% of forecasted DisCo electricity demand (see TCN supply gap illustrated in **Exhibit 9**).[xxvii] In addition to opportunities for energy efficiency or demand response, DER resources can provide generation capacity to bridge this gap.[xxviii]

[xxvi] An average demand growth forecast from the cited resources aligns with interviews with AEDC and IE staff.
[xxvii] The TCN supply gap of all 11 DisCos in 2024 was estimated by RMI to be approximately 30%, with more details on calculations in Appendix E. RMI estimates show the remaining six DisCos have a slightly larger supply gap which could be due to their higher billing losses, which means TCN allocation meets less of the actual customer demand.
[xxviii] While demand response and energy efficiency provide important mechanisms for addressing consumer demand growth, these are beyond the scope of this roadmap. Individual developers and DisCos may wish to pursue these mechanisms within their DER project's customer base.

Exhibit 9: The total TCN supply gap for the five DisCos combined demonstrates the need for new energy sources to meet growing demand.



Today, supply from embedded generation is insignificant relative to the scale of the TCN supply gap. Other mechanisms, like planned utility-scale projects, theoretically offer a larger impact per project but are frequently constrained today by transmission network capacity. For instance, the Presidential Power Initiative plans to build 2 GW of capacity by 2025 and up to 18 GW of capacity by 2030 (of which some portion will be embedded generation).[48] Similarly, new utility-scale capacity is planned to augment supply to Lagos and Abuja, specifically.[xxix] However, these projects cannot materially improve customer experience until transmission constraints are addressed.

Because of transmission constraints related to the development of larger utility-scale generation, DERs are especially important to improve service levels. Utility-enabled DERs can provide local capacity without significant transmission upgrades, allowing DisCos to begin closing the supply gap before transmission projects come online. **Section 4.4** describes sensitivity analyses that include the interaction between utility-scale and DER supply.

4.3 Across Nigeria, the DER market opportunity exceeds 20 GW over 10 years

RMI analysis of five DisCos indicates a DER opportunity of 10 GW over 10 years

Due to the DisCo supply gap explored in **Section 2**, there exists a huge potential for utility-enabled DERs across DisCos in Nigeria. RMI analysis suggests a DER market opportunity of 1 GW annually for the five DisCos, or about 2 GW per year across the country. This analysis included an estimation

[xxix] These new projects include Kainji hydro expansion, Zungeru hydro, and Egbin Phase II thermal. Exact dates for project commissioning and supply allocation among DisCos have not been announced.

of the DisCo supply gap, least-cost analysis to determine the optimal portfolio of DER resources to meet that gap, and sensitivity analysis.

This analysis assumes a gradual increase in the rate of new DER construction, recognizing that the DER sector is not yet delivering projects at gigawatt scale. The analysis assumes new DER capacity starting with 300 MW in 2024 and increasing to a cumulative total of 11 GW to meet demand in 2033, as indicated in **Exhibits 10 and 11**, which show new DER capacity and total grid capacity through 2033. The proportion of DER capacity by solar, gas, and battery storage varies by DisCo, mainly driven by land constraints in Lagos making solar more expensive, as well as geographic variation in gas prices and solar resource.

Exhibit 10: The base case DER market opportunity for the five DisCos analyzed indicates the cumulative opportunity of over 10 GW over 10 years.

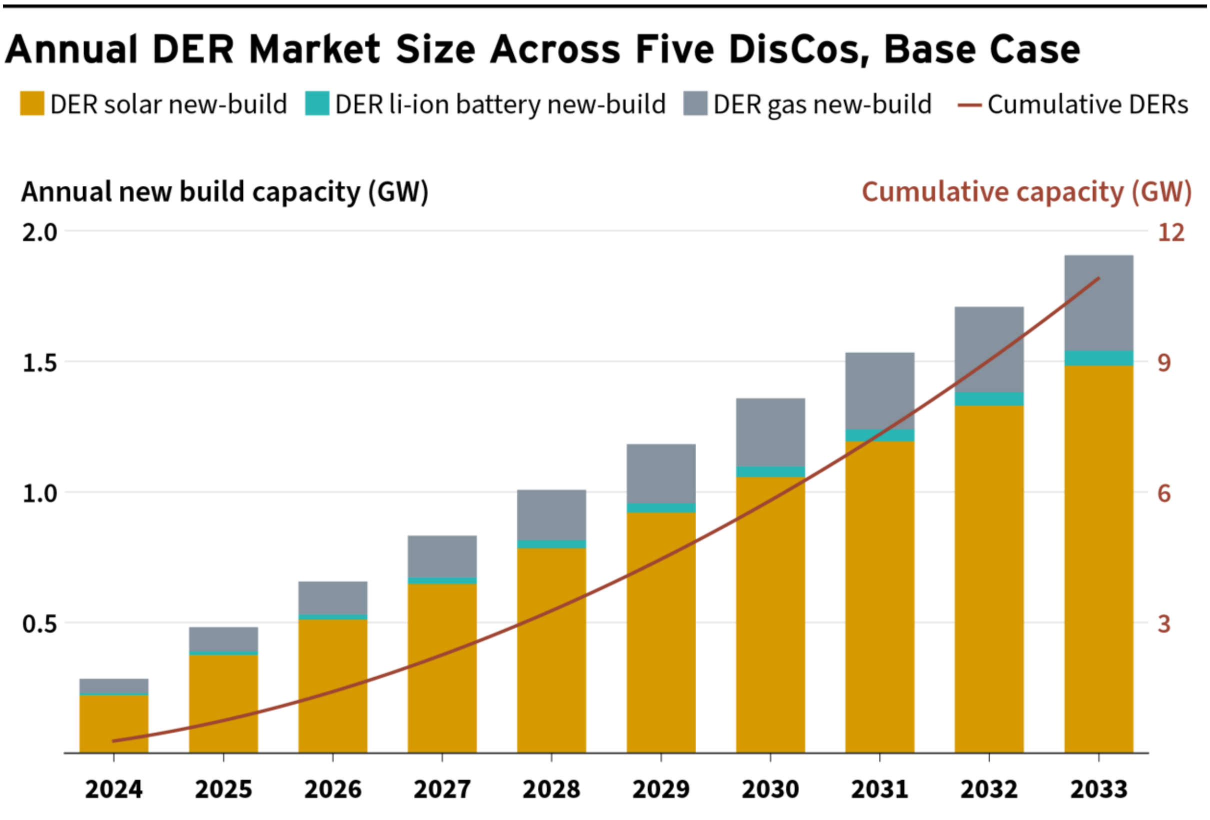
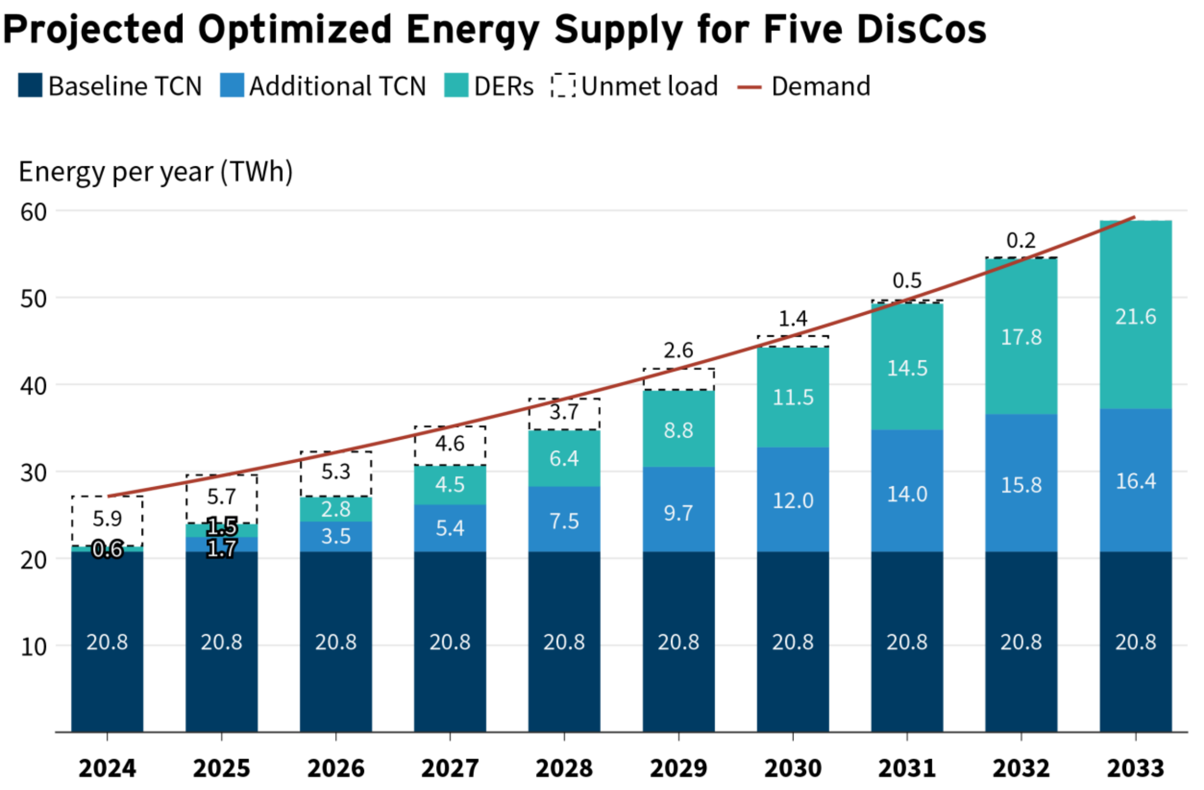


Exhibit 11 indicates that DisCos do not fully meet demand in the early years of the roadmap; this would require over 4 GW of new DER capacity, 15 times more than what is forecasted for 2024. This is not considered achievable given recent observed construction rates and pace of implementation in Nigeria. A more realistic pathway reflects DisCos ramping up DER deployment gradually over time to fully meet demand by 2033. **Appendix H** includes analysis results without constraining growth.

Exhibit 11: Projection of cumulative optimized energy supply for the five DisCos indicates significant growth in both TCN and DER capacity to meet customer demand.



The analysis indicates that growing contribution of newly installed solar PV — from 8% of total supply capacity (including TCN and DER generation sources) projected in 2024 to over 50% in 2033 — is the least-cost option to meet growing energy demand, with additional lithium-ion batteries and gas needed to ensure supply at night, during peak periods, and periods of low solar generation. Although solar constitutes the majority of new capacity, its capacity factor of 15%–20% (depending on the region) means it contributes a lower proportion of the total energy supply. **Exhibit 10** shows the total power capacity necessary to meet growing demand while **Exhibit 11** shows the energy contribution of those resources. The least cost analysis estimates the contribution to energy supply from solar will grow from 2% in 2024 to 22% in 2033. To meet the supply gap under current regulations and in the most logistically and cost-effective manner, it is recommended that DisCos explore innovative power procurement alternatives in addition to utility-enabled DERs, including direct power purchase agreements from unbuilt utility-scale DER renewable projects to stimulate new supply.

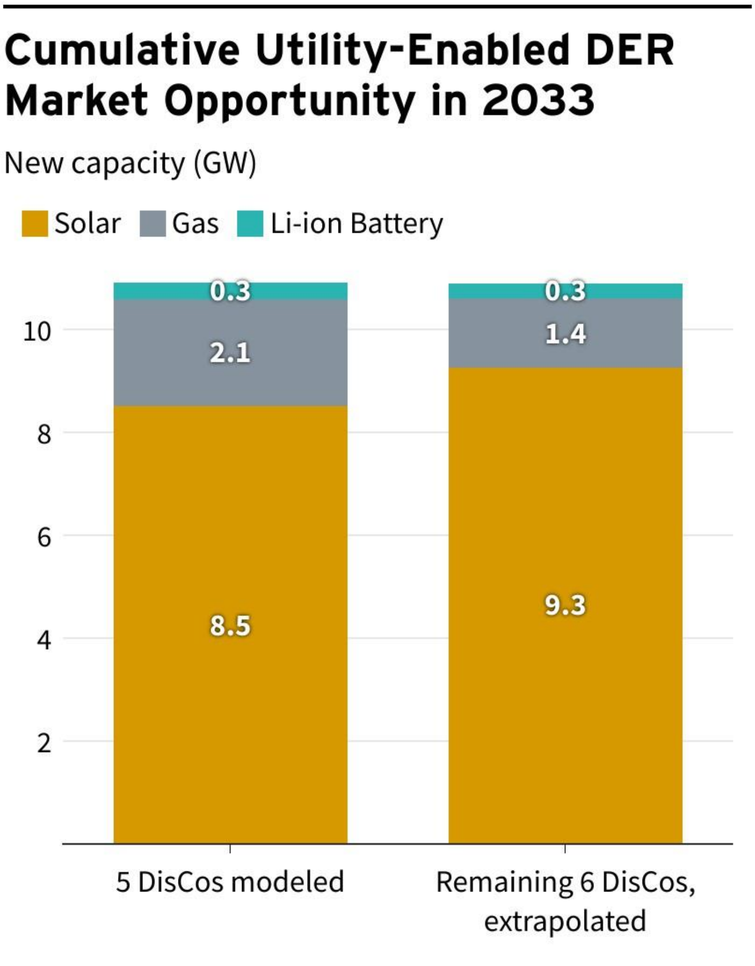
National extrapolation indicates a 22 GW DER opportunity within 10 years

DER market potential for the 5 DisCos modeled in detail by RMI was extrapolated to estimate the potential for the remaining 6 DisCos. Collectively, the 11 DisCos provide a market opportunity of 22 GW, based on customer demand estimated from 2022 feeder data.[xxx] The 5 DisCos accounted for 56% of total 33 kV electricity demand in Nigeria in 2022 and 59% of TCN allocation in 2024.

[xxx] This methodology is detailed in **Appendix E**.

Accordingly, the energy required from DERs for the remaining six DisCos is slightly lower than that from the five DisCos modeled. However, the capacity of DERs is roughly equivalent between the two groups of DisCos. Because the remaining six DisCos are all outside Lagos and do not suffer extreme land constraints like the Eko and Ikeja DisCos, a higher proportion of solar is optimal (see **Exhibit 12**). These 22 GW of DERs would result in an annual reduction of 33 million metric tons CO_2e due to diesel generation being replaced by solar, gas, and battery DERs.

Exhibit 12: Extrapolation of cumulative results for five modeled DisCos (AEDC, BEDC, EKEDC, IE, and KEDCO) to remaining six DisCos (EEDC, IBEDC, JED, KE, PHEDC, and YEDC).



Optimized capacity and energy mix from utility-enabled DERs varies by DisCo

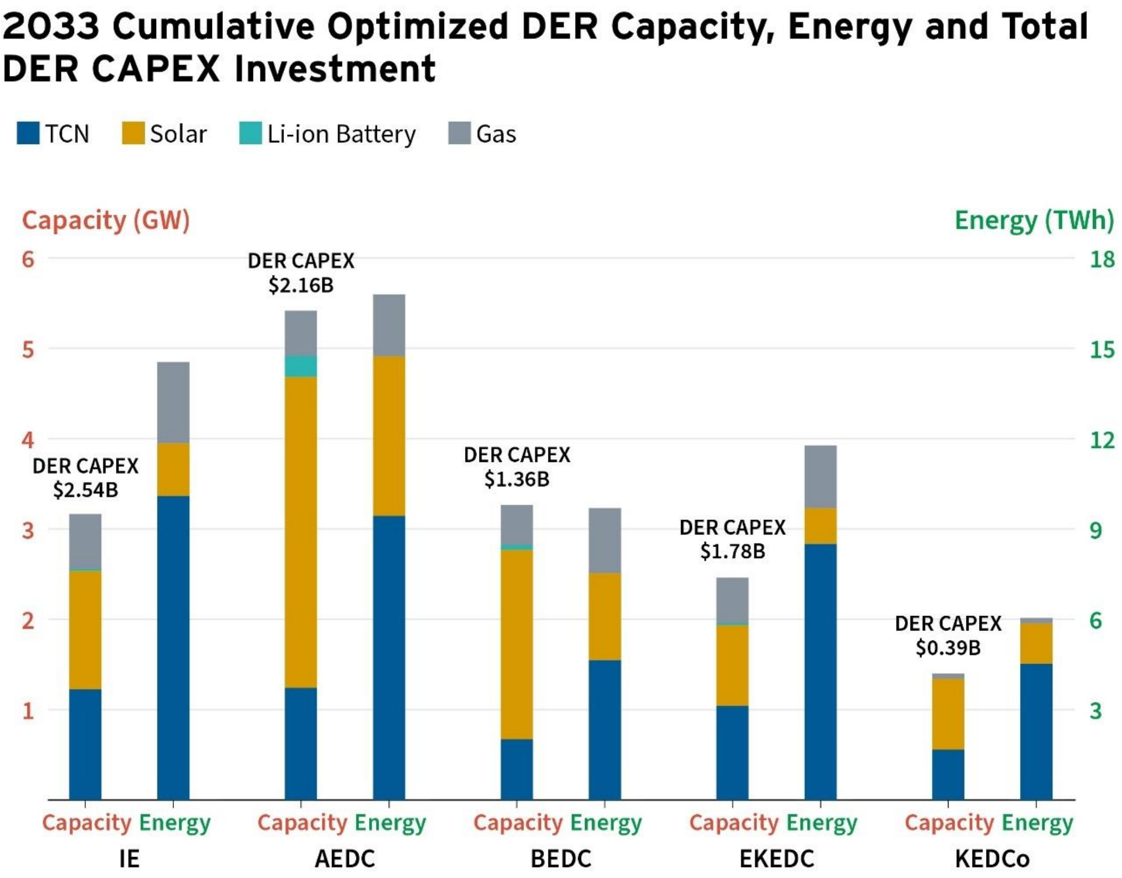
A mix of DERs is needed to provide reliable supply at all hours. Solar provides energy during the day, and gas or battery storage provides dispatchable supply during evening or peak hours. The breakdown of optimized capacities and energy from each resource varies by DisCo, mainly due to differences in land availability for solar and gas costs. RMI's analysis results in solar constituting over 80% of new DER capacity builds by 2033 across all five DisCos. However, the capacity factor of solar means it contributes a lower proportion of DER energy supply. In Lagos-based DisCos, the fraction of solar capacity is lower due to land constraints, so less solar energy is deployed than energy from gas.[xxxi] Outside of Lagos, more solar than gas energy is provided, but the proportion of solar is slightly impacted by the resource potential — for instance, KEDCO features a 3%–4% higher capacity factor for solar than in BEDC territory.

Since Lagos-based DisCos have a lower proportion of solar capacity, they have more energy dispatched from the gas capacity. The variation in gas fuel cost throughout the country impacts the optimal energy from gas.[xxxii] AEDC and KEDCO feature lower proportions of energy from gas than BEDC because gas is more expensive in the North. Battery storage can provide similar dispatchable supply and is more competitive in the North than in the South. Batteries will also become more competitive as battery prices decrease over time. The TCN supply gap is different for each DisCo based on historic service rates, and this also impacts the DER resource mix — lower TCN supply leads to a greater need for dispatchable supply.

Backed by existing government policies, the market for utility-enabled DERs in Nigeria presents significant investment potential for the private sector. Deploying the DER capacity to close the five modeled DisCos' energy supply gap (20%–50% in 2024) could enable capital investment of over $8 billion for generation assets and almost $4.5 billion for distribution assets over 10 years.[xxxiii] The breakdown for the generation investment opportunity in each DisCo is shown in **Exhibit 13**. The generation asset capital investment opportunity for the remaining six DisCos, at $5.5 billion, appears less than the five modeled DisCos due to the lower cost of solar outside Lagos.

[xxxi] See capital expenditure costs in **Appendix G.**
[xxxii] See gas fuel costs in **Appendix G**.
[xxxiii] The cost for distribution assets was estimated to be 35% of the cost of total capital expenditure based on an average of previous utility-enabled DER projects.

Exhibit 13: Cumulative utility-enabled DER capacity, energy, and capex investment opportunity for five DisCos.[xxxiv]



While solar PV presents the least-cost path to meeting most demand, significant penetration of grid-connected solar could cause instability on the aging distribution networks of Nigerian DisCos. Without adapting system operations, the variable nature of solar can result in voltage fluctuations and frequency deviations. Over the medium term, DisCos must ensure that interconnecting large shares of solar power does not jeopardize their purpose.

To support higher penetrations of utility-enabled DERs, DisCos should increase the flexibility of their grid operations. Grid planners can consider innovative technologies like battery energy storage systems and smart digital technologies to enable DisCos and developers to monitor and manage DERs in real time. Digital technologies, such as transformer monitors, can help to closely monitor power flows. Additionally, leveraging advanced inverter functionality when included in a utility-enabled DER system can help prevent voltage fluctuations on the distribution grid.

Utility-enabled DER projects drive revenue up and customer costs down

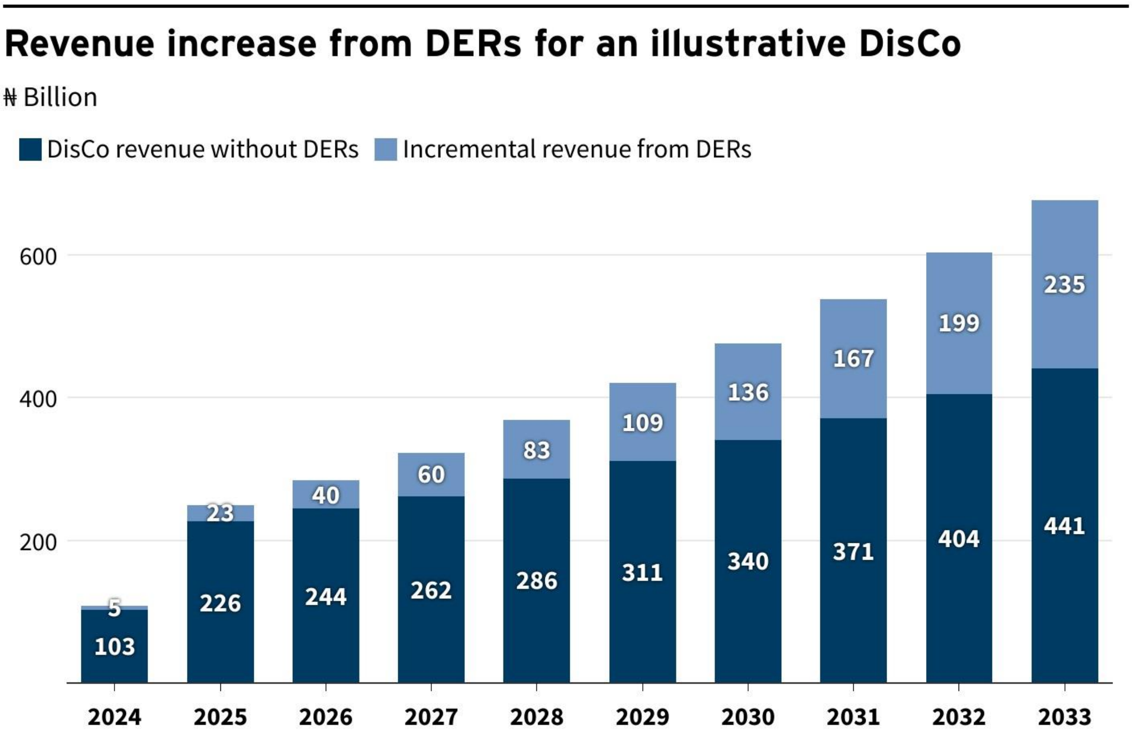
In addition to increasing energy supply, upgrading distribution network infrastructure, and improving customer metering, DERs have the potential to increase annual DisCo revenue by tens of billions of naira in the short term. Improvements to distribution networks and increased metering

[xxxiv] The DER opportunity for KEDCO appears smaller than other DisCos, but is proportional to its current and estimated future demand.

reduce ATC&C losses and increase profitability for DisCos while reducing energy costs for customers. As demonstrated in **Table 4**, utility-enabled DERs can help DisCos reduce ATC&C losses by over 20 percentage points. The achievable level of ATC&C loss reduction depends on a DisCo's current ATC&C loss rate — the higher current ATC&C losses are, the higher the potential for significant reductions through upgrades to distribution infrastructure financed as part of the DER project.

RMI's analysis finds that, on average, DisCos can increase their revenue by over ₦70 billion (~US$50 million) every year over the next decade through strategic use of utility-enabled DERs. In addition to increasing revenue by reducing ATC&C losses, DisCos can collect DUOS charges from certain DER projects which further boosts both revenue and profitability. For an illustrative DisCo shown in **Exhibit 14**, total revenue increases range from ₦5 billion in 2024 to ₦235 billion in 2033. The spike in revenue from 2024 to 2025 results from an increase in the DisCo's current allowable tariff, which is 54% below its cost-reflective tariff, to a cost-reflective tariff in 2025 based on NERC's 2024 MYTO.

Exhibit 14: By scaling DERs over the next 10 years, DisCos can substantially increase revenue flows.



With increased reliability of supply enabled by the addition of DERs, customers will need to self-generate significantly less electricity from fossil fuel sources. As a result, aggregate customer energy costs can drop by 20%–30% alongside avoided generator fuel costs of about ₦2 trillion annually across the country. Replacing existing fossil-fueled self-generation with DERs will reduce climate pollution from DisCo customers by about 33 million metric tons of CO_2e per year across all DisCos. **Table 4** presents a summary of estimated ATC&C loss reduction and revenue increase by 2033. **Appendix K** provides details about the methodology used to quantify these benefits.

Table 4: DER implementation enables significant benefits for DisCos through loss reduction and revenue increase.

DER Base Case Scenario (by 2033)	Unit	AEDC	BEDC	EKEDC	IE	KEDCO
Demand covered by DERs	%	48%	53%	27%	30%	27%
Current ATC&C losses	%	40%	42%	26%	15%	52%
ATC&C Loss Reduction	% points	18	22	6	2	15
Total increase in DisCo revenue by 2033	%	40%	55%	10%	5%	40%
Total annual increase in DisCo revenue	Billion ₦	313	235	88	50	116
Increase in DisCo revenue due to ATC&C loss reduction	Billion ₦	251	170	72	29	98
Increase in DisCo revenue due to DUOS[xxxv]	Billion ₦	62	65	16	21	18

4.4 Sensitivity analysis demonstrates DER flexibility to meet system needs

To understand whether the findings of this analysis would shift significantly under different economic and system conditions, RMI conducted sensitivity analysis across a variety of key parameters and assumptions. This analysis shows that while the mix of DER resources shifts depending on geography and conditions, in all cases a significant buildout of utility-enabled DERs is a least-cost solution for DisCos to meet the supply gap.

RMI engaged the five modeled DisCos to define parameters for the sensitivity analysis. Sensitivity analyses assessed the range of capacity requirements for DERs over the next 10 years. The scenarios are defined below, with additional detail available in **Appendices G and I**.

- *Base Case*: The base case scenario, already referenced throughout this roadmap, builds on hourly DisCo demand data. It assumes an average of 9% annual energy demand growth and 8% annual growth in TCN supply. The *Base Case* estimates a DER need of 11 GW across the five DisCos by 2033 and 22 GW when extrapolated across Nigeria where solar PV represents more than 80% of the total new DER installed capacity.
- *High Demand*: The scenario begins with the *Base Case* hourly demand profile but increases the annual growth rate to 15% — demand growth compounds to a 70% increase between 2024 and 2033. Increased growth reflects unmet or suppressed current demand. The *High Demand* scenario has a larger supply gap than the *Base Case*, resulting in a higher proportion of dispatchable supply from gas or Li-ion batteries than from solar.
- *High Capital Expenditure*: Higher capital expenditure (capex) values are estimated from historic project development costs for smaller interconnected minigrids, which lack economies of scale. Under this scenario, solar penetration is reduced for most DisCos compared to the *Base Case*; however, solar capacity needs remain largely stable for Lagos DisCos since it is already being limited by land constraints.
- *Low Capital Expenditure*: Lower capital expenditure values are estimated from historic project development costs for larger embedded generation projects, which are lower due

[xxxv] DUOS are not a mandatory component of a utility-enabled DER project, but rather depend on the business model selection and the project location details including the distribution network infrastructure status that the DER developer utilizes.

to economies of scale. Reduced capex costs increase solar and Li-ion battery penetration across all DisCos — doubling solar capacity needs for DisCos outside of Lagos.

- *High Fuel Cost*: The *High Fuel Cost* scenario assumes that natural gas is available and cost-effective to fill 50% of DER needs across the country by 2033. Like the scenarios with varied capital expenditure assumptions, increasing the fuel cost significantly impacts the technology mix for non-Lagos DisCos, decreasing the use of gas. At higher fuel costs, Li-ion batteries are more competitive with gas for dispatchable supply and more solar is needed to charge the batteries. However, higher fuel costs do not significantly change the ratios of gas, solar, and Li-ion battery technology in Lagos DisCos since space constraints limit the capacity of more solar.
- *Low Fuel Cost*: This scenario assumes greater quantities of low-cost natural gas fill more than 90% of DER needs across the country by 2033. AEDC and more-so KEDCO see a larger increase in natural gas capacity and consumption compared to the Base Case when the fuel costs are significantly reduced from *Base Case*, while the gas-to-solar ratio stays constant in Lagos DisCos due to a relatively smaller change from the *Base Case* gas price, since *Base Case* gas prices are lower in the South.
- *Low TCN*: The *Low TCN* scenario assumes TCN meets 70% of supply allocated to DisCos. The mix of resources to fill the larger supply gap varies, with DisCos in the South using more gas and solar, and AEDC and KEDCO using more solar and Li-ion batteries since gas is more expensive in the middle and North of the country.
- *High TCN*: TCN Supply is modeled to provide 30% greater supply than *Base Case*, based on the assumption that all planned utility-scale generation projects move forward and transmission constraints to utilize them are addressed. This is the only scenario that projects more energy provided by solar than by natural gas for Lagos-based DisCos.

Across all seven sensitivities, DERs are a cost-effective way to increase capacity to meet customer demand. Solar provides a majority of energy to non-Lagos DisCos, while gas appears more cost-effective for DisCos working within Lagos. Significant solar PV and gas capacity buildout is required across all sensitivities and all DisCos; however, Li-ion battery capacity is more competitive in locations with more expensive gas, and more capacity is added to provide dispatchable power in sensitivities with a larger supply gap.

4.5 Additional context reinforces initial modeling results

NERC action supports DER market growth

Within the total DER opportunity, RMI's *Base Case* analysis suggests an annual market opportunity of 1 GW of distributed solar PV for the five DisCos over the next decade. Of course, this average does not fully represent all DisCos, some of whom express that constraints on land availability and the current pace of project development make it challenging to achieve capacity at this scale. Additionally, the current NERC *Regulation on Embedded Generation* limits embedded generation units to 20 MW, above which the generation project must be connected to the TCN network.[49] Many smaller 20 MW installations would access fewer economies of scale than fewer larger projects, although existing and future aggregated procurement efforts could significantly help in mitigating that.

In March 2024, as part of the 2024 Supplementary Order to MYTO, NERC instructed DisCos to target 10% of demand allocation through embedded generation by April 2025 — with half of this to come from renewable sources.[50] RMI's analysis is more conservative, showing an average DER potential of 7% of demand allocation in 2025.[xxxvi] Each DisCo features DER potential between 4% and 11% of 2025 demand allocation, and a renewable proportion of 35%–90% within DERs by 2033.

DER market potential is comparable to other studies

RMI's analysis can be compared to Nigeria's Energy Transition Plan (ETP), which covers the whole country including off-grid demand and vehicle electrification,[51] and the 2022 *Lagos State Integrated Resource Plan* (IRP) created by Power Africa.[52] These studies include both centralized or utility-scale supply and decentralized supply, while this Roadmap focuses only on decentralized energy market potential for five DisCos.

RMI's demand estimates are compatible with those in both studies, after accounting for the difference in scope. Because the ETP assumes that centralized supply meets a majority of the country's demand, RMI's results predict more DERs and a higher ratio of solar to gas. The Lagos IRP recommends more installed capacity and more gas than RMI's analysis. This is because the IRP recommends all generation plants in Lagos except Egbin retire in 2026 and the same generation capacity be rebuilt. Due to the high solar potential, DisCos with land constraints (such as IE and EKEDC) may need to explore more innovative DER solutions such as rooftop solar, floating solar, and wheeling from locations with cheaper land.

Details on the comparison between these studies are shown in **Appendix J.**


Zawaciki interconnected minigrid, aerial view © RMI

[xxxvi] For the five DisCos assessed.

5. ACCELERATING UTILITY-ENABLED DERS TO MEET DISCOS' STRATEGIC GOALS

Rapid utility-enabled DER project implementation at cost-competitive rates is critical to meet DisCos' supply needs and improve supply reliability. DisCos in Nigeria have a unique opportunity to leverage the momentum gained in the development of utility-enabled DERs. Doing so will not only improve DisCo finances and customer supply but will also unlock Nigeria's renewable energy market and support the country's transition to cleaner energy.

At RMI's convenings in 2024, all DisCo leaders expressed enthusiasm for a DER rollout but desired greater clarity on how to achieve the DER vision. This section highlights key priority areas that DisCos and developers need to focus on to fulfill the Roadmap (**Section 5.1**). It provides a set of action-oriented recommendations for each priority area over a five-year period (short and medium term) and identifies a stakeholder responsible for implementing each recommendation (**Section 5.2**).

5.1 To accelerate deployment, DisCos need planning, development, a DER team, and engaged leadership

Four priority areas — effective planning, efficient and timely project development and implementation, a dedicated DisCo DER team, and engaged DisCo leadership — are the primary drivers at the DisCo level to immediately influence the pace and scale of utility-enabled DER project implementation (see **Exhibit 15**). DisCos and developers must focus on these priority areas to accelerate project deployment.

Exhibit 15: Priority areas to accelerate utility-enabled DER deployment.

Priority Area 1: Data-driven project identification and planning

Both DisCos and developers must ensure effective planning of utility-enabled DERs across their three main phases — initiation, preparation, and execution — to establish timely, least-cost implementation of utility-enabled DER projects. An effective planning process requires DisCos to proactively develop a centralized database of potential projects for an assessment of their technical and economic feasibility. While most DisCos engaged already have a list of potential sites and customers for utility-enabled DER projects, they need to centralize and automate the collection, storage, and retrieval of such data, and update the list periodically (including with site recommendations from developers and communities). Additionally, this project pipeline should be expanded and enhanced to capture sufficient details. Access to centralized, adequate data will help improve the assessment of projects by developers for financing and reduce project development lead times. For a complete understanding of DER potential at DisCos, a detailed feeder-level hosting capacity and grid stability analysis is needed. Such detailed analysis can also guide DisCos' DER procurement workplan for specific feeders.

Before beginning project implementation, the DisCo should appoint a set of internal project leads (the project team). If the project team decides that the developer is better suited to lead a particular phase, it can delegate that phase to the developer; but ultimately, the DisCo should be responsible for overseeing the entire process and should endeavor to lead these phases as these projects occur within their service territories.

Before finalizing a project agreement, developers should anticipate and mitigate potential risks that threaten timely execution. These include assessing financial risk, supply chain and broader economic impacts, social and community risk, and coordinating with the DisCo to ensure a dedicated project team is available for support.

Priority Area 2: Efficient and timely project development and implementation

Timely implementation of projects can be constrained by factors including the limited capacity of developers in the nascent utility-enabled DERs industry, logistics issues with supply chains, coordination between DisCos and developers on infrastructure upgrades, and inconsistent construction standards. Competitively procuring projects through a bidding process can help DisCos reduce lead times and achieve significant cost savings and value for money. This approach can also help DisCos attract and select developers with the financial capacity and technical ability to execute projects within reasonable timelines. By creating a competitive environment among DER developers with a clear and consistent set of procurement rules and criteria, DisCos can ensure that DER developers have an equal opportunity to participate, win the project contract, and benefit from better contract terms.[xxxvii]

DisCos need stakeholder engagement plans to align on different stakeholder objectives. While each stakeholder has a role to play in accelerating DER project deployment, DisCos should pursue strong stakeholder engagement and communication from the project initiation phase to build trust among stakeholders including community representatives and the developer. Resources like

[xxxvii] See the 2021 RMI and Regulatory Assistance Project report, *How to Build Clean Energy Portfolios: A Practical Guide to Next-Generation Procurement Practices* for more details on procurement practices, https://rmi.org/how-to-build-ceps, and *Building a Next-Generation Mix of Energy Resources: Practical Perspectives,* https://www.raponline.org/knowledge-center/building-a-next-generation-mix-of-energy-resources-practical-perspectives/.

the Regulatory Assistance Project's *Public Access and Participation Plans* can provide instruction on the most effective engagement mechanisms.[53]

Project developers should also build and maintain strategic relationships with technical partners, equipment suppliers, sponsors, and funders to increase market traction and accelerate deployment. Partnerships between developers, the private sector, and DisCos occur throughout the process, from project initiation through execution. Partnerships with key local government agencies such as the Rural Electrification Agency (REA) and regional state authorities also create an opportunity to unlock investment opportunities as well as to support permitting and regulatory process needs.

The recently commissioned 352 kWp Toto interconnected minigrid, for instance, was made possible through a robust collaboration between the DisCo (AEDC), the developer (PowerGen), and REA. Through this collaboration, the project benefited from REA's Nigeria Electrification Project Performance-Based Grant program funded by the World Bank.

Priority Area 3: Dedicated DisCo DER team

As discussed in **Section 3**, some DisCos already have staff who support the development of utility-enabled DER projects. However, the majority of these staff cannot commit the amount of time needed to facilitate effective project development and execution. An accelerated deployment will require more focused attention from staff dedicated to DER development.

Dedicating specific staff from across the DisCo (forming a "DER Team") will increase ownership and ensure that the team works effectively. It will streamline stakeholder engagement with DisCos, increasing implementation efficiency and building partner confidence in the DisCo relationship. The DER team can also facilitate workshops to educate other DisCo staff and senior leadership on the role of DERs. **Exhibit 16** shows DER team roles and outcomes.

Exhibit 16: DER teams will ideally play five key roles leading to critical outcomes for DER program success.

Role of DER Team	Potential outcome
Drive DER conversation with DisCo leadership and create awareness of DERs among DisCo staff	Knowledge of DERs improved among DisCo leadership, and capacity of staff built on the role of DERs in meeting DisCo strategic goals
Develop DER strategy to streamline DER project development and implementation processes	DER strategy developed and incorporated into DisCos overall strategy of meeting performance targets and increasing supply
Identify potential sites for project preparation and development, and accelerate the completion of utility-enabled DER projects	Pipeline of bankable DER projects developed and delays in project implementation mitigated
Sustain project development momentum amid events that threaten continuity of project implementation	DER solutions prioritized in DisCo's strategy across DisCo management and ongoing DER initiatives sustained
Create a path to institutionalize DER units at the DisCo and build staff capacity in DERs	Cross-functional team with DisCo leadership buy-in formed and funded to facilitate DER project development

DisCo DER staff capacity should be built to improve technical knowledge of DERs, especially DER business models, financial modeling, and partner and stakeholder needs. Development agencies and donor partners in Nigeria should combine resources, expertise, and knowledge to build DisCo DER staff capacity in development, financing, and implementation. DisCo and development agency partnerships can also support access to innovative financing mechanisms for DER projects.

"We have learned that we need to establish a fully-fledged DER unit in our DisCo that will drive all the deployments of DERs" – Nuru Wadana, Head Regulatory Compliance and Risk Management, KEDCO

Priority Area 4: DisCo leadership champions DER development

Engagement with DisCos revealed that achieving the three priority areas above without full buy-in and support from their board and management will not result in rapid deployment of utility-enabled DER projects. Conventionally, DisCo boards and management commit to a new technology or business model based on their familiarity with it and the perceived acceptability of the change. Some DER projects have stalled due to a limited understanding of a DisCo's board on the role of DERs in increasing DisCo revenues, reducing losses, and improving supply reliability and availability.

While acknowledging the early stage of utility-enabled DER programs, DisCo senior leadership must quickly increase their awareness of the benefits of DERs to the DisCo. To achieve this, RMI, informed by engagements with DisCos, recommends periodic briefing sessions with DisCo board members to demonstrate the impact of DERs on DisCo commercial and technical performance using the impact assessment results in **Section 4.3** as a guide. Such briefing sessions should be informed by data-driven recommendations of specific pipeline projects being considered by the DisCo.

Additionally, peer-to-peer learning through knowledge exchange platforms can enable DisCos in the early stages of DER development to gain insight from DisCos already implementing projects. Finally, ensuring strict regulatory compliance to NERC's embedded generation and renewable energy targets is key to driving DisCo senior leadership to develop utility-enabled DER projects.

5.2 DisCos can be fully DER-ready in fewer than five years

Focusing on the four priority areas highlighted in **Section 5.1** will significantly increase the pace of project development and execution. The five-year roadmap illustrated in **Tables 5a, 5b, and 5c** provides actionable recommendations for DisCos, developers, and development organizations to help achieve the four priority areas. Of course, the timeline will differ depending on the relevant stakeholders — for instance, some DisCos already have DER teams while others do not.

Table 5a: Short-Term (2024–2025) DisCo Actions for DER Deployment

Priority Area	Activity	Available Resources
Effective Project Planning	Create a database of potential DER projects by business models (with periodic updates) and develop a central platform to store and retrieve data needed for project identification.	RMI DER toolkit, WB DARES TA
	Create a systematic process flow for developing DER projects and identify key point of contacts within DisCo for each process and data item.	DisCo Organograms, RMI DER toolkit
	Support project developers by providing memoranda of understanding to justify project financing, making introductions to DisCo-approved contractors, and contractually allowing new DER projects to inject surplus power into the grid.	RMI DER toolkit, RMI *Electrifying the Underserved*[xxxviii,54]
	Clarify DisCo and developer roles and responsibilities during development, implementation, commissioning, and operations in contractual agreements and subsequent project documentation.	RMI DER toolkit, RMI *Electrifying the Underserved*[55]
	Assess feeder capacity to integrate DER and assess distribution network to identify upgrades and improvement requirements.	NREL Net Zero World TA,[56] WB DARES TA, GIZ IMAS TA
Efficient and Timely Project Development & Implementation	Conduct preliminary customer engagement to evaluate interest and develop a stakeholder engagement process.	RMI DER toolkit, WB DARES TA
	Establish a list of credible vendors used by DisCos.	
	Create and implement a competitive procurement framework.	RMI DER toolkit, WB DARES TA
Dedicated DisCo DER Team	Form a cross-functional DER team and appoint a team leader.[xxxix]	

[xxxviii] **Appendix C** of this RMI report provides guidance on tripartite agreement terms and may be a starting point for DisCo-developer negotiations.

[xxxix] Forming cross-functional DER teams at DisCos refers to assigning DisCo staff from different departments the task of working together to develop and implement DERs with relevant key performance indicators. Institutionalizing the DER unit involves a formal recognition of the team, with its own organogram, across the DisCo. DER teams must not only hold the title, but also have decision-making capabilities within the DER program.

	Develop a DER strategy that speaks to DisCos' overall performance plans and includes key performance indicators.	RMI DER toolkit and roadmap, NERC MYTO 2024 order
DisCo leadership champions DER development	Hold periodic DER briefing sessions with board members to present compelling analyses that highlight the evidence-based benefits of DERs.	RMI DER roadmap and DER toolkit
	Incorporate DER targets in DisCo key performance indicators.	NERC MYTO 2024 and future orders

Table 5b: Medium-Term (2026–2028) DisCo Actions for DER Deployment

Priority Area	Activity	Available Resources
Efficient Project Development & Implementation	Codify customer engagement mechanisms and conflict resolution frameworks for a full project lifetime.	Regulatory Assistance Project resource(s)[57]
	Establish a monitoring, evaluation, and learning (MEL) framework for continuous improvement.	
Dedicated DER Team	Conduct DER team continuous learning and development.	Free-of-charge training programs and courses[xl]
	Establish a system for continuous creation of awareness on DERs among DisCo staff, including top management.	RMI DER toolkit
DisCo leadership champions DER development	Ensure strict adherence to embedded generation and renewable energy targets.	NERC MYTO 2024 and future orders

Table 5c: Actions required by DisCo partners to effectively and efficiently implement and scale up utility-enabled DER projects to completion (short-term: 2024–2025, medium-term: 2026–2028).

Priority Area	Activity	Responsible Party	Available Resources
Effective Project Planning	Clarify DisCo and developer roles and responsibilities during development, implementation, commissioning, and operations in contractual agreements and subsequent project documentation (short-term).	DisCo and Developer	RMI DER toolkit, RMI *Electrifying the Underserved*[58]
	Review and update regulations, including Regulation for Embedded Generation, 2012, and Mini Grid Regulations, 2023, to accommodate market growth (medium-term).	NERC	WB DARES, GIZ IMAS[59]
	Organize match-making events to introduce DisCos, developers, and financiers (medium-term).	REA	WB DARES TA, financiers, development partners

[xl] For instance, RMI's 2022–2023 Fellowship Program that trained 20 individuals across four DisCos from various departments to compose initial DER teams. More information is available at https://www.energytransitionacademy.net/global-fellowship-program/.

Efficient Project Development & Implementation	Streamline and optimize regulatory approval and other enforcement (medium-term).	NERC, NEMSA[xli]	WB DARES TA, GIZ TA
	Review DER solution, term sheets, contractual agreement, and DUOS in detail to prepare for effective DisCo negotiations (short-term).	Developer	
	Prepare low-cost bids by assessing supply chain opportunities and delays and building relationships with original equipment manufacturers and reputable engineering, procurement, and construction contractors (short-term).	Developer	DART[60]
	Build and maintain strategic relationships with technical partners, equipment suppliers, sponsors, and funders (short-term).	Developer	RMI, GEAPP, GIZ, WB, USAID
	Work with DisCo and relevant stakeholders to improve the technical and financial feasibility of the project(s) (short-term).	Developer	WB DARES TA, GIZ TA, GET.invest Finance Catalyst[61]
	Access financing for grid upgrades tied to utility-enabled DERs (medium-term).	REA	WB DARES, GIZ IMAS TA, REA future funding allocations
	Establish a monitoring, evaluation, and learning (MEL) framework for continuous improvement (medium-term).	DisCo, NERC	
DisCo leadership champions DER development	Organize knowledge-exchange platforms for DisCo senior leadership (short-term).	Development Partners, NERC, REA	

[xli] NEMSA is the Nigerian Electricity Management Services Agency.

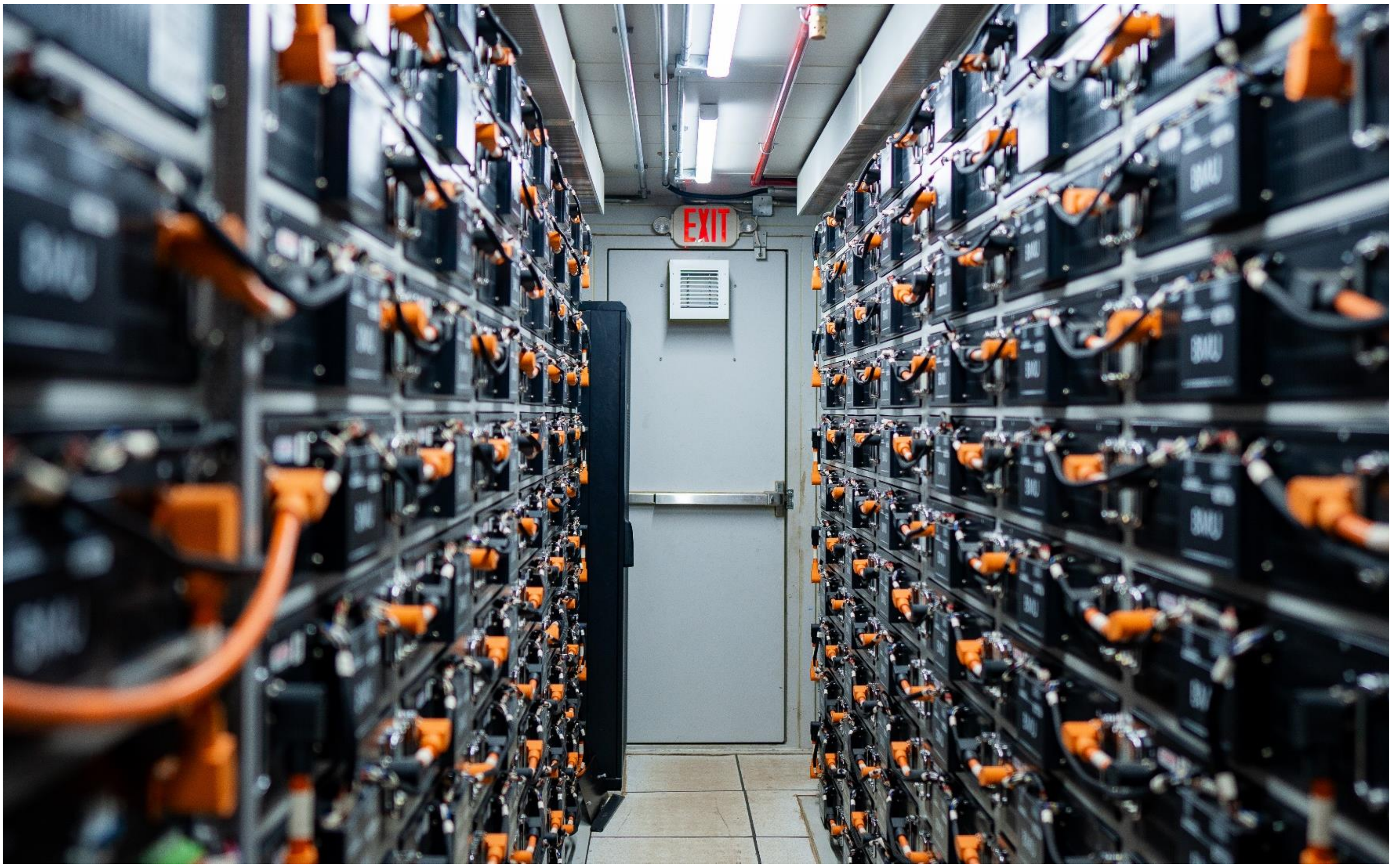
6. CONCLUSION

DisCos have a unique window of opportunity to reap the benefits of utility-enabled DERs by collaborating with private project developers and stakeholders. By doing so, DisCos can resolve longstanding power availability and reliability challenges, while bolstering revenues from increased energy sales and DUOS.

An accelerated pace of project development and implementation is imperative to make the most of the more than 20 GW utility-enabled DER opportunity laid out in this report, and to significantly support Nigeria in achieving its Energy Transition Plan goals by 2030. However, this investment opportunity of almost $14 billion can only be achieved by:

- Preparing robust project pipelines across business models,
- Embracing competitive procurement for least-cost project delivery,
- Fostering stronger collaboration between DisCos and developers,
- Establishing DER units at the DisCo level, and
- Securing adequate financing by the public and private sectors.

The Roadmap and the four recommended DisCo priority areas in this report, along with the *DER toolkit*, offer a suite of resources for DisCos, developers, and stakeholders to chart a course toward a more sustainable, resilient, and inclusive future for the Nigerian power sector.



APPENDICES

Appendix A: Additional roadmaps for the Nigerian energy sector

The following roadmaps offer alternative approaches framing the process to achieve high-quality, reliable electricity service in Nigeria. They each offer a unique perspective and are useful comparisons to RMI's roadmap presented in this document.

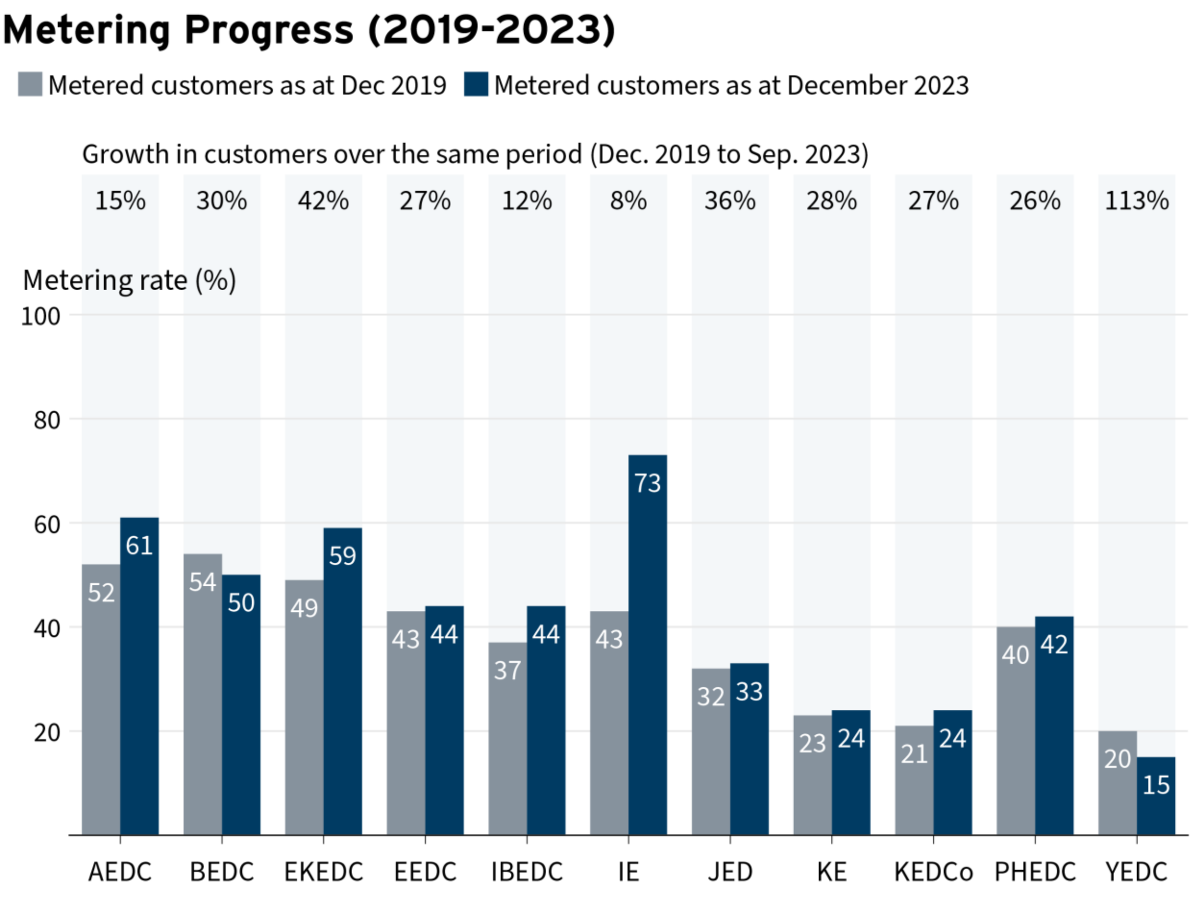
Table A-1: List of comparable roadmap documents.

.	Report	Author, Year	Key DER-related findings
1	Renewable Energy Roadmap, Nigeria, IRENA, 2023	IRENA, 2023	Distributed solar PV was identified as key resource in unlocking Nigeria's renewable energy sector
2	Energy Transition Plan	ETO, June 2021	Decentralized solar and wind capacity was estimated at 77 MWp as of 2020
3	National Renewable Energy Action Plan (2015–2030)	SE4All, 2016	Off-grid renewable minigrids were expected to increase to 5.3 GW by 2030
4	National Energy Master Plan	Energy Commission of Nigeria, 2014	Genset capacity was estimated at 80% of installed capacity of national grid
5	Renewable Energy Master Plan, Final Draft	Energy Commission of Nigeria, UNDP, November 2005	Decentralized nature of renewable energy informed roadmap development

Appendix B: Metering progress across all DisCos

The Federal Government of Nigeria set 100% customer metering as a priority. Between 2019 and 2023, in conjunction with significant growth in the customer base, nearly all DisCos improved their overall customer metering rates. **Exhibit A-1** demonstrates progress toward universal metering by each DisCo.

Exhibit A-1: Growth in DisCo metering rates from 2019 to 2023.

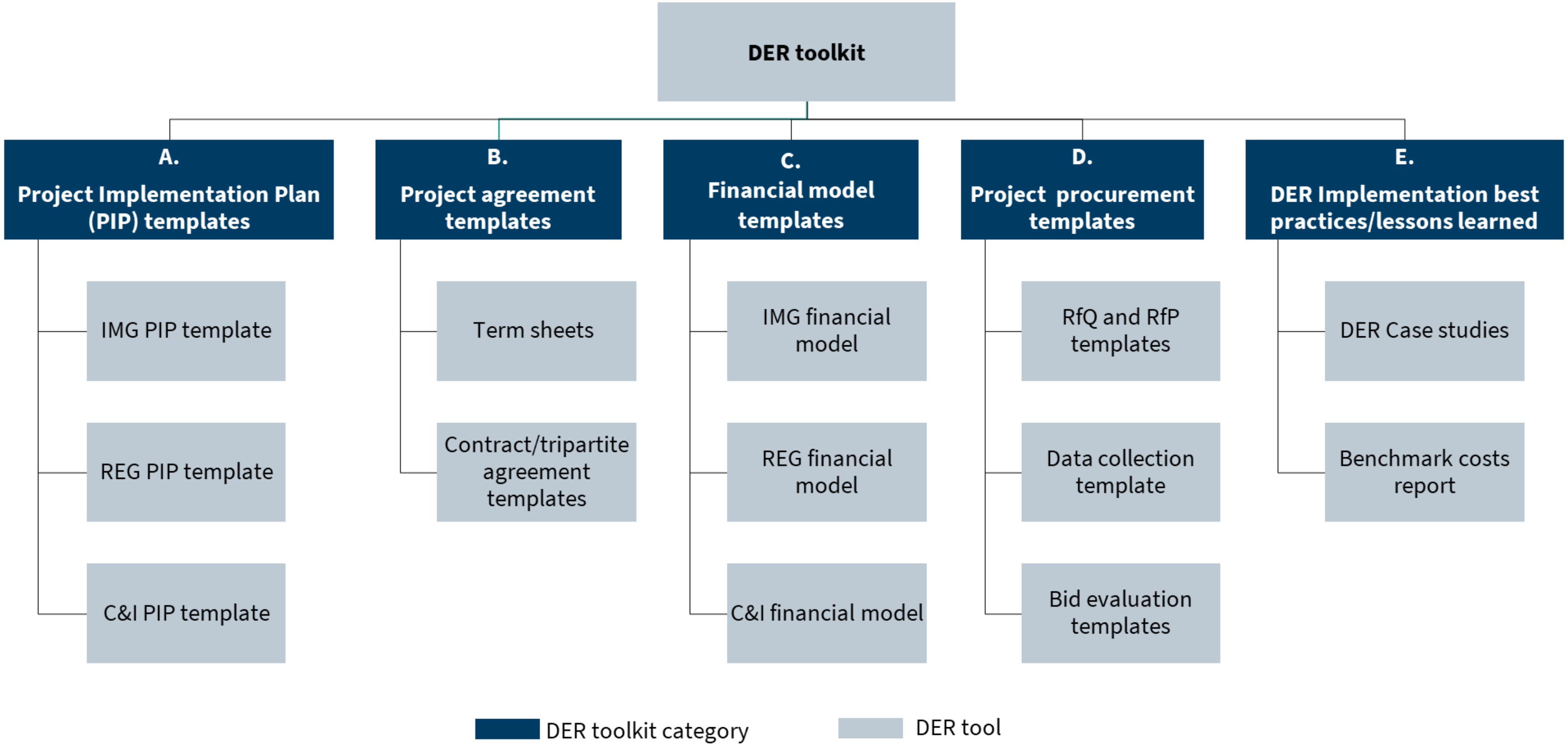


Source: Key operational and financial data of Nigeria DisCos—2023, NERC.

Appendix C: *DER toolkit* components

RMI's *DER Toolkit* provides a suite of resources to support DisCos navigating five key DER project phases, labeled A-E in **Exhibit A-2**. The DER toolkit is expected to increase the ability of DisCos and developers to implement utility-enabled DER business models by improving their understanding of these models. By adopting standardized and harmonized documentation between DisCos and developers, the toolkit is intended to simplify and accelerate project implementation, increase data transparency, and minimize misalignment during project implementation.

Exhibit A-2: Components included in RMI's *DER Toolkit* for DisCo implementation.



Appendix D: Business model schematics

Several of the business models discussed in this roadmap have been explored in standalone publications. The following diagrams attempt to visualize how the business models operate and compare; additional detail can be found in the standalone reports as cited.

Exhibit A-3: Comparing the impacts of DER models.[62]

	Renewable embedded generation	Utility-enabled C&I	IMGs
Does the DisCo maintain a direct relationship with its customers?	✓	X	X
Is the DER connected to the distribution network?	✓	✓	✓
Are a group of customers served as a cluster?	✓	✓	✓
Can the generation capacity be larger than 1 MW?	✓	✓	X

Exhibit A-4, from RMI's 2022 report on *Improving Electricity Supply for Large Customers in Nigeria* illustrates the roles and interactions within the utility-enabled DER business model for large C&I customers.

(a) **The DER developer** is responsible for installing and operating the DER system and its dispatch integration with the DisCo's electricity supply.
(b) **The DisCo** is responsible for supplying the customer with electricity from the grid during agreed-upon hours and for maintaining and operating its distribution network.
(c) **The customer** pays the DER developer for all electricity received (from both the DisCo's grid supply and the DER system) and the DER developer repays the DisCo for electricity supplied by the grid.

All three parties enter into a tripartite agreement to execute and operate the project.

Exhibit A-4: Large C&I business model.[63]

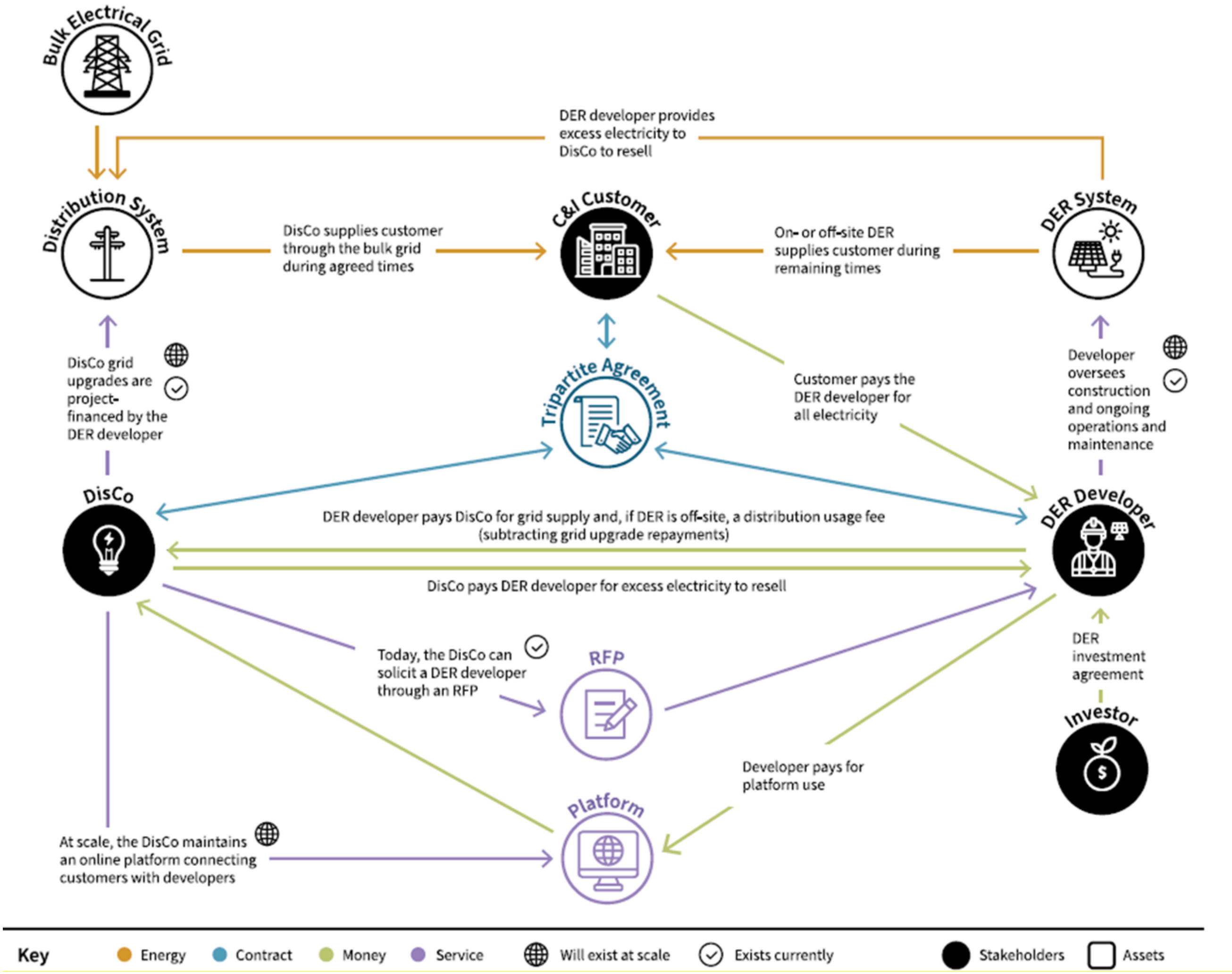
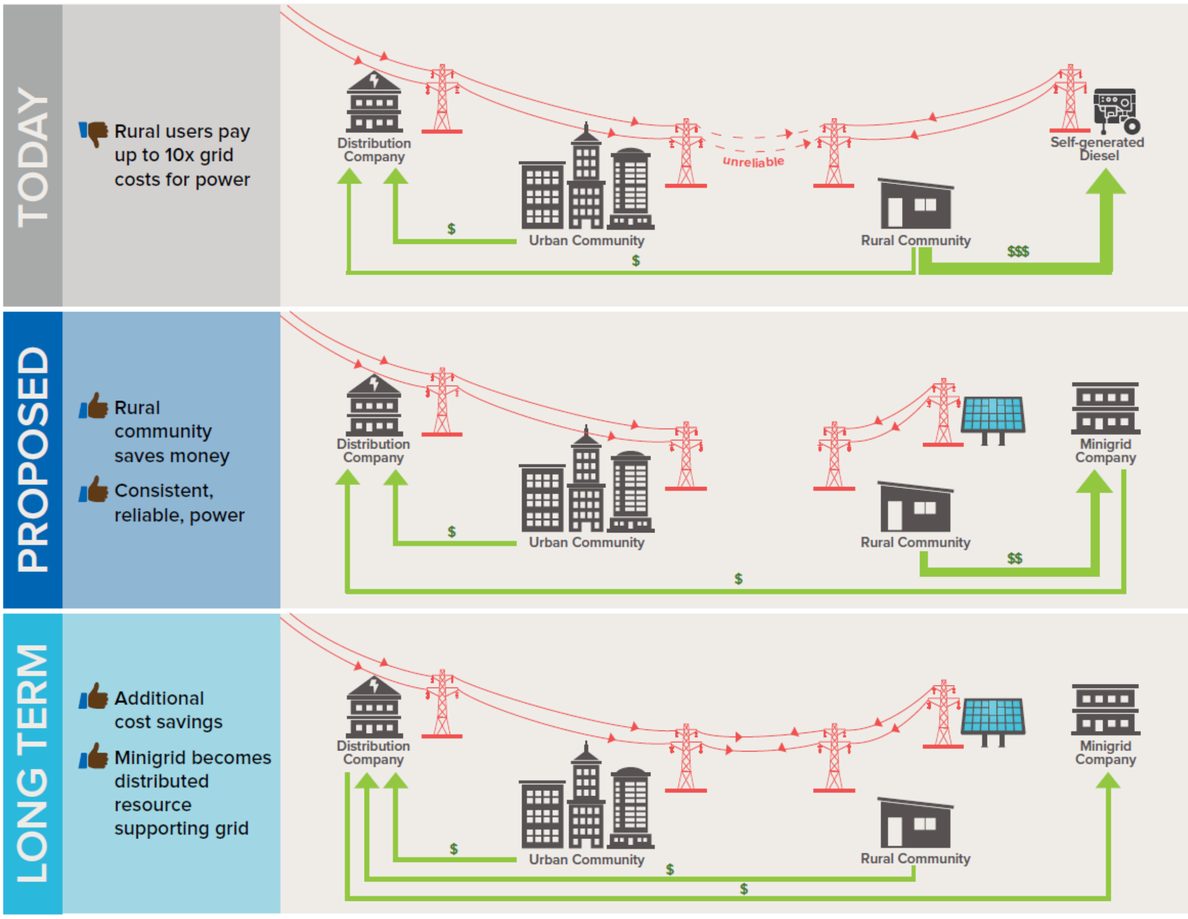


Exhibit A-5, from RMI's *Under the Grid* report, shows how undergrid minigrids can provide underserved communities with access to high-quality, reliable, and affordable electricity, while allowing DisCos to focus investment in high-priority urban areas.

Exhibit A-5: Interconnected minigrid business model.[64]



In the short term, undergrid minigrids can operate in isolation, but long-term grid integration creates a set of distributed energy resources that can trade power with the grid, providing additional benefits including grid resilience.

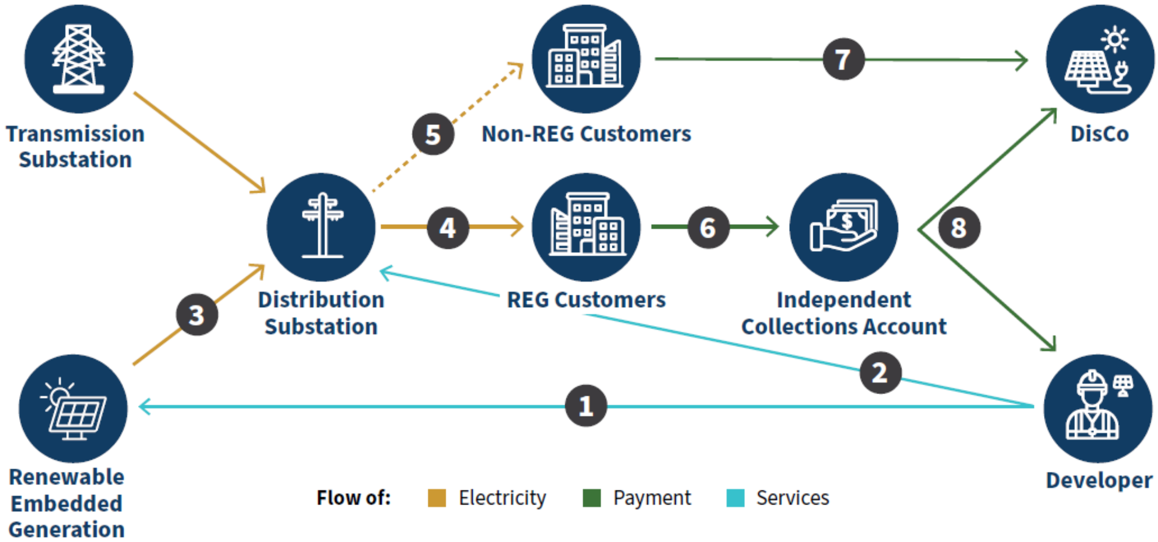
In a renewable embedded generation (REG) business model, a developer builds a solar PV embedded generation plant to increase supply to selected REG feeders along with enough battery storage and fossil-fueled backup to guarantee 24/7 reliability to premium customers. The hours of supply for non-premium customers also increase compared with current supply. A mix of REG electricity and electricity from the main grid is sold to REG customers at premium tariffs and to non-premium customers at service-based tariffs.[xlii]

Unlike the large C&I (**Exhibit A-4**) and interconnected minigrid (**Exhibit A-5**) business models, the REG business model directs customer payments from REG-served feeders into an independent collections account (ICA). The ICA is a payment mechanism that separates REG customer payments from the DisCo's existing collections accounts, providing revenue assurance for developers without

[xlii] Excess electricity is sold to customers on non-REG feeders at service-based tariffs.

requiring DisCos to enter escrow arrangements that tie up scarce capital. **Exhibit A-6** from RMI's *Unlocking Renewable Embedded Generation in Nigeria* report illustrates the REG business model.

Exhibit A-6: Renewable embedded generation business model.[65]



Appendix E: Overview of methodology

Modeling DER market opportunity for five DisCos

A three-step methodological approach was used in conducting the analysis for the five modeled DisCos. Each step is described below.

Step 1: Estimate DisCo demand and TCN supply for five modeled DisCos

- The Daily Demand Allocation Table from National Control Centre was used as basis for TCN allocation assumptions for each DisCo. The analysis assumed 8% annual growth in TCN supply, based on DisCo forecasts, expected to come from improvements in existing generation and capacity expansion.
- Following the collection of DisCo feeder demand and TCN supply and allocation data, DisCo feeder demand data was cleaned to produce aggregated demand profiles for the entire territory for each of the five DisCos: The feeder data was edited to ignore outages and load-shedding events, so the demand data used for the analysis includes latent demand (i.e., assuming customers did not suffer load shedding). Where possible, 11 kV data was used; otherwise, 33 kV demand data was scaled up to account for load shedding on 11 kV feeders.
    - Demand note 1: Demand data was obtained from hourly manual readings for each feeder by DisCo staff. The data is therefore prone to some errors.
    - Demand note 2: Using an aggregated demand profile as modeled in this Roadmap underestimates DER capacity since it assumes optimization across a whole territory is possible, where all DERs are optimized together and can supply feeders in different locations. However, realistically over the next decade in Nigeria, DERs will likely be operated separately to serve a few feeders as standalone systems. RMI analysis aggregates feeder demand, therefore it is conservative and underestimates the DER market potential.

Step 2: Optimize least-cost DER capacity in HOMER for each of five modeled DisCos

- Using expected demand for each DisCo, TCN supply, and resource costs, an optimization analysis was conducted using HOMER software to optimize solar, Li-ion, and gas DERs in 2033.
- A conservative 95% reliability constraint was used to avoid the overbuild of resources while maintaining a relatively high level of supply reliability.

Step 3: Build an Excel model to demonstrate capacity growth for each of five modeled DisCos

- DER new builds were ramped up from operational DERs and smaller new DER capacity in 2024 to the full amount needed in 2033 to meet demand. As discussed in the Roadmap, this ramping was conducted to assume a realistic initial rate of new builds and gradual annual increase.
- Economic metrics such as cost were then calculated based on the DER resource mix and quantity for each DisCo.

The modeling tool HOMER was chosen for this high-level analysis due to the data available from DisCos (manual recordings of feeder supply). More detailed capacity expansion modeling, feeder study, or grid stability analysis were not in the scope of this report; however, this type of detailed analysis will be necessary for a thorough understanding of DER potential in each DisCo territory.

This will require metering of feeders to accurately measure demand and supply, and a thorough review of feeder constraints and upgrades.

Extrapolating DER market opportunity for remaining six DisCos

The market opportunity for the remaining six DisCos was estimated using the results of the five modeled DisCos. The methodology for this extrapolation is detailed below.

Step 1: Estimate DisCo demand for remaining six DisCos

- 33 kV NERC feeder data for 2022 was aggregated to estimate annual 33 kV demand for all 11 DisCos.
- 33 kV NERC annual demand data was compared to latent 11 kV demand used for five DisCos, which was parsed to exclude load shedding in the initial modeling for the five DisCos.
- The 11 kV DisCo demand without outages was found to be 1.4–1.8 times larger than the 33 kV NERC demand. These ratios between 11 kV and 33 kV demand correlate to DisCos' reported billing efficiencies,[66] which varied from 70% to 90%, since outages are directly accounted for in technical losses.
- Ratios between 33 kV and 11 kV demand were extrapolated to the remaining six DisCos using 33 kV NERC data and reported billing efficiency values, to get 11 kV demand for the remaining six DisCos.

Step 2: Estimate supply gap for remaining six DisCos

- Calculate the supply gap between TCN supply and DisCo demand. TCN data from the Daily Demand Allocation Table from National Control Centre is used to estimate current TCN supply.

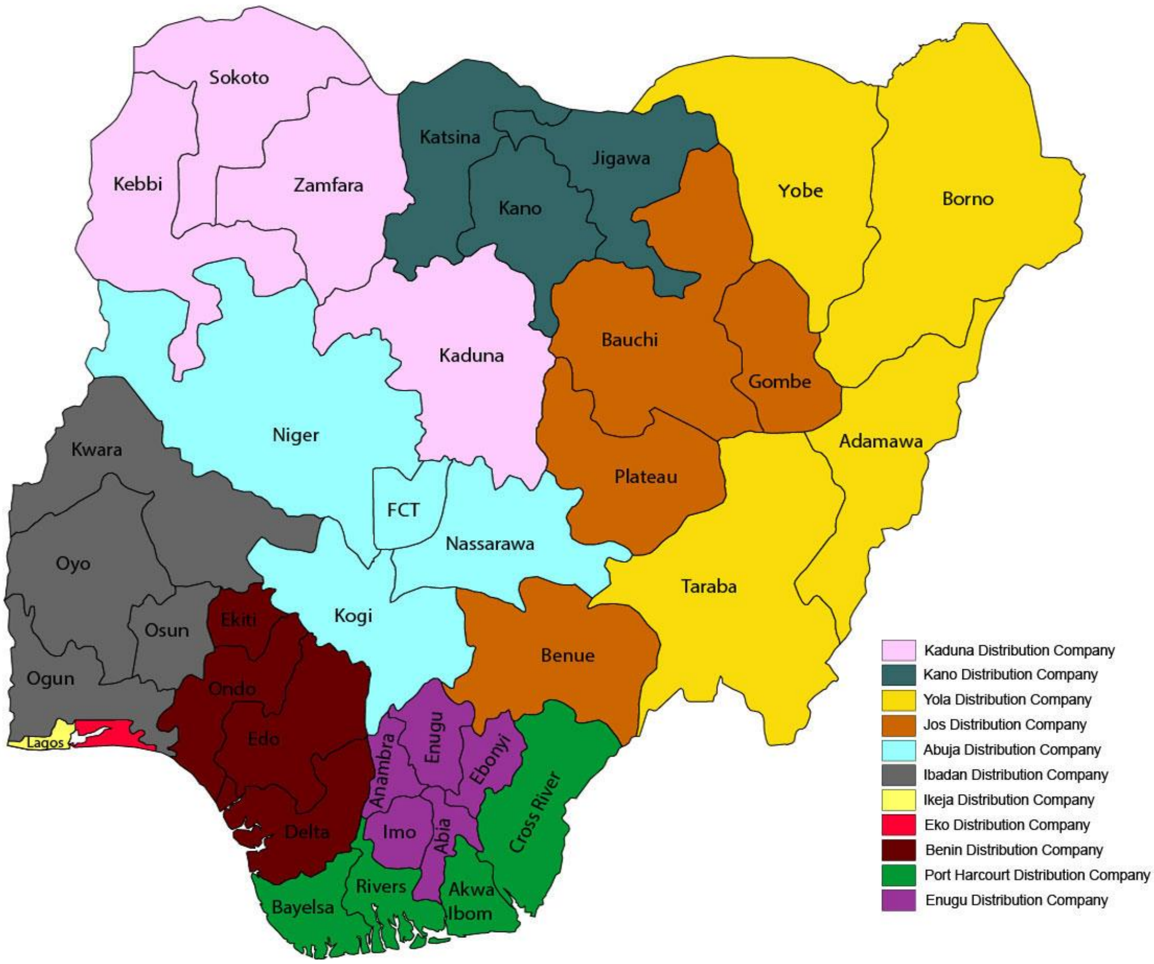
Step 3: Estimate DER potential for remaining six DisCos

- For each of the five DisCos initially modeled, calculate the ratios of the total capacity of DER values modeled in initial analysis for five DisCos to the TCN supply capacity, which vary from 2.6 to 7.7.
- These ratios of total DER capacity to TCN supply correlate to the supply gap proportion — a bigger supply gap means more DERs needed compared to TCN supply.
- Ratios between total DER capacity and TCN supply were extrapolated to the remaining six DisCos, using supply gaps calculated in Step 2.
- The total DER capacity for the remaining six DisCos was split into solar, gas, and Li-ion capacity based on gas pipeline availability. DisCos in the South were allocated the same proportions of resource mix as BEDC, DisCos in the mid region were allocated the same proportions as AEDC, and DisCos in the North were allocated the same proportions as KEDCO. Lagos DisCos' resource mix was not used to extrapolate to other DisCos, due to Lagos' unique land constraints, which are not as severe elsewhere.

Appendix F: Coverage Areas of Nigeria Distribution Utilities

Eleven DisCos provide electricity to customers across Nigeria. DisCo territories are depicted in **Exhibit A-7**.

Exhibit A-7: Distribution coverage of Nigerian DisCos.



Source: NBET.[67]

Appendix G: Scenario and sensitivity summary

Demand sensitivity

- The *Base Case* scenario uses average hourly demand data from DisCos assuming no load shedding, and a 9% annual growth rate — which is the average from historical DisCo data.
- The high demand sensitivity uses the same hourly demand profile as base case but replaces the 9% annual growth rate with a 15% rate, which is the high range from historical DisCo data. This growth compounds to a 70% higher demand in 2033. Due to knowledge of this unmet demand, the authors deem a lower than 9% annual demand growth to be highly unlikely and did not model a low-demand scenario.
- There is unmet or suppressed customer demand in DisCo territories, which is difficult for DisCos to quantify.[xliii] Some examples of this demand are from customers who are not yet connected to the grid but are located within DisCo territory, those who have defected from the grid due to unreliable supply, and those who would buy more appliances if they received reliable supply. Thus, potential demand likely deviates from current demand forecasts.

Cost sensitivity

Base, high, and low capital expenditure and project development values were obtained from operational, under-construction, and planned DER projects in Nigeria, assuming 60% new capacity from interconnected minigrids (less than 1 MW) and 40% from renewable embedded generation (more than 1 MW),[xliv] which have cost differences due to economies of scale. Large commercial and industrial customers are served within these two systems. The cost assumptions for these project types are shown in **Tables A-2 and A-3**. Annual change rates were obtained from Bloomberg New Energy Finance forecasts.[68] Project development costs were estimated to account for business development, licensing, design, and land.

Table A-2: Capex cost assumptions for analysis.

Resource	Base Case, 2024	High-Cost Sensitivity, 2024	Low-Cost Sensitivity, 2024	Annual Change Rate in Capex
Solar PV Capex[xlv]	$540/kW	$810/kW	$340/kW	4% decrease
Li-ion Battery Capex	$405/kW	$495/kW	$315/kW	4% decrease
Gas Capex	$810/kW	$990/kW	$630/kW	1% decrease
Project Development Costs	9% additional on capex	12% additional on capex	5% additional on capex	N/A

[xliii] Based on RMI's experience with the participating DisCos.
[xliv] C&I capex project costs are embedded as subsets within the cost estimates for IMG and REG.
[xlv] An additional $1,000/kW was included for IE and EKEDC DisCos in Lagos due to high cost of land for space-intensive solar PV. This will likely be a mix of rooftop and ground-mounted solar, depending on specific location. For context, the RMI estimate is conservative compared to the 2022 Lagos IRP,[xlv] which assumes a total solar capital expenditure of $1,000/kW, and optimistic compared to the 2021 World Bank report on distributed solar in Lagos,[xlv] which assumes a total solar capital expenditure of $2,270/kW in 2021.

Table A-3: Capex assumptions for interconnected minigrids and renewable embedded generation.

Resource	Interconnected Minigrids, 2024, Base Case	Renewable Embedded Generation 2024, Base Case
Solar PV Capex[xlvi]	$600/kW	$450/kW
Li-ion Battery Capex	$450/kW	$340/kW
Gas Capex	$900/kW	$680/kW

Base, high, and low fuel costs were obtained from developer data and are summarized in **Exhibit A-4**. The breakdown of piped gas and CNG accounts for existing pipelines in the South and the new Ajeokuta-Kaduna-Kano pipeline that is scheduled to be completed mid-2024 but may not be immediately available for commercial use.

Table A-4: Fuel cost assumptions for analysis.

Region/ DisCo	2024 Costs ($/m³)		% Piped Gas for DER Projects (remainder is CNG)					
	Piped Gas	Trucked CNG	Base		High-Cost Sensitivity		Low-Cost Sensitivity	
			2024	2033	2024	2033	2024	2033
South – IE, EKEDC, BEDC	0.3	0.34	80%	80%	50%	50%	100%	100%
Central – AEDC	0.3	0.46	0%	70%	0%	50%	0%	90%
North – KEDCO	0.3	0.58	0%	70%	0%	50%	0%	90%
Annual Change Rate in Capex	N/A	N/A	2% increase		10% increase		0% increase	

[xlvi] An additional $1,000/kW was included for IE and EKEDC DisCos in Lagos due to high cost of land for space-intensive solar PV. This will likely be a mix of rooftop and ground-mounted solar, depending on specific location. For context, RMI's estimate is conservative compared to the 2022 Lagos IRP,[xlvi] which assumes a total solar capital expenditure of $1,000/kW, and optimistic compared to the 2021 World Bank report on distributed solar in Lagos,[xlvi] which assumes a total solar capital expenditure of $2,270/kW in 2021.

TCN sensitivity

The low TCN supply sensitivity assumes 70% of allocated supply based on historical DisCo data. The high TCN supply sensitivity assumes 30% higher supply from TCN based on planned utility-scale plants assuming transmission constraints are adequately addressed.

Tables A-5 and A-6 present levelized cost of energy (LCOE) estimates for all electricity provided by DERs and assumptions based on region, resource type, and resource scale.

Table A-5: DER assumptions for LCOE calculations.

DER Assumptions (2024) Table A-2 and Table A-3	Capex Incl. Development and Land ($/kWh)	Fuel Cost ($/kWh)	Fixed O&M ($/kW-y)	Variable O&M ($/kWh)	Capacity factor (from HOMER)
Solar (Lagos)	1,679	N/A	10	N/A	15%
Solar (South, outside Lagos)	589	N/A	10	N/A	16%
Solar (Central)	589	N/A	10	N/A	18%
Solar (North)	589	N/A	10	N/A	20%
Gas (South)	883	0.029	N/A	0.015	51%
Gas (Central)	883	0.044	N/A	0.015	47%
Gas (North)	883	0.055	N/A	0.015	33%

Table A-6: Assumptions used for LCOE calculations for utility-scale projects.

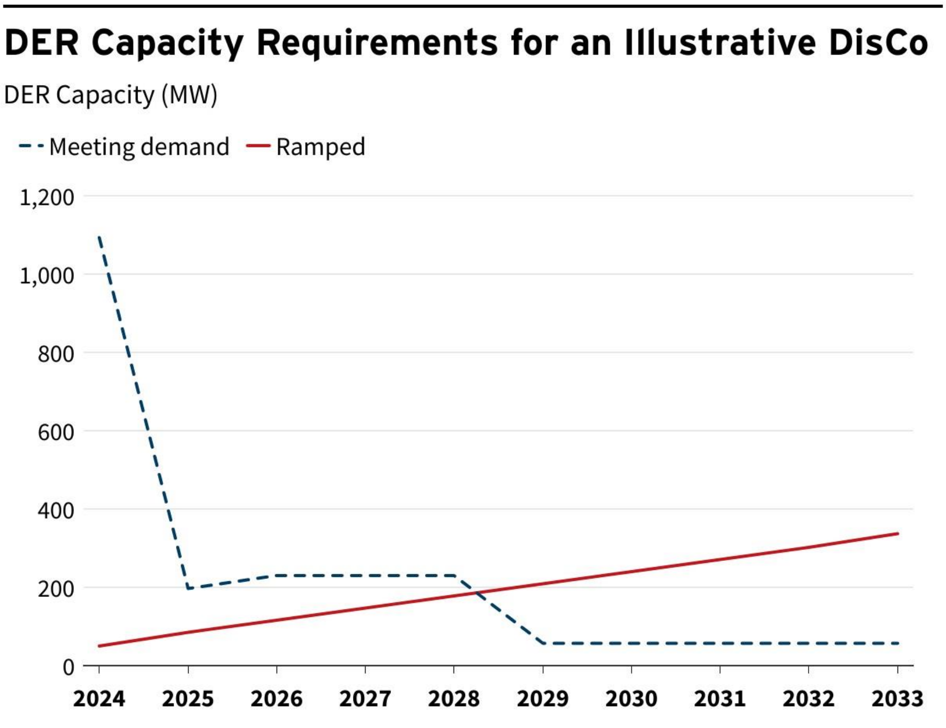
Utility-Scale Assumptions (2022-2025)	Capex ($/kW)	Fuel Cost ($/kWh)	Fixed O&M ($/kw-y)	Variable O&M ($/kWh)	Capacity Factor69	LCOE ($/kWh)	Source
CCGT Lagos[xlvii]	1,407	0.028	18	0.00611	60%	0.0792	CCGT NG (Lagos IRP)[70]
CCGT LNG Lagos	1,407	0.037	18	0.00611	60%	0.0876	CCGT LNG (Lagos IRP)[71]
GT Lagos[xlviii]	1,208	0.042	12	0.00652	50%	0.0938	GT (Lagos IRP)[72]
CCGT Lagos[73]	950	0.028	18	0.00611	60%	0.0657	CCGT (Egbin Phase II)[74]
CCGT Central[xlix]	1,260	0.042	18	0.00611	60%	0.0890	CCGT (Gwagwalada IPP)[75]
Solar Lagos	1,000	N/A	10	N/A	15%	0.1253	Rooftop & utility combined (Lagos IRP)[76]

[xlvii] Combined cycle gas turbine power plant.
[xlviii] Gas turbine power plant.
[xlix] Fuel cost and O&M costs from Lagos state IRP. Fuel cost scaled up by the same proportion as RMI DER fuel cost estimates for Central Nigeria.

Appendix H: Counterfactual DER growth trajectory

This report assumes a slow, intentional growth rate due to the impracticality of immediately meeting the supply gap. **Exhibit A-8** demonstrates the difference between immediately meeting all demand versus pursuing a ramped approach. Given the supply chain, DisCo capacity, developer capacity, finance availability, and other constraints, RMI believes that the ramped approach presents a much more feasible approach to DER implementation.

Exhibit A-8: Utility-enabled DER capacity requirement projections with and without gradual ramping for an illustrative DisCo. The "meeting demand" line assumes demand is fully met in 2024, which requires a large initial DER build out.



Appendix I: DisCo-specific modeling results

The following tables offer base case and sensitivity analyses results for DER implementation within each DisCo. These explore changes in total energy demand and resource allocation based on the assumptions described in **Appendix G**. Energy from TCN is based on allocated capacity. Energy from solar and gas were estimated with least-cost optimization analysis. On average across scenarios and DisCos, optimized DER projects include 30% more energy from solar than from gas. **Table A-7** shows the assumptions underlying the *Base Case* scenario.

Table A-7: Base case assumptions for all five DisCos including annual demand, TCN supply, and optimized energy supply.

Base case	Units	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Customer Demand											
Average annual demand	TWh/y	26	30	33	37	40	43	47	50	54	57
TCN Allocated Supply Forecast											
IE	TWh/y	5.4	5.8	6.3	6.8	7.3	7.9	8.5	9.2	9.9	10.7
AEDC	TWh/y	5.4	5.9	6.3	6.9	7.4	8.0	8.6	9.3	10.1	10.9
BEDC	TWh/y	2.9	3.2	3.4	3.7	4.0	4.3	4.7	5.0	5.5	5.9
EKEDC	TWh/y	4.6	4.9	5.3	5.8	6.2	6.7	7.3	7.8	8.5	9.1
KEDCO	TWh/y	2.4	2.6	2.8	3.1	3.3	3.6	3.9	4.2	4.5	4.9
Optimized Energy Supply to Meet Five DisCos' Demands with DERs											
Solar PV	TWh/y	0.3	0.9	1.6	2.6	3.7	5.1	6.6	8.3	10.3	12.4
Gas	TWh/y	0.2	0.6	1.2	1.9	2.7	3.7	4.9	6.1	7.6	9.2
TCN	TWh/y	20.8	22.4	24.2	26.2	28.3	30.5	32.8	34.6	35.6	35.4

RMI's analysis results in solar constituting 80% of new DER capacity builds by 2033 across all five DisCos. However, the low capacity factor of solar means it contributes only about 60% of DER energy supply. This varies by location, and DisCos in Lagos have lower solar capacities due to space constraints. DisCos in the North have relatively less energy from gas and more battery storage capacity than those in the South due to higher fuel costs resulting in less gas used for ramping. The *Base Case* modeling results are described in **Table A-8.**

Table A-8: *Base case* results for all five DisCos: 2033 optimized supply capacity, energy supply, and costs.

Base case	Units	IE	EKEDC	BEDC	AEDC	KEDCO
Optimized Supply Capacity across Five DisCos by 2033						
TCN	GW	1.23	1.04	0.67	1.24	0.56
Solar	GW	1.31	0.89	2.1	3.44	0.78
Li-ion battery	GW	0.02	0.02	0.05	0.23	0
Gas	GW	0.6	0.5	0.44	0.5	0.06
Total Optimized Energy Supply across Five DisCos in 2033						
Solar	TWh	1.74	1.18	2.88	5.3	1.34
Gas	TWh	2.7	2.08	2.16	2.05	0.18
TCN	TWh	10.1	8.51	4.65	8.23	3.88
Net Present Costs for New Build DERs across Five DisCos by 2050						

Capex solar	Million $	843	670	408	573	147
Capex Li-ion battery	Million $	9	90	21	9	0
Capex gas	Million $	241	201	177	176	22
Opex solar	Million $	45	119	72	31	26
Opex Li-ion battery	Million $	0.2	2.4	0.6	0.2	0.003
Opex gas	Million $	186	155	136	137	17
Gas fuel cost	Million $	834	648	652	645	58

Modeling results across all scenarios differ significantly depending on whether the DisCo is based in Lagos due to the space constraints in the city that limit affordable solar deployment. Two representative sets of results are displayed in **Tables A-9 and A-10** and reflect the differences between Lagos-based and non-Lagos-based companies.

Table A-9: Sensitivity results for illustrative DisCo outside of Lagos.

Sensitivities	Base Case	High Demand	High Capex	Low Capex	High Fuel Cost	Low Fuel Cost	Low TCN Supply
Total DER Capacity Needed by 2033 (GW)							
Solar PV	2.51	6.08	2.00	5.82	5.31	2.14	3.27
Li-ion battery	0.07	0.23	0.02	2.04	2.25	0.02	0.11
Gas	0.53	1.50	0.54	0.28	0.19	0.54	0.84
Total Energy Consumption in 2033 (TWh)							
Solar PV	3.45	8.37	2.76	8.01	8.76	2.95	4.51
Gas	2.59	7.61	2.77	0.52	0.28	2.72	4.02
TCN	5.57	5.31	5.90	4.66	4.59	5.80	3.76
Gas : solar ratio	0.75	0.91	1.0	0.06	0.03	0.92	0.89
Net Present Costs through 2050 (Million $)							
Capex solar	505	1222	676	777	1035	431	657
Capex Li-ion battery	26	93	8	418	594	8	44
Capex gas	218	620	280	85	79	223	347
Opex solar	89	216	71	207	183	76	116
Opex Li-ion battery	0.7	2.4	0.2	16	18	0.2	1.2
Opex gas	169	479	172	88	61	172	268
Gas fuel cost	805	2362	861	159	195	662	1252

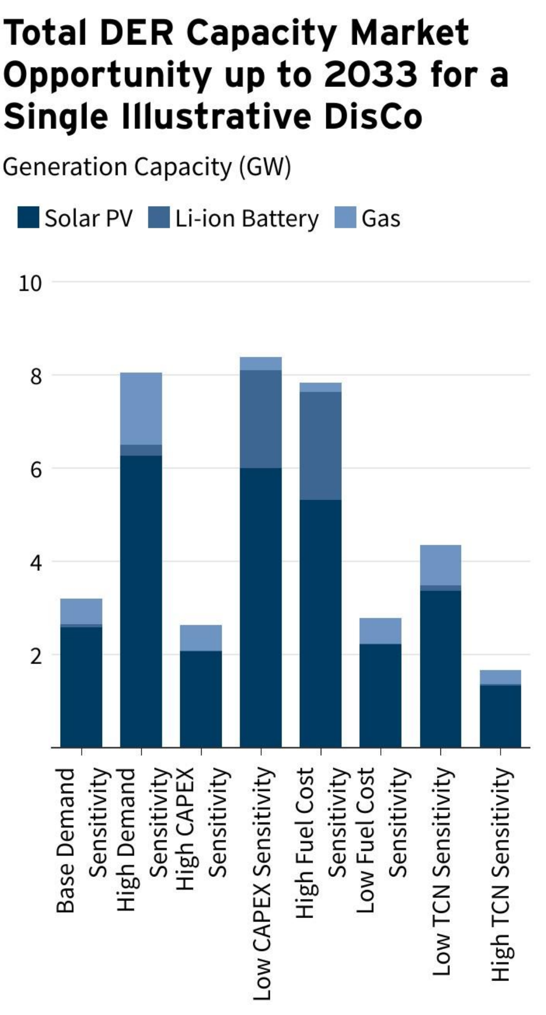
Table A-10: Sensitivity results for illustrative DisCo in Lagos.

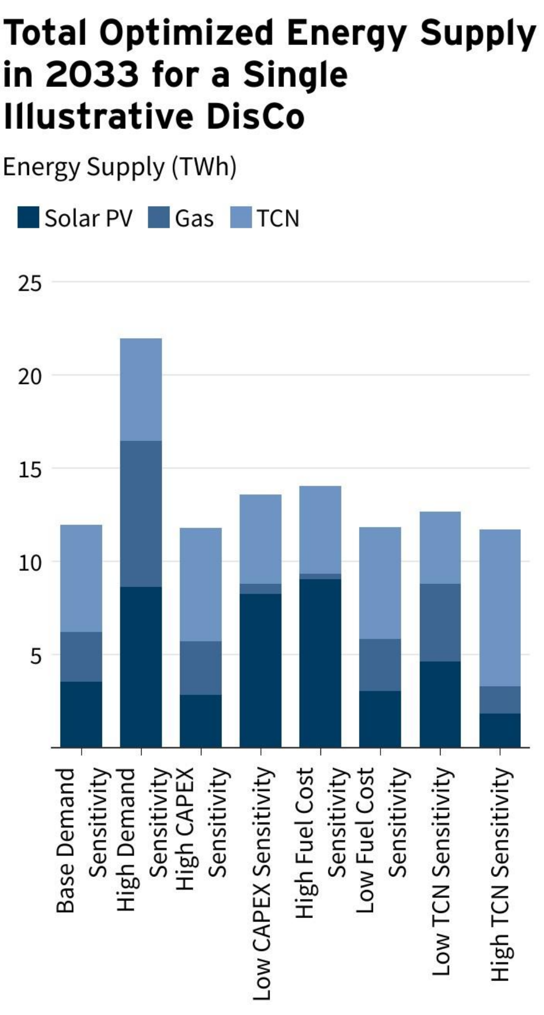
Sensitivities	Base Case	High Demand	High Capex	Low Capex	High Fuel Cost	Low Fuel Cost	Low TCN Supply
Total DER Capacity Needed by 2033 (GW)							
Solar PV	1.31	3.89	1.22	1.45	1.56	1.19	2.16
Li-ion Battery	0.02	0	0.03	0.05	0.01	0.02	0.01
Gas	0.6	1.8	0.6	0.6	0.6	0.6	0.9
Total Energy Consumption in 2033 (TWh)							
Solar PV	1.74	5.17	1.61	1.93	2.07	1.58	2.86
Gas	2.7	9.9	2.75	2.63	2.59	2.77	4.77

TCN	10.1	9.74	10.2	10	9.91	10.2	6.85
Gas:solar ratio	1.55	1.91	1.71	1.36	1.25	1.75	1.67
Net Present Costs through 2050 (Million $)							
Capex solar	843	2502	1314	620	1001	763	1386
Capex Li-ion battery	9	2	12	15	4	7	5
Capex gas	241	722	302	180	241	241	361
Opex solar	45	134	42	50	54	41	74
Opex Li-ion battery	0.25	0.04	0.26	0.49	0.09	0.17	0.14
Opex gas	186	558	186	186	186	186	279
Gas fuel cost	834	1987	560	535	806	474	955

Sample sensitivity results for a DisCo outside of Lagos are displayed in **Exhibit A-9**. These demonstrate the significant value of both solar and natural gas DERs in meeting latent demand for the case of a sample DisCo.

Exhibit A-9: DER power capacity (left) and energy supply (right) across sensitivities for an illustrative DisCo outside Lagos. These sensitivities show the significant contribution of DERs to meet total energy need and the role of solar to provide most energy in almost all scenarios.





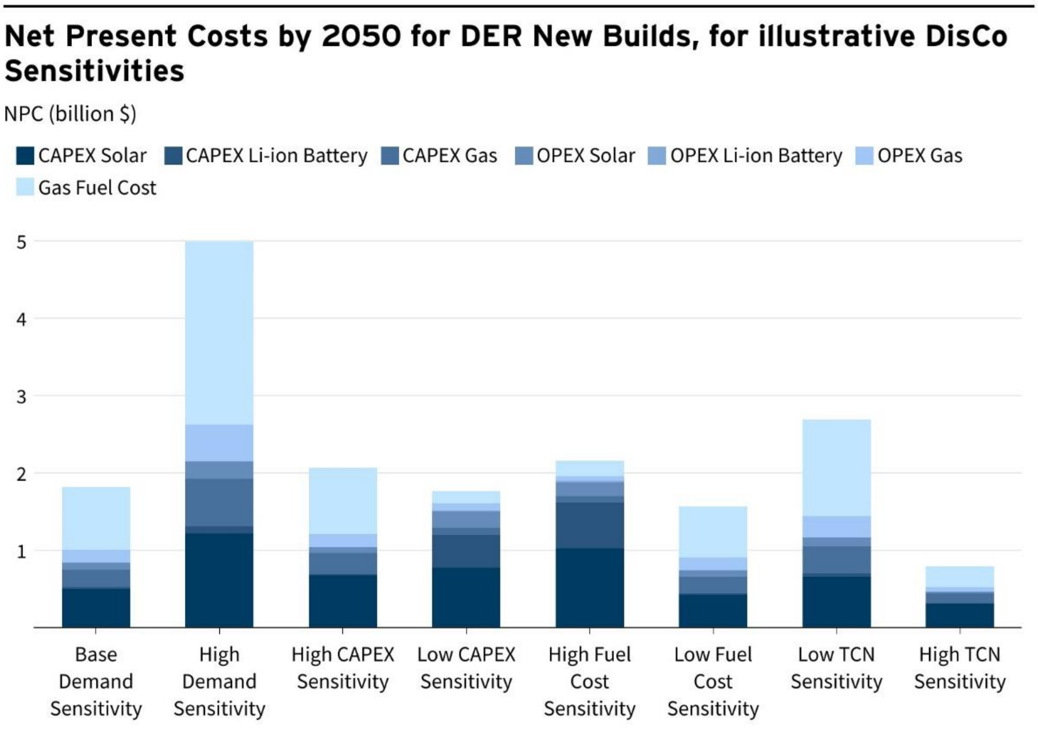
The capital expenditure and fuel sensitivities underscore the importance of DER costs and natural gas availability and pricing to outcomes of the least-cost analysis. For instance, the low capital expenditure and high fuel cost sensitivities feature less gas on the system due to the assumption of higher cost gas throughout the country from slower gas pipeline expansion, and lower DER costs due to improvements in supply chains or economies of scale. In these sensitivities, more lithium-ion battery storage is cost-effective over the total project lifetime (25 years, based on solar lifespan) as indicated in **Exhibit A-10**.

Conversely, the high capital expenditure and low fuel cost sensitivities feature slightly more energy from gas than solar compared to the base case. Even in these scenarios, however, solar is still more cost-effective for daytime energy supply. For DisCos in Lagos however, (results in **Table A-10**), the capital expenditure and fuel cost sensitivities analyzed do not significantly affect the optimized proportion of solar and gas DERs. This is due to high land costs in Lagos, which limit the solar capacity that can be built regardless of lower capex costs or higher fuel gas costs.

The high demand and low TCN sensitivities have a higher ratio of gas to solar PV than the *Base Case* scenario for non-Lagos DisCos, since they feature a consistent supply gap including during peak hours, which require dispatchable supply. However, for DisCos in Lagos, the ratio of gas to solar PV in the *High-Demand* scenario is similar to the *Base Case* scenario which already has a higher proportion of dispatchable supply. The low TCN sensitivity envisions that transmission constraints and limited utility-scale supply limit the availability of energy from TCN and indicates that this would increase demand for DERs.

Conversely, if utility-scale capacity is built and transmission capacity improved, the high TCN scenario demonstrates reduced need for DERs in all DisCos. Implementation of energy efficiency and demand response projects could also reduce the need for DERs, but RMI's conservative DER potential calculations assume that there remains sufficient latent demand to support these new projects.

Exhibit A-10: Sensitivity analyses demonstrate a range of new-build DER net present costs through 2050 for an illustrative DisCo. While capex and operating expenditures (opex) contribute to all cost stacks, solar capex and gas fuel costs are the primary drivers.



The sensitivity analyses conducted were assessed using a technology-agnostic, least-cost framework. Exogenous factors, such as climate change and shifting global perspectives on energy resources, could impact the likelihood of investments in technologies like long-term gas infrastructure but were not included as factors in this analysis; future studies may wish to further explore these factors. This roadmap also does not provide an explicit path to meet NERC's expectation of 10% DERs by 2025, but the authors note that some scenarios come quite close.

Today, climate pollution reduction is not a key focus of electricity improvement in Nigeria, where individuals' carbon footprints are extremely low compared to global averages, and cost and reliability of electricity are the major concerns.[77] However, a renewable-heavy mix like that shown in the high fuel cost or low capital expenditure sensitivity may be able to take advantage of low-cost climate financing, which may make it a more financially feasible option regardless of other factors. In a scenario where climate financiers seek to support DER mixes with higher proportions of renewable energy, the high fuel cost and low capital expenditure sensitivities have 40%–45% lower climate pollution than the *Base Case* scenario. The *Base Case* scenario has 23% lower climate pollution than typical grid emissions, with carbon intensity assumptions in **Appendix K**.

A comparison of the levelized cost of electricity (LCOE) between distributed- and utility-scale projects was conducted to demonstrate the cost-effectiveness of adding DERs to the grid. The comparison presented in **Appendix J** shows that, although DERs are slightly more expensive than utility-scale projects, the additional costs of transmission upgrades for utility-scale projects are generally costlier than distribution upgrades for DERs.[l] Moreover, the LCOE of solar is projected to

[l] DER advocates will need to overcome the challenge that transmission upgrades are not accounted for in the traditionally calculated LCOE of utility-scale projects.

decline more quickly than that of gas. Of course, many additional co-benefits (such as the dispatchability benefit of gas or the low emissions of solar) are not accounted for in LCOE estimates. DisCos and developers may want to consider the social cost of such factors when assessing their desired outcomes.

Appendix J: Contextualizing modeling results

Table A-11 compares the DER market potential estimated in this roadmap to assessments provided by other studies. The "nearest neighbor" reports to this roadmap are the *Energy Transition Plan* (ETP) and the *Lagos Integrated Resource Plan* (IRP). The *Roadmap* builds on a broader and more nationally representative base of data than the *Lagos IRP* but does not explicitly consider the full country and all 11 DisCos that the *ETP* considers. RMI's assessment (57 TWh/y in 2033) is comparable to the ETP, which includes all DisCos and estimates total energy demand of 156 TWh/y by 2030. Similarly, RMI's estimate and the *Lagos IRP*—2033 demand estimates are within 3% of each other.

Table A-11: Comparison of RMI DER Roadmap results with the Energy Transition Plan and the Lagos State Integrated Resource Plan.

Report	Scope relevant to DER Roadmap[li]	Demand Estimates	Utility-Scale Supply Forecasts	Distributed Scale Supply Forecasts
RMI's DER Roadmap – Base Case Scenario, Five DisCos	DERs for TCN supply gap for five DisCos 2024–2033	26 TWh in 2024, growing at 9% annually to 57 TWh by 2033	5G W TCN supply by 2033, using TCN growth forecasts from DisCos, which do not account for new utility-scale plants	8.5 GW solar, 2 GW gas, and 0.3 GW Li-ion battery storage by 2033, which doesn't account for new utility-scale supply
Energy Transition Plan (Federal Government of Nigeria, 2022) [78]	Total supply for whole country up to 2030 and 2050	Total centralized and decentralized 2030 demand for the whole country, including non-grid-connected demand and vehicle electrification, is 156 TWh, ~2.7x RMI's 2033 estimate for five DisCos	42 GW "centralized" supply by 2030 — the majority from gas and back-up generation	8.2 GW "decentralized" supply from minigrids, new solar plus battery storage, and oil and gas generators by 2030
RMI's DER Roadmap – Base Case Scenario, Lagos DisCos (IE & EKEDC)	DERs for TCN supply gap for Lagos and IE 2024–2033	26.7 TWh in 2033	1.1 GW additional TCN supply	1.1 GW gas, 2.2 GW solar
Lagos Integrated Resource Plan (Deloitte and USAID, 2022) [79]	Supply for Lagos through 2040	2033 "most likely" demand forecast value in IRP is 27.5 TWh, which is 3% higher than RMI's 2033 base case estimate for EKEDC and IE	7.6 GW new gas and 1.7 GW new utility-scale solar by 2040	1.7 GW rooftop solar

DER Costs Compared to Current Retail Tariffs and New Utility-Scale Projects

Across the five DisCos, the LCOE for solar and gas DERs is higher than generation retail tariffs. This means premium tariffs will likely be needed to provide customers reliable supply from DERs. To meet the supply gap under current regulations and in the most logistical and cost-effective manner, it is recommended that DisCos explore innovative power procurement alternatives in addition to utility-enabled DERs. NERC, in its 2024 MYTO tariff order for instance, mandated DisCos

[li] The ETP and Lagos IRP have a larger scope overall.

to secure adequate bilateral contracts to help meet their energy requirements and facilitate a transition from Nigerian Bulk Electricity Trading (NBET). This allows DisCos to directly engage with GenCos for energy supply, which could ease supply constraints for some DisCos though there would still be a national shortage unless GenCos install new generation facilities. Another opportunity could be for DisCos to sign direct power purchase agreements from unbuilt utility-scale DER renewable projects, which would stimulate new supply.

Table A-12: Levelized cost of energy (LCOE) comparison between DERs and utility-scale projects.

LCOE ($/kWh)	DER (RMI Assumptions)		Utility-Scale (Public Data)	
	2024	2033	2022, Lagos IRP	Planned Projects[lii]
Solar (Lagos)	0.205	0.180	0.125[liii]	N/A
Solar (outside Lagos)	0.072	0.049	N/A	N/A
Solar (Central)	0.064	0.043	N/A	N/A
Solar (North)	0.058	0.039	N/A	N/A
Gas (South)	0.080	0.072	0.079–0.094[liv]	0.066[lv]
Gas (Central)	0.097	0.075	N/A	0.089[lvi]
Gas (North)	0.125	0.080	N/A	N/A

[lii] Projects that are planned to come online in the next decade (Egbin phase II and Gwagwalada IPP).
[liii] IRP combines rooftop and utility-scale and does not differentiate costs between the two.
[liv] Depending on turbine type (CCGT or GT) and fuel type (pipeline or LNG).
[lv] Egbin phase II CCGT.
[lvi] Gwagwalada IPP, CCGT.

Appendix K: Impact of deploying utility-enabled DERs

Calculation Methodology

The calculation methodology for the results discussed in **Section 4.3** is described below:

ATC&C Loss Reduction

1. ATC&C losses for areas of the DisCo's distribution network, where utility-enabled DERs have reduced ATC&C losses through distribution network improvements and increased metering penetration, were conservatively estimated at 9.75% (95% billing efficiency and 95% collection efficiency). These areas can be referred to as DER service areas.
2. It was assumed that non-DER service areas (i.e., parts of the distribution network where ATC&C losses are not improved by utility-enabled DERs) remain at the DisCo's current ATC&C loss levels.
3. The DisCo's overall ATC&C loss level was then calculated by finding the weighted average of ATC&C losses in DER service areas and non-DER service areas.

Energy Sales Revenue Increase

1. Using TCN capacity growth projections and the Roadmap modeling results, the amount of energy each DisCo is expected to purchase from the national grid for sale to customers in 2033 was estimated.
2. DisCos' revenue under a *Business-as-Usual (BAU)* scenario was calculated by multiplying this amount of energy purchased from the grid by the DisCo's average tariffs across the network and accounting for ATC&C losses.
3. DisCos' average tariffs are based on NERC's approved tariffs for DisCos from 2024 to 2027 published in the DisCo's 2024 MYTO order.[80] A 1% growth in tariffs was assumed from 2028 to 2033 based on the estimated growth in tariff from 2025 to 2027.
4. Revenue under the *Base Case DER* scenario was calculated similarly, with the addition of revenue from DUOS charges to DER developers. DUOS revenue was estimated by multiplying each DisCo's tariff (from their MYTO model) by the amount of energy sold by DER developers that is subject to DUOS charges.

Reduction in Annual Customer Energy Spending

The reduction in customer energy costs assumes that the electricity supplied by DERs displaces fossil-fueled self-generation. The total amount of energy consumed in the *BAU* scenario and the DER *Base Case* scenario was therefore assumed to be the same, and the amount of energy from DERs was assumed to be equal to the amount of energy from fossil-fueled self-generation. Using this assumption, the reduction in customer energy costs was calculated using the following approach:

1. Business-as-usual customer costs were estimated by summing the cost of fossil-fueled self-generation and the cost of energy purchased from the main grid. The cost per unit of fossil-fueled self-generation is estimated at ₦300/kWh.
2. Energy costs for the *Base Case DER* scenario were estimated by summing up the cost of energy from the DERs and the cost of energy purchased from the main grid. The cost per unit of electricity from the DERs is estimated at ₦200/kWh.

Reduction in Climate Pollution

Climate pollution for the *BAU* scenario was estimated using average grid carbon intensity of 442g CO_2e/kWh and the total diesel consumption calculated above, assuming an average carbon intensity of 870g CO_2e/kWh — which assumed a mix of 10% small, 45% medium, and 45% large diesel generators and carbon intensities of 1,580, 883, and 699 respectively.[81] In the *Base Case DER* scenario, it was assumed that climate pollution happens only from the grid, with the same carbon intensity, and gas DER projects. Gas carbon intensity was assumed at 553 gCO_2e/kWh and scaled based on the quantity of gas generation provided by the HOMER optimization.[82]

Table A-13 Inputs for impact analysis of deploying utility-enabled DERs.

Input	Unit	AEDC	BEDC	EKEDC	IE	KEDCo	Source
Average tariff across DisCo	₦/kWh	63.2	60.1	59.5	56.9	58.8	2024 NERC MYTO Order
Cost of energy from the grid	₦/kWh	70.6	70.6	70.6	70.6	70.6	2024 NERC MYTO Order
BAU average billing efficiency	%	73%	86%	88%	87%	70%	NERC Quarterly Report (Q3 2023)
BAU average collection efficiency	%	81%	67%	84%	98%	68%	NERC Quarterly Report (Q3 2023)
BAU ATC&C loss	%	40%	42%	26%	15%	52%	NERC Quarterly Report (Q3 2023)
DUOS charges	₦/kWh	16	17	15	14	16	Provided by DisCo
Average DER tariff	₦/kWh	200	200	200	200	200	RMI estimate
Average fossil-fueled self-generation tariff	₦/kWh	300	300	300	300	300	RMI estimate (conservative)
Percentage of DER energy subject to DUOS charges	%	50%	70%	30%	30%	70%	Estimated based on expected business model mix
Energy Mix by Source (Base Case 2033)							
Solar PV	GWh	5,149	2,739	1,180	1,740	1,340	RMI modeling
Gas	GWh	2,050	2,160	2,080	2,700	176	RMI modeling
TCN	GWh	8,230	4,650	8,510	10,100	3,880	RMI modeling

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