Unlocking Renewable Embedded Generation in Nigeria

Report / September 2022

Authors

Authors
Olamide Edun, Lion's Head Global Partners
Osa Imoukhuede
Ola Okeowo
Wayne Omonuwa
Ighosime Oyofo, Lion's Head Global Partners
Sakhi Shah

Authors listed alphabetically. All authors from RMI unless otherwise noted.

Contributors
The authors thank the following individuals for their meaningful contributions:
Suleiman Babamanu, RMI
Olamipo Ogunsanya, Lion's Head Global Partners
James Sherwood, RMI

Contacts
Suleiman Babamanu, sbabamanu@rmi.org
Osa Imoukhuede, oimoukhuede@rmi.org
Wayne Omonuwa, womonuwa@rmi.org

Copyrights and Citation
Osa Imoukhuede, Wayne Omonuwa, Ola Okeowo, Sakhi Shah, Olamide Edun, and Ighosime Oyofo, *Unlocking Renewable Embedded Generation in Nigeria*, RMI, 2022, **https://rmi.org/insight/unlocking-renewable-embedded-generation-in-nigeria/**.

Acknowledgments

UK PACT
GREEN RECOVERY
CHALLENGE FUND

This report is based on a feasibility study supported by a grant from the UK Partnering for Accelerated Climate Transitions Program (UK PACT). UK PACT is a £60 million flagship program under the International Climate Finance (ICF) portfolio. It is part of the United Kingdom's £5.8 billion commitment to ICF by 2021 to tackle climate change.

UK PACT's mission is to support partner countries to increase their ambition to tackle climate change and accelerate their own clean growth transitions; to increase the capacity and capability of partner countries to meet those raised ambitions and reduce their emissions through providing the relevant skills and funds; and to help countries to reduce harmful carbon emissions and alleviate poverty, unlocking opportunities in the global net-zero economy.

The authors thank the following individuals and organizations for offering their insights and perspectives on this work:

Saheed Busari, Ibadan Electricity Distribution Company
Raymond Eromosele, Viathan Engineering Limited
Opeyemi Folayan, Eko Electricity Distribution Company
Fatima Haliru, Ikeja Electric
Omosede Imohe, Abuja Electricity Distribution Company
Murtala Jinadu, Ibadan Electricity Distribution Company
Collins Obi, Abuja Electricity Distribution Company
Mide Popoola, Viathan Engineering Limited
Sam Rea, UK Ofgem
Obianuju Ukwueze, Ikeja Electric
Michael Uvere, Eko Electricity Distribution Company
Abdulmutalib Yussuff, UK Partnering for Accelerated Climate Transitions

About Us

About RMI

RMI is an independent nonprofit founded in 1982 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 greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

About Lion's Head Global Partners

Lion's Head Global Partners (LHGP) is an investment bank operating across frontier and emerging markets globally. LHGP provides tailored and innovative financial solutions by leveraging its global relationships and networks and local market understanding to deliver the best financial solutions to diverse challenges.

Contents

Executive Summary

Embedded generation gives Nigerian electricity distribution companies (DisCos) the opportunity to improve their supply of electricity to customers independent of the problematic national grid while maintaining control of their franchise areas. The renewable embedded generation (REG) business model described in this report enables DisCos and developers to collaborate to deliver improved electricity services to customers through embedded generation.

Despite its potential, the growth of embedded generation in Nigeria has been limited, mostly due to concerns about DisCos' ability to pay for electricity purchased. As a result, existing embedded generation business models in Nigeria either involve energy project developers supplying DisCos with excess electricity from generation assets built for another purpose (e.g., on-grid generation plants with excess capacity, captive generation plants, or minigrids) or a developer supplying a distribution network not operated by a DisCo (e.g., through an independent electricity distribution network or a sub-franchising agreement).

Although these business models allow developers to reduce the risk of DisCo nonpayment, they have limited scalability. Through their franchises, DisCos have the exclusive right to supply electricity to most areas of the country and therefore alternative electricity suppliers can only supply areas where the DisCo does not currently operate or where the DisCo grants them permission to supply customers.

The REG business model improves supply for customers by combining solar photovoltaic (PV), battery storage, and thermal generation. Through the inclusion of solar PV, the REG plant increases supply for all customers in the REG customer cluster while the inclusion of battery storage and thermal generation enables the provision of 24/7 reliable power to a subset of customers called premium customers. The model addresses the concerns of DisCo nonpayment by directing REG customer payments into an independent collections account (ICA). The ICA uses customer meter numbers to identify customers on REG feeders and directs their payments into a separate account that is not directly managed by the DisCo.

Providing additional generation to DisCos increases their electricity sales and therefore their revenue. In addition, the REG business model provides DisCos with capital to improve their distribution network and meter their customers, reducing their losses and improving their profitability. Furthermore, by charging customers cost-reflective tariffs, the REG business model boosts DisCos' profitability. Finally, the REG model also helps DisCos prevent premium customers from defecting from the grid while bringing back those who may have already defected.

The REG business model also reduces electricity costs for customers compared with their current mix of grid supply and self-generated electricity. Premium customer costs can be reduced by up to 50%, while nonpremium customer costs are reduced by 20%–30%. For developers, the REG business model provides access to a larger customer pool, a de-risked structure for collaborating with DisCos, and access to funding from climate-focused financiers.

To implement a DisCo-initiated REG project, the DisCo will have to identify and analyze potential REG clusters to select an appropriate location, prepare the project for developer procurement by collecting data and engaging customers, and conduct a rigorous process of developer procurement to select a qualified developer to implement the project. After a developer has been selected, both parties will negotiate contracts; conduct project development activities such as collecting detailed data, designing the REG solution, and obtaining land; construct and test the REG solution; and operate the generation and distribution assets as required to ensure customers have improved supply.

For successful project implementation, the DisCo and the developer need to work together to collect and analyze accurate data on customer electricity demand, customer population within the REG cluster, commercial data on electricity consumption and DisCo revenue in the cluster, distribution network data, and demographic data. By collecting data across these categories, the developer and the DisCo will be able to accurately size the REG system, estimate financial returns for the project, determine which distribution network upgrades are required, and ensure that the project is designed to meet the needs of all customers.

DisCos, developers, electricity users, investors, and regulators can work together to support the REG business model to contribute to improving electricity service delivery in Nigeria. To do this, demonstration projects that can showcase the model and test the business model concepts will need to be executed. The document templates used for the REG demonstration projects need to be standardized within the industry and widely disseminated for scaling. Finally, the lessons from the demonstration projects should be captured and shared widely with stakeholders to improve the design of future projects.

Introduction

Embedded generation is electricity generation that is connected at the distribution level rather than at the transmission level. This gives Nigerian electricity distribution companies (DisCos) the opportunity to improve their power supply to customers independent of the national grid. Given the well-documented generation and transmission challenges on the Nigerian national grid, this option is valuable for DisCos, particularly in areas with high concentrations of commercial and industrial (C&I) customers who need reliable electricity and are likely to disconnect from the grid if DisCos cannot guarantee reliability.[1]

Although Nigeria enacted a regulation enabling embedded generation in 2012, growth has been limited.[2] Concerned about DisCos' ability to pay for electricity purchased and the poor state of the network infrastructure, energy project developers have been wary of starting embedded generation projects to sell electricity to DisCos.

Exhibit 1 Comparing embedded generation to other distributed energy resource (DER) models

	Embedded generation	Franchising	DisCo-enabled C&I	Interconnected minigrids	Off-grid minigrids
Does the DisCo maintain a direct relationship with its customers?	✓	X	✓	✓	N/A
Is the DER connected to the distribution network?	✓	✓	✓	✓	X
Are a group of customers served as a cluster?	✓	✓	X	✓	✓
Can the generation capacity be larger than 1 MW?	✓	✓	✓	X	X

Source: RMI

The few existing embedded generation projects in Nigeria are fossil fuel based.[3,i] However, steep cost declines for renewable energy technologies such as solar photovoltaic (PV) modules and lithium-ion batteries — both declined in cost by about 90% between 2010 and 2020 — have made them viable options for embedded generation projects.[4]

---

i The majority of fuel-based embedded generation projects are not procured by DisCos. Instead, they are procured by developers supplying C&I customers.

By reducing fuel consumption, these technologies can decrease the overall cost of embedded generation projects and limit exposure to volatile fossil fuel prices. Additionally, as investors increasingly seek to align their investment portfolios with net-zero targets, funding for renewable energy projects is becoming more accessible.

To catalyze the growth of embedded generation in Nigeria, UK Partnering for Accelerated Climate Transitions (UK PACT) funded RMI and Lion's Head Global Partners (LHGP) to collaborate with a group of core partners to develop the Renewable Embedded Generation (REG) project. Those partners are Abuja Electricity Distribution Company, Eko Electricity Distribution Company, Ibadan Electricity Distribution Company, Ikeja Electric, the Lagos State Government Ministry of Energy and Mineral Resources, and Viathan Engineering Limited.

In this project, RMI, LHGP, and the core partners developed the REG business model, created a replicable data-driven methodology for identifying and prioritizing REG projects, and prepared pilot projects with partner DisCos for implementation. Throughout the project, the business model was shared with a broad group of electricity sector stakeholders to gather feedback and improve the model design, including the Nigerian Electricity Regulatory Commission (NERC) to ensure regulatory compliance and support for the business model.

This report aims to share the REG business model with the broader electricity sector. It provides:

- A summary of the problem the REG business model is intended to solve and how it differs from existing embedded generation business models
- A description of the REG business model and detailed explanations of its key innovative features
- The benefits of the REG business model to critical stakeholders
- Critical considerations for implementing the business model

The Need for the Renewable Embedded Generation Business Model

The Existing Situation

The Nigerian national grid falls short of providing reliable electricity supply to consumers due to problems across all segments of the electricity value chain. At 12.5 GW, the installed generation capacity is less than half the estimated peak customer demand.[5] Worse, much of this installed generation capacity is usually unavailable or goes unutilized due to gas supply constraints. Consequently, Nigeria's peak generation is only 5.8 GW.[6] The transmission network only has a wheeling capacity of about 7.5 GW — less than the installed generation capacity — and due to its radial network and outdated infrastructure, grid outages are frequent.[7]

In 2022, the national grid experienced numerous system collapses.[8] In 2020, aggregate technical, commercial, and collection (ATC&C) losses in the distribution sector averaged 49% across all DisCos and up to 78% for some DisCos due to outdated network infrastructure, rampant energy theft, and low metering levels.[9] This compounds Nigeria's generation and transmission problems. Due to the high losses, DisCos cannot pay for electricity purchased from the national grid, limiting the funding available to the generation and transmission sectors.

As a result of these problems across the sector, many electricity users have to supplement their power supply with self-generation, mainly through inefficient, noisy, and polluting diesel or petrol generators. There are 14–42 GW of distributed diesel generators in Nigeria.[10]

> **DisCos lose revenue and electricity costs increase for customers due to the high cost of self-generation. Additionally, the defection of customers like these from the grid reduces cross-subsidization of residential and small and medium-sized enterprises by these large C&I customers, increasing tariffs for residential customers and SMEs.**

Many customers, mainly C&I, are willing and able to pay for reliable power. However, because DisCos cannot meet this need, these customers have completely or partially defected from the grid and rely on self-generation — usually from diesel generators but increasingly from solar PV DER systems or gas generators — for reliable power. For example, in 2022, Lagos Business School, a large C&I customer, secured funding to reduce its soaring operating electricity costs by installing solar PV. [11] Meanwhile, Nigerian Breweries PLC signed an agreement to outsource critical power loads for its breweries in Kaduna using renewable energy.[12]

When this happens, DisCos lose revenue and electricity costs increase for customers due to the high cost of self-generation. Additionally, the defection of customers like these from the grid reduces cross-subsidization of residential and small and medium-sized enterprises (SMEs) by these large C&I customers, increasing tariffs for residential customers and SMEs.

The Unfulfilled Potential of Embedded Generation

NERC developed the 2012 Embedded Generation Regulation to enable DisCos to take advantage of the potential that embedded generation offers, but uptake in Nigeria has been slow, with only a handful of embedded generation projects currently operating.

The primary reason for this, according to discussions RMI has had with DisCos, developers, and investors, is concerns among energy project developers about DisCos' ability to pay for electricity supplied. As discussed above, DisCos' high ATC&C losses lead to liquidity issues that limit their ability to fulfil their obligations to suppliers and make additional investments to their infrastructure. Given these concerns, existing embedded generation business models in Nigeria are designed to avoid or reduce the risk of DisCo nonpayment. No embedded generation projects in Nigeria are explicitly built to supply electricity to DisCos.

By bypassing the national grid's generation and transmission challenges and increasing the amount of electricity DisCos have available to sell to customers, embedded generation can help DisCos improve supply on their networks and prevent key customers from defecting.[ii] Because DisCos drive the procurement of embedded generation, the DisCo can ensure that this additional supply is developed in the areas where it will be most beneficial. Embedded generation can also improve reliability to other customers beyond the customers it directly supplies because electricity from the national grid that would have been initially supplied to those customers can now be redirected to other customers.

The Importance of DisCos' Ability to Off-Take Embedded Generation

Developers' reluctance to build embedded generation projects to supply electricity to DisCos is a rational response to the risk of DisCo nonpayment, but it restricts the scalability of embedded generation. Through their franchises, DisCos have the exclusive right to supply electricity to most areas of the country. As a result, alternative electricity suppliers can only supply areas where the DisCo does not currently operate or where the DisCo grants them permission to supply customers.

Exhibit 2 discusses existing embedded generation business models in Nigeria, how they limit the risk of DisCo nonpayment, and their scaling limitations.

ii Transmission challenges have contributed to grid collapses in Nigeria. These can be attributed to factors including vandalism or theft of transmission equipment, capacity constraints from the transmission substation, and aging national grid infrastructure.

Exhibit 2 Existing embedded generation business models in Nigeria

Business model	How it reduces DisCo nonpayment risk	Scalability limitations
Existing on-grid generator with excess capacity enters a bilateral agreement to sell electricity to a DisCo	For both business models, the generation plant was built for another purpose and is only supplying the DisCo from excess capacity that would otherwise have gone unused. Consequently, if the DisCo is unable to pay for electricity supplied, the developer can stop supplying the DisCo with no adverse effects on the expected returns from the project's main customer(s).	Because on-grid supply in Nigeria is inadequate to meet demand, there is a limited amount of excess supply on the grid. This excess supply is only available in certain areas or during specific periods, which is inherently unscalable.
Existing off-grid generator (e.g., captive or minigrid) with excess capacity enters a bilateral agreement to sell electricity to a DisCo		Similar to the first business model, excess off-grid capacity is only available in certain areas and at certain times, limiting its scalability. Given the distribution network's limitations, improvements are often required for supply from these sources to be integrated into the DisCo's distribution network, but DisCos are unable to invest in these improvements due to liquidity constraints.
Newly built embedded generation plant supplies customers through an independent electricity distribution network (IEDN)	In these business models, the developer supplies electricity to a distribution network not operated by a DisCo. As such, the nonpayment risk of supplying electricity to DisCos is eliminated.	IEDNs require regulatory approval, which is only granted under a restricted set of circumstances. Additionally, even when it is possible to obtain an IEDN license, the project may face right-of-way issues for construction of distribution lines.
DisCo cedes section of its network to sub-franchisee, sub-franchisee procures embedded generation for area		DisCos are unwilling to cede certain areas of their network to other parties, so the sub-franchising model can only be applied in a limited number of areas.

Source: RMI

The REG Business Model

To scale embedded generation in Nigeria, new business models must incentivize developers to build new embedded generation plants to supply electricity to DisCos by providing a mechanism to separate embedded generation project revenue from the DisCo's broader liquidity issues.

The REG business model is designed to achieve this. In this business model, a developer builds a renewable embedded generation plant that combines solar PV, battery storage, and thermal generation, and supplies electricity to the DisCo through this plant. The DisCo integrates the electricity supplied from the REG plant with supply from the main grid to increase supply for all customers within the selected customer cluster (see Exhibit 3).[iii]

By including battery storage and thermal generation, the embedded generation installation enables the DisCo to provide 24/7 reliability for a specific subset of REG customers called premium customers, while the solar PV generation increases daytime supply for all customers, including nonpremium customers.

Improvements to the distribution network need to accompany the introduction of additional generation through REG to provide customers with a reliable supply. To achieve this, the embedded generation developer will also fund distribution network upgrades and metering in the customer cluster to minimize distribution network outages. These upgrades will be carried out by the DisCo (or a chosen contractor) and be repaid from the DisCo's share of the REG project's revenue over an agreed-upon timeline between the DisCo and the developer.

Premium customers receive a higher level of service than nonpremium customers, so they pay a premium tariff.[iv] Nonpremium customers continue to pay the service-based tariff for the number of hours of supply they receive. Supply-level differentiation between premium and nonpremium customers is implemented by installing smart controls on the distribution network that can respond to commands from the network operator to disconnect supply to specific sections of the network.

Improving the Scalability of Embedded Generation

To address concerns about Nigerian DisCos' liquidity issues, the REG 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 requiring DisCos to enter escrow arrangements that tie up scarce capital.

---

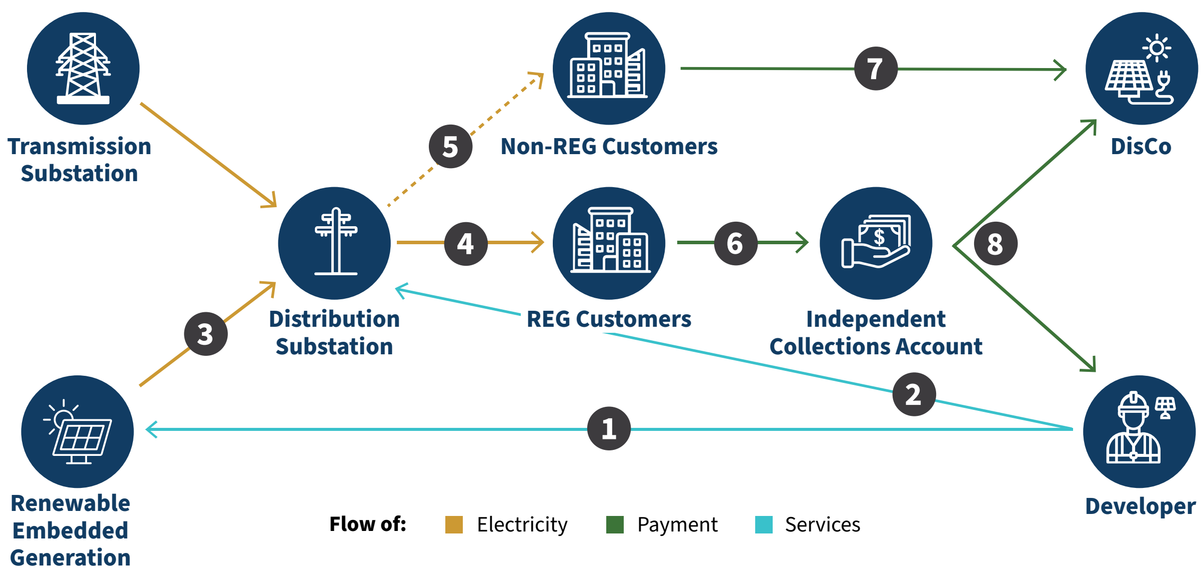
iii A REG customer cluster primarily refers to the group of customers selected to receive supply from the REG installation. In areas where customers are connected through 11 kV feeders, the cluster could be a section of an 11 kV feeder, a single 11 kV feeder, or a group of 11 kV feeders. Where customers are directly connected to 33 kV feeders, the cluster will most commonly be a section of the 33 kV feeder.

iv A premium tariff is a service-based tariff agreed upon between the DisCo and the customer in a power purchase agreement.

The ICA uses customer meter numbers to identify which customers are on REG feeders and directs their payments into a separate account that is not directly managed by the DisCo. At the end of each month, the ICA manager makes disbursements to the developer and the DisCo for electricity supplied.

Depending on the preferences of the developer and the DisCo, the ICA could be managed by a third-party contractor or a special-purpose vehicle (SPV) co-managed by the developer and the DisCo. See Appendix A for additional details on the ICA.

Exhibit 3 **The REG business model**



1. A developer builds a solar PV embedded generation plant to increase supply to the feeder along with enough battery storage and fossil fuel backup to guarantee 24/7 reliability to premium customers
2. The developer funds distribution network upgrades and metering
3. The REG interconnects at a distribution substation. Premium customers receive 24/7 supply; the hours of supply for nonpremium customers increase compared with current supply
4. A mix of REG electricity and electricity from the main grid is sold to REG customers at premium tariffs for premium customers and service-based tariffs for nonpremium customers
5. Excess electricity is sold to customers on non-REG feeders at service-based tariffs
6. Customer payments from REG-served feeders go into an ICA
7. Customer payments from non-REG feeders go into the DisCo's existing accounts
8. Disbursements are made from the ICA to the DisCo and the developer

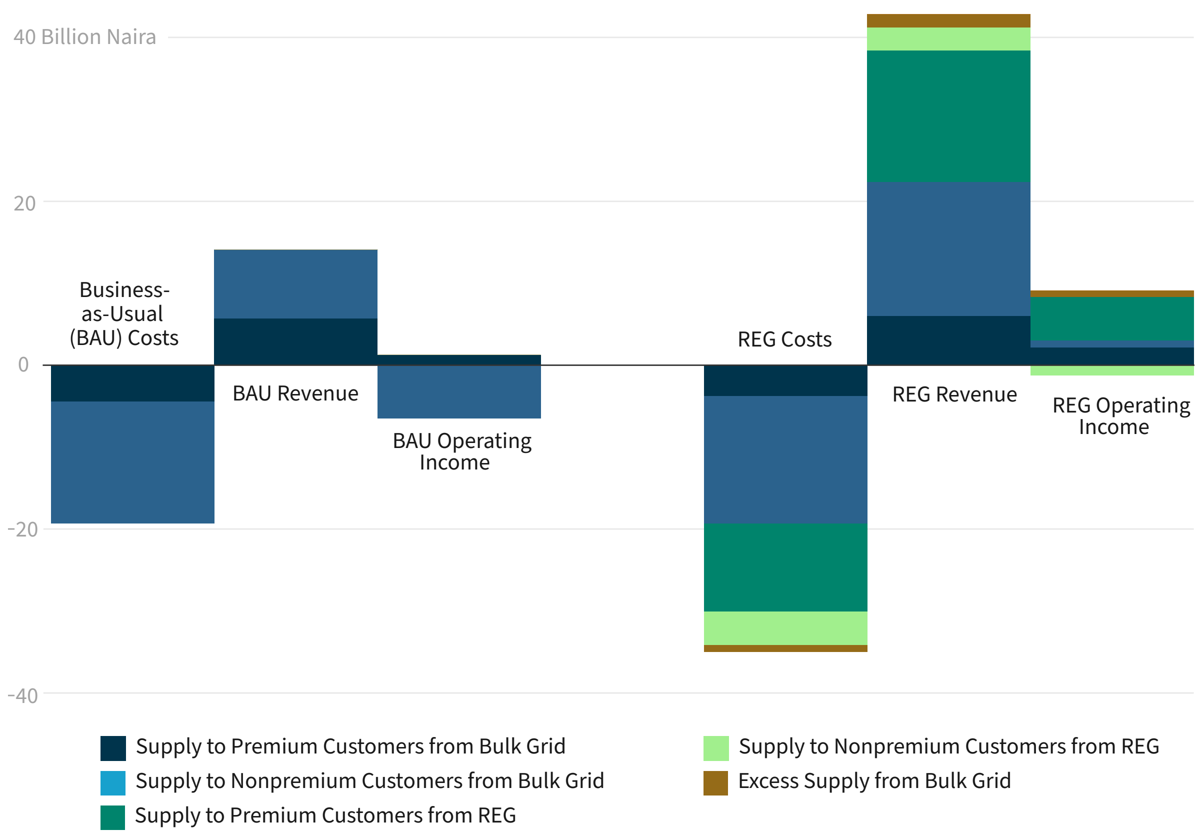
Benefits of REG for Participants

A Business Opportunity for Nigerian Distribution Companies

The REG business model provides many benefits to DisCos. By providing additional generation to DisCos, it increases their electricity sales and, therefore, their revenue. In addition, the REG business model provides DisCos with access to financing to improve their distribution network and meter their customers, thereby reducing their losses and improving their profitability. Also, by charging premium customers a premium tariff and improving supply for nonpremium customers (potentially moving them to a higher tariff band), the REG business model further boosts DisCos' profitability.

The REG model also helps DisCos prevent premium customers from defecting from the grid while bringing back those who may have already defected without requiring them to cede those customers to other service providers.

Exhibit 4 **Net present value (NPV) of DisCo operating income on an illustrative feeder improves with REG**



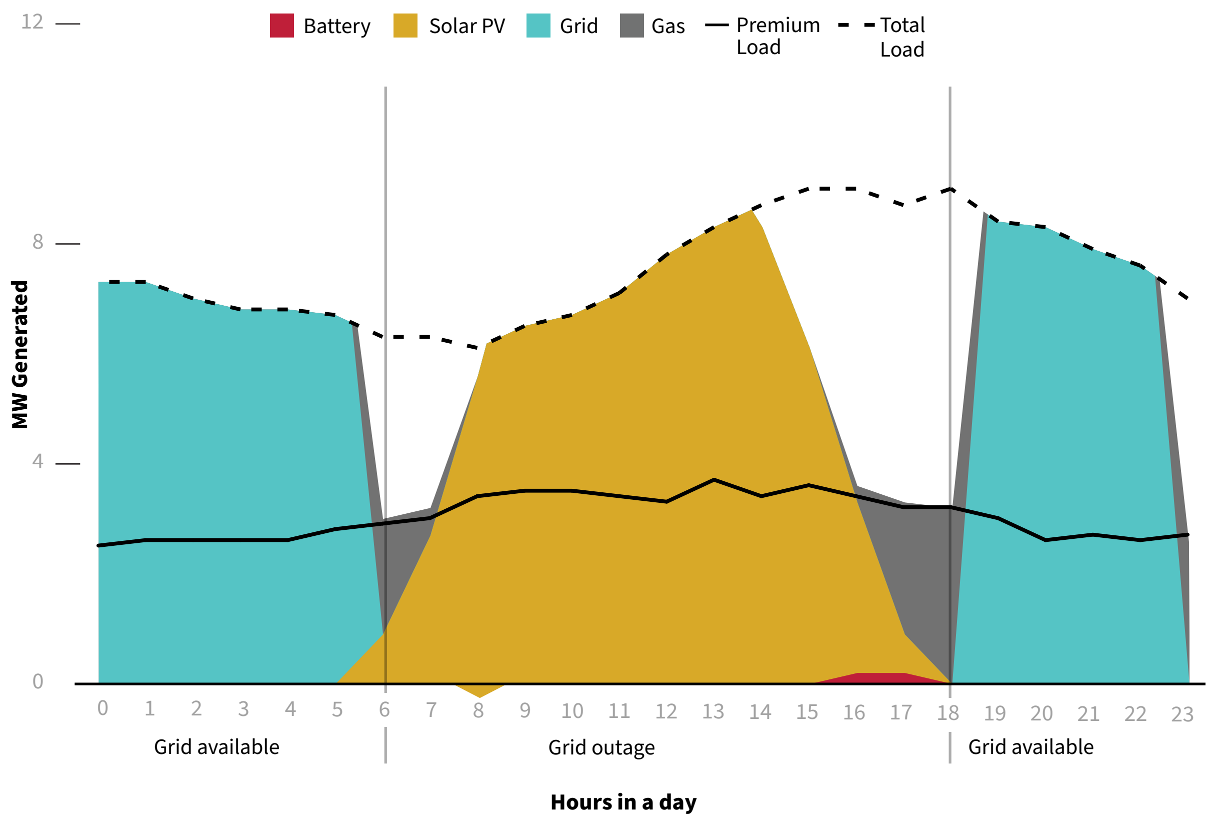
Source: RMI

Exhibit 4 shows how the REG business model improves DisCos' operating income compared with business as usual (BAU). This example uses an illustrative feeder on tariff band D with a peak load of 13 MW, assumed to have 30% premium customer load and 70% nonpremium customer load.[v] The REG system required to serve this feeder consists of 12.5 MW of solar, 2 MW of gas, and 0.5 MWh of lithium-ion battery storage.

Exhibit 5 shows the dispatch of REG on the illustrative feeder for a representative day, though grid outages are randomized in the model and happen at different times every day. Solar generation is used for all customers, while gas and battery storage are only used for premium customers to guarantee 24–hour reliability. More details on the modeling approach and assumptions are included in Appendix B.

The DisCo's initial BAU operating loss of 5 billion naira over 20 years on this illustrative feeder is improved to a positive operating income of 8 billion naira from implementing REG. Before REG, revenue collected from nonpremium customers was lower than the cost of serving them due to high ATC&C losses, which meant the DisCo was making a loss on the feeder. Grid upgrades and smart metering solutions significantly reduce these losses; however, DisCos still make a slight loss on nonpremium customers with REG because nonpremium customers remain on service-based tariffs, which are not cost-reflective of REG energy.

Exhibit 5 REG business model electricity dispatch on a representative day



Source: RMI

v Tariff band D corresponds to 8 hours of supply daily, on average.

The benefits of providing REG to premium customers make up for this: DisCos gain additional electricity sales at premium tariffs from REG, which replaces the self-generation that customers usually rely on during grid outages. Revenue also comes from excess grid energy due to ATC&C loss reduction, which can be redirected to other feeders.

Cost Savings for Commercial, Industrial, and Residential Customers

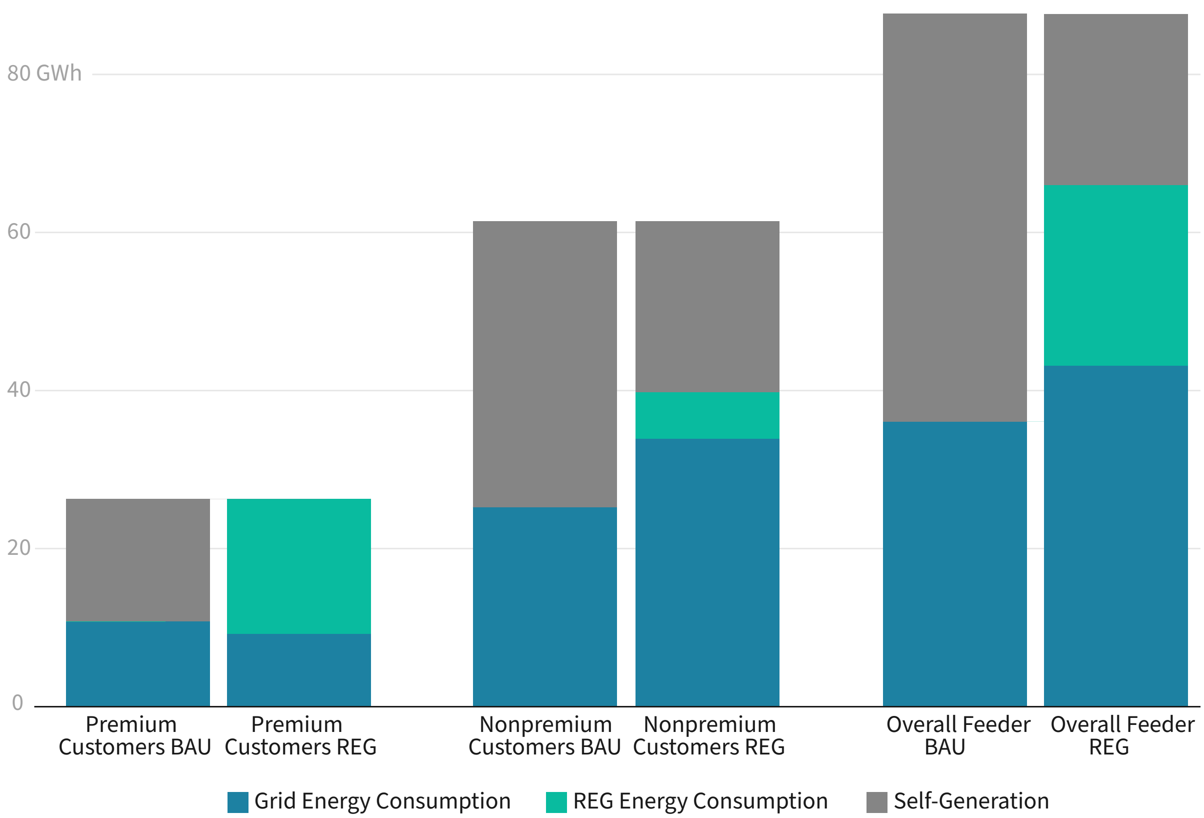
The REG business model reduces electricity costs for customers compared with their current mix of grid supply and self-generated electricity. Premium customers are expected to be large commercial, industrial, and high-income residential customers; these customers are willing to pay higher cost-reflective tariffs for 24-hour reliability. Nonpremium customers are expected to be small commercial and residential customers.

Premium customer costs decline by 40%–50% because the REG completely replaces self-generation (see Exhibit 6). This more than compensates for the tariff increase from service-based tariffs to a premium tariff of 90–110 naira/kWh, a blended tariff that includes grid and REG energy.

A reduction in self-generation, made possible by new REG supply and increased grid supply — from grid upgrades and ATC&C loss improvements — decreases costs for nonpremium customers by 20%–30% (see Exhibit 5). Therefore, these customers can avoid high diesel costs during some outages.

Although the REG is not designed to guarantee supply to nonpremium customers, when an outage occurs during daylight hours and if sufficient spare gas capacity is available for balancing, solar energy from the

Exhibit 6 **Customer energy consumption breakdown**



Source: RMI

REG can be used to supply nonpremium customers. Nonpremium customers are expected to have three to four more hours of supply per day from the grid and REG combined compared with the current grid supply, so they can be moved up from tariff band D to band C.[vi]

An Attractive Investment Opportunity for Developers and Financiers

The REG business model is an attractive investment opportunity for developers and financiers. The collaboration among all parties on the REG business model provides access to a larger customer pool for DER developers and greater investment opportunities for financiers. Currently most DER developers work on smaller projects for single customers or in areas where the DisCo is not operating. However, the REG business model allows developers to build larger projects that serve clusters of customers.

The clear definition of assets, cash flows, and customers will also lead to more confident investment in the REG business model, particularly as pilot projects demonstrate success. Customer usage data will become more valuable over time, allowing developers and third-party companies to leverage the data generated for additional services. With this increased visibility, potential investors can begin to regard the REG business model as substantially de-risked, helping to crowd in further investment and leading to faster and more widespread deployment across the country.

Additionally, the structure of the REG business model allows developers to charge a premium and cost-reflective tariff to provide customers with the optimal mix of reliability and power. Investors are, therefore, able to earn a sufficient return within the regulatory framework.

The REG business model also opens new investment opportunities for investors. As this business model becomes more established, and with continued assistance from regulators, there will be more opportunities for diversified investment strategies. DER developers will continue to grow and transition from smaller corporations requiring private bilateral or syndicated funding to larger institutions that can access the local capital markets (directly or through intermediaries), offering diversified investment opportunities to domestic institutional investors.

There is demonstratable demand from domestic and international investors for clean-energy projects that support the energy transition. This business model provides a viable avenue for climate-focused investors to deploy their funds toward larger-scale renewable energy projects. REG projects will have a positive impact on carbon reduction, given the model's focus on low-reliability areas and areas with a need to replace existing and expensive diesel self-generation. As a result, the economic and the impact cases are aligned.

vi Tariff band C corresponds to 12 hours of supply daily, on average.

Critical Considerations for Implementation

Implementation Actions

This section discusses the proposed process for implementing a DisCo-initiated REG project. Although projects can also be initiated by customers and developers, it is expected that most REG projects will be initiated by DisCos. This is because DisCos have the most information about which areas of their network are likely to benefit most from embedded generation and which areas have been targeted for other supply improvement initiatives.

The major steps for implementing a REG project are:

1. **Identify potential REG clusters:** The DisCo gathers and analyzes customer data to identify areas with significant commercial potential, as evidenced by high usage of self-generation, high demand for electricity, and a high presence of maximum-demand (MD) customers who can serve as premium customers. The DisCo then visits these short-listed sites to verify the initial data analysis and gather additional context for the area. Finally, if necessary, the DisCo demarcates the sections of the cluster that will be included in the REG project.

2. **Prepare the project for developer procurement:** The DisCo further develops the business case for implementing the REG project in the cluster to ensure that qualified developers can be attracted to participate in the procurement process. Successfully executing a REG project requires a developer with strong financial backing, appropriate technical expertise, and a solid track record of project execution. Such developers will only be interested if they are convinced the project is commercially and technically viable.

   As a result, the DisCo needs to collect information that will allow prospective developers to assess the project accurately by assessing the current state of the distribution network in the area, engaging potential premium customers to gauge their interest, gathering data for a preliminary financial analysis, and developing the internal processes for the operation of the ICA.

3. **Procure a developer:** This is a two-stage process. First, the DisCo issues a request for qualifications (RFQ) to identify a pool of prequalified developers, to whom it then issues a request for proposals (RFP). This process enables the DisCo to manage the provision of potentially sensitive data by ensuring that only developers prequalified through the RFQ process receive detailed data on the site. Additionally, it reduces the effort required to assess full proposals; only a smaller number of developers will get to the RFP stage, where they will submit full proposals.

   To reduce the time required for developer procurement, the DisCo can periodically issue RFQs not attached to a specific project so that it can move directly to issuing an RFP. An essential part of the RFQ/RFP process is making sure that developers have actionable gender equity and social inclusion (GESI) plans and monitoring and evaluation processes for these plans.

4. **Negotiate contracts:** Two key contracts or agreements govern the stakeholder relationships for a REG project: the embedded generation agreement between the DisCo and the developer and the power purchase agreement (PPA) between the DisCo and the premium customers. In this step, the DisCo negotiates these contracts with the developer and customers to ensure that stakeholders understand their roles and responsibilities, that all parties are happy with the allocation of duties, and that the operating framework for the project is clear to all parties. These agreements will cover issues such as the tariffs for electricity sales, expected levels of reliability, how the ICA will be managed, processes for resolving disputes between parties, and the allocation of risks.

5. **Develop the project:** The selected developer collects detailed data on the cluster so it can design a REG solution that meets customers' needs, identifies a suitable site to install the REG solution, begins the process of obtaining the land, and works to secure financing and any necessary regulatory approvals.

   Concurrently, the DisCo conducts grid integration studies to clarify how the embedded generation will interconnect with the distribution network, validate the initial distribution network assessment, and determine the operational adjustments required to facilitate differentiated supply levels for premium and nonpremium customers. Additionally, the DisCo builds staff capacity to ensure its employees can make the operational adjustments required by the REG business model and provides support to the developer as needed.

6. **Construct and test:** The developer builds and installs the REG system while the DisCo upgrades the distribution network. The developer funds the required upgrades, but they are carried out by the DisCo or a chosen contractor.

   For the REG project to operate as designed when fully launched, the REG system construction and the distribution network upgrades should be completed in phases. The REG system should be tested in a portion of the cluster before expanding operations to the whole cluster. Testing, evaluating, and refining the newly developed operational processes in a smaller, controlled area before implementing them more widely limits the consequences of any issues and minimizes potential customer dissatisfaction.

7. **Operate the project:** The developer and the DisCo operate and maintain the generation equipment and the distribution network, respectively, to supply energy to the customers.

If a developer initiates a project, it is responsible for the identification of potential REG clusters and project preparation, and developer procurement is skipped. The remaining steps are carried out similarly to the DisCo-initiated project guidelines, with the developer leading the project development and construction and testing steps.

If a customer initiates a project, the step of identifying potential REG clusters is skipped, and all other actions proceed as discussed.

A timeline of the implementation steps is included in Appendix E.

Data Collection

Successfully implementing a REG project requires the DisCo and the developer to collect and analyze detailed and accurate data on the REG cluster. This ensures that the developed REG solution will meet the customers' needs and allows participating parties to estimate the expected benefits of participating in the REG project.

Five types of data are required for implementation:

- **Electricity demand data:** Customer demand data is essential for accurately sizing the REG solution. Undersizing can lead to outages, and oversizing can lead to poor financial returns. When the project is operating, monitoring customer demand enables network operators to analyze customer electricity consumption trends and identify additional generation needs.

- **Customer population data:** Data on the size and composition of the customer base in the REG cluster enables accurate estimation of revenue, metering costs, and potential load growth.

- **Commercial data:** This refers to data on customer electricity consumption, tariffs, ATC&C losses, and the ability to pay for electricity. Customer commercial data helps to validate financial modeling and estimate the financial value that can be unlocked by loss reduction. Additionally, continuing to collect this data while the project is operating will enable the measurement of the REG project's impact on the DisCo's commercial performance.

- **Distribution network data:** By collecting data on distribution network issues, the location of these issues, and their impact on network operation, the DisCo and the developer can accurately estimate the cost of addressing network issues. By monitoring the distribution network when the project is operational, losses, energy theft, and faults can be identified quickly and rectified as soon as possible.

- **Demographic data:** Data on income, gender, age, disabilities, and more for customers in the REG cluster can be used to measure the REG project's impact on different customer groups, particularly marginalized groups. This data can be used to establish a baseline of the demographics in the cluster and ensure that marginalized groups are identified, and their needs are accounted for in the project's design. In the operation stage, continued data collection is required to measure the impact of the REG project on marginalized groups.

See Appendix F for more details on the data required for the initiation, development, and operation of a REG project.

The Path Forward

Stakeholders have an excellent opportunity to use the REG business model to help close the energy access gap in Nigeria. DisCos, developers, financiers, government and regulators, and other sector enablers can work together to make this happen for the benefit of all. The existing embedded generation regulation allows stakeholders to implement the business model immediately by following these steps:

- **Execute demonstration projects:** Demonstration projects are necessary to prove the case for the REG business model. To accomplish this, demonstration projects need to move toward construction and financing. DisCos and developers need to undertake good-faith efforts to test demonstration projects and fully understand the opportunity presented. Initial pilot projects have also been designed to be independently viable and sufficiently sized to be attractive as stand-alone financing opportunities to investors seeking carefully managed early-stage development risk within the sector.

  The key to unlocking the demonstration projects is identifying sources of equity, or junior equity, which can serve as a de-risking mechanism for projects by taking a first-loss position and can help crowd in additional equity or even junior debt. This would be different from a typical grant in that it still has the expectation of a return, albeit a much lower one, and is in place to help prove the commercial viability of the demonstration projects. Junior equity can help create a pathway toward more sustainable financing, particularly once investors gain more comfort with the business model and the returns from the demonstration projects.

- **Standardize document templates:** Document templates used for REG demonstration projects need to be standardized within the industry and widely disseminated for scaling. During the demonstration projects, developers and DisCos can prepare these and incorporate lessons learned. Some of these documents include the RFQ and RFP used during procurement of a developer, contracts between the developer and the DisCo, and contracts between the DisCo and premium customers. Financial models are needed to calculate indicative investor returns with all standard inputs to the model.

- **Share lessons from demonstration projects:** Lessons learned from the demonstration projects need to be captured and shared with all stakeholders within the industry. Operations insights should be collected and analyzed for the demonstration projects. This operational data can offer insights into the projects' operations and identify areas where operational performance can be improved in future projects. This can be done through a REG installation register that will contain the location and details of demonstration REG projects, provide project visibility to stakeholders, and facilitate lesson learning from the demonstrative projects.

How REG Can Progress Gender Equity and Social Inclusion

DisCos need to consider GESI when assessing the customers who will benefit from REG. Women and marginalized groups are disproportionately affected by lack of access to energy. REG and similar projects should try to bridge this gap by focusing on affordability and access. The REG business model addresses the need for affordability by including nonpremium customers who stay on service-based tariffs but benefit from grid upgrades, metering, and improved supply, which premium customers subsidize. Additionally, REG will benefit marginalized communities and contribute to a just energy transition by providing employment opportunities for members of marginalized communities in the construction and operation of REG projects.

Initial data collection for REG customer clusters should be sex-disaggregated and focus on diverse customer segments and their energy needs during project development. The project is an opportunity to empower women in the selected communities, which can lead to economic growth and improve quality of life for women and their families.

Also, the energy sector remains male-dominated, with few women in leadership, technical, and supervisory positions. Research suggests that integrating women into all stages of the energy value chain leads to more effective and efficient clean-energy initiatives, unleashes greater return on investments, and expands emissions reduction opportunities.[13] GESI considerations should be included in the initiation, development, construction, and operation phases of the REG project.

Initiation phase:

- Encourage women-led developers to bid by directly advertising the procurement to female-focused energy groups.
- Include the percentage of women staff as a metric when assessing developers' bids.
- Require developers to have a gender equality/gender-based violence officer.
- Require capacity building around skills and jobs for women and other marginalized groups in the bid criteria.

Development phase:

- Collect data prioritizing diverse groups to ensure all perspectives are considered, including women, young people, and other groups marginalized by disability, occupation, religion, or ethnicity. Consult with community leaders and women's organizations.
- Conduct an environmental and social impact assessment during site selection to determine the effects of the generation plant on women and children in the area and explore opportunities for equity and inclusion measures.

Construction phase:

- Collect data related to skills development, employment opportunity, and customer-related aspects to ensure customer-centric energy services delivery.
- Provide skills training for women and youth to benefit and play roles in the construction and operation of REG.
- Maintain constant community engagement throughout the project lifetime.
- Provide hands-on learning opportunities for women engineers. An on-site training program can be designed to enhance their exposure to the construction and operation of energy systems and aid their professional growth. This will help create an entry point for women in the communities and beyond to gain valuable exposure to career pathways in the energy sector.
- To combat sexual exploitation and abuse at the worksite and community level, build in measures to ensure women and girls are safe at construction sites, including transport, codes of conduct, and sharing details on age-of-consent agreements with employees on site.

Operations phase:

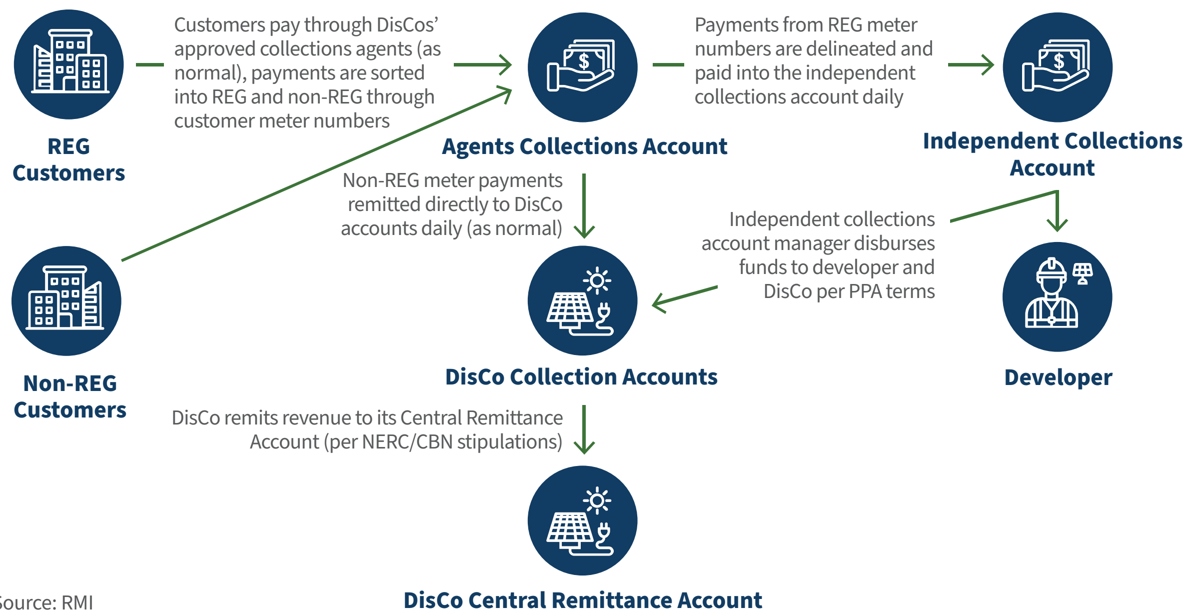
- Train women and vulnerable groups in operational processes such as maintenance, security, and customer care.
- When hiring operational staff, focus on women’s employment and other social inclusion measures. Use language encouraging women candidates, set targets, and approach women's professional associations to identify talent.
- Design customer care and payment methods with a consumer-centric focus, prioritizing affordability, usability and accessibility, transparency, customer care, and safety, in line with processes already familiar to communities. Consult with community leaders, women’s groups, and members on the design of these processes.
- Explore roles for community members in service delivery and bill payment, such as energy theft reduction through community mobilization.
- Document various GESI outcomes and impacts, such as time poverty reduced, income enhanced for women-led enterprises, and jobs created.

This list is not exhaustive and will vary by context but provides an overview of how equity can be integrated into a REG project throughout its lifetime.

Appendices

Appendix A: The Independent Collections Account

Exhibit A1 **How the ICA can leverage DisCos' existing collections processes**



Source: RMI

Appendix B: Modeling Approach

This approach was used to estimate the costs and benefits of REG for customers, DisCos, and developers:

1. Use HOMER Pro software to size the REG system's solar, gas, and batteries using load data from DisCos and resource cost estimates.
2. Calculate the developer PPA tariff needed to recover costs for the REG system in line with the developer's target internal rate of return (IRR).
3. Calculate customer tariffs by adding the DisCo distribution use of system (DUOS) cost, grid upgrades, and metering costs to the developer PPA tariff.
4. DisCo costs come from the developer PPA, and DisCo revenues come from the customer tariff and DUOS.
5. Grid upgrade and metering costs are passed on to premium customers.

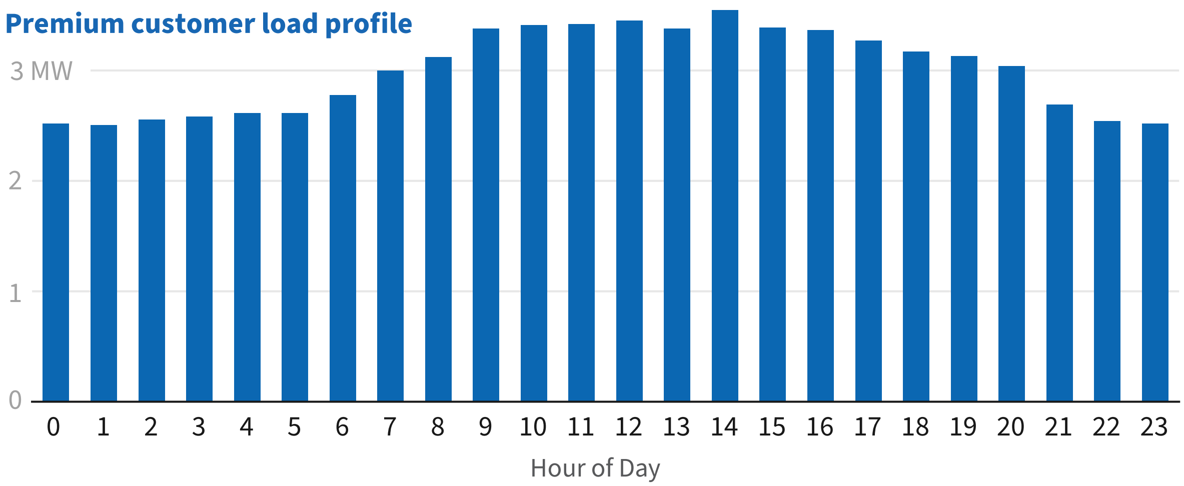
Appendix C: Customer Assumptions for an Illustrative Example

Generic Analysis Load Profile

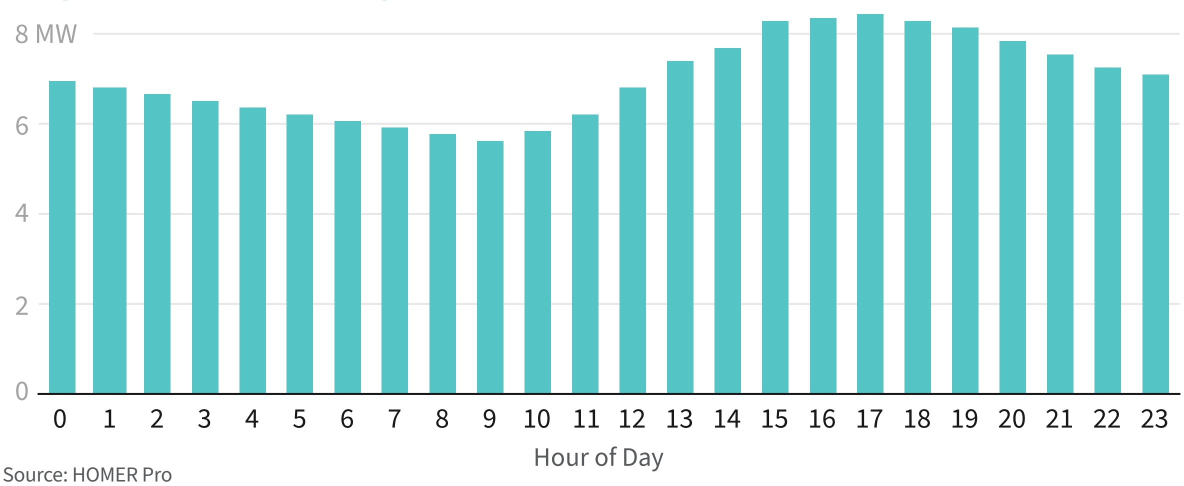
Premium and nonpremium load profiles were created using generic data for industrial, commercial, and residential customers. The illustrative feeder load profiles used to size the REG system are shown in Exhibit A2.

Exhibit A2 **Average daily load profiles for premium and nonpremium customers on REG feeder**

Premium customer load profile



Nonpremium customer load profile



Source: HOMER Pro

Customer Segmentation

It was assumed the illustrative feeder has 100 MD premium customers and 3,000 non-MD customers who are nonpremium customers in the REG model.

ATC&C Loss Estimates

On the illustrative feeder, we assume MD customers initially have 100% billings efficiency and 95% collections efficiency, which increases to 98% with REG. We assume non-MD customers initially have 70% billings and collections efficiency, increasing to 90% with REG.

Appendix D: Cost Assumptions for an Illustrative Example

We use the assumptions in Exhibit A3 for the illustrative example. These assumptions were gathered from conversations with partners and public reports.

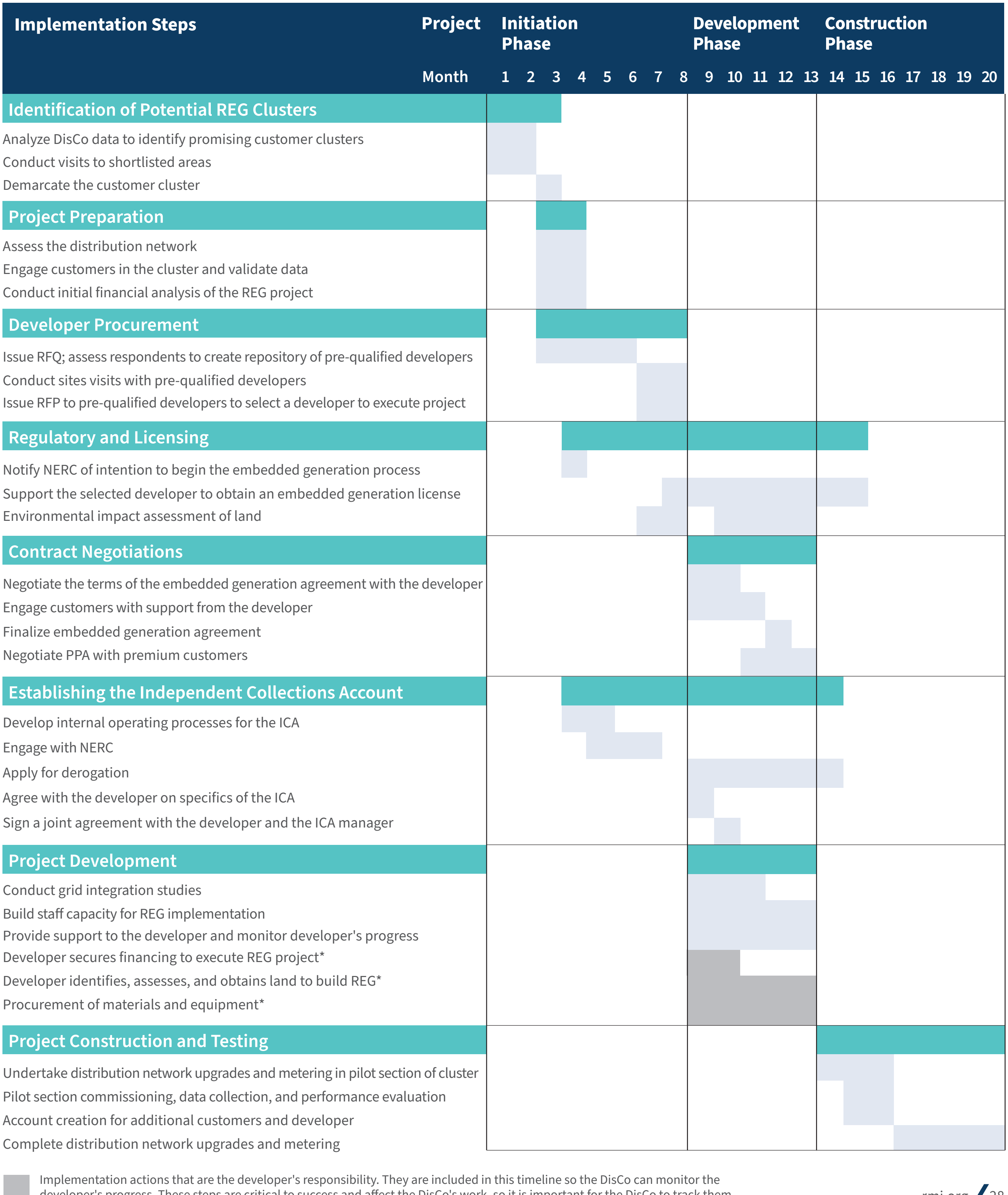
Exhibit A3 Assumed costs in the illustrative example

System costs		Source
Solar PV capex, including inverter, mounting structure, installation and civil works, balance of system (lifetime = 25 years)	US$670/kW	Conversations with DER developers
Lithium-ion battery capex (lifetime = 7 years)	US$300/kWh	
Solar charge controller capex	US$200/kW	
Gas capex (lifetime = 80,000 hours)	US$800/kWh	
Solar PV fixed operations and maintenance (O&M)	US$10/kW-y	
Lithium-ion battery fixed O&M	US$3/kWh-y	
Gas fixed O&M	US$0.10/kW/h	
Grid upgrades, metering costs (includes new smart meters for customers)	370M naira	
Fuel costs		
Diesel	600 naira/liter[vii]	National Bureau of Statistics
Gas	140 naira/m^3	
Financial inputs		
Exchange rate (5% annual increase)	500 naira/US$	RMI assumptions based on conversations with DER developers
Escalation rate for fuel costs, service-based tariffs, REG PPA, and REG customer tariffs	5%	
Length of contract	20 years	
Developer IRR target used to set PPA price	22%	

vii The cost of diesel in Nigeria has increased above 800 naira/liter since the analysis was completed. However, this assumption was maintained as it provides a more conservative assumption for customer savings. Incorporating the new diesel costs will increase the attractiveness of the REG model compared with self-generation.

Appendix E: REG Project Implementation Steps

Exhibit A4 Timeline for REG implementation



Appendix F: Data Methodology

Exhibit A5 **Project initiation phase**

Data Category	Data Item	Relevance to REG Project Implementation
Electricity Demand Data	**Peak customer demand** (i.e., the highest recorded hourly electricity demand for the customer cluster).	Customer demand data supports accurate sizing of REG equipment, which prevents over/undersizing and ensures the project can meet customer demand while providing attractive financial returns to the developer and investors.
	Hourly electricity demand in the customer cluster. This should be collected over a minimum period of seven days.	
Customer Population Data	**Total number of DisCo customers in the customer cluster.**	Customer numbers help developers estimate the financial potential of a prospective embedded generation area.
	Number of MD and non-MD customers in the customer cluster.	This can be used to estimate the number of premium and nonpremium customers and will support accurate financial modeling.
	Number of metered and unmetered customers in the customer cluster.	This will help estimate metering costs.
	Number of defected and unconnected MD customers in the cluster. This refers to MD customers within the cluster who were previously connected to the DisCo's supply but have since disconnected due to dissatisfaction with the level of supply or those who have never been connected to the DisCo's supply.	This data helps with estimating the correct number of premium customers in the cluster and allows the selected developer to target these MD customers for customer engagement during the development phase.
Commercial Data	**Total monthly grid energy consumption by MD and non-MD customers in the cluster.**	This data can be used to estimate billing and collection losses as well as to validate estimates of the size of the financial opportunity.
	Total monthly amount billed and collected for energy consumed by MD and non-MD customers in the cluster.	
Distribution Network Data	**List of issues on the distribution network** that prevent the network from having maximum uptime. This can include undersized conductors, faulty equipment, or vegetation that results in tripping.	This data will be used to estimate network issues and the cost of addressing them. This is necessary to accurately calculate the total cost of the project.

Project initiation phase, continued

Distribution Network Data	**Estimated cost of addressing each distribution network issues** (i.e., the cost of equipment and labor required to fix issues identified).	This data will be used to estimate network issues and the cost of addressing them. This is necessary to accurately calculate the total cost of the project.
	Single-line feeder diagrams of the distribution network showing key infrastructure on the network such as the substations, feeders, and transformers.	
	Supply of electricity from the national grid. This refers to data on the supply of electricity from the transmission network to the DisCo's distribution network.	This data will be used to assess the potential for the DisCo to improve its supply to the area if losses are reduced and the distribution network is improved.
Demographic Data	**Organizational structure of customers.**	This will be useful for understanding the relevant communication lines for community members and ensuring that further customer engagement and data collection can be done efficiently and with the support of the appropriate community leaders or prominent residents of the area.

Exhibit A6 **Project development phase**

Data Category	Data Item	Relevance to REG Project Implementation
Electricity Demand Data	**Total hourly load for the customer cluster.** Total electricity demand for all customers in the cluster, preferably over a 365-day period. Where unavailable, a minimum of one month of data is required to begin system design and results can be updated as more data is obtained.	Accurate load data is required for sizing the REG installation. A full year of data is preferred because this captures load seasonality and allows the REG to be sized for a variety of load conditions.
	Total hourly load for premium customers in the cluster. Total electricity demand for premium customers in the cluster, preferably over a 365-day period. Where this is unavailable, a minimum of one month of data is required to begin system design and the results can be updated as more data is obtained.	This allows the battery storage and fossil fuel backup of the REG to be sized to ensure that premium customers have 24/7 reliability. Again, a full year of data is preferred but where unavailable, a minimum of one month of data can be used.
Customer Population Data	**Number of unconnected customers in the cluster.** This refers to customers within the cluster who have never been connected to the DisCo's supply.	This data can be used to estimate customers' willingness and ability to pay for energy and to confirm that the REG solution provides a cheaper source of electricity to customers.
Commercial Data	**Current monthly spending on self-generation,** particularly for premium customers.	This data can be used to estimate customers' willingness and ability to pay for energy and to confirm that the REG solution provides a cheaper source of electricity to customers.
Distribution Network Data	**List of distribution network issues verified by the developer.**	This data will be used to identify the issues that must be addressed on the network and the cost of addressing them. This is necessary to accurately calculate the total cost of the project.
	Cost of addressing distribution network issues verified by the developer.	
	Updated single-line feeder diagrams.	
Demographic Data	**Number of male and female customers in the cluster.**	This data can be used to establish a baseline of the demographics in the cluster and ensure that marginalized groups are identified and their needs accounted for in the project design.
	Number of people living with disabilities in the cluster.	
	Number of people living in poverty in the cluster.	
	Age distribution of customers in the cluster.	

Exhibit A7 **Operational phase**

Data Category	Data Item	Relevance to REG Project Implementation
Electricity Demand Data	**Total hourly customer load.**	Data on customer demand and REG system supply should be collected so the network operator can analyze consumption trends and identify opportunities to improve REG performance. Additionally, this helps to identify any additional generation needs.
	Hourly premium and nonpremium customer load.	
	Hourly solar PV, thermal plant, and battery storage electrical output.	
Customer Population Data	**Number of unconnected customers in the cluster.** This refers to customers within the cluster who have never been connected to the DisCo's supply.	Monitoring the number of premium and nonpremium customers as well as customer growth helps to ensure that the DisCo has a good understanding of the customer base and can identify changing customer needs.
	Customer growth.	
Commercial Data	Total **monthly grid energy consumption** by *MD and non-MD customers* in the cluster.	Collecting this data will enable measurement of the REG project's impact on the DisCo's commercial performance.
	Total **monthly amount billed and collected** for the energy consumed by *MD and non-MD customers* in the cluster.	
Distribution Network Data	**System average interruption frequency index (SAIFI) for every year of operation.**	Collecting this data will help with monitoring and evaluating the performance of the distribution network and identifying areas for improvement.
	System average interruption duration index (SAIDI) for every year of operation.	
	Distribution network faults and causes.	

Endnotes

1 Economist Intelligence Unit, "Challenges Facing the Nigerian Power Sector," *Economist Intelligence*, accessed July 28, 2022, **http://country.eiu.com/article.aspx?articleid=1003980684&Country=Nigeria&topic=Economy_1**.

2 "NERC (Embedded Generation) Regulations, 2012," Nigerian Electricity Regulatory Commission (NERC), 2012, **https://nerc.gov.ng/index.php/component/remository/Regulations/NERC-(Embedded-Generation)-Regulations-2012/?Itemid=591**.

3 "List of Licensees," NERC, accessed July 6, 2022, **https://www.nerc.gov.ng/index.php/library/documents/func-startdown/430/**.

4 Kristin Toussaint, "The Price of Solar Electricity Has Dropped 89% in 10 Years," Fast Company, December 9, 2020, **https://www.fastcompany.com/90583426/the-price-of-solar-electricity-has-dropped-89-in-10-years**; Hannah Ritchie, "The Price of Batteries Has Declined by 97% in the Last Three Decades," Our World in Data, June 4, 2021, **https://ourworldindata.org/battery-price-decline**.

5 "Transmission," NERC, accessed July 6, 2022, **https://nerc.gov.ng/index.php/home/nesi/404-transmission#:~:text=Nigeria's%20transmission%20network%20consists%20of,20%2C000km%20of%20transmission%20lines**.

6 "Again, New Peak Successfully Transmitted," Transmission Company of Nigeria, March 11, 2021, **https://www.tcn.org.ng/blog_post_sidebar110.php**.

7 "Transmission," NERC, accessed July 6, 2022.

8 Kingsley Jeremiah and John Akubo, "Nationwide Darkness as Nigeria's Grid Collapses Seventh Time in 2022," *The Guardian Nigeria*, July 21, 2022, **https://guardian.ng/news/nationwide-darkness-as-nigerias-grid-collapses-seventh-time-in-2022/**.

9 "ATC&C Losses," NERC, **https://nerc.gov.ng/index.php/library/industry-statistics/distribution/119-atc-c-losses**.

10 *Nigeria Minigrid Investment Brief*, Rural Electrification Agency, December 2017, **https://rea.gov.ng/Nigeria_MinigridInvestmentBrief_171202-V2.pdf**; Dalberg, *Putting an End to Nigeria's Generator Crisis: The Path Forward*, Access to Energy Institute, June 2019, **https://a2ei.org/resources/uploads/2019/06/A2EI_Dalberg_Putting_an_End_to_Nigeria%E2%80%99s_Generator-Crisis_The_Path_Forward.pdf**.

11 Okechukwu Nnodim, “French Agency Funds 350 KW Solar Power Project in Lagos,” Punch Nigeria, June 23, 2022, **https://punchng.com/french-agency-funds-350kw-solar-power-project-in-lagos/**.

12 Nomvuyo Tena, “Nigerian Breweries Signs Renewable Energy Power Purchase Agreement,” ESI Africa, May 27, 2022, **https://www.esi-africa.com/renewable-energy/nigerian-breweries-signs-renewable-energy-power-purchase-agreement/**.

13 US Agency for International Development, “Advancing Gender in the Environment: Making a Case for Women in the Energy Sector,” Advancing Gender in the Environment (AGENT) Energy Brief Series, 2018.

Osa Imoukhuede, Wayne Omonuwa, Ola Okeowo, Sakhi Shah, Olamide Edun, and Ighosime Oyofo, *Unlocking Renewable Embedded Generation in Nigeria*, RMI, 2022, **https://rmi.org/insight/unlocking-renewable-embedded-generation-in-nigeria/**.

RMI Innovation Center
22830 Two Rivers Road
Basalt, CO 81621

www.rmi.org