



Green Power for Mobile

In partnership with the Netherlands



GPM Case study: Airtel, Madagascar

Background

Country: Madagascar

Madagascar is an island country comprising of the island of Madagascar and many smaller peripheral islands in the Indian Ocean. Madagascar is the world's fourth largest island and is home to unique wildlife and diverse ecosystems. Madagascar's landscape is characterized by a central highland region at altitudes ranging from 750 to 1500 meters above sea level, sloping down to low land forest escarpments along the east coast and highly arid terrains in the west leading to the Mozambique Channel. The hot rainy season lasts from November to April and the cooler dry season runs from May to October.

Madagascar has a population of 22 million (estimated as of 2012)¹ and its economy is driven by agriculture and ecotourism. Agriculture contributed to over 29% of the national GDP in 2011 and employs over 80% of the country's population².

¹ <http://en.wikipedia.org/wiki/Madagascar>

² CIA – The World Fact Book (<https://www.cia.gov/library/publications/the-world-factbook/geos/ma.html>)

Operator: Airtel

With over 2.5 million mobile connections and a market share of over 40% , Airtel is a leading GSM mobile operator in Madagascar. The operations started under the brand name of Airtel post-acquisition by Zain in 2010. Historically the operations started in 1997 under the name of Madacom until 2006, followed later by Celtel from 2006 to 2008.

Madagascar is one of the 17 countries in Africa where Airtel operates and Airtel Madagascar is part of the global Bharti Airtel Group.

Overall Context

Telecoms Industry - Madagascar

The mobile telecoms industry in Madagascar is represented by three main players: Airtel, Orange and Telma. Madagascar has a 'unique mobile subscriber' base of close to 4 million and mobile connections of around 6.4 million. The mobile penetration in Madagascar stands close to 29% while the mobile subscriber growth is below 3%.³

Airtel leads the market with over 40% market share, followed by Telma and Orange at 31% and 29% of the market share respectively.³

Power Supply Scenario - Madagascar

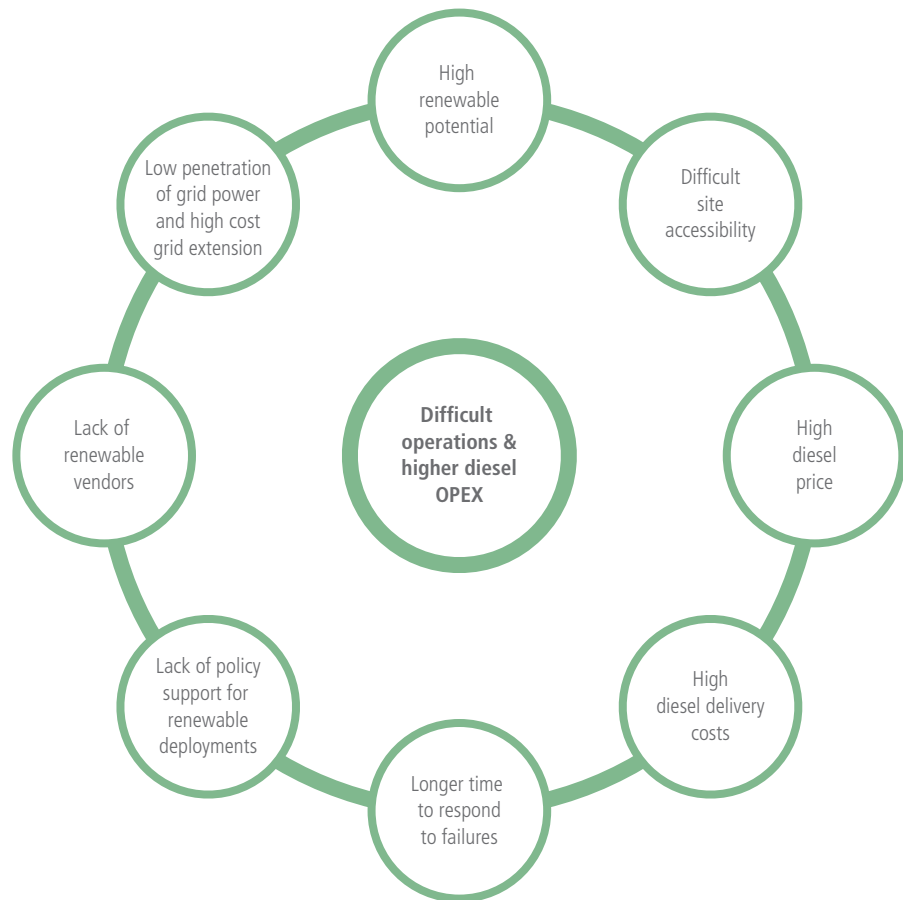
Madagascar's power supply sector is characterized by low generation capacities and limited grid infrastructure. Madagascar has three main grids namely Antananarivo grid, Toamasina grid and Fianarantsoa grid, operated and administered by the national utility JIRAMA.

Madagascar has 114 centers of power generation facilities of which close to 100 plants are diesel based and the remaining are hydroelectric generation plants. Electricity generation only covers 15% of the national needs⁴. Access to electricity remains as low as 20% and only 5% of the rural population have access to electricity⁵. The national electricity grid is limited to the major cities and the rest of the electrified regions and communities rely on isolated mini grids. The reliability and availability of the grid power supply has improved over the years, however the low generation capacities fall short of meeting the demand.

Operator Challenges – Airtel

The limited reach of grid power infrastructure has led to rely on diesel generators to power the growing network of telecom sites in Madagascar. Airtel has implemented battery hybrid solutions at all of their off-grid sites in order to reduce the dependence on diesel power thereby reducing energy OPEX. However, the costs of powering the off-grid sites still remain high, owing to high diesel costs, operational difficulties and regular maintenance of diesel generators. Airtel is also presented with a major challenge in terms of site accessibility increasing the cost of operations and maintenance.

The overall context in which Airtel operates is presented below.



Challenges encountered during the completion of the Feasibility Study

A comprehensive green power feasibility analysis of the entire network of telecom sites requires extensive data about the network. In addition to the technical data on site, configuration and power requirements, other specific details about each site including geography, accessibility, logistics and renewable energy resources are critical to the analysis.

GPM has collected extensive data for all the sites in Airtel's network and an initial analysis, followed by data validation, has been performed to guarantee the accuracy and depth of the final results of the study. GPM has faced challenges in obtaining accurate technical and market information for green power design and analysis.

Another key challenge during the Feasibility Study was to conduct field visits to off-grid sites due to the country's topography.

GPM has chosen a representative list of sites to get an overall understanding of the site equipment and operating conditions.

Feasibility Study and Approach

The Feasibility Study has been carried out according to GSMA's Green Power for Mobile methodology involving detailed data collection, data analysis, green power model design, business case development, implementation prioritization and financial analysis followed by recommendations.

Network & Data Analysis

Airtel has shared data on the entire network in order to carry out this green power Feasibility Study. The data was collected extensively to understand overall network characteristics including power infrastructure, geography, accessibility infrastructure, environment, logistics and operational parameters. The data was then validated through several iterations.

Airtel Madagascar has a network of 492 telecom base station and transmission sites across the country. Out of the total network, 234 sites are connected to commercial power and the remaining 258 sites are off-grid running on diesel generators as a primary power source.

The grid power supply scenario for the grid connected sites is fairly reliable with power average outages of less than 5 hours per day. Airtel has implemented battery hybrid solutions for the majority of these sites.

The 258 off-grid sites in the network relying on diesel generator as primary power source are implemented with DG-battery hybrid power systems. The average daily run of diesel generator is ~10 hours, with planned battery autonomy of close to 14 hours.

After thorough analysis of the network data, GPM has concluded that the on-grid sites may not be adapted to a Green Power design as grid power availability is, on average, more than 17 hours per day. Therefore, only the 258 off-grid sites are considered for Green Power feasibility analysis. However, generic recommendations have been proposed for energy efficiency and OPEX reduction for the entire network of telecom sites.

Network Analysis: Off-Grid Sites

The majority of off-grid sites in Airtel's network are outdoor sites and green-field sites. Site accessibility is a big challenge and significantly influences site operations including regular diesel transport to the sites. Nearly 90% of the off-grid sites have accessibility challenges due to difficult terrain and poor road infrastructure.

The overall daily power requirement for the network of 258 off-grid sites is 4,674 kWh. The average site load is close to 800W. The daily diesel OPEX incurred to run the network of 258 off-grid sites is US\$7,847 with approx. 5,565 litres of diesel required daily (at an average daily DG run time of 10.3 hours). This amounts to an environmental impact of 15 tons of CO₂ emission on a daily basis. The average battery backup planned for a site is around 14 hours.

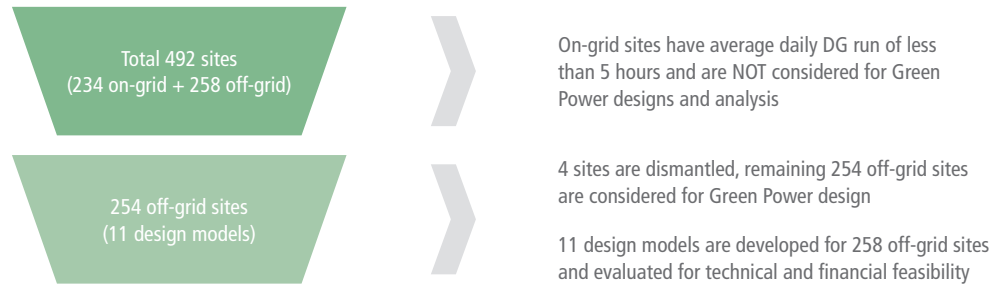
Table 1: Network Analysis: Off-Grid Sites

	Network	Load	Power Source
Characteristics	<ul style="list-style-type: none"> ■ 35 indoor, remaining are outdoor sites ■ 10 are Platinum sites, 7 are Gold, and remaining are Silver sites in terms importance; Only 10 are 3G sites ■ 19 sites are currently deployed with Green Power ■ Majority of the sites are greenfield sites 	<ul style="list-style-type: none"> ■ Overall average site load of 0.77 kW ■ Overall Daily power requirement of 4,674 kWh 	<ul style="list-style-type: none"> ■ Daily DG run : 10.3 hours (avg. per site) ■ Battery backup planned: 13.7 hours (avg. per site) ■ Approx. 5,565 L of diesel consumed daily
Observation	<p>Accessibility</p> <ul style="list-style-type: none"> ■ Only 11% of the sites have Easy Accessibility ■ More than 68% are moderate and 20% are difficult in accessibility 	<ul style="list-style-type: none"> ■ The average load per site is relatively low as majority of the sites are remote low traffic sites and are out-door sites. 	<ul style="list-style-type: none"> ■ Daily diesel OPEX of ~ US\$ 7,847 ■ Approx. 5,565 L of diesel consumed daily ■ Daily DG run of 2,650 hours (Overall network) ■ Daily CO₂ emission of 15 Tons

Model Design & Solutions

Based on the overall network data analysis, GPM has considered the 254 off-grid sites for the conduct of the feasibility analysis and renewable power solution design and. The overall approach to design modelling is highlighted below.

Figure 1: Design Approach



APPROACH

Site grouping

- 254 sites are divided into 5 renewable energy groups based on renewable potential at each site
 - Each group has similar renewable energy resource for potential design
- The sites in each renewable energy group are re-grouped based on load characteristics design models
 - 11 design models are developed based on site grouping
 - Each model represents similar renewable resource and load characteristics across modelled group of sites
 - Business cases are developed for each model to analyse financial feasibility and returns

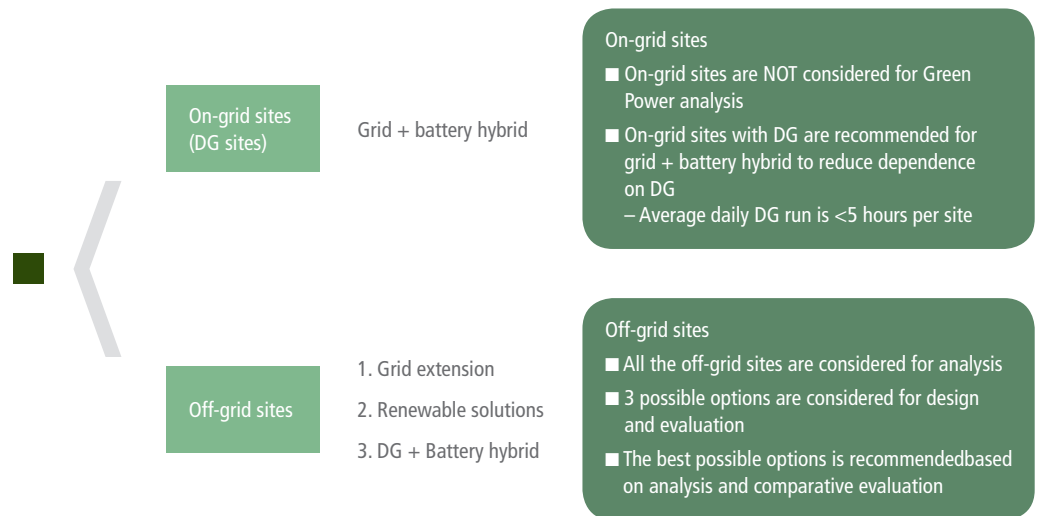
The sites are first grouped based on similar renewable resource potential and later regrouped based on site load characteristics for solution design and dimensioning. Thus, 11 design models are derived based on site grouping. Each design model represents similar characteristics (renewable resource and load) across modelled group of sites.

Solution Analysis and Evaluation

Every green power design thus developed is considered for comparison and evaluation against other possible alternative options. Three green power solution designs are evaluated for for all the 254 off-grid sites.

For each design model representing a group of modelled sites, a site-by-site evaluation of solutions is performed and the most feasible solution is chosen for a particular site in the design group. The evaluation approach and the solution options considered are highlighted below.

Figure 2: Options Evaluation Approach



Business Cases and Financial Evaluation

Business cases are developed for each design model over a 10 year business plan and compared against other solutions. The business cases are prepared taking into account market data and rates provided by the operator and vendors. Each business case demonstrates an overview of CAPEX, OPEX, savings and investment metrics such as NPV and ROI.

The evaluation approach and a sample evaluation are presented below.

- Firstly, every site in the design model is evaluated for feasibility of grid extension and all the feasible sites are recommended for Grid Extension
- Secondly, the green power designs for the remaining sites are evaluated against the existing DG + Battery hybrid case. The option with better feasibility indicators is selected for respective sites.

Based on design analysis and comparative evaluation of different options, each site is recommended with the best feasible solution.

Prioritization & Investment Plan

After careful analysis, solution design and evaluation of options, the sites are grouped into implementation priorities for phased deployment. The prioritization is based on a prioritization matrix which takes into considerations various technical and financial metrics including site importance, site accessibility, financial feasibility, OPEX reduction potential and environmental impact.

Sites with high importance (3G and Hub sites) and difficult accessibility are ordered higher in priority for implementation. Sites with better financial indicators such as shorter payback period and higher OPEX reduction are given higher priority. Also, green sites are given higher rank in prioritization as compared to DG + battery hybrid sites.

Based on the prioritization criteria, four implementation priorities are proposed. Every priority is supported with investment plan and financial analysis.

Results and Recommendations

The recommendations of GPM fall in to two categories,

1. Energy solution recommendations
2. Energy efficiency recommendations

The recommendations for energy solutions is based on comprehensive technical analysis, design and evaluation of the sites through GPM Feasibility Study, while the energy efficiency recommendations are based on qualitative analysis through site surveys and operational parameters.

1. Energy Solution Recommendations

After thorough design, analysis and evaluation of possible options, GPM has come up with the following solution recommendations for 254 off-grid sites considered for design. The table below shows the number of sites adapted to each category of solution.

Table 2: Network Analysis: Off-Grid Sites

Model	Grid Extension	Green Power	DG + Battery hybrid
IN1_S	0	0	4
IN1_SW	3	0	6
IN2_S	1	0	7
IN2_SW	2	0	4
OD1_S	18	50	0
OD1_SW_I	8	25	0
OD1_SW_II	0	22	0
OD2_S	6	35	0
OD2_SW_I	2	8	0
OD2_SW_II	2	5	0
OD3_S	6	2	0
Total	48	147	21

A total of 147 sites have been proposed for Green Power solution. 48 sites have been recommended for connecting to the commercial grid as the most feasible option. The remaining 21 sites will remain on DG + battery hybrid power solution since they are not feasible for green power or grid extension.

Solution dimensions

The solution dimensions for all the 11 design models developed are presented below. Each design proposes optimum solution dimensioning and equipment sizing to minimize the cost of energy produced and maximum utilization of the energy generated.

Table 3: Solution and Equipment dimensions

Design Model			Proposed Solution						
No. of Sites	Model	Model Load	PV	Wind	Battery	DG	Controller	Converter	Land Requirement (Sq.m)
4	IN1_S	1.2 kW	4.80 kW	-	2 x 600 Ah	15 KVA	100 A	12 kW	34.56
9	IN1_SW	1.2 kW	2.88 kW	3.00 kW	2 x 600 Ah	15 KVA	60 A	9 kW	20.736
8	IN2_S	1.8 kW	7.20 kW	-	2 x 600 Ah	15 KVA	150 A	12 kW	51.84
6	IN2_SW	1.8 kW	5.76 kW	3.00 kW	2 x 600 Ah	15 KVA	120 A	12 kW	41.472
68	OD1_S	550 W	2.88 kW	-	1 x 600 Ah	15 KVA	60 A	6 kW	20.736
33	OD1_SW_I	550 W	3.36 kW	-	1 x 600 Ah	15 KVA	80 A	6 kW	24.192
22	OD1_SW_II	550 W	3.36 kW	-	1 x 600 Ah	15 KVA	80 A	6 kW	24.192
41	OD2_S	900 W	4.32 kW	-	1 x 600 Ah	15 KVA	100 A	6 kW	31.104
10	OD2_SW_I	900 W	3.36 kW	3.00 kW	1 x 600 Ah	15 KVA	80 A	6 kW	24.192
7	OD2_SW_II	900 W	3.36 kW	3.00 kW	1 x 600 Ah	15 KVA	80 A	6 kW	24.192
8	OD3_S	1.4 kW	6.72 kW	-	2 x 600 Ah	15 KVA	150 A	12 kW	48.384

Implementation Priorities

Based on the final recommendations, the sites have been grouped into implementation priorities to assist in investment planning and phased deployment of the recommended solutions. The prioritization is performed based on the prioritization criteria explained in earlier sections. A total of 4 priorities are derived covering 48 sites proposed for grid connection and 147 sites proposed for green power. The remaining 21 sites recommended for DG-battery hybrid are given last priority in the order of implementation.

The below table summarizes the priority-wise performance indicators for 147 sites proposed with green power solutions.

Table 4: Priority Summary: Green Sites

Priority	Number of Sites	Energy contribution (Avg)			Battery Autonomy (Avg. Hrs)	DG run (Avg. Hrs/yr per site)	Diesel Savings (L/yr)	Green Power Generation (kWh/yr)	CO2 Emission Reduction (tonnes/yr)	Payback Period (yr)
		Solar	Wind	DG						
I	27	92%	0%	8%	31.7	108	198,296	174,114	559	2.19
II	44	91%	0%	9%	36.4	84	351,839	225,148	969	1.94
III	61	92%	0%	8%	30.4	115	436,050	416,335	1,240	2.26
IV	15	49%	43%	7%	23.3	132	134,965	163,279	352	2.97
Total	147						1,121,150	978,876	3,120	

Investment plan

The 147 sites identified to convert to green power solutions are presented with a detailed analysis to give a clear understanding of investments in the proposed solutions as well as the associated financial and environmental benefits of implementing the proposed green power solutions. The calculations are based on a 10 year project lifespan.

The summary of these investments, performance indicators and financial returns are given below for the 147 green sites.

Table 5: Priority wise Investment summary

Priority Financial Summary									
Priority	No. of sites	CAPEX (\$)	OPEX (\$/yr)	OPEX Saving (\$/yr)	Payback period (Yrs)	ROI (%)	IRR (%)	NPV (\$)	
I	27	39,428	943	18,011	2.19	46%	44%	50,738	
II	44	36,516	871	18,794	1.94	51%	50%	57,421	
III	61	40,251	962	17,788	2.26	44%	43%	48,839	
IV	15	58,116	1,130	19,639	2.97	34%	33%	41,815	
Overall	147	40,805	949	18,319	2.23	46%	44%	51,040	Per Site
		5,998,279	139,444	2,692,901					Total

Investment Alternatives

The operator is presented with various models of funding for the implementation of green power solutions on their network.

CAPEX based model

In this approach, the operator is responsible for mobilizing the investment required for implementing green power solutions. One option for the operator is to budget the entire investment from its own reserves or from the investment pumped in from its investors. Another option is to explore funding alternatives with financial institutions through various financial instruments including debt financing.

GPM provides access to various funding alternatives for green power implementation through the IFC (International Finance Corporation). The IFC has come up with various financial instruments such as debt, quasi-equity etc. to finance and promote green power implementations.

Outsourced model or OPEX based model

The outsourced model or OPEX based model provides the operators with an alternative to deploy green power solutions on their network. In this approach the operator outsources the deployment of green power solutions to third party energy service companies (ESCOs). The ESCOs will take the investment responsibility and provide the operator with energy services based on a fixed cost basis or a variable rate based on kWh consumed.

GPM can assist the operator in developing an outsourced energy model by bringing in and connecting with third party energy service providers.

2. Energy Efficiency Recommendations

For overall energy optimization, GPM came up with a list of recommendations which could help Airtel to reduce their energy requirement at every site.

Below are some of the generic recommendations to optimize and reduce energy requirements and improve equipment performance.

Existing Network

- Implement smart energy monitoring and site equipment control mechanism to control site operations
- Implement smart power source control mechanism to intelligently select between various power sources including Renewables, Grid power, Batteries and DG
- Energy Optimization and Efficiency
 - Upgrade or swap indoor equipment to outdoor equipment for Off-grid sites
 - Reduce overall site load and optimize energy requirements
 - Improve equipment performance for extreme weather conditions
 - Replace old diesel generators for improved performance and reduced O&M costs
 - Reduce fuel consumption
 - Reduce number of site visits and reduce operational expenses
 - Improve performance during extreme weather conditions especially during winter

Future Network

- Consider Light Rural site solutions for extending network to remote, low ARPU, low traffic regions
 - Feasibility of renewable alternatives to power
 - Less or zero dependence on diesel power
- Deploy outdoor equipment for upcoming network rollout for better network energy efficiency

Implementation of these recommendations would enable Airtel Madagascar to improve energy efficiency of the network, reduce OPEX and remove dependency on diesel generators to power the network.

Summary

After a comprehensive Green Power Feasibility Study, GPM concluded that:

Green Power Solution Recommended for	147 Off-grid Sites
Grid extension recommended for	48 Off-grid Sites
Recommend DG + Battery hybrid for	21 Off-grid sites
No Green Power Recommendation for	On-grid Sites
A list of generic recommendations those can save up to 40% of energy OPEX.	

The investment parameters and financial metrics for implementing the green power recommendations are provided below.

CAPEX requirement for Green Power Solution deployment	US\$ 6.0 million
Current Energy OPEX for all sites	US\$ 2.83 million/yr
Energy OPEX post Green Power deployment	US\$ 0.14 million/yr
OPEX Savings by implementing Green Power Solutions	US\$ 2.69 million/yr
Average Pay back period	2.23 years
Average NPV	US\$ 51,040
Average ROI	46.0%
Reduction in CO2 emissions	3,120 Tons/yr

Green Power for Mobile Programme

Promoting Green Power to Extend Mobile beyond the Grid

An estimated 1.6 billion people live without electricity. An additional 1 billion people live in areas with unreliable access to power. In order to expand into areas without regular electricity, mobile networks have primarily used diesel generators for power. However, as diesel prices rise and mobile network infrastructure is built in increasingly inaccessible regions, mobile operators need a viable alternative to diesel, such as solar and wind power. Recent technological improvements and cost reductions in green power solutions have made this alternative more commercially attractive. Coupled with the environmental benefits of reduced diesel use and subsequent emissions, green power solutions provide a promising opportunity for operators.

The Green Power for Mobile programme has set the goal of helping the mobile industry use renewable energy sources, such as solar, wind, or sustainable biofuels, to power 118,000 new and existing off-grid base stations in developing countries. Achieving that target would save up to 2.5 billion litres of diesel per annum and cut annual carbon emissions by up to 6.8 million tonnes.

The Green Power for Networks work stream within the Green Power for Mobile programme focuses on aiding the mobile industry to deploy solar, wind, or sustainable biofuels technologies to new and existing off-grid base stations in developing countries. The Green Power for Networks work stream supports the mobile industry in this initiative by providing: Network Feasibility Studies and Complete Network Assessments on technical and financial viability of renewable energy for BTS sites.

Aiding network operators to deploy renewable energy, GPM will be promoting the expansion of mobile networks into regions currently lacking coverage (to bring coverage to the unconnected) and the systematic reduction of reliance on diesel consumption by operators.

Figure 3 – Project Locations and Operator Partners:



GSMA Contacts

If operators are interested in finding out more about this service or the GPM programme please enquire at the contact information given below:

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