DESIGN AND IMPLEMENTATION OF NATIONAL ELECTRIFICATION STRATEGY (NES)

FINAL REPORT ON NATIONAL ELECTRIFICATION STRATEGY

Prepared for:

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List of Abbreviations

AAAC	All Aluminium Alloy Conductor
AAC	Aluminium Alloy Conductor
AB Cable	Aerial Bunch Cable
AB Switch	Air Break Switch
AC	Alternating Current
ACDB	AC Distribution Board
ACER	Agency for the Coordination of Energy Regulators
ACSR	Aluminium Conductor Steel Reinforced
AGM	Absorbed Glass Mat
Ah	Ampere hour
BG	Bank Guarantee
BoM	Bill of Material
BoQ	Bill of Quantity
BoS	Balance of Systems
BPP	Battery Protection Panel
Capex	Capital Expenditure
CB	Circuit Breaker
CO	Corporate Office
CT	Current Transformer
DC	Direct Current
DCDB	DC Distribution Board
DFIs	Development Financial Institutions

DG	Diesel Generator
DO Fuse	Drop Out Fuse
DOD	Depth of Discharge
DOP	Delegation of Power
DPR	Detailed Project Report
DTR	Distribution Transformer
EAPP	Eastern Africa Power Pool
EARP	Electricity Access Roll-out Program
EDCL	Electricity Distribution Company Limited
EES	Energy Efficiency Strategy
EIC	Engineer-in-Charge
ELV	Extra low voltage
EMD	Earnest Money Deposit
EQCC	EDCL Quality Control Coordinator
EQI	Execution Quality Index
EQM	EDCL Quality Monitors
e-RA	e-Reverse Auction
ESMAP	Energy Sector Management Assistance Program
ESSP	National Energy Sector Strategic Plan
EUCL	Energy Utility Corporation Limited
FOR	Free on Road
FQP	Filed Quality Plan
FRP	Fibre reinforced plastic
GCC	General Conditions of Contract
GDP	Gross Domestic Product
GI	Galvanised Iron
GIS	Geographical Information system
GoR	Government of Rwanda
GWh	Giga Watt Hour
HOD	Head of Department
HT	High Tension
IDF	Integrated Distribution Framework
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEM	EU Internal Electricity Market
IGBT	insulated-gate bipolar transistor
IPPs	Independent Power Producers
ISO	Isolator
JAB	Array Junction Box
JBs	Junction Boxes
kg/m2	Kilogram per meter square
kVA	Kilo Volt Ampere
kW	Kilo Watt
KWh	Kilo Watt Hour
L-1	Lowest Evaluated Responsive Tender
LA	Lighting Arrestor
LCPDP	Rwanda Least Cost Power Development Plan
LD	Liquidated Damages
LED	Light Emitting Diode
Li-ion	Lithium Ion

LOA	Letter of Award
LOI	Letter of Intent
LT	Lowest tenderer
LTO	Limited Tender Invitation
LV	Low Voltage
MC4	Multi-Branch Connector
MCB	Miniature Circuit Breaker
MCCB	Mould Case Circuit Breaker
MER	Central American Electricity Market
MG	Micro Grid
MINECOFIN	Ministry Of Finance and Economic Planning
MININFRA	Ministry of Infrastructure
MIS	Management Information System
MIT	Massachusetts Institute of Technology
MOSFET	Metal Oxide Silicon Field Effect Transistor
MOVs	Metal Oxide Varistors
MPPT	Maximum Power Point Tracker
MRP	Material Requirement Planning
MS	Mild Steel
MV	Medium Voltage
NDC	No Demand Certificate
NELSAP	Nile Equatorial Lakes Subsidiary Action Plan
NEP	National Electrification Plan
NES	National Electrification Strategy
NiCd	Nickel Cadmium
NiMH	Nickel metal Hydride
NIT	Notice Inviting Tender
NOA	Notification of Award
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OO	Other Offices
PBG	Performance Based Guarantee
PCU	Power Conditioning Unit
PDN	Power Distribution Network
PERG	Plan d'Electrification Rurale Global
PF	Power Factor
PIA	Project Implementing Agency
PO	Project Offices
PPAs	Power Purchase Agreements
PPE	PPE,
PQ	Pre-Qualification
PQCC	Project Implementing Agency's Quality Control Coordinator
PR	Purchase Requisition
PT	Potential Transformer
PTW	PTW
PV	Photovoltaic
PVC	Poly Vinyl Carbon
QA	Quality Assurance
QCM	Quality Control Mechanism
QE	Quality Engineer

QMS	Quality Management System
QoS	Quality of Services
QR	Qualification Requirements
RA	Reverse Auction
RC	Rate Contract
REG	Rwanda Energy Group
REM	Reference Electrification Model
REP	Rwanda Energy Policy
RER	Rwandan Electricity Rules
RES	Rural Electrification Strategy
RFP	Request for Proposal
RoW	Right of Way
RURA	Rwanda Utilities Regulatory Authority
SCC	Special Conditions of Contract
SCR	Scheme Completion Report
SHS	Solar Home Systems
SLA	Service Level Agreement
SO	Sub Offices
SPV	Solar Photovoltaic
STC	Subject to Contract
TECO	Technical Closure
THD	Total Harmonic Distortion
ToD	Time-of-Day
TPIA	Third Party Inspection Agency of PIA
UPS	Un-irrupted Power Supply
USD	US Dollar
UV	Ultra Violet
V	Voltage
VAH	Volt ampere hour
VCB	Vacuum Circuit Breaker
VRLA	Valve Regulated Lead Acid
W	Wattage
WASAC	Water and Sanitation Corporation
WO	Work Order
Wp	Watt (peak)
XLPE	Cross Linked Poly Ethylene
ZO	Zonal Offices

Definitions

Grid-Standard Electrified 2019	Already Electrified consumers through existing grid connected electricity network
Grid-Standard Fill-in 2024	Un-electrified consumers in the villages that was already electrified through pre-existing grid connected electricity network in that villages
Grid-Standard Extension RCS	It is proposed number of un-electrified consumers that exists in un-electrified villages, which are proposed to be electrified through grid connected electricity network and proposed in the present implementation plan of Grid Extension.

Grid-Standard Microgrids RCS	It is proposed number of un-electrified consumers that exists in un-electrified villages, which are proposed to be electrified through micro grid and proposed in the present implementation plan of Micro Grid.
Off-Grid (SAS or MG) RCS	It is proposed number of un-electrified consumers that exists in un-electrified villages, which are proposed to be electrified through micro grid or SAS.
Off-Grid (only SAS) RCS	It is proposed number of un-electrified consumers that exists in un-electrified villages, which are proposed to be electrified through SAS only.
Off-Grid (Existing 2019)	Already Electrified consumers through existing Micro Grid or SAS in the villages
Off-Grid (HRZ)	Some consumers are under the villages are completely inside high-rish zones whose customers have not been considered for the RCS and will be electrified only with solar kits.

Abstract

The government of Rwanda recognizes the vital role that electricity access plays in accelerating economic development through improving health and standards of living. Energy and particularly access to electricity is Government's key priority. This is why significant investments have been made and progress registered led to over 40.5% of households getting access to electricity by August 2017 and why the government has set the target of Universal Electrification for the year 2024.

The aforementioned initiative to extend access to electricity involves a coordinated effort across all power sector participants to connect new customers, focusing also on powering productive activities.

This document focuses on the definition of the "Grid Service Area", incumbent to EUCL. According to the institutional design established by REG – EDCL in the project, this Grid Service Area comprises (a) the customers selected for a connection to the Rwandan Central Distribution Network and (b) the customers that will receive their electricity supply through an isolated grid-compatible microgrid, as REG–EUCL will also take responsibility for the investment, implementation and maintenance of the microgrid networks, as well as for the electricity retail business with the customers base (bill collection, quality assurance and customer management), taking care of the appropriate remuneration of the Independent Power Providers (IPPs) that will supply electricity to each microgrid.

The least-cost achievement of Universal Access in Rwanda will also require the supply of DC Solar Kits for low-demand residential customers (below 50 Wp as defined by EDCL). It will also determine where a full-fledged stand-alone AC solar system should be provided to larger customers who are too isolated from the network and from other customers to techno-economically justify an individual connection to the central grid or an off-grid microgrid.

This Report will serve as a base for discussion of the institutional arrangements, grid and off-grid tariff calculation, remuneration of IPPs, financial implementation and other regulatory and energy policy mechanisms with all the involved stakeholders, that will be finally specified along with the detailed description for the Implementation of the National Electrification Strategy NES and the detailed Preparation of the National Electrification Plan NEP.

Keywords: Universal Access to Electricity, least-cost planning, grid extension, off-grid electrification, grid-compatible micro-grids, solar kits.

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Design of National Electrification Strategy - Review Assessment of current electrification programs prepared by REG / EDCL and confirmation on institutional, technical and financial aspects

Section-1. Least-cost planning using the Reference Electrification Model

1.1 Lessons learned from past electrification plans and strategies in Rwanda

In 1991 the first electrification master plan for Rwanda was drafted by Hydro Québec International with a planning horizon reaching to 2010 (Fichtner and Republic of Rwanda EWSA, May 2011). The electrification plans, policies, and programs which followed in the years leading up to present day Rwanda will be discussed in further detail in ANNEX 1: Detailed analysis of past electrification plans and strategies in Rwanda of this report, but as the references are many, a timeline has been provided to assist the reader in following the narrative. Items referenced in this report are shown in blue text in Figure 1-1, with the two reports which constitute the main focus of the discussion displayed in bold font. Any items shown in grey have been included for context only and do not figure materially into the report.

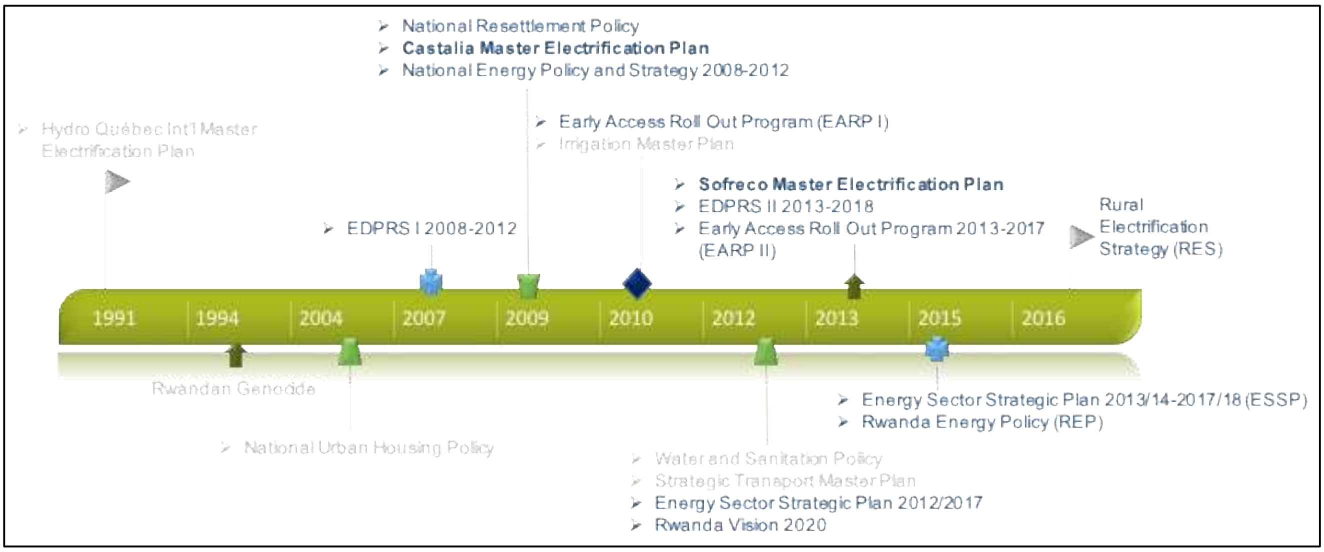


Figure 1-1: Timeline of Electrification Plans, Policies, and Programs in Rwanda

For this project, the two master electrification plan reports identified, those written by the consultants Castalia and Sofreco, respectively, have been reviewed along with their supporting documents for the purposes of identifying the methodology followed by each in the creation of a national electrification plan for Rwanda. The two methodologies will then be compared in order to identify common elements, unique attributes, strengths, and weaknesses. These findings, as detailed in ANNEX 1, have been used to form the basis of a critique of the capabilities of the Reference Electrification Model, so that recommendations may be formed concerning both the future use and development of this techno-economic planning tool.

1.2 The Reference Electrification Model: A decision support tool for the development of the Rwandan National Electrification Plan

1.2.1 Context

The **Reference Electrification Model** (REM) developed jointly by the Massachusetts Institute of Technology (MIT) and Universidad Pontifical Comillas Institute for Research in Technology (IIT) addresses the need for a tool that supports decision making on which technology to use to electrify any given area (cell, village or group of individual customers), through application of techno-economic modelling. It allows decision makers and planners to apply policy objectives and given assumptions to the physical landscape and existing infrastructure, using scientific data to calculate the most viable solutions.

The outputs provided by REM rely on a combination of **ground data**, **calculated assumptions** and **strategic decision-making**, and as such, the tool should be used in close interaction with the lead agency and departments for planning.

1.2.2 Objectives and methodology: REM Techno-Economic Procedure for Least-Cost electrification planning

The REM consists of two major steps: (1) clustering using a bottom-up approach and (2) final decision on the best electrification mode for each cluster.

Prior to step 1, in order to avoid multiple detailed evaluations of the optimal generation mix for each one of the many cluster combinations that REM has to try, REM calculates optimal generation designs for representative off-grid systems and stores the corresponding data in a look-up table.

In order to find these generation designs REM minimizes costs (both investment and operation cost plus a penalty for the amount of demand that is not met) using an optimization strategy with a master/slave strategy. The master part makes decisions about the design variables, using a direct pattern search approach, and the slave part performs a simulation with a load following dispatch strategy for each representative microgrid (other dispatch strategies have been included in other versions of REM).

If in the clustering or in the final designs algorithms REM needs information related to a generation design that is not in the look-up table, it interpolates using the closest designs. The generation technologies that REM presently considers are solar, batteries and diesel generation. The cost of the charge controllers and inverters is also included (if needed).

1.2.2.1 STEP 1. Clustering.

REM groups a large number of buildings into potential electrical sub-systems. This step is very important, because it will condition the spatial distribution of off-grid and on-grid systems. Since the number of possibilities for this is unmanageable in an exhaustive way, REM implements the following strategy:

a. A systematic bottom-up greedy algorithm, based in local decisions, to build clusters at two hierarchical layers, as shown in Figure 1-1. The first layer is built with off-grid assumptions, and the second layer with grid-extension assumptions.
b. Local decisions depend on the balance between savings (size-related economies of scale) and extra costs (network investments to connect buildings).
c. Economies of scale may derive from administrative or business models, network components/designs and generation components/designs. The results depend critically on accurate inputs or estimations of these size-related factors.

d. Since the number of possible local decisions may be huge in real-life problems, some simplifications are applied:
   i. Connectivity options are limited to the sub-set of most promising grouping solutions identified through graph theoretical results.
   ii. Extra network costs are estimated by simplified representations of the networks.
   iii. Generation costs are obtained interpolating in the look-up table calculated in the generation sizing block of REM

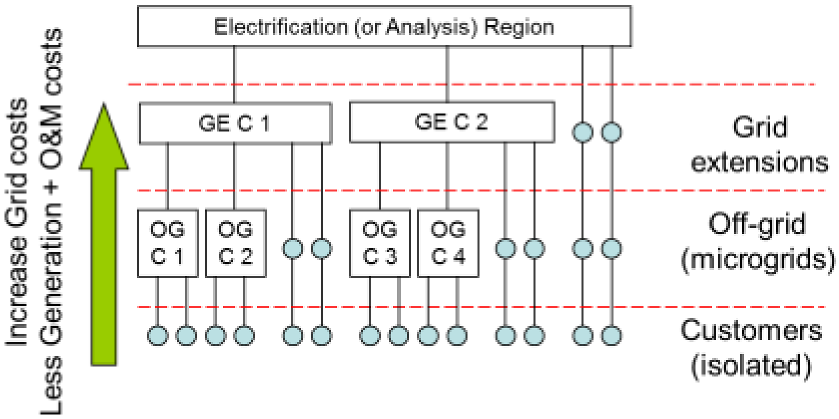


Figure 1-2: Example of structure of clusters (results from the clustering process)

For the Rwanda NEP, the minimum size of any Grid Extension cluster (GE) has been set by EDCL to the level of an administrative cell. Therefore, either the whole cell is connected to the grid, or it will all be electrified off-grid (with a combination of microgrids and stand-alone solar kits).

1.2.2.2 STEP 2. Final decision on the best electrification mode for each cluster.

After the clusters have been identified, the cost of the electrification options at different layers are calculated for each cluster as follows:

a. For the grid-extension option:
   i. Find the nearest viable connection points to the existing grid
   ii. Design the lowest cost distribution network to connect the buildings to the grid. This is done using the Reference Network Model [1].
   iii. Calculate the final cost, considering
      1. Cost of energy purchased from the grid
      2. Network costs (investment, maintenance and losses)
      3. Cost of non-served energy because of imperfect grid reliability
      4. Administrative and connection costs.

b. For the microgrid option:
   i. Calculate the cost of generation. This cost is either obtained interpolating in the look-up table calculated in the generation sizing block of REM, or performing a full optimization process for this particular cluster, considering the hourly dispatch for the total consumption of the customers within a specific microgrid.
   ii. Calculate the network cost as in 3.a.ii (RNM tool, but adapted to a microgrid case)
   iii. Calculate the final cost, considering:

1. Generation costs (investment, operation, maintenance, and non-served energy).
2. Network costs (investment, maintenance and losses).
3. Administrative and connection costs.

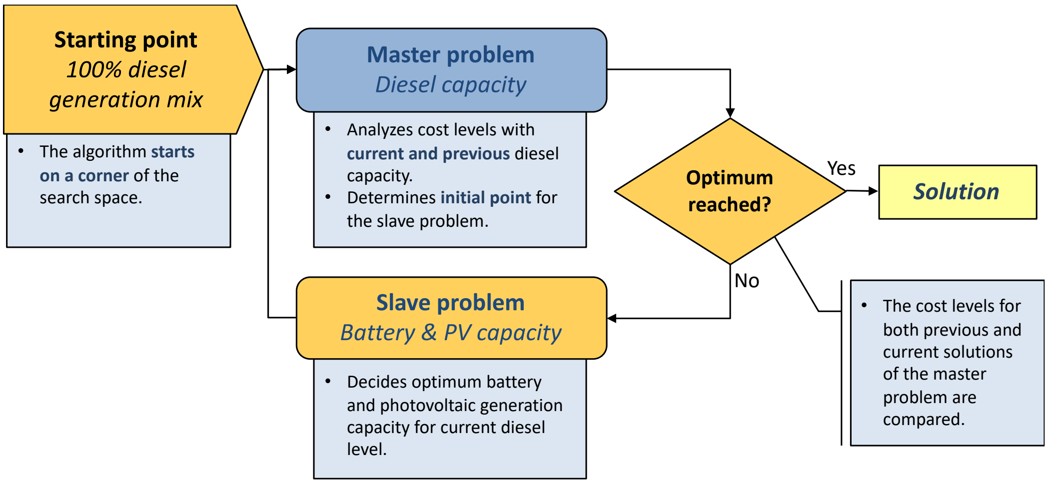


Figure 1-3: Master-Slave decomposition for the optimization of microgrid generation

c. For the single-building option: If the peak load of the customer is less than 50Wp, then this cost corresponds to that of the Solar Kit specified by EDCL for those consumers. If the consumption is higher (isolated productive or community loads), proceed as in the microgrid case, except for the network design and cost steps (no network present).

d. After the cost of the three electrification modes is calculated, the lowest-cost combination of clusters and their electrification modes is picked. Figure 1-2 shows a case in which the optimum solution is made of one grid-extension (groups "A" and "B" of customers), one microgrid (group "C"), and a set of isolated systems (group "D"). There is also the possibility of biasing solutions to be of particular types, by overriding the minimum-cost criteria to some extent.

Therefore it is important to notice that no heuristic rule is applied for the determination of the electrification mode (grid or off-grid), either based on the distance to the grid or density of load, but instead a thorough calculation of the actual implementation cost for each mode (grid extension, microgrid or solar kit/stand-alone system) is performed before the final decision is taken, based on pure techno-economic and social criteria.

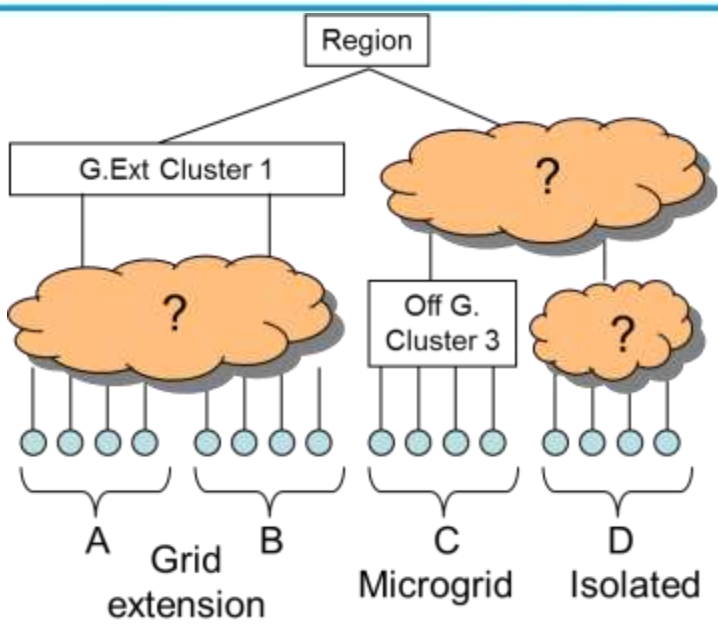


Figure 1-4: Example of minimum-cost electrification solution

1.2.3 Different types of input data

As said before, the outputs provided by REM rely on a combination of **ground data**, **calculated assumptions** and **strategic decision-making**. The classification of inputs into these three groups is not always clear, so the following is just a reasonable example.

1. Ground data. Inputs that are considered fixed data (although they may represent future plans or states of the system)
    a. Location of buildings (and therefore also the population density). It is necessary to know the latitude and longitude of all buildings in the study area, as well as the type of building if different types of demand profiles are used.
    b. Existing distribution feeders (MV), and therefore the distances from buildings to the existing grid. The location of the existing distribution feeders and transformers must be obtained for the study area. In the absence of this data, it is possible to estimate it with the RNM tool (greenfield mode), provided that the already electrified customers are given.
    c. Energy resources (solar power availability, diesel cost if available and allowed, micro-hydro sites). The availability of different energy resources in a given area is necessary in order to determine the suitability of different types of generation.
    d. Topography data (altitude map and penalized areas). RNM and REM use these data to design networks and incorporate restrictions in the clustering step.

2. Calculated assumptions. Inputs that are adjustable to different scenarios.
    a. Grid energy cost. Cost of energy estimated at MV feeders.
    b. Grid reliability. Reliability of the supply of electricity from the existing grid. This value can be expressed either as a single overall percentage, or broken up into hourly-related percentages (off-peak reliability, peak reliability and so on). Reliability is important to the

concept of CNSE. It could also be linked to grid-energy cost figures, in case of evaluating generation and grid reinforcements in future scenarios.

c. Demand profiles (critical and non-critical, demand growth rate). Following the classification of buildings, the demand for each building needs to be characterized. To design electrification solutions for un-electrified buildings it is necessary to estimate how much electricity each building might consume if it had access to electricity. Since the model will try to meet specified demand at the lowest techno-economic cost, more detail about demand at each individual load point is likely to have an influence on the results. Once the demand profile is constructed, it must be classified into one of two tiers: 1) essential or critical load (e.g., lighting) or 2) non-critical load (e.g., television).
d. Network components (catalogue of lines and transformers). Power capacity and cost characteristics are the most relevant parameters.
e. Microgrid generation components (catalogue of PV panels, batteries, diesel generators, and power conversion equipment)

3. Strategic decision-making. Inputs that are related to social and business models.
   a. Administrative costs. They account for the general management cost of the system and they may have different values for different electrification modes, and economies of scale depending on the size of the systems. These costs are calculated differently for off-grid and grid extension systems. In REM, the administrative cost of a system only depends on its number of consumers. The input parameters that REM requires to calculate this cost are the administrative cost of a small, medium-size and large microgrid as well as the number of consumers of a small and a medium-size microgrid (REM assumes that the number of consumers of a large microgrid is equal to the total numbers of consumers of the case study).

      In an off-grid system the administrative cost is approximated with an analytic expression, which is calculated with these input parameters. Specifically, the model uses an exponential function in order to ensure that the per-consumer administrative costs is a decreasing function of the number of consumers.
      The administrative cost of a grid extension is calculated with a constant per-consumer cost (it does not depend on size of the system) equal to the input parameter assigned to a large microgrid. This ensures that the administrative cost of a grid extension is always lower than the administrative cost of a microgrid.
   b. Cost of Non-Served Energy (CNSE). REM is basically a cost-driven tool, so the lack of quality/reliability of power supply must be translated to cost (it may also be imposed as a constraint in the case of microgrids). CNSE is the cost, to consumers, of energy that is not served. This concept is actually quite subjective, but is intended to represent the cost (i.e., the loss of utility) incurred by consumers when there is no electricity at a time when they were planning to use it. REM requires two values for CNSE, one for essential load and another for nonessential load. There could be multiple ways of arriving at a value for CNSE, but one way of calculating CNSE value is to adopt -as a proxy- the cost of an alternative energy solution (e.g., kerosene) that might be used when electricity is not available.

When it comes to calculating the cost of non-served energy, REM applies different procedures with off-grid systems and grid extension designs. In off-grid systems REM multiplies each amount of demand (essential and nonessential) that is not met by the dispatch algorithm by the corresponding penalty. On the other hand, with grid extension designs REM assumes that the non-served energy is split homogenously between essential demand and nonessential demand before multiplying these numbers by the corresponding penalties. For example, if the grid has a 90% reliability and the essential and nonessential demands in an hour are 5 kWh and 1 kWh then REM assumes that there are 0.5 kWh and 0.1 kWh of non-served essential and nonessential demand in that hour, respectively.

c. Minimum microgrid quality/reliability of power supply. In addition to CNSE, this constraint may also imposed in the case of microgrids, in terms of percentage of energy served.
d. Discount rate, needed to translate upfront investments to annuities. It is related to the business/investment models. Different values may be set for different electrification modes
e. Grid connection criteria. Some practical criteria may be applied to bias grid connection of customers that are not too far from the grid (and not far from other customers). This may be not consistent with cost minimization, but related to social or political strategies.

1.2.4 Sensitivity analysis (qualitative)

The different inputs described in the previous section are analyzed here with respect to their influence on the expected results. The proposed classification and terms is respected, but two intermediate results are also used in the explanations, i.e., economies of scale and size.

- Economies of scale, as said before, are the basis for local clustering decisions. They are also critical in the “detailed design” step. Since they may derive from different sources or inputs, they will be mentioned explicitly along the explanations
- Size of clusters (or sub-systems), in terms of number of buildings connected to each other. It is an intermediate result from clustering that may affect a lot the final solutions. Size is affected in different ways by different inputs, and therefore it will be used in the cause-effect reasoning processes

Obviously, economies of scale are closely related to size by definition (savings due to size), but we will try to identify the two effects individually when possible.

The expected results of REM are affected by the different input data elements in the following way:

1.2.4.1 Ground data.

a. Location of buildings (in terms of population density). Higher population density produces larger sizes of systems. They will result in larger microgrids (if far from the grid) and more grid-extensions (if not far from the grid). The influence of size in grid extensions is closely related to network catalogues components (the right power capacity and the right economy of scale may lead to relevant savings).

b. Existing distribution feeders (in terms of distances to buildings). Part of the connection costs are proportional to distance, so systems next to the grid will obviously tend to become grid extensions (here the availability of small network components is critical).
c. Energy resources (solar power availability, diesel cost if available and allowed). High solar power availability and low diesel prices favor microgrids.
d. Topography data (altitude map and penalized areas). Adverse terrain characteristics produce smaller systems and even isolated solutions.

1.2.4.2 Calculated assumptions.

a. Grid energy cost. Obviously, higher energy costs produce more microgrids and less grid-extensions (small influence in isolated systems, except when they are special high-demand customers). The effect of this parameter on the solution is smooth if buildings-to-grid distances are relevant. In case of short distances, changes may be dramatic (connection cost thresholds depend mainly on transformers, instead of lines).
b. Grid reliability. This parameter affects dramatically the presence of grid extensions if CNSE is significant, since non-served energy is directly penalized by CNSE (critical and non-critical). In contrast with microgrids, grid reliability is a user input that cannot be mitigated by extra investments.
c. Demand profiles (critical and non-critical, demand growth rate). Critical energy is important since its CNSE value is usually high. More critical energy means higher cost in grid extensions (if reliability is not 100%). In microgrids it may just impose more reliability to the solutions, but the cost is not that much affected, since non-served energy costs are replaced by generation costs. The effect of demand growth rate is similar to the effect of smaller components in the catalogues (network and generation). Higher demands produce bigger sizes and better economies of scale in the system, and therefore they favor bigger microgrids and more grid-extensions. The p.u. cost ($/kWh) usually decreases as demand increases.
d. Network components (catalogues of lines and transformers). Smaller and less expensive components tend to produce bigger microgrids and more grid-extensions, since they allow more connections with the same savings.
e. Microgrid generation components. Smaller and less expensive components tend to produce bigger microgrids and more grid-extensions, due to the bottom-up clustering strategy (initial decisions are possible). Beyond that, what is relevant is the presence of economies of scale in generation components. Diesel generators usually provide these economies of scale, both in investment costs and in operational costs (efficiency). In the case of batteries and PV panels, in which big systems are made of many small components, economies of scale should be modelled explicitly in realistic terms. Economies of scale produce bigger microgrids, and indirectly they even may produce more grid-extensions (since large systems are more likely to be connected to the grid). The specific micro-hydro sites will be analyzed in section 10 onwards for the detailed implementation of the NEP in a second phase. Whereas most hydro sites will be connected to the central grid, those who are far from the grid will provide a lower cost alternative for microgrid clusters nearby, so a case by case analysis will be developed for either alternative (grid or microgrid) for each microgrid site.

1.2.4.3 Strategic decision-making.

a. Administrative costs. They may have different fixed values for different electrification modes (grid extension or microgrids) or also include p.u. costs as a decreasing function of size, to reflect economies of scale in the administration of larger systems, as for instance in fee collection tasks. The influence of economies of scale is quite relevant; as it has been already stated, they favor big microgrids and more grid-extensions in the final solution. As these costs are estimated, they are reflected separately in the final solution.
b. Cost of Non-Served Energy (CNSE). CNSE should be set to a value bigger than the typical energy cost in the system. CNSE is closely related to grid reliability in the case of grid-extensions, since non-served energy is directly penalized by CNSE (critical and non-critical). In the case of microgrids, the effect is not so dramatic, since non-served energy costs are replaced by generation costs. Also in microgrids, the use of CNSE as a reliability driver may be replace (or coordinated) with the use of minimum reliability constraints (next input described)
c. Minimum microgrid quality/reliability of power supply. This constraint may be imposed in the case of microgrids, in terms of percentage of energy served. The effect is to guarantee a minimum reliability level for every off-grid solution, despite the cost.
d. Discount rate, needed to translate upfront investments to annuities. The effect is obviously to change the annual costs, imposing a shorter or longer recovery of the investment. Since different values may be set for different electrification modes, it may bias the final solution one way or another (grid-extensions, microgrids or isolated systems).
e. Grid connection criteria. They may bias grid connection of priority customers that are not too far from the grid (and not far from other customers), so that the effect on the final solution is directly predictable in qualitative terms. The quantitative effects are quite interesting, since they may be used to estimate the actual cost of the particular criteria applied.

Section-2. Setting the main design features for the NEP

2.1 Input data, inferences and main assumptions

Most of the effort by the Consortium with EDCL in the first Phase of this study has been devoted to gathering the existing data described in the previous section, considering the different sources available, any inference processes that could be derived from them, and where information was not directly available the determination and validation by the technical team at EDCL of the different assumptions proposed by the consortium.

2.1.1 Location and characterization of expected demand

The detailed design of network and generation infrastructure developed by REM for the National Electrification Plan requires to determine, as exactly as possible, the location and characteristics of the different loads that will be supplied either by the central network, microgrids or isolated systems.

2.1.1.1 Residential customers

The location of residential customers was determined considering (a) the existing database of customers developed for the 2013 Sofreco Report, (b) the 2017 High Resolution Settlement Layer HRSL for Rwanda (Columbia University Center for International Earth Science Information Network)[1] and (c) the expected growth in Urban and Rural Areas for 2024.

This information about location of buildings did not include whether these customers were electrified (connected to the grid) or not. To determine the location of the customers actually supplied (or about to be) by LV network, a 37.5m buffer around the existing and already planned LV lines was calculated, as specified by EDCL, considering those customers inside the buffer as already electrified (as they were within reach of the existing network using side drop lines). The customers located inside forbidden areas (high-risk wetlands and other areas non suitable for residential settlements) are not considered within the scope of the plan, as they are expected to move to villages according to the villalization program.

EDCL provided statistical information, classifying, for each cell in the country, the households in two customer types according to their demand. Type 1 households are expected by EDCL to demand initially only a very low level of supply (below 10Wp in 2017 for two lights, a phone charger and may be a high-efficiency radio). Type 2 customers will demand less than 50Wp. Larger domestic customers, well above those two essential levels, are a rare minority (below 5 customers per thousand).

[1] www.ciesin.columnia.edu/data/hrsl

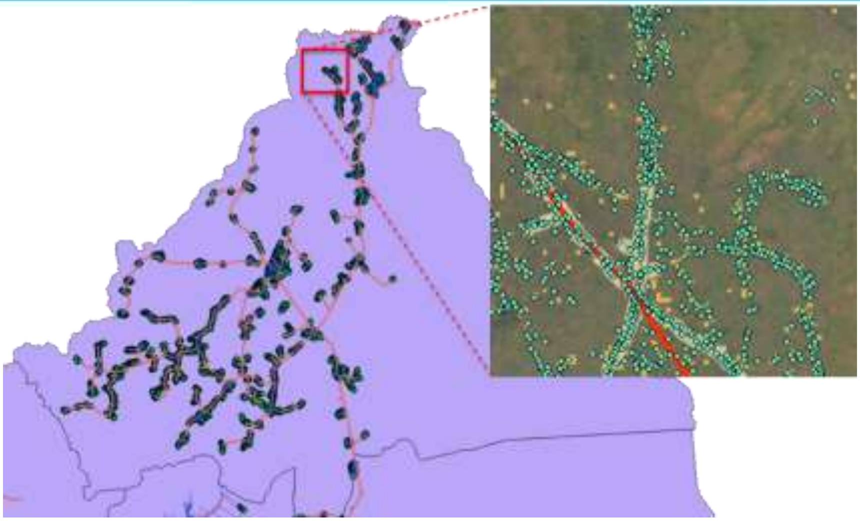


Figure 2-1: Sample image of different data sources:
Sofreco (green dots), HRSL (yellow squares), MV (red lines) and LV (green lines) and 37.5 m buffer (light yellow) combined for the determination of location of non-electrified residential customers in Nyagatare district

Residential customers connected to minigrids are assumed to have an equivalent profile as those connected to the central grid, with equivalent supply and technical standards. The hourly profile of consumption expected from them has been extrapolated from average feeder data provided by EDCL and from the field study developed by MIT-IIT Universal Energy Access Lab in 2015 for the village of Karambi, Mutete Sector, Gicumbi district[2] for the purpose of inferring the consumption profiles every hour of the day by low and high income households. In case these customers are assigned a Solar Kit, all Categories 1, 2 and 3 residential customers (below 50Wp in 2017) are assigned by default a 10 Wp DC Solar Kit (2 lamps and a phone charger) as per EDCL characterization.

An average demand growth of 8.40% per year and customer has been sanctioned by EDCL according to historical data of connected customers in Rwanda.

A larger relocation of population is expected to happen in the long term, after 2024, as the villalization program develops. Different hypotheses will be considered for the long term scenarios for 2030, agreed to be analyzed during Phase 2 of the project, including also higher demand growth hypotheses.

2.1.1.2 Productive and community customers

For the present plan, a total number of 20 different types of productive and community customers and two residential customers have been considered, according to EDCL specifications.

REM type	Customer type	Power (kWp) (year 0)	Power (kWp) year 7
Customer_type1	Airport	6,000.00	10,552.52
Customer_type2	Cell office	2.00	3.52

[2] Santos, Javier, “Metodología de ayuda a la decisión para la electrificación rural apropiada en países en vías de desarrollo” Universidad Pontificia Comillas, 2015.
Li, Vivian, “The Local Reference Electrification Model: comprehensive decision-making tool for the design of rural microgrids” Massachusetts Institute of Technology, 2016.

REM type	Customer type	Power (kWp) (year 0)	Power (kWp) year 7
Customer_type3	Coffee washing station	1.50	2.64
Customer_type4	Health center	1.80	3.17
Customer_type5	Health post	1.00	1.76
Customer_type6	IDP Model Village (avg.)	13.00	22.86
Customer_type7	Irrigation pumping	3,000.00	5,276.26
Customer_type8	Markets	8.00	14.07
Customer_type9	Milk collection center	1.40	2.46
Customer_type10	Mining	25.00	43.97
Customer_type11	Preprimary school	0.40	0.70
Customer_type12	Primary school	0.40	0.70
Customer_type13	Secondary school	1.30	2.29
Customer_type14	Sector Office	1.40	2.46
Customer_type15	Tea Factory	3,800.00	6,683.26
Customer_type16	Technical Schools	26.00	45.73
Customer_type17	Telecom Tower	280.00	492.45
Customer_type18	Universities and Institutes	130.00	228.64
Customer_type19	VTC	280.00	492.45
Customer_type20	Water pumping stations	40.00	70.35
Customer_type21	Residential 10W	0.010	0.018
Customer_type22	Residential 50W	0.050	0.088

Table 2-1: Classification of Customers and their peak consumption for the REM Reference Case Scenario

EDCL provided a GIS file including the location of productive and community customers, their present electrification status (yes/no) and their expected peak and average yearly demand in 2018.

Figure 2-2 shows a sample of hourly profiles obtained from the field study in Karambi village, Gicumbi district, which has been taken into account to estimate the shape of the hourly demand curve for each individual customer, each one subject to the peak and average demand data provided by EDCL.

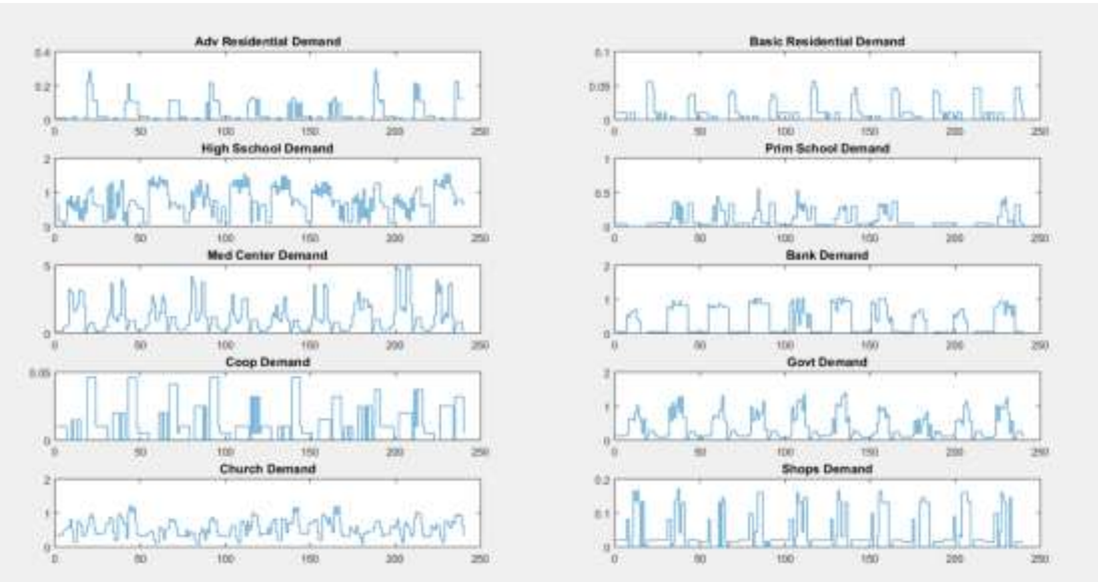


Figure 2-2: Sample demand profiles for domestic, community and productive loads in Karambi village (Santos J. 2015, Li, V. 2015)

All community and industrial customers are supplied in AC, disregarding whether they are connected to the central grid, a microgrid or are supplied with an individual stand-alone system.

2.1.1.3 Quality of Service

As described in Section 1.2, REM considers both the reliability of the central network (for the grid connected customers) as well as the performance of microgrids and isolated systems (for the off-grid customers).

Different scenarios can be calculated using REM, according to different reliability hypotheses. For the central network we have analyzed scenarios ranging from a 100% reliable network (considering that the country will improve from the present status through the necessary investments in central generation and transmission and distribution reinforcements) down to 85% considering that the scenario in 2024 will be similar to the one today.

For the purpose of this report, in order to determine which villages should be on and off-grid, we are providing the 100% reliable network scenario so the final status of a customer in the long term is determined by this ideal solution. Another high-demand scenario has been developed to determine the outer boundaries of grid extension in case household demand rises above the essential levels described above, above Tier 3 for low income households and above Tier 4 for high income ones.

As for the microgrid generation, the expected system reliability is very high (above 97% in the scenario described in this document) and even better than in many places serviced by the main network. REM determines this reliability level according to the inferred cost of non-served energy for critical and non-critical loads (0.75 $/kWh and 0.30 $/kWh respectively), and a hard low-end reliability constraint (which in this case is set to at least 80%). The value of the critical cost of non-served energy (in $/kWh) was estimated considering the present expenditure of firms in diesel backup systems that supply around 15% of their energy consumption in a year as backup for blackouts. This cost per kWh is high because the customers are required to size their diesel generators according to their peak demand power, even if the diesel only produces 15% of their total energy consumption in a year. The non-critical cost of non-served energy was assigned a value in the order of the average cost of generation of a small AC Solar Home System.

Finally, for very small residential customers below 50Wp, REM will consider the social cost of grid connection or microgrids against the supply with a small 35$ DC Solar Kit, that will repaired and upgraded as needed in the future. The overnight cost of purchase of these systems is very low, but they can only supply a fraction of the customer demand for a limited amount of hours. Therefore, loss of utility of these systems, as compared to grid and microgrid connections, is high. This value of non-served energy for DC systems is different to the one considered for critical and non-critical connected demand, as described above, and has been estimated in the order of the cost of other alternatives (in $/kWh) as kerosene lamps, candles or disposable battery lights (0.9 $/kWh).

Failure rates of equipment and technical characteristics (e.g. voltage drop at the connection point) are built into the techno-economic catalogue, and therefore comply with the specifications established by EDCL.

2.1.2 Existing infrastructure

2.1.2.1 Existing distribution network (MV and LV)

REM computes millions of alternatives to find the optimal least-cost design for grid connection systems, as well as for microgrids and stand-alone systems, comparing them and determining, for each household, the solution that minimizes the social cost (including cost of non-served energy).

Regarding grid connection, each network extension system designed by REM must be connected to the existing (or already projected) MV network layout. A detailed GIS layout of all existing and already planned MV and LV lines has been taken into account to optimize the connection of newly designed grid extension to the existing infrastructure.

Upstream reinforcements are estimated by the cost of energy purchased from the grid for distribution, and are not included in the scope of the present study, but could be the subject of a subsequent analysis.

The cost of the energy supplied by the main grid at bulk MV distribution level has been set to 0.12 $/kWh for the Reference Case Scenario. This is indeed significantly lower than Rwanda's 2017 energy cost; however, we note that it is many times larger than the global level, and close to double that of the neighbouring land locked country of Uganda. Indeed, it will be necessary for Rwanda to move away (as it plans to do) from excessive diesel generation and seek to achieve to be economically competitive energy costs by adopting a lower cost generation mix. Sensitivities have been analysed to assess the impact of higher energy costs, up to 0.20 $/kWh.

2.1.2.2 Least-cost network planning, catalogue and quality standards

EDCL established the MV and LV catalogue to be considered for new grid extensions and off-grid electrification in this NEP for 2024 (please refer to ANNEX 2: RCS REM input catalogue tables for further details on catalogue components and characteristics). Components selected for the Reference Case Scenario, either MV or LV lines as well as transformers, had been specified bestowing the best practices and experience of EDCL according to the following considerations:

- Given this target and that the coverage of the existing MV network is already high in every district of Rwanda, new grid extensions and MV lines do not need to be spread over very large distances to reach different customers.
- In this RCS only highly populated and priority industrial and community loads (the least-cost connections) are expected to get coupled to the central grid, in compliance with the 52% grid extension target for 2024.
- These priority loads and high density areas need, according to the experience of REG, the promotion of high quality of service standards, already in place in the country. The purpose of this strategic approach is to guarantee the necessary quality to foster economic growth.

Therefore the Reference Case Scenario for REM has been specified by EDCL to select the least-cost electrification design, but according to initial high quality standards. Where the grid will not reach, customers will be supplied either with grid-compliant microgrids (that may eventually get connected to the grid in the future) or, because of budget constraints, with only a transitory DC solar kit or stand-alone AC system, expressing EDCL purpose of electrifying the whole the country with grid-equivalent service in the future.

Therefore, for this Reference Case Scenario, the use of low-cost distribution technologies (e.g. SWER lines or two phase wires that could lower the cost of long distance distribution lines) has not been considered, but could be analyzed in the future to connect the more distant clusters of customers, specially where there is local generation installed already (e.g. microgrids or large AC stand-alone loads), that contributes to enhance the quality of service for these remote customers.

The use of lower rural electrification standards has also been discussed, but these standards have also been set to high quality levels of service as per specification of EDCL (e.g. 4% maximum voltage drop at the end LV customer). The useful life of the network has been set to 25 years and the financial discount rate is 8%.

2.1.3 Off-grid generation techno-economical catalogue

This concentrated effort for grid extension in high density of load areas results in a Base Case Scenario that shows a large share of off-grid electrification in Rwanda (both microgrids and solar kits). This will result in an increase in the market size for PV panels, batteries and other off-grid equipment. Therefore we expect that with higher volumes of purchases, the prices will become similar to those of other international markets. Per system costs such as infrastructure investment (e.g. small control buildings or fuel tanks) are also taken into account, as well as installation and maintenance labor costs.

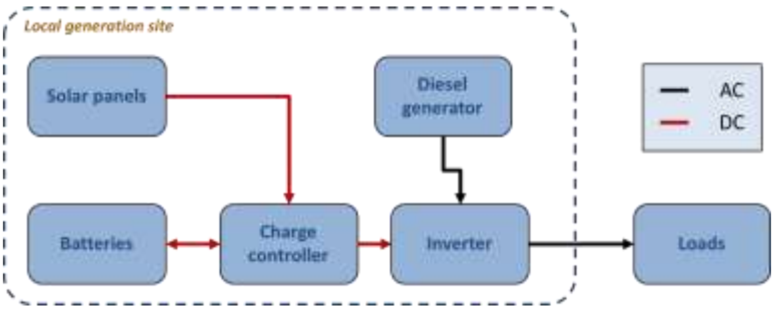


Figure 2-3: REM standard Microgrid Generation scheme

REM assumes that each off-grid system has a single centralized generation system. The architecture is flexible, as not all components are always required. There are alternative architectures, but this one was selected because it can be supported with available off-the-self components, and it provides AC service, allowing a more straightforward comparison with grid extension designs.

The sizing of each micro-grid is optimized considering the hourly solar performance profile, the aggregated customer profiles and the existing solar, storage and diesel hybrid generation alternatives.

For each point in the search space, REM performs a simulation using the load following dispatch strategy. This strategy tries to meet the demand using solar energy first, batteries in the second place, and diesel as the last resource. The battery is only charged with solar energy.

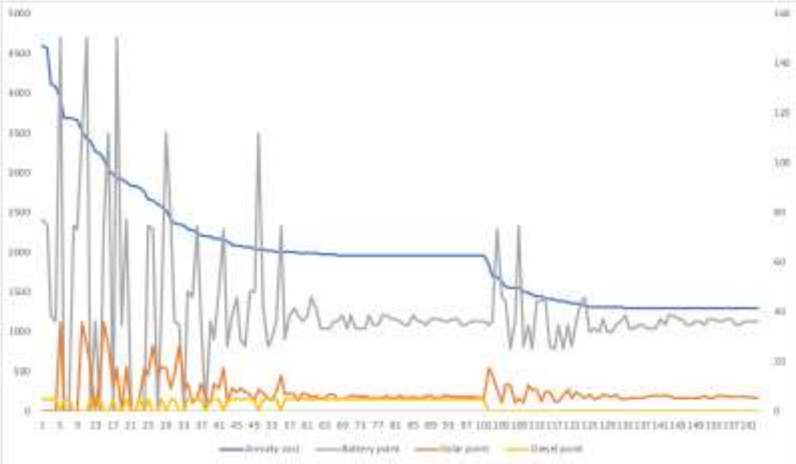


Figure 2-4: REM optimization pathway for a 1kWp microgrid

There optimization of each generation design includes the examination of the different diesel / solar / storage choices to minimize the annuity cost of generation (as shown in figure2-4). This design considers the aggregated demand profile and also the cost of lack of reliability, taking into account that some designs will not be able to meet all the expected demand at certain hours of the year.

2.1.4 Topographical restrictions

There are a number of features that are taken into account at different moments in our methodology. First for the definition of our beneficiary population (outside any forbidden areas) and then to determine the cost of generation (solar map of Rwanda) and network: slope of the terrain, areas of special difficulty (wet lands, rainforest areas) or even forbidden.

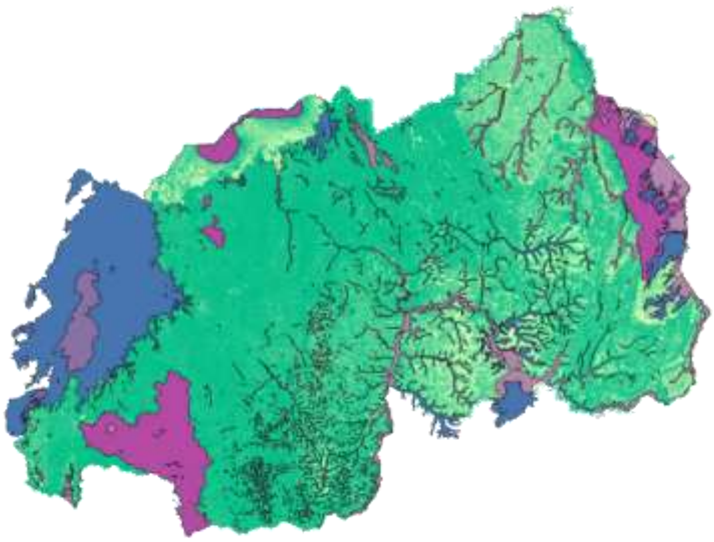


Figure 2-5: Example of Rwanda topographical features: Water bodies and wet lands, protected areas, national parks and altitude lines

2.2 REM algorithmic configuration

2.2.1 Free clustering vs. cell and village level grid-extension constraints

The decision making algorithms of the REM model have been adapted to meet the requirements specified by EDCL for Rwanda.

A first comparison was developed to analyze the impact of making decisions for grid connection at a whole cell level (every customer within the cell boundary would be either grid connected or off-grid), and comparing those with the results at village level (smaller boundaries) or with the general REM free clustering algorithm (that only considers optimal groups of customers according to their layout and their demand, not restricted by administrative boundaries).

Though algorithms restricted by cell or village boundaries were slightly less optimal (within a -2% margin), EDCL considers that not discriminating anyone within an on-grid village (that could be left off-grid in the free clustering configuration) is essential for the success of the implementation electrification plan, counterweighing the loss of optimality according to the preferences of the final customers.

2.2.2 Cell level REM Exhaustive vs. Non-Exhaustive algorithms

Another issue to be considered is how to consider productive loads inside villages which are better off-grid as a whole. Even if the village is off-grid, the connection of high-demand productive loads (e.g. Telecom towers) to the grid can result in a lower electrification cost, and can also benefit other nearby customers with a grid connection (though not the whole village in these cases). REM allows to evaluate individually the connection to the grid of any load (or group of loads) inside an off-grid clusters (called the Exhaustive Algorithm configuration in REM). EDCL determined that connection of customers around productive loads, excluding others within the same village, could be considered as inequitable by those other citizens not so near the productive facility.

For this reason the NEP plan has been configured to not consider the choice of individual grid connections inside off-grid village (Non-Exhaustive algorithm) to determine the choice of electrification modes for each village. But in the implementation phase, any load can always be connected to the grid if it is considered a priority, even if the cost of connection is higher than the cost of the stand-alone solution.

2.3 Selection of Reference Case Scenario for the NEP

After the different previous analyses were discussed in detail with EDCL, the following Reference Case Scenario (RCS) for the initial proposal of Grid and Off-Grid areas for the National Electrification Strategy is:

- Algorithm: Grid extension decision taken at administrative cell level, non-exhaustive.
- Cost of energy from the central grid: 0.12 $/kWh
- Reliability of the central grid: 100%
- National catalogue and network standards: equal for grid extension and grid-compatible microgrids.
- International catalogue for off-grid generation.
- Smallest microgrid size: 50 customers or 3 kWp.

- Discount rate 8%
- Administrative charges per grid-connected customer: 9 $/year
- Administrative charges per microgrid customers
    - Medium size microgrid (100 customers): 16 $/year
    - Large size microgrid: Asymptote at 9$/year
- Per customer costs (as per EDCL specifications)
    - Grid extension and microgrids connection cost: 65 $/customer (meter and connections)
    - Solar kits: 35 $/solar kit (retail price specified by EDCL of a basic SE4all Tier 1 system)
- Average cost of diesel: 1.2 $/l
- Average cost of labor: 1.6 $/hour
- Already electrified customers (2017): 721 512
- Non-electrified customers (2017): 1 612 432
- Number of cells: 2 148
- Number of villages: 14 816
- Forbidden areas: Excluded from the National Electrification Plan

Section-3. Techno-economic least-cost plan for Universal Access in 2024

3.1 Techno-economic optimum for the Reference Case Scenario: Global results for Rwanda

The least-cost balance for this Reference Case Scenario (RCS) is defined by the cost of service of grid extension vs. the alternative cost of microgrids and, where appropriate, solar kits or stand-alone systems. As detailed in Section 1.2 REM calculates the Cost of Service for any given alternative (evaluated as an annuity in USD/year) considering:

- Grid Extension:
  - Cost of energy purchased from the grid, in our case at a cost of 0.12$/kWh, and supplied to the customers, according to their demand, including network losses,
  - Cost of network investment, operation, preventive and corrective maintenance, according to the catalogue and standards defined by EDCL for Rwanda NEP.
  - Other supply costs: Connection, protections and meters, administrative, billing, fee collection overhead costs incurred by the distribution company (EUCL).
  - Social cost of non-served energy. In this RCS this cost will be zero, as the scenario considers as a hypothesis that the reliability of supply in 2024 will be 100%.
- Microgrids:
  - Cost of distributed generation: According to the hourly demand profile of the customers connected to the microgrid, the associated network losses and the solar profile, considering hourly variations, and to the generation catalogue established for the RCS. See figure 3-1 for a sample of this scenario for the district of Nyagatare.
  - Cost of microgrid network, including also investment, operation, preventive and corrective maintenance.
  - Other supply costs, also incurred by the incumbent microgrid company (in this scenario, according to REG specifications, also EUCL).
  - Social cost of non-served energy, according to the specific reliability of the microgrid every hour of the year, considering the different costs of Non-Served Energy for Critical and Non Critical loads / hours.
- Solar Kits and Stand Alone Systems
  - Cost of distributed generation, according to the choice of supply:
    - DC Solar Kits for isolated residential loads under 50 Wp
    - AC Stand-Alone Solar Systems for other eventually isolated high-consumption community and productive customers.
  - Administrative costs:
    - Solar Kits: No other administrative costs are included in this case, as every guarantee or commercial insurance is considered as included in the retail price.
    - AC Stand-Alone Solar Systems. Due to the higher cost and maintenance of these larger systems, a pay per service fee is considered, equivalent to that of very small microgrids.
  - Social cost of non-served energy, according to the loss of load in each specific case.

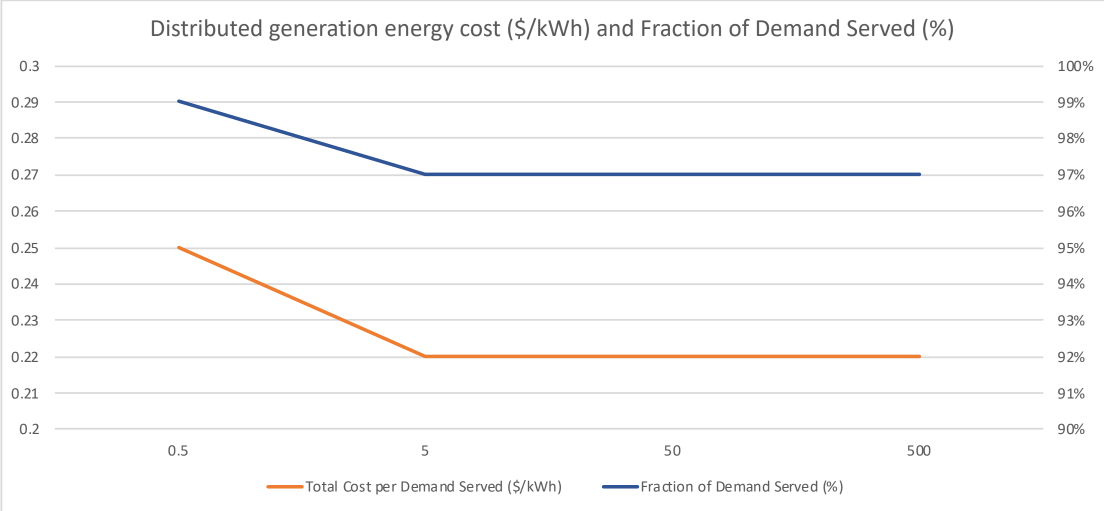


Figure 3-1: Optimal generation cost ($/kWh secondary axis) and average reliability (% energy demand served) of a hybrid solar-diesel microgrid in Nyagatare, for microgrids between 500 Wp (50 type 1 households equivalent) up to 500 kWp

The minimum microgrid size allowed was equivalent to a village of 50 type 1 households (less than 500Wp demand). The cost of generation per kWh for these very small microgrids is a 15% higher than the cost for larger microgrids.

kWp	0.5	5	50	500
Total Cost per Demand Served ($/kWh)	0.25	0.22	0.22	0.22
Fraction of Demand Served (%)	99%	97%	97%	97%
Peak Demand 2017 (kWp)	0.50	5.00	50.00	500.00
Peak Demand 2024 (kWp)	0.81	8.11	81.12	811.23
Average Demand 2024 (kW)	0.311	3.107	31.072	310.724
Yearly Energy Demand 2024 (MWh/yr)	2.72	27.22	272.19	2,721.94
Solar Capacity (kWp)	3	29	288	2832
Battery Capacity (kWh)	19.32	182.16	1854.72	17951.04
Generator Capacity (kW)	0	0	0	60
Financial Cost per Demand Served ($/kWh)	0.25	0.21	0.21	0.21
Percentage of diesel used (%)	0	0	0	0
Total Cost ($/year)	680	5,948	58,940	588,129
Total Cost per user ($/year)	13.61	11.9	11.79	11.76

Table 3-1: Optimal reference designs for solar microgrids generation in Nyagatare, for systems between 500 Wp (smaller microgrid size allowed 50 type 1 households) up to 500 kWp

The generation for each actual microgrid designed by REM will be sized according to the actual users connected to that microgrid clusters, considering their customer types and the demand expected in 2024. PV panels, batteries and, where applicable, diesel generation is optimized to establish the reference cost that can be used to evaluate tender proposals for IPPs in microgrids, as will be further detailed in section 4 onwards reports.

Diesel penetration in the optimal designs, considering the average cost of fuel is 1.2$/l, is insignificant and only appears as small backup power in systems over 500 kWp. This cost is much higher in isolated rural areas and highly volatile, therefore the conclusion is that diesel, if allowed, will be reserved for backup and mainly in very large systems.

3.1.1 Rwanda National Electrification Plan system map

Figure 3-2 below shows the map of systems designed by REM for the Reference Case Scenario. Blue and red lines correspond to medium voltage (MV) and low voltage (LV) connections to the central grid. Green LV lines define connect customers to off-grid microgrid generations and, eventually, orange lines would represent MV networks for very large minigrids (not present in this scenario). Purple points represent stand-alone solar kits and SHS.

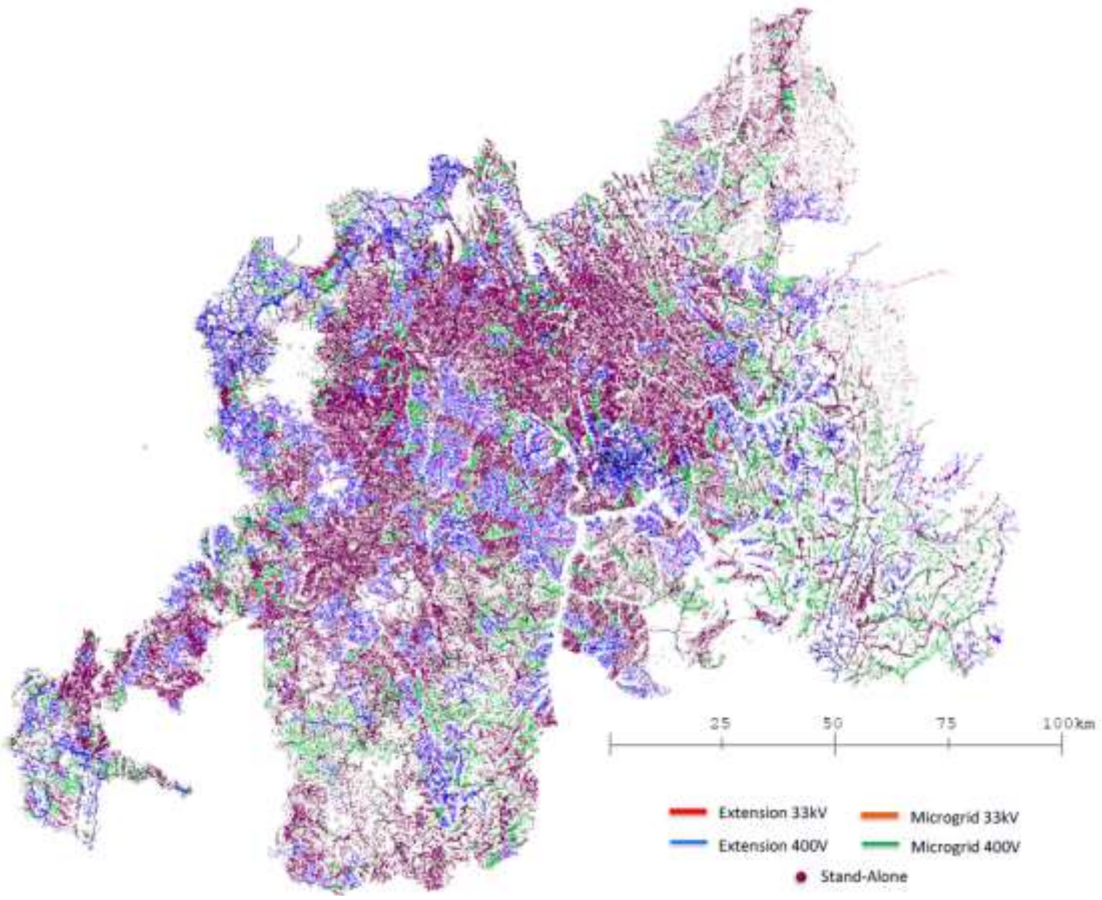


Figure 3-2: Systems map for the Rwandan National Electrification Plan – Reference Case Scenario

For the whole of Rwanda, Figure 3-3 shows the share of the different electrification modes, both in terms of number of customers supplied by grid extension, microgrids and solar kits (a), and regarding the amount of energy supplied to the whole population electrified by the NEP 2017-2024 (b) under the Reference Case Scenario.

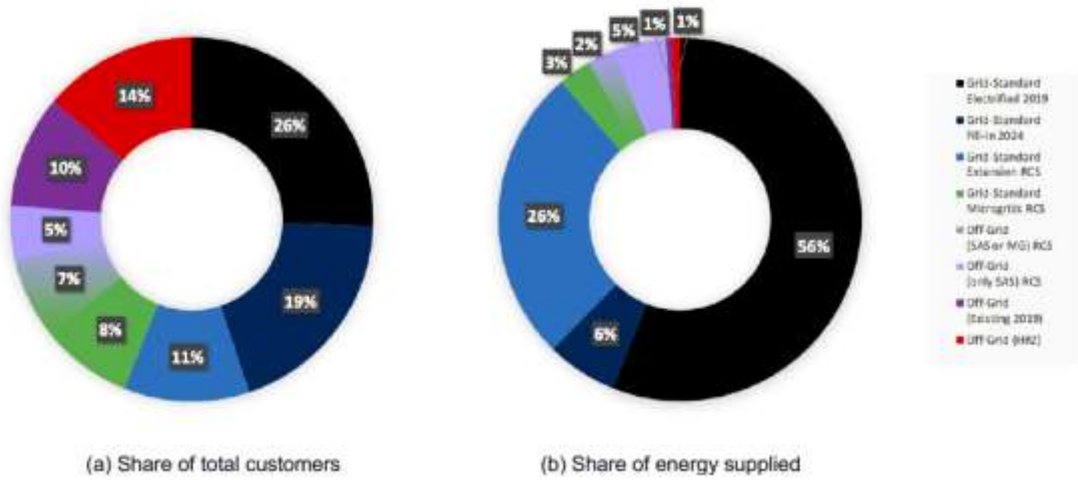


Figure 3-3: Share of total customers and of energy supplied per electrification mode in the Reference Case Scenario 2024

The share of **grid extension in 2024 will reach 56.1% in 2024 of all Rwanda** in the National Electrification Plan - Reference Case Scenario, including 25.6% of already existing connections in January 2019, 19.3% fill-in connections in already electrified villages already, and an additional 11.2% extension of the grid to new villages in 2024. **Off-grid connections will represent 43.9%** of the universal electrification target, of which Grid Standard Microgrids serving a whole village would represent 8.2%, and DC Solar Kits or AC Stand-Alone Systems would account for 35.8%, of which 7.3% are villages where coexistence of solar kits and microgrids could be a choice to consider at the implementation phase, 4.7% are in villages where only SAS is the recommended option, 10% are offgrid customers already electrified in 2019, and 13.7% correspond to customers in High-Risk Zones to be provided with solar kits as well, as detailed in Table 3 below.

Out of a total of nearly 3.9 million connections, including residential, community and productive customers, 2.5 million (64.2%) would be high-quality grid standard solutions (2.2 million connected to the central network and 317 thousands clustered in village microgrids), while almost 1.4 million would receive a DC solar kit, or a fully fledge AC stand-alone-system for large isolated loads, as a transitory solution.

It is important to notice that the total amount of energy demanded by the 56.1% of grid connected customers’ accounts in fact for 88.6% of the total energy consumption of the electrified customers see Figure 3-3 b and Table 3-2). 8.2% Microgrids would supply 2.9% of the energy whereas 35.8% standalone systems would represent 8.4% of the energy demand, as most of the productive and community loads, with a higher weight in the energy mix, are connected by REM to the central grid or to microgrids. The main figures associated with each electrification mode are shown in the table below. The total energy consumption estimated for the Reference Case Scenario reaches 1.78 TWh/year in 2024. This figure reflects on one side that the number of new customers connected through this NEP will be 2.2 times the present number of grid connections, including many significant high-consumption industrial and productive customers. The expected per customer demand growth per year in the RCS is 8.4%, a high figure that results in the design of a robust network that can accommodate future growth and will not become a bottle neck for economic activities in the country.

Electrification 2024	Grid Standard Electrified 2023	Grid Standard Fill-In 2024	Grid Standard Extension RCS	Grid Standard Microgrids RCS	Off-Grid (SAS or MG) RCS	Off-Grid (only SAS) RCS	Off-Grid (Existing 2023)	Off-Grid (MG)	TOTAL
Number of Customers 2024	990,037	746,669	431,366	316,838	281,533	181,264	388,827	533,538	3,870,072
Fraction of Customers 2024	25.6%	19.3%	11.1%	8.2%	7.3%	4.7%	10.0%	13.8%	100.0%
Overnight Investment (USD M$)	-	448.00	315.67	199.77	24.93	16.05	-	18.67	1,023.10
Fraction of Overnight Investment	0.0%	43.8%	30.9%	19.5%	4398.4%	1.6%	0.0%	1.8%	100.0%
Energy Consumption 2024 (GWh/yr)	997.13	752.02	467.81	52.44	43.98	28.32	9.53	13.07	2364.30
Fraction of Energy Consumption 2024	42.2%	31.8%	19.8%	2.2%	1.9%	1.2%	0.4%	0.6%	100.0%
Overnight Investment p.c.(USD/customer)		600.00	731.79	630.53	88.56	88.56		35.00	
Overnight Investment p.u.(USD/kWh)		0.60	0.67	3.81	0.57	0.57		1.43	

Table 3-2: Summary results of the Reference Case Scenario NEP 2024

The cost of fill-in connections in already electrified villages has been estimated according to an average cost of connection of 600 $/customer as per EDCL indications. A more indepth study, though is beyond the scope of this NEP, could be developed but would require a very thorough analysis of the status of the present MV and LV network components and their load. As for the new grid standard extension, the average investment cost is 729 $/customer and averages many different connection types and circumstances. Considering the load and distance to the existing MV grid, some large systems show an average of 301$/customer, whereas others climb up to 5,901 $/customer, nearly twenty times more, in the Reference Case Scenario (depending not only on the distance of the village to the grid, but also on the loads in the grid extension piece). Grid standard Microgrids have an average overnight cost of 630 $/customer, which in this case includes network (67%) and generation (33%) investment costs. In this case the cost per customer ranges from 449 $/customer to 3,684 $/customer for those microgrids where large anchor loads increase the cost of generation (74% in this case) in relation to the network (26%).

Table 3-3 shows how the average investment cost of connection to the grid is split according to the relative weight of the different customer types. The network cost per customer is calculated according to their peak load in 2024, according to the NEP timeline, with an average cost of 364.15 $/kWp. Therefore, while large industrial connections would cost several millions of dollars, residential connections, with a subsistence peak load in the range of tens of watts will individually represent a very small amount of the total share of the grid cost.

Customer type	Power (kWp) (year 0)	Power (kWp) year 7	GE NPV cost per customer	GE NPE cost per kWp (year 7)
Airport	6,000.00	10,552.52	25,847,150	2449.38
Cell ofice	2.00	3.52	8,616	2449.38
Coffee washing station	1.50	2.64	6,462	2449.38
Health center	1.80	3.17	7,754	2449.38
Health post	1.00	1.76	4,308	2449.38
IDP Model Village (avg.)	13.00	22.86	56,002	2449.38
Irrigation pumping	3,000.00	5,276.26	12,923,575	2449.38
Markets	8.00	14.07	34,463	2449.38
Milk collection center	1.40	2.46	6,031	2449.38
Mining	25.00	43.97	107,696	2449.38
Preprimary school	0.40	0.70	1,723	2449.38
Primary school	0.40	0.70	1,723	2449.38
Secondary school	1.30	2.29	5,600	2449.38
Sector Office	1.40	2.46	6,031	2449.38
Tea Factory	3,800.00	6,683.26	16,369,862	2449.38
Technical Schools	26.00	45.73	112,004	2449.38
Telecom Tower	280.00	492.45	1,206,200	2449.38
Universities and Institutes	130.00	228.64	560,022	2449.38
VTC	280.00	492.45	1,206,200	2449.38
Water pumping stations	40.00	70.35	172,314	2449.38
Residential 10W	0.010	0.018	43.08	2449.38
Residential 50W	0.050	0.088	215.39	2449.38

Table 3-3: Breakdown of average network cost per customer in the Reference Case Scenario

The energy consumption is higher for grid-connected customers (1,129 $/customer) than the one of microgrids customers (172 $/customer). This is due to the fact that large industrial and productive customers are mainly connected to the grid, therefore their energy demand is enormous (with peak consumptions up to 6 MW) in comparison with the very small demand of the average residential customer (from 10 to 50 W).

The average total per unit cost of energy for the system is high (0.255 $/kWh), especially if we compare it with the cost of purchasing energy from the upstream network (0.12 $/kWh). The level of consumption is small compared to the capacity of the network components used in the catalogue, meaning than in average the cost of new distribution, both grid and off-grid, multiplies in more than twice the cost of centralized energy from the grid in the Rwandan System. The average cost for grid standard extension is 0.199 $/kWh, while for grid standard microgrids it climbs up to 0.593 $/kWh. This is due not only to the higher cost of off-grid generation, in comparison to the cost of energy from the grid, but also because of the better use of the grid made by high-consuming grid connected customers.

3.1.2 Costs breakdown of individual grid extension and microgrids.

It is also important to realize that the cost of supply for grid standard extension customers is not homogeneous for all the 931 individual grid extension projects summarized in Figure 13. The average size of 463 customers per grid extension section and 0.199 $/kWh do not reflect the diversity of situations shown in the Figure. Starting with those sections in downtown areas or nearby very high-end industrial loads, the cost of service for those customers will be around 0.13 cents actually. When the weight of these large energy consumers diminishes, the cost of service rapidly starts to increase for the connection of disperse loads, even if they are cheaper than off-grid alternatives (microgrids or solar kits / SHS) rapidly reaching over 0.40 $/kWh for still large size grid extension sections, and then growing up to 0.80 $/kWh for large grid sections far from the existing MV grid and with a very low energy consumption (shown in the figure as the generation cost, as compared to the annual network cost).

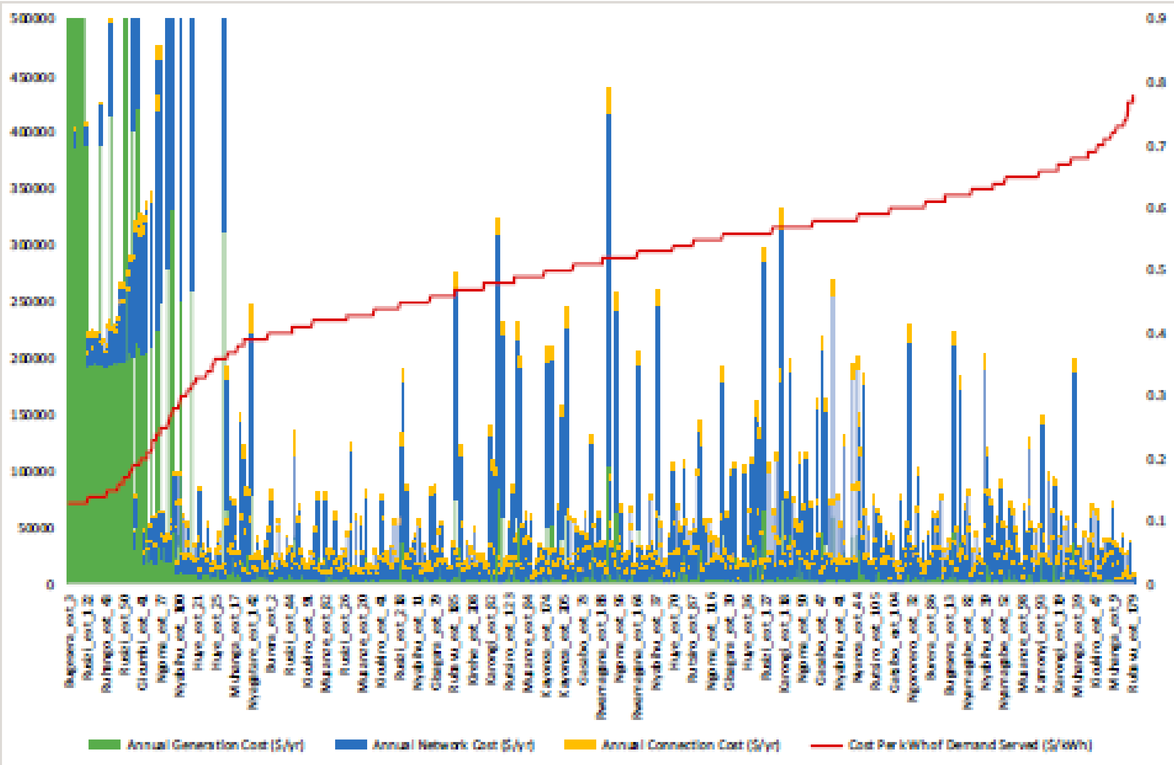


Figure 3-4: Breakdown of selected individual grid-extensions costs. Rwandan National Electrification Plan – Reference Case Scenario

A similar breakdown can be shown for the 2843 microgrids, which are much smaller in average size (152 customers per microgrid) as shown in Figure 3-5. Most of the microgrids are in the final trench over 0.50 $/kWh, but very dense microgrids shown in the Figure, that include mid-size productive loads far from the grid can get their costs down to 0.23 $/kWh, very competitive with the cost of the grid. Therefore it is individual balance between the costs shown in Figures 24 and 25 the one that determines the frontier between the grid the microgrids, a qualitatively different approach to the use of heuristics like the distance to the grid or the density of loads, which do not resemble correctly the actual complexity of grid and off-grid system design calculated by REM.

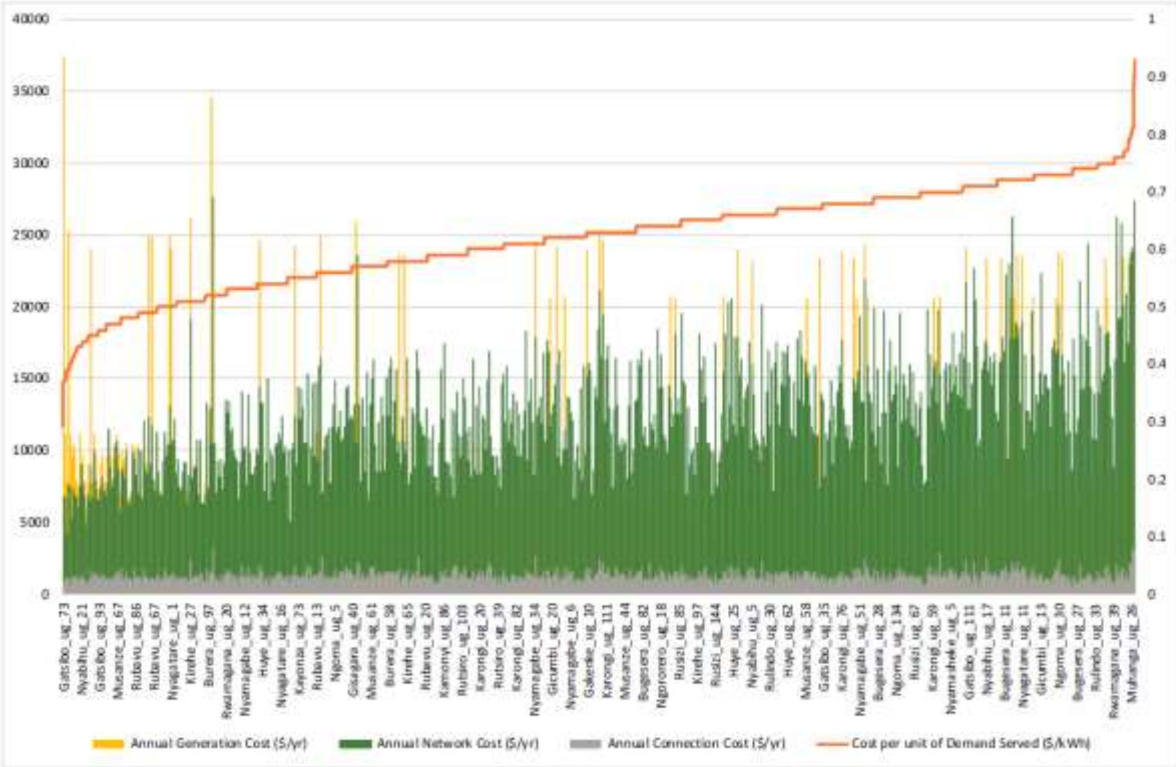


Figure 3-5: Breakdown of selected individual microgrids costs. Rwandan National Electrification Plan – Reference Case Scenario

3.1.3 Solar Kits and Stand-Alone Systems in the Reference Case Scenario

Finally, REM also will include the design of those isolated loads that are being served (from a least cost perspective) by an isolated system, instead of connected to the grid or a microgrid.

Customer type	PV Array Size (kWp)	Battery Bank Size (kWh)	Annual Demand (kWh)	Fraction of Demand Served (p.u.)	Cost Per kWh ($/kWh)	NPV per Customer ($)
Pre-primary	2	14	2,178	0.93	0.26	5,572
Primary School	2	14	2,178	0.93	0.26	5,572
Secondary School	7	46	7,077	0.95	0.22	16,157
Sector Office	8	50	7,621	0.95	0.22	17,330
Technical Schools	145	925	141,541	0.96	0.21	304,880
Telecom Tower	1,584	9,853	1,524,289	0.96	0.21	3,317,780
VTC	1,584	9,853	1,524,289	0.96	0.21	3,317,780
Cell Office	11	71	10,888	0.95	0.22	24,368
Water pumping	223	1,422	217,756	0.96	0.21	468,608
Residential 10W	0	0	54	0.45	0.36	94
Residential 50W	0	0	272	0.09	0.36	94
Coffee Washing	8	53	8,166	0.95	0.22	18,503
Health Center	10	64	9,799	0.95	0.22	22,022
Health Post	6	36	5,444	0.95	0.23	12,638
IDP Model Village	73	463	70,771	0.96	0.21	152,848
Markets	45	285	43,551	0.96	0.21	94,422
Milk Collection	8	50	7,621	0.95	0.22	17,330
	53	**333**	**51,392**	**0.80**	**0.26**	**111,846**

Table 3-4: Solar Kits and Stand-Alone Systems design and average cost breakdown for the Reference Case Scenario (Solar Kits Cells)

In the Reference Case Scenario we find that the majority of these loads are low-consumption residential customers of Types 1 and 2 (consuming less than 10 W and 50 W) provided with a DC Solar Kit. In this cases the reliability resembles the share of their grid connected demand that would be served by the selected Kit, not the reliability of the Kit itself, which should provide the service according to those essential needs it is covering. There are also other loads that at each district are in off-grid villages and do not get connected to nearby customers. This is the case for more than 300 schools in the country, almost the same amount of cell Offices. The cost of supply of an AC Stand-Alone System for those demands is very competitive (in between 0.21 $/kWh and 0.26 $/kWh), making them a possible suitable solution for community and productive loads far from the grid and below the minimum threshold established for a microgrid (i.e. 50 customers or at least 3 kWp demand). The proposed IDP model village sites under development have been modelled as a single load for the purpose of REM, but naturally they will be receive microgrid supply as they are built.

3.1.4 Rwanda National Electrification Plan: villages map

The basic block for grid/off-grid electrification choice in Rwanda is the administrative cell boundary. REM calculates the least-cost option for the whole customers (productive, community or residential) inside the cell, so they will all get either connected to the central network or provided an off-grid solution.

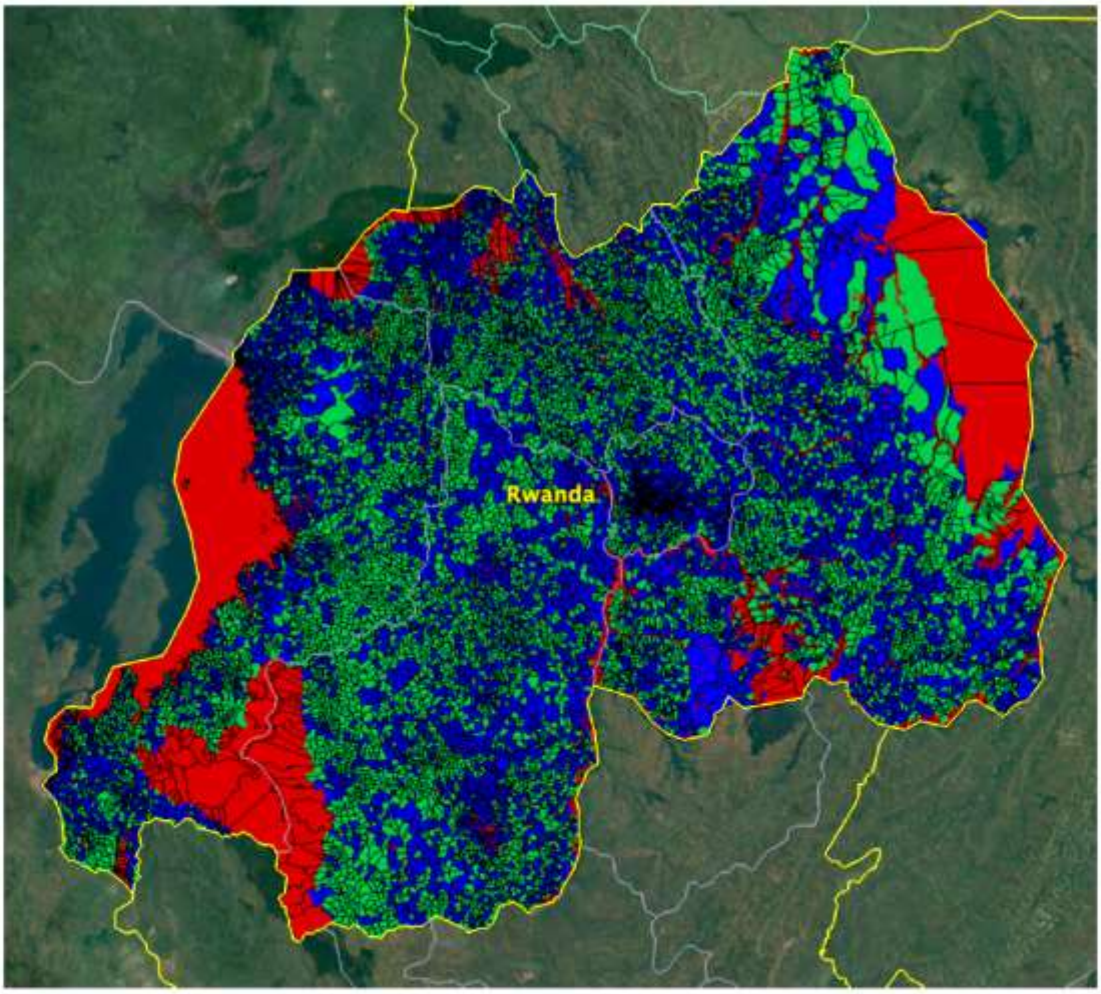


Figure 3-6: Satellite projection of grid extension villages (blue), microgrid villages (green) and solar-kits/stand-alone systems (purple) for the Reference Case Scenario

Figure 3-6 shows the map of the grid connected and off-grid villages for the National Electrification Plan of Rwanda. The National Electrification Plan has classified all the cells in the country according to the following electrification modes.

- Grid Extension Villages. These include:
  - Grid Standard Extension RCS Villages: Out of 14,816 villages in Rwanda, 2,476 shall be connected to the grid in the Reference Case Scenario. They will require the development of new infrastructure (MV transformers, MV and LV lines). A full list is provided in ANNEX 3: NEP Grid Standard Extension villages connected to the existing central network in the RCS.
  - Grid Standard Fill-In Villages: 4,662 villages have already got a MV line and transformer providing electricity service. From 2019 to 2024 the challenge for these villages is to connect any facility or household not yet connected or built anew in the area. The list of Fill-In Villages can be found in ANNEX 6: NEP Fill-in villages already below the existing central network.

- Off-Grid Villages:
  - Grid Standard Microgrid RCS Villages: Additionally, the basic block in off-grid villages to decide whether microgrids or solar kits are the least-cost solution is the village boundary. 2,568 Villages have been classified for microgrid electrification when the least cost option is to electrify the customers in the village with a microgrid. A detailed list of the villages where the least-cost option is a microgrid is shown in ANNEX 4: NEP Grid Standard Microgrid villages in the RCS.
  - DC Solar Kits or AC Stand-Alone Systems RCS Villages. All these 5,110 villages are selected for electrification with isolated systems, either DC solar kits for small customers (low-income households) or full-fledged systems which provide 24 hours service for larger customers (isolated productive and community loads). In some of these villages, smaller clusters could still be suitable for microgrid electrification, as shown in Table 3, but the villages where the whole population could be electrified with one or several Microgrid Systems have been prioritized and in all the remaining off-grid villages, solar kits and stand-alone systems will be promoted. A complete list of these villages can be found in ANNEX 5: NEP DC solar kits or AC stand-alone systems villages in the RCS.
  - NEP High Risk Zones: The households in these areas, regardless of the village they belong to, will be electrified with Solar Kits as required by MININFRA, and they have not been considered for grid standard electrification (either grid extension or microgrid). Some villages are completely inside these high-rish zones shown in red in Figure 15 above, while others villages may have some areas inside HRZ, whose customers have not been considered for the RCS and will be electrified only with solar kits.

It is **important to notice** that this NEP for Rwanda does only focus on the new infrastructure that is required to connect additional customers so that Universal Access can be achieved in 2024.

Reinforcements and densification of the existing MV and LV distribution network are not within the scope of this report. Consequently, the classification of off-grid villages therefore only answers to a techno-economic optimization criteria where new infrastructure is required. Some of the off-grid villages are nearby existing MV and LV lines, which could still retain some extra capacity to accommodate new connections without additional MV lines or transformers. To fully ascertain the possibility of connecting these undergrid NEP off-grid villages to the existing grid, an additional individual field study will be required for each one of them, to accurately establish the existence and the amount of idle capacity in these lines and transformers, and to determine the cost of connecting these new customers to the already existing grid.

Annexures: Design of National Electrification Strategy

ANNEX 1: Detailed analysis of past electrification plans and strategies in Rwanda
https://drive.google.com/open?id=1iodk0I7Pq7CVtwyYrEBxShCK0ety2Hg3

ANNEX 2: RCS REM input catalogue tables
https://drive.google.com/open?id=14jb8AM_iRolcbLuKhEl4A1O0YmlEIlpz

ANNEX 3: NEP Grid Standard Extension villages connected to the existing central network in the RCS
https://drive.google.com/open?id=1xcYiyteUUz76srcq3VmUe_TeNKvV7t_k

ANNEX 4: NEP Grid Standard Microgrid villages in the RCS
https://drive.google.com/open?id=1OVVr1-3krLCQOmfMdX0XaX6wHuONZuEI

ANNEX 5: NEP DC solar kits or AC stand-alone systems villages in the RCS
See attached ANNEX_5_Rwanda NEP_7.0_SAS_Villages.xlsx file.

ANNEX 6: NEP Fill-in villages already below the existing central network
See attached ANNEX_6_Rwanda NEP_7.0_Fill-in_Villages.xlsx file.

Implementation of National Electrification Strategy - Institutional, Regulatory and Financial Recommendations for the National Electrification Plan in Rwanda

Section-4. Introduction- Institutional, Regulatory and Financial aspects

The tasks performed in this Final Report on the design of the National Electrification Plan (NEP) of Rwanda are part of a larger set of activities contributing to meeting the target set by the Rwandan Government to achieve 100% electrification by 2024. This target was set by the National Strategy for Transformation (2017) and it is one major contributing element to the high-level Energy Sector Strategy Plan (ESSP, September 2018) for 2018/19-2023/24.

It is important to realize that the Government of Rwanda (GoR) has established an ambitious and comprehensive energy planning strategy that has been made explicit in an ensemble of documents whose content is summarized later in this document, as well as the description of the roles played by the several institutions involved in its implementation.

The 100% electrification target by 2024 has the objective of contributing to economic growth and poverty alleviation. With the support of multiple development partners, Rwanda has successfully accelerated the rate of growth in access to electricity. The access rate increased from 10% in 2010 to 13% in 2012 to 28.6% in 2016, and to 43% in 2018[3], almost exclusively by grid extension. But the pace of grid extension is insufficient to achieve the access targets and there are less expensive off-grid solutions to meet the estimated demand of many of the still non-electrified customers. Thus, the Government has set a parallel track for off-grid electrification, aiming to achieve the 2024 target through both grid extension and off-grid solutions, including off-grid solar solutions and mini-grids.

The Energy Sector Strategy includes a full-fledged electrification master plan that comprises enhancements in the whole chain from power acquisition via the transmission grid to distribution networks. This comprehensive electrification plan is described at a high level in the ESSP document, including an assessment of the present access situation in Rwanda, an implementation plan, risk analysis, monitoring and reporting systems, costs estimation, and financing strategy.

The present report only focuses on the new MV and LV distribution infrastructure and the on- and off-grid technologies that are required to connect additional customers so that universal electricity access can be achieved in 2024, where "densification" has been treated separately[4]. For this important

[3] Sources: MININFRA and ESMAP et al. report "Rwanda: Beyond connections. Energy access diagnostic report based on the multi-tier framework", June 2018.

[4] Some electrified villages have customers that have not been connected yet. REG has instructed us that all non-electrified customers within the administrative boundaries of those villages (new small grid extensions) or within 37,5 meters of an existing LV line (fill-in) should be connected to the main grid (even if REM in some cases would choose not to). The existing MV and LV lines are assumed to still retain some extra capacity to accommodate these new small extensions or fill-in connections. The completion of the electrification of these villages and customers is termed "densification" herein after in this report. The cost of densification has been estimated in a simplified way, as well as the cost of the upstream reinforcements of the HV distribution and the transmission networks, and the extra generation costs to meet the new demand that is connected to the main grid. To evaluate more accurately the infrastructure and cost of connecting these under-grid non-electrified villages and customers to the existing grid, an additional study would be required for each one of them, to establish the

fraction of the electrification plan (excluding densification), this report presents the least cost option alternative to meet the GoR target, subject to some constraints that were necessary to ensure technical viability and consistency with the priorities set up by the ESSP. In addition to a sound estimation of the investment and operation costs, the results obtained make possible to inform prospective off-grid investors about what areas are not contemplated for grid extension for the temporal scope of the plan (now to 2024). The detailed results of our study will also inform the implementation of the National Electrification Strategy (NES) and the preparation of the National Electrification Plan (NEP).

The ESSP electrification plan is very ambitious compared to the present level of electrification pace, in particular when the corresponding needs for financial and human resources are considered. The electrification ratios resulting from the Master Plan in the present report represent significantly increased efforts compared with the past. This implies a substantial development of additional financial and institutional resources in the future, in particular as rural electrification is extended into more remote areas.

The present report reexamines the ESSP energy strategy in connection with the institutions responsible for the implementation of the electrification plan. It provides comments on the proposed implementation of the plan and the potential financing alternatives. It should be noted that the detailed cost estimates provided by the analysis in this report refer only to a fraction of the total cost of the electrification plan, while the cost of the remaining part of the plan has been only estimated roughly or ignored: densification, and the “upstream total investment and operation costs” of necessary reinforcements in the networks of HV distribution and transmission, as well as in centralized generation are considered, but only in a crude way; and the assumptions of the ESSP on the cost of improving the reliability or reducing losses of the existing networks have not been revised.

existence and the amount of idle capacity in these lines and transformers precisely, and to determine the cost of connecting these new customers to the already existing grid.

Section-5. The Energy Strategy

In this section, we start by briefly describing the current situation of the power sector in Rwanda, with a focus on the lack of access of a large fraction of the population, and the insufficiency of the current electrification pace to reach the goals that have been set up. Then, in the following subsection, we concisely summarize the present high-level strategy, as a first step for the posterior assessment in the following sections.

5.1 The current situation

This section and the next one are based on the information provided by an ensemble of official documents recently published on the energy sector in Rwanda, and the power sector in particular. The last Annual Performance Report (August 2017) of EDCL describes key achievements in the scope of its mandate, registered over the fiscal year 2016/2017 (July 2016 through June 2017), as part of the implementation of the 5 Years' National Energy Sector Strategic Plan (ESSP)[5]. Current information is also provided by the 2018 World Bank report "Rwanda – Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework"[6]. Additional information has been obtained from the "Rwanda Energy Group (REG) Strategic Plan 2019-2024"[7], the "Rwanda Least Cost Power Development Plan (LCPDP) 2019-2040)"[8], the "Rwanda - First Programmatic Energy Sector Development Policy Financing Project"[9], and the 2019 Rwanda Economic Update by the World Bank Group.[10]

The section covers the different supply activities – centralized generation, transmission and distribution – as well as the characterization of the demand.

Generation.

The total installed capacity to generate electricity in Rwanda is 221.9 MW, with 154.1 MW of available capacity, as of June 2019[11] from more than 40 power plants, mainly hydro. By installed capacity in the generation technology mix, 46.3 % is from hydrological resources, followed by thermal sources (fuel 25.7% and peat 6.7%) adding 32.4%, methane Gaz (13.4%), Solar (5.4%) and Imports (2.4%) according to REG in 2020. Currently, thermal units, especially diesel, contribute a big share to the installed capacity of the Rwandan system. These units, however, are only operated during peak hours due to their high operation cost. REG ensures maximum use of cheaper hydro power options, but this

[5] http://mininfra.gov.rw/fileadmin/user_upload/new_tender/Energy_Sector_Strategic_Plan.pdf
[6] https://openknowledge.worldbank.org/handle/10986/30101
[7] https://www.reg.rw/public-information/policies-regulations/
[8] http://www.reg.rw/public-information/reports/ Prior to this LCPDP, current practice mostly relied on ad hoc unsolicited proposals from project developers to identify new generation investment options, without competitive processes and without adequate consideration of the relative costs and benefits of different options resulting from properly conducted least-cost planning. This imposes undue financial burden on the sector, putting at risk achievement of the Government's affordability and expansion targets. MININFRA has adopted a resolution requiring the LCPDP to be updated on an annual basis by REG.
[9] World Bank. 2017. http://documents.worldbank.org/curated/en/321321512356422171/Rwanda-First-Programmatic-Energy-Sector-Development-Policy-Financing-Project

[10] World Bank Group (2019) Lighting Rwanda. Rwanda Economic Update. June 2019. Edition No. 14.
[11] http://www.reg.rw/public-information/reports/

presents challenges during the dry season. Currently, peak demand and reserve during peak are served by mainly diesel-powered power plants, as well as seasonal inputs from the big hydro storage power plants on the system. The use of diesel during these hours hikes up the generation cost, and consequently the electricity tariff. Importing power from Uganda replacing diesel production would significantly reduce the generation cost prior to Hakan entry in 2020. No imports would be needed beyond this year, as there will be more than enough domestic capacity to satisfy the existing national demand, unless a strong demand growth happens in association with a vigorous electrification plan.

A number of projects to build new power plants are underway and will add more capacity on the existing national grid from 2020 onwards. The summation of current installed capacity and large power projects that have been committed and are currently under construction by 2025 is 506.2 MW, amounting to 390.36MW of firm capacity, with the new capacity being about 50% hydro and the rest peat, methane and solar power plants. With the assumed rate of demand growth of 10%, there will be a surplus of generation capacity. If the existing and planned interconnectors for the six Nile Equatorial Lakes Subsidiary Action Plan (NELSAP) member countries – i.e. Burundi, Democratic Republic of Congo, Kenya, Rwanda, Tanzania and Uganda – actually happens, it would be possible to export power elsewhere. From 2020 – 2025, peak exports of average 47.10 MW are possible, as well as stimulation of growth of existing demand (particularly industrial demand to improve the country load factor) to over 10% to absorb the incoming capacity in the short term. Accelerating access by grid extension is another possibility.

The estimated surplus of generation capacity after 2020 will create pressure on the tariff and – if the tariff remains below costs – on the need for Governmental subsidies. The new capacity – hydro, peat and methane from lake Kivu – requires high investment costs. The variable costs are (artificially) low, as Rwanda does not assign much value to its methane or peat reserves. Since high capital charges will be incurred – whether the plants are dispatched or not – these charges will have to be absorbed by the tariffs or subsidies. According to the aforementioned Lightning Rwanda World Bank report[12], this surplus capacity will result in a total subsidy requirement of around 2% of the GDP between now and 2025, if a rate of demand growth of around 8% per annum is assumed. Increasing demand is therefore a key priority for the Government, as the capital costs would be diluted into larger demand.

Rwanda relies on hydropower for a significant share of its generation capacity (currently 46.3%). Therefore, the short- and long-term sustainability of power supply are exposed to climate risks. Over the past 30 years, Rwanda has experienced unusual irregularities in climate patterns. Without appropriate planning, these irregularities may affect the availability and reliability of hydropower supply and may increase the need for costly fossil backup or emergency generation. Appropriate planning procedures will create a more secure energy mix by including complementary renewables and engaging in regional trade—thus mitigating climate risks.

Transmission.
Rwanda's transmission network is of three main voltage levels; 70, 110, and 220 kV. By the end of March 2017, there were about 744.7 km of transmission lines, evacuating power from various points

[12] https://openknowledge.worldbank.org/handle/10986/31932

of generation across the country, as well as facilitating regional interconnectivity. Of the total network laid out so far, 480.4 km (64.5%) are 110 kV and 264.3 km (35.5%) are 220 kV transmission lines. The remaining 70 kV lines that existed until 2013 were upgraded to 110 kV to improve network reliability and power supply stability amidst the country's changing power demand profile. Substantial investments in transmission infrastructure have been made in recent years to reinforce the existing network, and important additional investments are planned until 2024 to make adjustments and allowances for the future generation capacity as well as for increases in regional power trade and improvements in the present level of reliability of supply.

***Distribution*.**

In 2017, Rwanda electricity distribution network had a total of 5,590 km of medium voltage (MV) lines of diverse voltages: 30kV, 15kV, 17.32 kV and 5.5 kV, as well as 10,572 km of low voltage lines (LV) giving on-grid electricity access to 34% of Rwanda households. As from April 2019 the total length of existing MV lines (as per NEP 2024) had increased to a total of 7,741 km, connecting 36% of the total customer base according to EDCL data.

A key driver in the expansion of on-grid access has been the Electricity Access Roll-out Program (EARP), which was launched in 2009 by the GoR and the development partners and updated in 2017 to facilitate the upfront consumer payment and to increase the rate of connections.

The GoR has also supported the provision of off-grid access through the Rural Electrification Strategy (2016). There is support for low-income households in accessing basic solar home systems (with a cost of \$50-\$100 per solar kit) that meet minimum technical specifications and warranty requirements. Many off-grid companies are now operating in Rwanda, supplying systems to houses both through governmental programs and independently. Some mini-grids are developed by private sector with donors that totally or partly subsidize the costs and/or cross-subsidize tariffs if suitable anchor loads are available, with the GoR playing a key role in identifying appropriate sites and establishing regulation that mitigates some future risks (e.g. clarifying what happens “when the grid arrives”).

Consumption.

Total annual electricity consumption is 527 GWh. Average per capita consumption (for those with electricity access) is 43 kWh, but only 30 kWh in rural areas[13], well below urban consumption and ten times less than the Sub-Saharan African average at 478 kWh/year/capita (this last data of 2015). In 2018, about 43% of Rwandan households had access to electricity.[14]. As of April 2019, the number of Rwandan customers with connection to the grid had grown to approximately 37% (990 thousand), and another 14% (390 thousand) were supplied by an off-grid solution (solar kits).

According to ESSP, out of 8,855 productive users identified, 2,733 (31%) do not have an electricity supply. Of the 69% that are electrified, 6,100 have on-grid connections and only 22 off-grid. Table 16 from the ESSP report shows the breakdown by consumer type.

[13] Source: WorldData.info, see https://www.worlddata.info/africa/rwanda/energy-consumption.php
[14] Rwanda is small but densely populated. Its 26,338 square kilometers hold 11.6 million people, resulting in a high population density of 415 inhabitants per square kilometer. Roughly 86% of Rwanda’s population lives in rural areas.

Table 16 Productive users to be connected by type

User category	Number	User category	Number
Beverages and Tobacco	14	Mining facility	80
Cell Office	843	Pre-primary school	214
Coffee Washing Station	109	Primary school	700
Food Processing	41	Secondary school	281
Health Facility	104	Sector office	25
IDP Model Villages	35	Tea factory	2
Industry park	1	Technical school	14
Irrigation pumping facility	13	Telecom tower	97
Market	111	University and Institutes	1
Milk Collection centre	15	Water pumping facility	33
Total			**2,733**

Table 5-1: Productive users to be connected by type (Table 16 of ESSP report)

***Losses*[15].**

Transmission and distribution losses in Rwanda as at June 2017 were 22%, significantly higher than the international benchmark of 6% to 8%. Of this total, 17% were technical losses and 5% commercial. This was equivalent to 128 GWh in lost energy per year, resulting in an annual financial cost of $28 million. Even if losses are held at current levels, the financial cost to REG will increase significantly as demand grows.

5.2 The current energy strategy.

This ESSP builds on the progress made under EDPRS II (Economic Development and Poverty Reduction Strategy), sets new targets and identifies new approaches, which will deliver improved performance. The ESSP is developed in more specific terms in other plans than focus on partial areas within the power sector. The most prominent ones are the National Energy Policy (NEP in 2015) and the Rural Electrification Strategy (RES) (2016).

The *National Energy Policy (NEP)* (2015) is the high-level policy document which guides and influences decisions on the extraction, development and use of Rwanda's energy resources in a transparent and sustainable manner. It sets out governing laws and regulations, strategic directions and guiding principles that Rwandan institutions and partners shall adopt and adhere to, in subsequent implementation of actions. The NEP and ESSP are mutually reinforcing: the NEP outlines a long-term vision, provides high-level goals, and recommends clear and coordinated approaches for achieving that vision; the ESSP outlines targets and an implementation framework against which to measure progress towards the realization of the policy.

[15] Total losses amount to the energy that is injected into the transmission and distribution grids but that is not paid for by users. Total losses consist of technical losses (energy dissipated in the electric equipment) and commercial losses (non-paid or stolen electricity).

The *Rural Electrification Strategy (RES)* published in June 2016 sets out a clear development plan for the off-grid sub-sector, including that 48% of all households would have their electricity needs met by off-grid solutions by 2024. Expansion of the grid would continue through the Energy Access Roll-out Program (EARP), with 52% of households connected to the grid[16]. It is recognized that off-grid solutions, including solar home systems (SHS), would play a key role (48%) in achieving full electrification for all households in Rwanda by 2024.

Regarding electrification, ESSP sets a number of high-level target objectives, along with high-level plans to achieve them:

- Increase generation capacity to ensure that all demand is met, and a 15% reserve margin is maintained.
- Improve reliability of electricity supply: average number of power interruptions per year reduced to 14.2 and average number of hours without power to 91.7.
- Increase household access to electricity to 100%.
- Increase productive user access to electricity to 100%.
- Provide the existing and new major national and urban roads with street lighting.
- Reduce losses in the transmission, distribution networks and commercial losses to 15%.

Generation.

Current projections for peak demand in the ESSP, including 15% reserve margin, estimate reaching between 282 MW and 376 MW by 2024. At the start of the ESSP the installed generation capacity was 218 MW. New investments will be based on the Least Cost Development Plan (2017), ensuring that resources are deployed efficiently. This will be updated regularly. The generation mix would have around 52% of renewable sources by 2024 – above the SE4ALL minimum and far above the international average. Independent Power Producers (IPPs) will continue to be encouraged to finance and deliver generation projects through Power Purchase Agreements (PPAs). This will reduce the pressure on Government resources, attract internationally state-of-the-art technologies and reduce costs through competition. Underutilization of generation infrastructures must be minimized, with tight alignment between supply and demand, so that the fixed costs in the PPA contracts will be shared among the largest possible number of kWh of demand.

Transmission and distribution.

The existing transmission and distribution networks need important upgrades to improve the reliability of the power system and to reduce losses, according to the prescribed targets. In the ESSP these upgrades are separately considered from the needs for network extension and reinforcements to provide access to the unelectrified customers.

A number of initiatives are underway to reduce technical losses. Infrastructure, such as capacitor banks and advanced metering (which can support the quantification of losses) are being installed, and

[16] This initial hypothesis in the Rural Electrification Strategy (2016) and the ESSP (2018) has been reviewed in the analysis performed in this document, in view of the actual progress that has been made and the last available data.

transmission and distribution lines and substations, are being upgraded. As a critical step to reducing commercial losses, smart metering is being installed at large customers.

Given forecast population increases, 3.72 million households (100%) will have access to electricity by 2024. As of 2018, 43% of Rwandan households had access to electricity. According to the ESSP, by 2024 this will be expanded to 100%, with 52% of the customers connected via grid extension and 48% connected via off-grid technologies. These ratios have been modified in the present study, using the advanced geospatial methods and optimization techniques explained in Section 1.2 of this Report Design of the National Electrification Plan in Rwanda. According to the ESSP estimates, around 1,036,000 households would be connected to the grid to achieve 100% access in 2024. Starting in 2018, this would require about 170,000 new connections per year. To support increased access, it is planned that 5,600 km of MV lines and 8,050 km of LV lines will be constructed during the period. The EARP will continue to drive grid connections. In this evaluation, the ESSP used a cost estimation of roughly $700 per connection.

The remaining 1,500,000 households, according to ESSP, will be electrified with off-grid solutions. This would imply 250,000 connections per year, starting in 2018. Standalone off-grid access provides timely, affordable electricity, with per-connection cost estimated at $100. Combining it with grid expansion reduces the financial burden on the utility and offers access to remote households or productive users who would otherwise have to wait years for the grid. It is expected that off-grid access will be delivered through the Rural Electrification Strategy (RES) with essential the support of the private sector.

***Productive users*.**

All productive users will be connected, up from the current level of 72%. 2,421 productive users across Rwanda currently have no electricity connection. Productive users utilize energy for activities that enhance income and welfare and include health and education facilities, public infrastructure and industry. Connecting productive users away from cities (this would be contrary to the strong urbanization trend throughout Africa) would support rural economic development and, as they have a higher ability to pay for energy services than households, improve the economic sustainability of the sector. The cost of supplying all 8,855 productive users is US$30.2.

Street lighting.

Street lighting will be expanded to all national roads (existing & new) and urban roads. Expected results include reductions in crime and traffic accidents, as well as revitalizing rural communities.

***Reliability*.**

In addition to connecting new consumers, the reliability of electricity supply will be improved significantly for both households and commercial consumers with the ambitious targets that were mentioned above. In principle these improvements will benefit mostly existing customers. The ESSP indicates that 5600 km of MV lines and 8050 km of LV lines will be needed to extend access by grid extension, without mentioning any required HV distribution and transmission network reinforcements.

Efficiency.
Improving efficiency will be a priority across all sub-sectors, as established in the Energy Efficiency Strategy, which consists of a range of initiatives which will improve efficiency across the entire electricity value chain, from generation, through transmission and distribution to end-user consumption. As demand increases, reducing losses will have an increasingly significant impact on the financial performance of REG, as well as reducing the environmental impact of the sector.

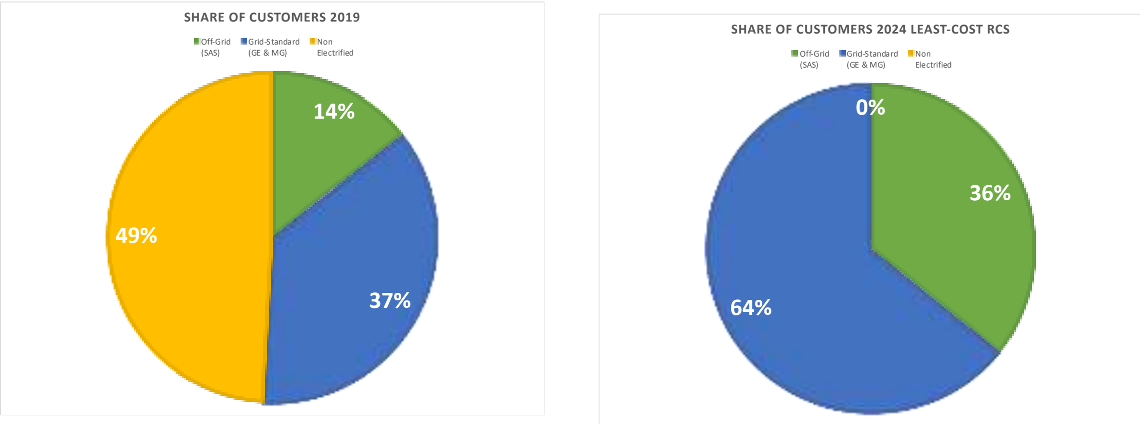
Costing.
The total cost of implementing the ESSP between 2018 and 2024 is estimated at $3.12 billion[17]. This is the total cost for the three considered subsectors: electricity ($2.73 billion), biomass ($184 million) and petroleum and gas ($207 million). Electricity expenditure is largely driven by building new power stations ($1.45 billion) and improving the reliability and reducing losses of the existing networks, both transmission ($207 million) and distribution ($86 million). On-grid connection costs for households are estimated as $674 million and off-grid as $160 million. The estimated cost of providing electricity to un-electrified productive electricity users is $30 million. Street lighting estimated cost is $123 million. See Table 24 from the ESSP report for further details.

Regional integration.
Regional integration will increase significantly, with much stronger network interconnection expected by 2022. Connecting the power systems of regional countries will improve network stability and will also present opportunities for inter-country trading of power. In Rwanda, significant augmentation of per kWh costs will be incurred if new generation capacity happens to be too large for the network to export to other countries.[18]

5.3 Verification and update of the electrification results.

Our results, elaborated during the end of 2018 and first months of 2019, with hypotheses agreed with EDCL and the last available data, provide a verification and refinement to the prior results of electrification in the ESSP, but only for households, commercial and industrial loads outside the direct range of the existing MV and LV distribution network (these villages have been defined as fill-in and densification areas, where an initial estimation of the investment cost required to connect all the expected new customers in these areas has been provided, but further field, satellite and techno-economic work will be required with EDCL to determine the precise individual cost of each of these connections and the associated reinforcements required upstream the distribution grid).

[17] Please note that currency quantities in this report are expressed in USD, unless otherwise stated.
[18] Currently, the only major inter-country power flow in the region is the export from Ethiopia to Sudan. However, a number of transmission lines are under construction between countries in the region and it is expected that by 2022 East Africa should be almost fully integrated. Further, the region will be connected to the South Africa Power Pool (SAPP) via the Tanzania-Zambia line. Rwanda is developing connections with the DRC, Burundi, Uganda and Tanzania. These connections will support network stability and enable regional trading of power.

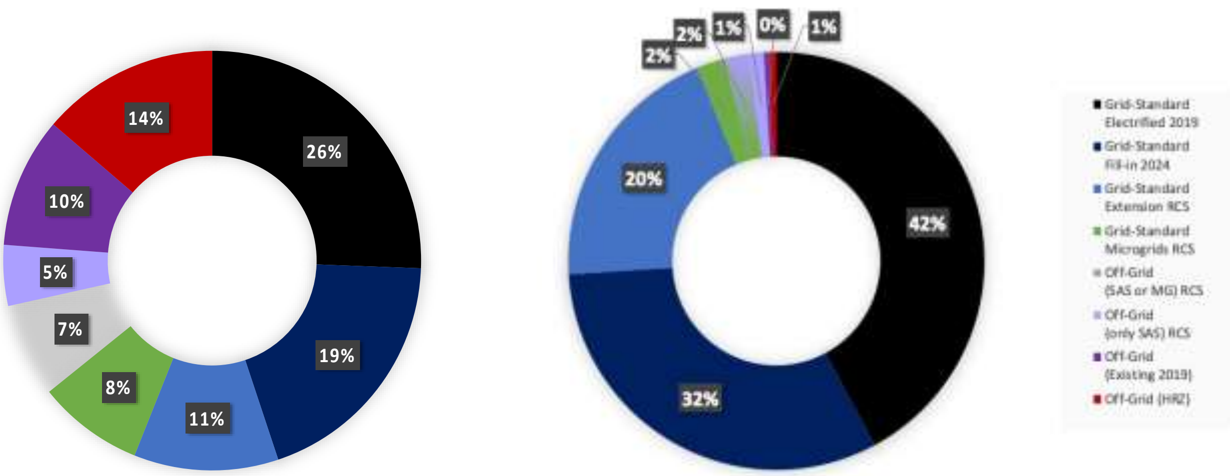


(a) Share of electrified customers 2019 **(b) Share of electrified customers NEP 2024**

Figure 5-1: Share of total customers per electrification mode in 2019 and in the NEP Reference Case Scenario 2024

The National Electrification Plan of Rwanda now envisions that in 2024 2.5 million customers (64%) will be supplied by a standard grid connection (comprising both those connected to the central network, 56% and those in islanded grids, 8%) while 1.4 million customers (36%) will have a stand-alone system. The share of grid extension has increased from previous estimations (52%) because of the additional field data gathered and the higher granularity of the least-cost analysis developed in section-1 of this report.

Figure 5-1 shows a detailed breakdown of the different electrification modes, as detailed in Section 3.1 of this Report – Design of the National Electrification Plan in Rwanda. A vast majority of community and industrial customers will be connected to the "standard grid" (centralized or islanded off-grid mini-grids) totaling 96% of the energy consumption in 2024. 1.4 million isolated customers only account for 4% of the energy consumption as they are supplied mostly with DC solar kits.



(a) Share of total customers **(b) Share of energy supplied**

Figure 5-2: Share of total customers and of energy supplied per electrification mode in the Reference Case Scenario 2024

Our NEP 2024 Implementation Report shows that extending the grid to 430 thousand customers outside the areas within the present reach of the central network requires an overnight investment of $316 million, requiring 1,165 km of MV, 13,475 km of LV lines and 1,500 distribution transformers. This imposes a major challenge on the centralized system, which will need to supply an estimated energy consumption of 2,220 GWh in 2024 (as compared to 527 GWh in 2017 plus another 128 GWh in technical losses), resulting in a growth of 340%. The (non-densification) new grid extension designed for the NEP 2024 accounts only for 470 GWh, as most of this growth is expected to happen within the existing grid, due to 747 thousand new fill-in connections within the area already covered by the network (752 GWh) and to the demand growth of the present customers (which might reach up to 1000 GWh with an expected growth rate of 8% per year). Upstream reinforcements in the existing MV and HV network need also to be studied and accounted for, as well as the resulting improvements in technical losses. Islanded networks (i.e. non-connected mini grids) will account for an additional 50 GWh consumption, while off-grid standalone solutions will account for around 90 additional GWh of energy supply.

The figures obtained in our analysis, with a total cost of new connections and densification of $763 million for NEP 2024, are higher than the figure estimated by ESSP of $704 million (which includes C&I and residential customers, but excludes street lighting, not considered for the NEP), an increase of $59 million. As per off-grid connections NEP REM calculations show a required investment of $59 million for standalone systems and $200 million for mini-grids, compared to $160 estimated by ESSP, an increase of $99 million. Thus, our estimates indicate that the total budget for the ESSP should be increased by $158 million, totalling $2.89 billion for electricity and $3.28 billion for the whole energy sector.

This exceptional electrification effort, should it fully achieve the objective of 100% connection meeting the expected demand levels, also puts stress on the generation capacity. The assumed investment plans of the current energy strategy described in Section 5.2, instead of resulting in a surplus of installed capacity, will just reach to match the high increase in demand of existing and newly connected customers in 2024 and will imperil the targeted reserve margin. The financial implications of these figures are discussed in section 8 of this document.

Section-6. The Institutional Aspects

The ESSP report acknowledges that financing this ambitious plan is a major challenge and that lack of economic resources may result in a slower pace in the deployment of the considered measures. Regulatory and institutional shortcomings may also limit the development of the plan. This is the subject of this and the following sections. The institutions involved will be considered first, followed by some comments on the planning process itself.

6.1 An institutional map and assessment.[19]

The Government of Rwanda (GoR) in 2014 reformed the energy and water sectors with the separation of energy from water operations, with the objective of increasing the efficiency of operations, attracting more investment; improving planning and accountability, and increasing access to services by the population. These changes have enhanced the institutional capacity of the government entities charged with implementing the commitments of the ESSP. To this end, the GoR created two corporate entities which were subsequently incorporated in July 2014 with 100% government shareholding.

The Rwanda Energy Group (REG) was incorporated to expand, maintain and operate the energy infrastructure in the country through its two subsidiaries the Energy Utility Corporation Limited (EUCL) and the Energy Development Corporation Limited (EDCL). The object of creating these subsidiaries was to focus attention to enhancing efficiency in utility operations on one hand and ensure timely and cost-efficient implementation of development projects on the other. The REG holding structure provides the overall coordination and ensures effective development of energy and investment plans. Separately, the Water and Sanitation Corporation (WASAC) has the mandate to develop and operate water and sanitation infrastructure and deliver related services in the country.

The institutional structure of the electricity sector involves three key institutions: (a) Ministry of Infrastructure (MININFRA), who sets the policy and strategy for the sector; (b) Rwanda Utilities Regulatory Authority (RURA), who regulates the sector, approves electricity tariffs, etc.; and (c) Rwanda Energy Group (REG) with its two subsidiaries – Energy Development Corporation Limited (EDCL) and Energy Utility Corporation Limited (EUCL), who are responsible for new energy development activities and electricity utility operations, respectively. The Rwanda Energy Policy (REP) sets out the overall vision and policy framework, whilst the Energy Sector Strategic Plan (ESSP) translates the policy directives and principles into concrete measures necessary to reach medium-term targets.

Starting from the top down, it corresponds to the Government of Rwanda (GoR) via the Ministry of Infrastructure (MININFRA) to determine the structure of the power sector (as it has done recently with the restructuring of the power and water sectors in 2014 and the creation of EDCL and EUCL), and to establish the high level energy policy (as it has done with the Energy Sector Strategic Plan (ESSP) for 2018/19-2023/24), in coordination with wider, national policies and objectives for other sectors, as are set in 2018 by Vision 2050 (it replaces the previous Vision 2020 and sets out high-level sectoral

[19] The initial description of the main concerned institutions has been taken from the "energy Sector Strategic Plan (ESSP) 2018/19 – 2023/24", Ministry of Infrastructure, September 2018, section 2.9.

targets to 2050) and NST-1 (sets sectoral targets to be achieved by 2024) which together will support Rwanda in achieving its ambitions.

The Rwanda Utilities Regulatory Authority (RURA) regulates the activities of public utilities involved in renewable and non-renewable energy, electricity, industrial gases, pipelines and storage facilities, and conventional gas extraction and distribution. RURA's principal mandate is to ensure consumer protection from uncompetitive practices while ensuring that such utilities operate in an efficient, sustainable, and reliable manner. Regarding electricity, RURA is also responsible for updating the electric grid code, ensuring quality of service standards for power, assessing and reviewing energy tariff structures, and licensing all power generation, transmission, and distribution companies.

As a REG's subsidiary, EUCL provides energy utility services through operations and maintenance of existing generation plants, transmission and distribution network, and retail of electricity to end-users.

The other subsidiary, EDCL, is more relevant for the planning activities that are covered in this report. During the execution of this project we have mostly interacted with EDCL personnel. EDCL oversees the development and implementation of Rwanda's energy infrastructure, facilitating the energy investment process, undertaking energy planning, monitoring and evaluation, plus reporting on all developments around the sector, within the aforementioned scope. EDCL has four main processes feeding into the core business: i) Policies planning; ii) Marketing planning and development; iii) Distribution planning and development within already electrified areas; and iv) Operation and maintenance of power plants and transmission and distribution networks owned by the utility. EDCL will also play a key role in the execution of power purchase and power sales agreements with IPPs and other regional utilities for import and export. The Roles and responsibilities of various stakeholders in Rwandan Power sector were discussed in clause no. 10.10 of Section-10 of this report.

Differently from most developing countries with lack of electricity access, Rwanda does not have a Rural Electrification Agency. This should not be seen as a shortcoming, given the scarce – although obviously always very welcome – contribution that REAs have made to the electrification process in general, due to the typical paucity of their economic resources. Institutionally speaking, Rwanda is a very centralized country, with a well-designed and robust institutional and regulatory framework. As indicated above, the right institutions exist, and they are properly designed to fulfil their role. Moreover, these institutions, with the support of a diversity of donors, have developed a very comprehensive and hierarchically structured planning strategy, as mentioned before. Nothing to object to the institutional framework and the content of the planning; on the contrary most other countries in the region should follow Rwanda's example. However, sound planning and institutions are necessary, but not sufficient conditions for the success of an electrification plan. Political support, good coordination among institutions and with donors and DFIs, good chemistry between the people leading the institutions, technical capability to execute the plan, presence of companies that are capable to deploy the necessary off-grid solutions, and, obviously of critical importance, the availability of financial resources, complete the sufficient package of factors that guarantee the success. In this project we have examined the former, but not the latter, which would have required a level of interaction with our Rwandese partners that has not been possible during the time scope of the project, since the attention has been placed almost exclusively in the techno-economical dimension of the electrification planning activity.

The issues that so far have prevented a speedier path of the electrification process seem to be related to other topics: i) misalignment of power supply and demand, because of a lack of sufficient investment in generation in the past – and still presently and expected until 2020 – which has not been able to cope with demand growth, combined with insufficient interconnection with neighbouring countries from which power could be imported; ii) high electricity prices[20], as a consequence of the previous factor, coupled with some lack of efficiency (e.g. high technical network losses), the inevitable high costs of electrification in rural areas with disperse and very low level of demand, and the resulting limited affordability of the possible electricity solutions for rural households and businesses (which are primary constraints to attract and further scale-up investment flows); iii) limited financial resources – as a result of the previous issues – to accomplish all that has to be done regarding the necessary investments to improve the service in the existing connected system, as well as the necessary investments to extend the grid and to provide off-grid electrical supply.

6.2 The planning process and the role of EDCL.

This section only refers to the fraction of the entire energy sector plan in the ESSP that is covered by this study, i.e. the design of electricity supply solutions for those customers that are still un-electrified and outside the reach of the present network, with the detailed design of the MV and LV extensions of the grid, and the off-grid solutions – grid-standard mini-grids and standalone systems. The use of the Reference Network Model for this purpose has been thoroughly documented in section 1 to 3 of this Report, Design of the National Electrification Plan for Rwanda in 2024.

This effort, developed together by the consultants and EDCL planning experts, has led to the development not only of these reports, but also of the data base and detailed project-by-project technical and economic design and specifications required for the implementation of the NEP 2024.

To allow for further reviews of the plan, which might be required at the implementation phase to correct the initial plan in response to any divergence from the original roadmap (i.e. implementation deviations, annual budget availability, changes in demand growth, cost of equipment, among many others) the EDCL personnel with responsibility in designing the approach to be used for electrification planning attended the training course offered by the Tata / MIT / Comillas team, with the purpose of making a decision whether the REM model – in its present version or with any required enhancement

[20] Rwanda has a particularly high average cost of service delivery, estimated at about US$0.32 per kWh. The current electricity mix is about 52/48 percent hydro/thermal, and the thermal generation is based on imported diesel fuel. Regional droughts put additional constraints on the hydropower supply which, exacerbated by lack of adequate grid interconnection capacity, leave Rwanda with limited possibility of sourcing electricity from its neighbors. Electricity tariffs are relatively high compared to other countries in the region — US$0.22 per kWh — and are not cost reflective. Additionally, the average cost of grid connection is heavily subsidized: out of about US$560 connection cost per household, consumers pay about US$75 connection fee over a 2-year period (with data from 2017).
See http://documents.worldbank.org/curated/en/599771487529927175/pdf/ITM00184-P160699-02-19-2017-1487529923719.pdf

– is a software tool that EDCL staff should learn how to use and have available for modifications to the present plan or to upgrade or design another one in the future.

Whatever the decision about the final planning software to be adopted, our clear recommendations, after having worked together with EDCL during this project, are:

i) Increase the GIS and computing capabilities of the EDCL staff working on distribution network planning. Professionals from RURA or MININFRA could also participate. Enormous amounts of digital geo-referenced information are becoming increasingly available at a reasonable cost. Parallel to this is the development of software tools that can use this information. The energy companies of the future will be based on data from their customers and installations so that they could provide the services that electricity can provide as demanded by their customers. Rwanda is leading other countries of the region in this respect. This leadership, in data and applications software should be maintained.

ii) EDCL staff should be fully in charge of applying the software models that finally are adopted to any revision or future new electrification plan. These computer tools and the corresponding data bases should be operated by EDCL staff rather than external consultants. Previous Master Plans have had limited functionality due to the need for consultants in updating the tool. This does not mean that EDCL staff in charge of electrification planning must be capable of fully understanding the design of the software, or even of enhancing its capabilities if needed. This could be left to the software developer. But they must be able to use it at any time, change the initial hypotheses, modify any scenarios and adapt the plan to any new circumstances. In the long run EDCL need to consider the N-1 network confriguation during network planning using softwares considering future aspects for better reliability of the network.

iii) It is evident now that the least cost solution (including the cost of non-served energy, obviously) to the provision of service to unelectrified customers is a combination of delivery modes. Therefore, any adopted software must have the capability of identifying where projects should be implemented by grid extension, by mini-grid, or by solar kits or any other kind of standalone system.

iv) Some aspects of the data collection procedures have to be continuously improved. It should be consistent throughout the country or across institutions. Demand characterization of industries, businesses and community services should be well captured and georeferenced, as well as the location and load status of the distribution lines and transformers to be able to assess the need for reinforcements not only in the distribution network but also at transmission and generation levels. Some service providers have the capacity to collect data and maintain GIS systems while others do not. Depending on the Master Plan technology used, data collection may need intensified cooperation between REA and service providers.

v) Updates on grid data, completed projects, ongoing investments, and also more general data like population, topographical features or the technical catalog, should be regularly integrated in the data base that supports the planning software tool by EDCL staff. The EDCL GIS unit should be able to create maps of the country showing where grid extension, mini-grid and standalone electrification projects have been planned, based on the regularly updated data described above.

vi) Strengthen the link of the electrification planning platform and the ongoing Master Plan with the data bases and plans of other ministries, with the purpose of coordinating activities or providing useful information sectors such as Health, Education, Housing, Communication, or Transportation. The dynamic transformation of the economy and society in Rwanda will require a fluent exchange of information and cross-government coordination so the electrification planning responds to the needs of energy by other key sustainable development plans and policies.

vii) The plan has to be implemented respecting transparency and participation aspects in a double sense: i) reach all potential beneficiaries, i.e. the governmental and local authorities and the communities where electrification activities will take place; ii) involve also the ensemble of stakeholders other than REB, RURA and MINIFRA, such as donors, DFIs, mini-grid developers, solar kit vendors, NGOs, etc. Both constituencies must be informed, consulted and their opinions seriously considered in all phases of the process.

viii) Due to such high volume electrification project, large no. of assets will create, EDCL must be capable of monitoring and managing these newly created assets. They have financial and regulatory impact thus assets needs to be managed during creation, transfer and retirement satges using latest Asset Management Softwares either through thier staff or through technology experts in this area.

ix) EDCL may require dedicated workforce or technology experts having vast experience of managing large electrification projects as envisaged in NEP 2024 in due timelines and ensuring safety and quality aspects while following international standards and guidelines.

Section-7. The Regulatory Aspects

The current energy strategy considers the entire chain of activities that have traditionally comprised the supply of electricity: large generation, transmission, distribution and retail, as well as mini-grids and standalone systems for electricity provision. Section 7.1 briefly covers all of them. The specific topic of tariff design, focusing on rural electrification customers is discussed in section 7.2. Finally, a possible new approach to the choice of business model for the distribution activity, including organizational, structural, and regulatory aspects, which could be useful for financing what remains to be electrified, as well as to improve reliability and reduce losses, is presented in para 0 of this report.

7.1 General regulatory aspects.

The activities of large generation and transmission, on the one side, and distribution on the other side, will be commented separately. The reason for this is the different regulatory approaches that are typically used, and the different level of experience that exists in attracting investment successfully in every case.

Generation.

The levels of investment per capita (MW of installed capacity in generation and also in km of high voltage lines in transmission) are substantially lower in SSA countries – including Rwanda – than in other parts of the world. As indicated above, the energy strategy in the ESSP includes important investments in generation and interconnections with neighbouring countries, which, if materialized, will properly address the present adequacy shortage. How to finance these investments?

There are abundant examples of private investments in large and medium size generation plants in sub-Saharan Africa (SSA). Since 2008, IPP additions have consisted of 46% solar, 19% wind, 11% hydro, 9% gas, 5% biomass and waste, plus 10% in other technologies. Private investments of Independent Power Producers (IPPs) are typically supported by contracts under the form of Power Purchase Agreements (PPAs) with well-known formats[21]. Lack of investment may be due to convertibility risk, lack of legal security, or general perception of country risk, although this perception may not be justified, since the default risk in SSA countries is actually low. Another factor that may impede the construction of large power plants that exploit the existing hydro resources, or with sizes that achieve good efficiency levels, is the lack of integration among the SSA countries, which prevents reaching the necessary economies of scale. Perceived off-taking risk is another deterrent to private investment in generation, and there are approaches – like the one proposed by Africa GreenCo[22] – to mitigate this problem. Auctions for utility-scale solar and wind power plants are becoming common in SSA countries and in general have been successfully implemented, resulting in multiple IPPs[23]. Therefore,

[21] Independent power projects in sub-Saharan Africa. Lessons from five countries. https://openknowledge.worldbank.org/handle/10986/23970

[22] See "Africa GreenCo. An Overview". Africa Greenco, 2019 https://africagreenco.com/wp-content/uploads/2019/08/AGC-Overview.pdf and "Africa GreenCo, Feasibility Study", Africa GreenCo, 2017. http://africagreenco.com/wp-content/uploads/2017/03/AFRICA-GREENCO-FEASIBILITY-STUDY-1.pdf

[23] "Renewable energy auctions. Cases from sub-Saharan Africa". IRENA, 2018. http://www.gsb.uct.ac.za/files/IrenaAuctionsSubSaharanAfrica2018.pdf

the barriers to private investment in generation have been identified and the approaches to overcome them are known. The focus now should be not on the method itself, but on the external conditions that make it possible (e.g. legal security, sound governance, country risk, convertibility risk, and so on).

The efficient scale for new generation projects is too large for many developing countries, many of which are in sub-Saharan Africa, and Rwanda is certainly one of them. The Program for Infrastructure Development in Africa (PIDA) estimates that at least 20 countries have demand below the efficient level for a single power plant. In addition, there is insufficient transmission capacity to support regional trade. Well-designed power pools and adequate transmission infrastructure are therefore of essence.

Transmission and power pools.

More or less the same can be said about private investments in transmission lines, although the number of cases and volume of investment in SSA has been much smaller. Lines that are internal to a country are often built by the national transmission and system operator, but they could be left to independent private investors. This is more frequently the case with cross-border transmission lines. There is ample experience with private investment in transmission lines in Latin America and South East Asia, but only a few cases in SSA[24]. A deterrent for investors in cross-border transmission lines can be the lack of a sound commonly agreed procedure to allocate the transmission costs and, consequently, the risk of not receiving an adequate economic compensation. Again, the barriers to investment and the approaches to overcome them are known, although their acceptance and implementation might not be easy. Insufficient transmission capacity impedes the installation of large generation plants, but it particularly limits hydro, solar and wind resources.

Rwanda, due to its geographical position in SSA (it is surrounded by Uganda, Burundi, Tanzania, and Democratic Republic of Congo), forms part of the East Africa Power pool[25] and the Multinational Power Grids Interconnection Project for the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) countries. The objectives of the Eastern Africa Power Pool include (a) the reduction of power costs within the region (b) facilitation of power trade between the members (c) increasing energy availability to citizens of member countries (d) increase the grid security of the member countries. As a prerequisite to the success of these efforts, adequate power grid interconnections between the member countries need to be established[26].

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[24] Linking Up- Public-Private Partnerships in Power Transmission in Africa. World Bank Group. 2017. http://www.worldbank.org/en/topic/energy/publication/linking-up-public-private-partnerships-in-power-transmission-in-africa

[25] The Eastern Africa Power Pool (EAPP) was established in 2005 with the signing of an Inter-Governmental Memorandum of Understanding (IGMOU) by seven Eastern Africa countries, namely: Burundi, Democratic Republic of Congo (DRC), Egypt, Ethiopia, Kenya, Rwanda and Sudan. In further development, EAPP was adopted as a specialized institution to foster power system interconnectivity by the heads of states of the Common Market for Eastern and Southern Africa (COMESA) region. Tanzania, Libya and Uganda have joined EAPP in March 2010, February 2011 and December 2012 respectively. http://eappool.org

[26] Now including the interconnections between Ethiopia and Kenya, Uganda and Kenya, Kenya and Tanzania, Uganda and Rwanda,[8] and between Uganda and the Democratic Republic of the Congo. The newly proposed Burundi-Rwanda interconnection project is ranked among the priority integrative projects that will help to

Despite commendable economic growth, Rwanda has a low per capita Gross Domestic Product (GDP) of US$ 696 and a low per capita electricity consumption (30 kWh) compared to Uganda (66 kWh), Kenya (140 kWh), and Tanzania (85 kWh). Furthermore, comparing the average Rwandan electricity tariff of US$0.22/kWh with the average tariffs of the remaining countries in the region, which fit in a range of US$0.12 to US$0.18/kWh, we find that Rwanda's electricity price is about 22.2% more expensive than the highest electricity tariff in the Eastern African countries.

An enhanced power trade should help in reducing these differences. This critically depends on the capacity of the interconnections, the strength of the regional governance and the soundness of the regional trading and network cost allocation rules. As indicated before, a clear example of the need for clear and enforceable electricity trade rules is the challenge for Rwanda in obtaining power from Kenya through Uganda to replace the expensive diesel generation that Rwanda needs to cover its peaks of demand when there is no sufficient hydro production.

In general, the SSA power pools (even including the SAAP, with more than 15 years of existence) lack executive powers in the two key regional institutions: the regional system operator and the regional regulator. These institutions exist in the four power pools in SSA, but they are too weak. The regional regulators of the SSA power pools are understaffed and have almost no executive power. The regional system operators are not mandated to do regional transmission planning and there is no enforcement power in the regional institutions to make any transmission network plan happen. Establishing a comparison with the European Union Internal Electricity Market, we find that the regional regulator, ACER (the Agency for the Coordination of Energy Regulators) also has limited executive powers in most topics (not all). However, the European Commission is the strong back-up regional regulatory institution, while the African Union is not an African government with executive power, as the European Commission has. As another example, the Central American Electricity Market (MER) has two strong regional institutions: CRIE is the regional regulator, whose members are taken from the commissioners of the six participating countries, and EOR, the regional system operator. This institutional dimension needs much improvement in the SSA power pools, given the criticality of the integration of the SSA countries into functional power pools, and even more in the particular case of Rwanda.

As in the case of large generation and transmission lines, the effective measures to improve the efficiency of the power pools and to facilitate investments in generation and transmission of regional dimension are known, although they have been implemented only in a few power pools in the world, and not in the SSA power pools.

The goal in the design of a power pool is the Single Market Paradigm, i.e., the outcome of the regional regulation should approach as much as possible a sound regulation for a single system of the regional dimension. When the prevalent rules of the operation of the pool prevent this from happening, efficiency and security of supply deteriorate. In SSA power pools, poor implementation of physical bilateral contracts distorts the economic dispatch of generation & demand. Resistance to accept

optimize the use of energy resources by pooling the power generation and transmission facilities of the East Africa region.

security of supply at regional level impedes that firm cross-border contracts have dispatch priority in emergency situations, undermining the willingness for joint construction of large power plants.

The weakness of regional institutions – the regional regulator and the regional system operator – results in the absence of transmission planning at regional level or, when it does exist in some form, it is not enforced. The weakness of institutions also results in lack of harmonization in other aspects where it is necessary: regional market rules, capacity mechanisms, and well-designed incentives – to renewables, efficiency programs, etc. Regional-wide regulation is necessary to mitigate some persistent risk factors in long-term contracts when established among parties in a multinational power pool: i) hedging price differences between countries; ii) regulatory intervention in scarcity situations; iii) uncertainty in the determination of transmission charges. Poorly designed or uncertain transmission charges are barriers that make difficult financing the necessary investments in transmission network infrastructure.

There are proven regulatory solutions to address all these regulatory issues. In this case, the experience in the implementation of the EU Internal Electricity Market (IEM), with all necessary adaptations to the conditions of the SSA power pools, has a significant value. Rules such as "beneficiary pays" (applied to interconnection infrastructures) or "transmission charges must not depend on commercial transactions", have been successfully implemented in the IEM and have universal validity.

In the European Union, ENTSO-E, the association of system operators has a strong technical capability. ENTSO-E is charged with the responsibility of proposing detailed grid codes and it is mandated to produce 10-year EU-wide transmission network plans every other year, as well as longer term plans. ENTSO-E activities are closely supervised by the regional regulator, the Agency for the Cooperation of Energy Regulators, ACER.

An interesting possibility to improve the rules of a power pool while strong governance is still lacking is "regulation by consensus". This how the first EU Directive (1996) of the Internal Electricity Market was initially implemented. Given the inactivity of the European Governments at the time in starting the implementation of the Directive, a group formed by the existing electricity regulators of some member states, government representatives from some others, and the major system operators, met in Florence in what was called the Florence Forum, and passed regulation by consensus, without any formal approved regulation at EU level. The regulations approved in the successive Florence Forums were implemented immediately, and years later they were formally written into EU approved legal documents.

Distribution.

The activity of distribution, jointly with retailing in all developing countries, is closest to the end customers and is at the origin of the failure in the electrification process in many countries. Contrary to the cases for centralized generation and transmission, where the problems and solutions have been identified and multiple success stories exist, distribution in rural areas still presents major conceptual challenges from regulatory and business model perspectives. At the root of the problem is typically the insufficiency of politically influenced tariffs to cover the high costs of rural electrification, resulting in a dire financial situation of the distribution companies without resources to invest and maintain the facilities, poor quality of service, customer disaffection and defection, and a vicious circle of theft and unpaid bills that further deteriorates the revenues of the distributor.

The immense majority of distribution companies in low access countries are insolvent, since the collected revenues from those customers that are connected to the main grid fall short from recovering the cost of supply. In many cases these revenues are not even sufficient to cover the operation and maintenance costs of the distribution activity[27]. This statement also applies to vertically integrated utilities, where distribution is a business unit within the entire company.

Here we shall use the term "distribution" in a broad sense, encompassing all the electrification modes that can be employed to supply electricity: extension of the main grid, mini-grids or standalone systems. Off-grid solutions can be the least cost option in a diversity of situations: low and dispersed demands, far from the existing grid, in geographical areas with difficult access, when the main grid supply is unreliable or the voltage is inadequate, or when the incumbent utility does not have the technical or finanacial resources to provide the service.

Mini-grids.[28]

The potential for off-grid electrification is very high in Rwanda, as our study has clearly shown. So far, the off-grid market has been generally dominated by solar lanterns and solar home systems, which are well suited to sparsely populated rural areas marked by low energy demand of around 2-7 kWh/month. In the past few years, there has been a steady increase in the deployment of mini-grids in the country, especially resulting from private sector initiatives.

Rwanda has established an encouraging legal and regulatory framework for off-grid electrification. Energy regulation for mini-grids started in 2004, and since then, the country has introduced several adaptations. However, deployment has picked up only since 2015.

For mini- grids, RURA developed a simplified licensing framework, which streamlines the licensing and permitting process, presents options to mini-grid companies when the national grid arrives, and lays out the principles for setting cost-reflective tariffs. This regulation applies primarily to mini-grids with installed capacity between 50kW and 1MW, as systems below 50kW are exempted from licensing.

Rwanda's National Electrification Plan (NEP) officially demarcates areas for on and off-grid expansion providing clarity to both developers and rural communities, and their definition has been supported by our study. The 2018-2024 Energy Sector Strategic Plan released in September 2018 mitigates the risk of uncertainty around grid expansion (what will happen when the main grid will arrive to my mini-grid?) with the implementation of the NEP as published.

[27] Making Power Affordable for Africa and Viable for Its Utilities. (Kojima & Trimble, 2016). https://openknowledge.worldbank.org/handle/10986/25091

[28] A very detailed description of Rwanda's regulation on mini-grids can be found in the report "Policies and Regulations for Renewable Energy Mini-Grids", IRENA, 2018.

However, because of the lack of experience in the implementation of the most recent mini-grid regulation, mini-grid companies remain concerned about the workability of the existing framework, especially when it comes to setting cost-reflective tariffs and negotiating the interconnection to the national grid with EDCL/EUCL.

Standalone systems.
For vendors of standalone solar systems (largely solar-kits, but also more powerful systems that could supply small industries, commerce's, or health centers) the legal and regulatory arrangements do not represent a major barrier to market growth. More broadly, the sector needs clear specification of equipment quality consistent with internationally agreed standards and an effective mechanism to enforce these standards. Standalone systems companies can also provide the service for a fee, without selling the device, replacing it when it does not perform well, in a similar form to what mini-grids and the main grid do.

7.2 Revenue requirements, tariffs and subsidies.

Background.
Supplying geographically dispersed low-level rural loads is much more expensive per connection and per kWh than electrification in urban areas. These per-unit costs increase as electrification goes deeper into more isolated areas, far from the existing grid. If the regulated revenue requirement for the discos were cost-reflective, the corresponding tariffs for all end customers would have to increase whenever new rural customers become connected, since charging a cost-reflective local tariff in rural areas is politically fraught and unaffordable for impoverished customers. In reality, in the vast majority of low-access countries, tariffs are set well below costs and are equalized for each category of customers, regardless of their geographic location, or whether they are rural or urban. Thus, extending access automatically results in a deficit in the remuneration of discos. Under existing conditions of politically dictated tariffs that are below costs, rural electrification is a sure loss, in the absence of subsidies.

We conclude that a subsidy is needed for any disco that expands access if governments and regulatory authorities are not willing to raise local tariffs that reflect actual costs. Distribution of electricity in rural areas with disperse and low demand has never been economically viable in any developed or developing country, without subsidies – under diverse formats, ranging from tariff cross-subsidization to direct payments to the incumbent disco or territorial concessions under mutually agreed conditions. This applies both for on- and off-grid solutions. And this makes discos particularly dependent on legal security in their country.

Investability requires legal security, in the sense of a stable and predictable regulatory environment. The investor in distribution must have a reasonable certainty to receive a regulated remuneration – the "revenue requirement" – that will cover its cost of service – efficiently provided – including an attractive rate of return on the invested capital. Legal security is a country-specific characteristic and affects all types of investment, but rural electrification adds a notch of difficulty since it needs to be subsidized, which is not the case with other segments of the electricity supply chain. And subsidies – although they should be based on objective criteria – strongly depend on regulatory and policy decisions. The disco runs the risk that the subsidy may be insufficient or delayed – possibly indefinitely

– with dire consequences. Guarantees that subsidies will be paid must therefore be provided by national governments and underwritten by deep-pocketed financial institutions. Experience so far has shown that external guarantees are not easily obtained in countries with dubious legal security or with high sovereign debt – conditions common among low-access countries.

The case of Rwanda.

Pursuing the ESSP objetives poses a number of challenges for the GoR relating the cost of power supply, tariffs and affordability, as well as fiscal risks[29].

1. *Very high cost of electricity service.* The very rapid expansion of the generation sector, the low economies of scale, the relative isolation of the country, and the use of expensive technologies to exploit domestic resources as peat or methane, has resulted in a very costly energy mix (around US$0.28/kWh in FY2016/17). The surplus of generation already installed and committed will be almost enough to provide for the targets of NEP 2024, but in the future it is essential that new generation abides to least-cost planning principles, competitive procurement and efficiency gains brought by economies of scale and streamlining fuel logistics.

2. *High tariffs constrain the economic growth of Rwanda.* The high cost of generation results in electricity tariffs ranging from 0.12$/kW to 0.28$/kW (depending on the customer type), unreflective of the cost of service and heavily subsidized, but still high in comparison with other countries in the region. The present tariff for residential type 1 customers is still very high for rural population, where the inability to pay for pre-paid electricity prices could be close to 50% of the expected demand, according to estimations provided by REG. The lack of appropriate quality of service also hinders customer engagement and willingness to pay, specially for small productive activities, while large industrial customers resort to very expensive backup systems.

3. *The government budget for the resulting viability gap represents 10% of the public expenditure.* Total budget transfer to the power sector has declined to 1.35% of the GDP in 2017/2018[30] but future investments as required by the Universal Access target in NEP 2024 are likely to again increase this figure, unless larger than expected demand growth mitigates the impact of new generation**.**

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[29] Aghassi Mkrtchyan, Peace Aimee Niyibizi, Joern Huenteler, Yadviga Viktorivna Semikolenova, Norah Kipwola and Arun Singh . "Rwanda Economic Update: Lighting Rwanda." *The World Bank*, 25 June 2019. http://documents.worldbank.org/curated/en/593831561388957701/Rwanda-Economic-Update-Lighting-Rwanda.

[30] Besides covering the costs minus revenues gap (budget transfers to support REG's operating expenditures categorized under the Treasury's "Recurrent Budget"; the Government also provides budget transfers to support sector investments, or the "Development Budget").

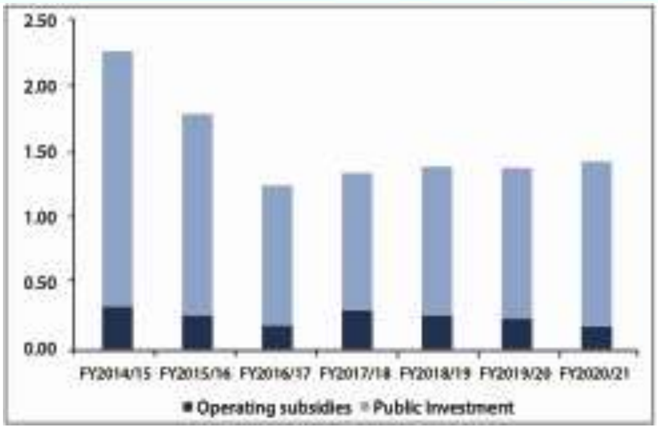

Figure 7-1: Subsidies to the power sector as a percentage of the GDP. Source MINECOFIN[31]

The Government's medium-term fiscal budget presently does not fully account for fiscal risks from anticipated cost escalations in the power sector that will arise from:

i. NEP 2024 large-scale investments in grid expansion and densification to meet the 100% electrification targets (to be developed by REG).
ii. Operating subsidies and investment required to comply with the mini-grid deployment as in NEP 2024 (to be developed by REG and private investors).
iii. Investment required by NEP 2024 to provide off-grid isolated customers with solar kits or other standalone supply solutions.

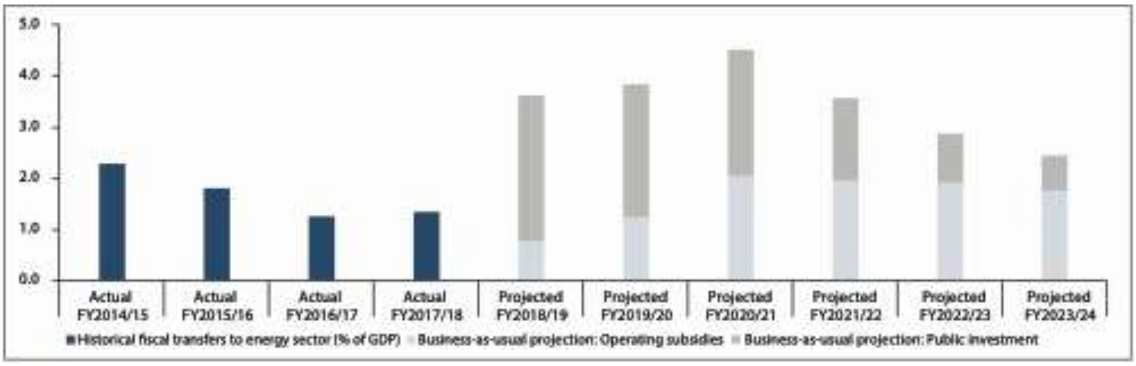

Figure 7-2: Potential escalation in the subsidies to the power sector as a percentage of the GDP. Source: For actual historical data: MINECOFIN; for projection: World Bank Analysis

4. *The GoR also provided sovereign guarantees for power purchase agreements (PPAs) between REG and independent power producers (IPPs).* The impact of attraction of private capital to NEP 2024 is further analysed in Sections 8.2 and 8.3.

In search for a workable approach.

Since in most countries the existing distribution paradigm is not working, and electrification is making insufficient progress, both in volume and in quality of service, it seems necessary to search for some

[31] Ministry of Finance and Economic Planning (MINECOFIN), Budget Framework Paper 2018/2019-2020/2021, April 2018. http://www.minecofin.gov.rw/fileadmin/templates/documents/Budget_Management_and_Reporting_Unit/Budget_Framework_Papers/2018-2021_Budget_Framework_Paper.pdf

kind of new business model approach can be well adapted to the objective of universal access in the developing country context and rural electrification in particular. Such a business model must comply with several requirements that are indispensable for any universal electrification approach to succeed.

- ***Inclusiveness.*** Inclusive electrification within a designated region requires there to be an entity that assumes real – not just formal – responsibility for serving *all* consumers in the region, irrespective of their level of demand and under minimum quality conditions. In some low-access countries, establishing this actual commitment within a designated region may be accomplished in a single step, or it may be the end step in a multi-year evolutionary process.
- ***Permanence.*** Access to electricity must be assured indefinitely – that is, permanently over time. This requires an institution in charge with a long-term vision and commitment.
- ***A mix of delivery modes.*** The least-cost electrification plan to meet rural demand in a territory will involve a combination of on- and off-grid modes that distribution responsible entities must deploy efficiently, balancing cost, reliability, and customer preferences, among other factors.
- ***Harnessing external resources.*** Without some external intervention it is difficult to imagine how most incumbent discos could leave their present dire technical, managerial, and financial conditions. Many will have to partner with external entities able to access capital, advanced technologies, and management expertise, so that reliable service, loss reduction, and a new consumer engagement approach can be achieved.

The MIT/Comillas Universal Energy Lab has been working in the definition and preliminary steps of implementation of a business model approach that meets all the above requirements. We call this approach the "Integrated Distribution Framework (IDF)" and a description can be found in the Annexure 1 of this report. [32.]

[32] See "The Global Commission to End Energy Poverty. Inception Report". MIT Energy Initiative for the Rockefeller Foundation. September 2019. www.endenergypoverty.org. See also I.J. Pérez-Arriaga, R.J. Stoner, R. Rahnama, S.J. Lee, G. Jacquot, E. Protzer, A. González-García, R. Amatya, M. Brusnahan, P. Dueñas, F.J. Santos. "A utility approach to accelerate universal electricity access in less developed countries: a regulatory proposal". Economics of Energy & Environmental Policy. vol. 8, 1, pp.33-50 March 2019.

Section-8. The Financial Aspects

The scope of this chapter is limited from a quantitative perspective to examine the financial aspects of the fraction of the power sector that has been analysed in this project, i.e. the electrification plan for those presently non-electrified potential customers.

This section focuses on three aspects that may add value to the techno-economic analysis in the other chapters of this report. In the first place, the financial impact of the pending electrification activities on the power sector, from a private and public funding perspective, will be detailed. Some general considerations on how the power sector strategic plan ESSP can be financed, and the electrification plan specifically, will follow. Finally, the macroeconomic implications of the entire strategy for the power sector as presented in the current ESSP will be explored.

8.1 The financial impact of the "last mile electrification".

In this section we evaluate the difference between the cost of the electrification plan that has been presented as the reference case in this report (the Base Case Scenario of NEP 2024) and the amount that can be recovered from the present tariffs in 2019 paid by the end customers, establishing the basis for the need of adjustment of sustainable future tariffs and subsidy schemes of a 100% electrification scenario, which will need a careful assessment by the Government of Rwanda and any agents involved in the electrification process.

Several clarifications are necessary, so that it is understood what is comprised by the NEP 2024 electrification plan and what is not: i) the REM Base Case Scenario integrated least-cost grid/off-grid design does not include the non-electrified buildings located in villages already connected (but not in full) to the national network; ii) for these villages already connected, NEP 2024 provides an initial estimation of the densification cost of connecting all not-yet-electrified customers, considering the information available at EDCL for this study, but it will require further field, satellite and modelling analysis to develop a detailed densification techno-economic design and plan already under consideration; iii) it does not include public lighting; but it includes: iv) all types of non-residential businesses such as schools, health centers, shops, churches, or other community loads, plus larger commercial and industrial loads; v) the investment, operation and maintenance costs of all new investments in MV and LV lines, MV/LV transformers and all the necessary equipment to produce, convert and store off-grid electricity; vi) the cost of wholesale energy as withdrawn from the HV/MV transformers, which in a crude form includes an estimation of the cost of upstream reinforcing the MV and HV distribution network, the transmission network and the centralized generation.

8.1.1 Grid extension

A recent World Bank study[33] for 39 countries in SSA shows that the national viability gap in Rwanda is the seventh highest in Africa, despite the high tariffs, because of the expensive price of the energy mix (around 0.28 $/kWh in 2017). In the study of the Base Case Scenario of NEP 2024, as described before, REM considers the network costs of grid extension, the acquisition of energy at the HV/MV

[33] Making Power Affordable for Africa and Viable for Its Utilities. (Kojima & Trimble, 2016). https://openknowledge.worldbank.org/handle/10986/25091

distribution transformers (which includes the price of wholesale energy production, plus the cost of transmission and high voltage distribution networks). The revenues result from applying the present tariffs that will apply to these new grid-connected customers for their estimated consumption in 2024.

For new customers connected to the Rwanda national grid according to the NEP 2024 Reference Case Scenario, the average per unit cost of service calculated by REM is 0.199 $/kWh[34]. This cost can be broken down into two components: 0.120 $/kWh as the cost of energy withdrawn from the grid at MV level, and 0.079 $/kWh as the cost of investment (0.065 $/kWh) and operation and maintenance (0.014 $/kWh) of the new MV (excluding reinforcements) and LV network infrastructure required to connect and supply the customer.

Table 5-1 shows the breakdown of the applicable tariff to each type of customer, the annual energy consumption and the corresponding expected annual revenue for each one of the categories. This result can be compared with the actual incurred cost of supply, as provided by the REM model for each category of customer. Large and small industries, water pumping and residential 1 result in a deficit for the power sector. Any tariff below 0.134 $/kWh will not cover the operating costs of supply; this includes residential 1, industry large and industry medium. Other customers above this cost of service would generate a surplus for the power sector, including residential 3, health facilities, non-residential large or telecom towers.

Customer type NEP 2024	Applicable tariff	RWF/kWh	USD/kWh	Energy p. c. (kWh/year) 20242	Tariff income p. c. (USD/yr)	Cost of Service p.c. (USD/yr) A	Viability Gap p. c. (USD/yr) B C=
Airport	Industry large	97	0.11	35,407,055	3,777,933	509,862	3,268,071
Cell ofice	Non residential large	222	0.24	11,802	2,882	3,416	(533)
Coffee washing station	Industry small	126	0.14	8,852	1,227	692	535
Health center	Health facilities	192	0.21	10,622	2,243	2,373	(130)
Health post	Health facilities	192	0.21	5,901	1,246	1,318	(72)
IDP Model Village (avg.)	Residential 3	210	0.23	76,715	17,721	20,176	(2,455)
Irrigation pumping	Water pumping	126	0.14	17,703,527	2,453,709	1,384,416	1,069,293
Markets	Non residential large	222	0.24	47,209	11,529	13,662	(2,134)
Milk collection center	Industry small	126	0.14	8,262	1,145	646	499
Mining	Industry medium	98	0.11	147,529	15,904	2,449	13,455
Preprimary school	Non residential large	222	0.24	2,360	576	683	(107)
Primary school	Non residential large	222	0.24	2,360	576	683	(107)
Secondary school	Non residential large	222	0.24	7,672	1,873	2,220	(347)
Sector Office	Non residential large	222	0.24	8,262	2,017	2,391	(373)
Tea Factory	Industry large	97	0.11	22,424,468	2,392,691	322,912	2,069,778
Technical Schools	Non residential large	222	0.24	153,431	37,468	44,403	(6,935)
Telecom Tower	Telecom towers	182	0.20	1,652,329	330,796	332,779	(1,983)
VTC	Industry large	97	0.11	1,652,329	176,304	23,794	152,510
Water pumping stations	Water pumping	126	0.14	236,047	32,716	18,459	14,257
Residential 10W	Residential 1	89	0.10	59	6	(0)	6
Residential 50W	Residential 3	210	0.23	295	68	78	(9)
					181	234	53

[34] For a more detailed breakdown of these figures, please see section 3.1 of this Report. The methodology to calculate this optimum is also explained in section 1.2 of this Report.

Table 8-1: Difference between the expected annual revenue per customer according to present 2019 tariffs and the cost of service for new standard grid extension customers in NEP 2024

It is important to notice that for this estimation, given the lack of detailed information about the hourly profiles for industrial customers, this report assumes that the flat rate tariff is applicable to all of these customers, not considering that some of them will have smart meters and will be subject to time-differentiated rates and perhaps tariffs with separated energy ($/kWh) and fixed ($/yr) or capacity ($/kW) charges.

The estimated viability gap of $23 million/year shown in Table 5-2 below corresponds to the additional economic effort implied by the NEP grid extension in Rwanda, under the assumption that the present tariff structure remains stable, and that the cost of bulk power will reach the efficiency target determined by EDCL for NEP 2024. All are strong and ambitious assumptions, and the implications for the future tariff structure, funding and subsidy schemes need to be carefully pondered to guarantee the feasibility of reaching the 2024 goals for grid extension.

Customer type NEP 2024	Applicable tariff	Tariff Income (USD/yr)	Cost of Service (USD/yr) A B=C+D+E	CAPEX (USD/yr)	OPEX (USD/yr) C	Upstream energy cost (USD/yr) D	Viability Gap (USD/yr) E F=
Airport	Industry large	3,777,933	7,046,004	2,307,054	490,103	4,248,847	3,268,071
Cell ofice	Non residential large	438,084	356,998	116,891	24,832	215,275	(81,087)
Coffee washing station	Industry small	12,269	17,615	5,768	1,225	10,622	5,346
Health center	Health facilities	13,460	12,683	4,153	882	7,648	(778)
Health post	Health facilities	12,463	11,743	3,845	817	7,081	(720)
IDP Model Village (avg.)	Residential 3	372,146	320,593	104,971	22,300	193,323	(51,553)
Irrigation pumping	Water pumping	24,537,089	35,230,020	11,535,271	2,450,516	21,244,233	10,692,931
Markets	Non residential large	299,742	244,261	79,978	16,990	147,293	(55,480)
Milk collection center	Industry small	2,290	3,288	1,077	229	1,983	998
Mining	Industry medium	588,436	1,086,259	355,671	75,558	655,031	497,823
Preprimary school	Non residential large	22,481	18,320	5,998	1,274	11,047	(4,161)
Primary school	Non residential large	61,678	50,261	16,457	3,496	30,308	(11,416)
Secondary school	Non residential large	86,176	70,225	22,994	4,885	42,347	(15,951)
Sector Office	Non residential large	12,105	9,864	3,230	686	5,948	(2,241)
Tea Factory	Industry large	9,570,763	17,849,877	5,844,537	1,241,595	10,763,745	8,279,114
Technical Schools	Non residential large	37,468	30,533	9,997	2,124	18,412	(6,935)
Telecom Tower	Telecom towers	19,516,982	19,399,997	6,352,089	1,349,417	11,698,491	(116,985)
VTC	Industry large	1,586,732	2,959,322	968,963	205,843	1,784,516	1,372,590
Water pumping stations	Water pumping	261,729	375,787	123,043	26,139	226,605	114,058
Residential 10W	Residential 1	1,165,324	2,368,737	775,589	164,764	1,428,384	1,203,414
Residential 50W	Residential 3	15,615,335	13,452,172	4,404,609	935,701	8,111,863	(2,163,163)
		77,990,684	100,914,559	33,042,184	7,019,375	60,853,001	22,923,875.43

Table 8-2: Total expected annual revenue according to present 2019 tariffs and the cost of service for new standard grid extension customers in NEP 2024

Additionally, for the purposes of the NEP 2024 REM calculations, any existing or future subsidy upstream the MV distribution level (either for generation, transmission or allocated to HV/MV distribution) has been estimated as directly integrated in the price of energy withdrawn for the grid at the low voltage side of the HV/MV distribution transformers (in the Reference Case this withdrawn energy price is 0.120 $/kWh).

Moreover, the individual cost of every grid extension project has been calculated by REM for NEP 2024, as detailed in depth in Section 3.1.2 of this Report on Design of the National Electrification Plan of Rwanda. The per-unit cost for all these individual projects ranges from 0.13 $/kWh for high density areas or large industrial customers, up to 0.80 $/kWh in very remote villages with small consumption, as can be seen in figure5-1 below. The average cost of 0.199 $/kWh acknowledges an implicit cross-subsidy, where more expensive projects (up to 0.80 $/kWh at the right end of the figure) are balanced by more efficient projects (down to 0.13 $/kWh at the left end). Cross-subsidization among customers happens when some of them have per unit ($/kWh) costs above their regulated tariffs and conversely.

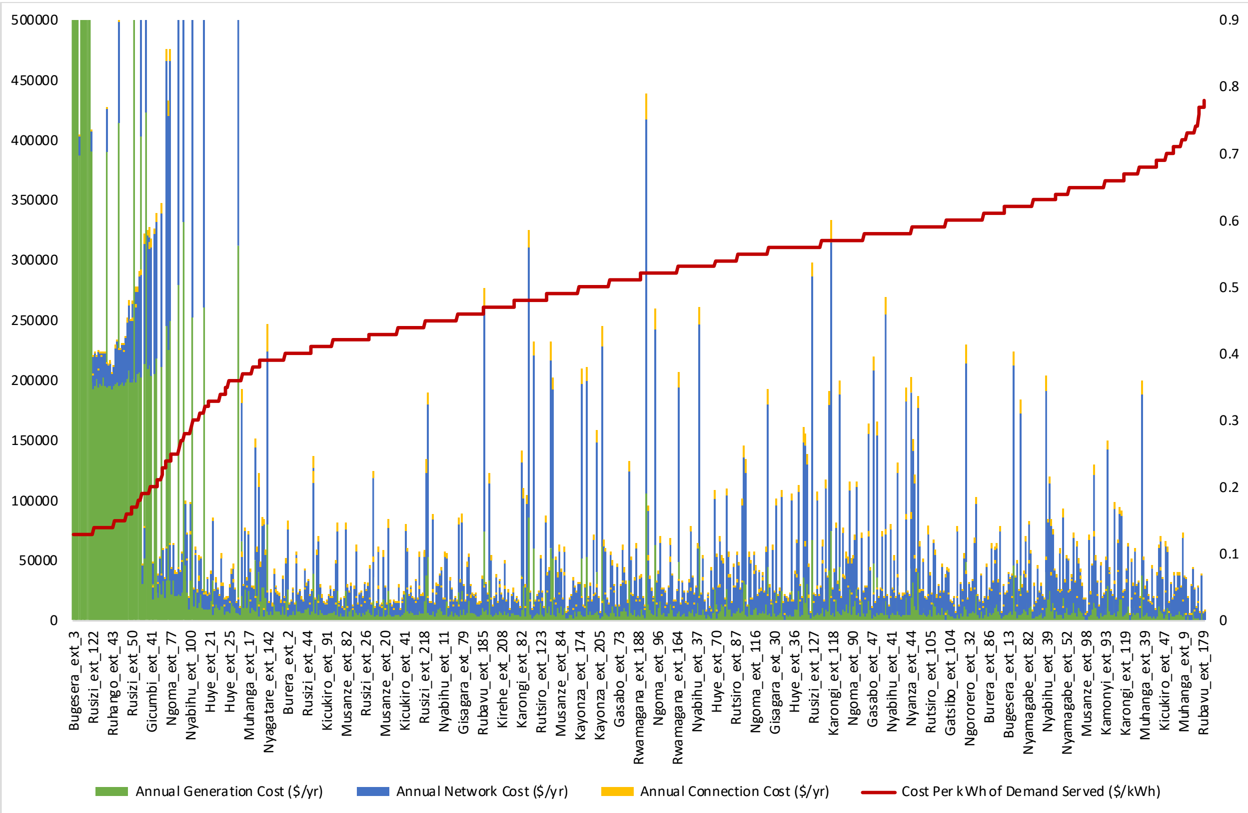

Figure 8-1:. Breakdown of costs annuities ($/yr left vertical axis) and per unit costs ($/kWh right vertical axis) of selected clusters (horizontal axis) supplied with grid standard extensions. Rwandan National Electrification Plan – Reference Case Scenario (from section 1 of this Report NEP 2024)

8.1.2 Mini-grids

The least-cost electrification mode for 317 thousand non-electrified customers (8.2% of the customer base) in 2500 villages is a grid-standard mini-grid in NEP 2024. Comparing the cost of grid extension and mini-grid supply to the same cluster of customers, the cost of projects of grid connection to the main grid would range from 114% up to 495% (almost five times) more than the equivalent supply by a grid-standard mini-grid.

Despite being the least-cost solution, still the average per unit cost of service of mini-grids is 0.593 $/kWh, almost three times higher than the average cost for the grid extension areas. This higher figure is explained first by the higher cost of standalone generation (around 0.22 $/kWh for a 97% reliable solar-battery generation), which is 0.10 $/kWh higher than the estimated cost of energy withdrawn from the grid in 2024 in the REM Base Case Scenario for the National Electrification Plan of Rwanda, as seen in the previous section. Second, but more important, the isolation of many areas that should be supplied by mini-grids and their low density of load results in less efficient mini-grids, as compared to those in high density areas.

This average cost is, again, the result of the aggregation of thousands of individual grid standard mini-grid projects, as can be seen in figure 5-2 below.

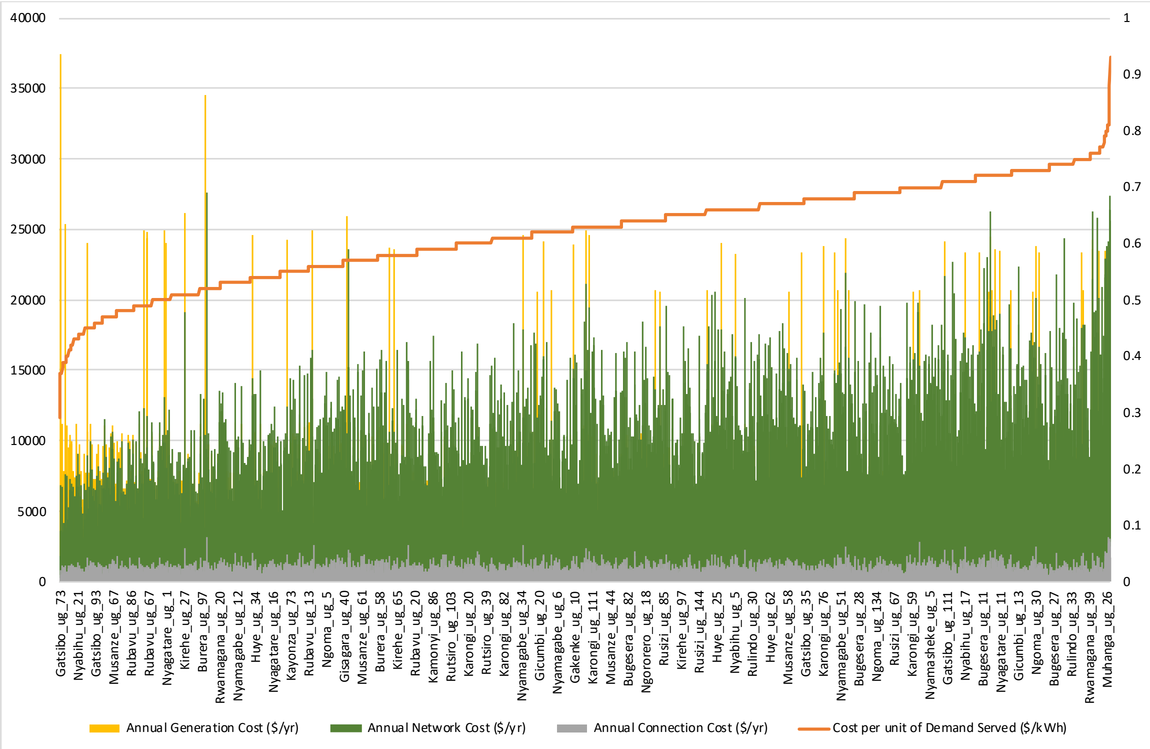

Figure 8-2: Breakdown of costs annuities ($/yr left axis) and per unit costs ($/kWh right axis) of selected individual mini-grid projects (horizontal axis). Rwandan National Electrification Plan – Reference Case Scenario (from section-1 of this Report NEP 2024

The costs of service of these mini-grids range from 0.23 $/kWh (for very dense mini-grids with large anchor loads and an average consumption of about 7,000 kWh/year, where the network cost represents only 14% of the total cost of service) to 0.95 $/kWh (mostly for Tier 1 residential mini-grids, with energy demand of 113 kWh/year, where the cost of network is 72% of the total cost of service of the mini-grids).

REM computes the cost of supply of each mini-grid that has been included in the electrification plan. It has been seen that the mini-grids differ widely in their per unit cost of supply, which for the sake of simplicity has been expressed in $/kWh. This cost of service can be used as an objective indication of the cost of supply that competitive bidders could offer in an auction to be chosen to deploy the mini-grid subject to some quality of service targets, perhaps among others. Should the mini-grids be subject to regulated tariffs, REM´s results can also inform the regulator about the subsidy that ideally each minigrid would require.

If it happens that the detailed ground truth of the customers to be electrified and their estimated consumption diverges from the assumptions of NEP 2024 (issued in 2019), REM can be used again to easily recalculate the reference cost of service for each system, updating the Rwanda NEP data base with the new input information obtained from direct field work analysis or reported by the incumbent company.

Two different options for the participation of private actors in mini-grid investment and management have been mentioned in previous conversations maintained with Rwandan stakeholders:

A. Fully private developers implement, maintain and operate the mini-grids, including fee collection and customer engagement. Tariffs are freely negotiated with the beneficiaries.
B. EUCL, as the incumbent distribution utility, undertakes the complete installation, maintenance and operation of the mini-grids, and integrates the grid-standard mini-grid users within their customer base, together with those connected by grid-standard extension, all under the same regulated tariff and with EUCL compensated with a subsidy to cover the viability gap. Independent developers would be allowed to do the same, again under the general regulated tariff and receiving the economic compensation. Opportunity may be given to the community leader of the area to operate as Input Based Franchisee Model, in which a fixed amount of fees/commission target related to collection and O&M activity of minigrid may be given to them as part of agreement. Other possibilities are contemplated, including that EUCL be in charge of the network development of all mini-grids and the role of the private sector would be limited to that of an Independent Power Producer (IPP), providing the generation and storage required by the mini-grid, with an adequate quality of service and at the lowest possible cost.

8.1.3 Standalone Systems

The NEP 2024 Least-Cost Plan establishes that almost one million residential customers in very disperse and remote areas, including those in high-risk zones, will be assigned DC solar kits as a transitory measure to achieve universal access in Rwanda for a basic level of electricity service at least. The NEP 2024 has also determined how many very isolated community and productive loads might also better be serviced by an AC standalone system which provides a service equivalent to the grid but at a much lesser cost, requiring an overall investment of nearly $60 million.

The pay-as-you-go technology can be used in the “classical” business model of paying for the service plus some extra charge that allows the purchase of the device after 2 or 3 years of payments. The alternative business model consists of a simple pay per service with no limit in time, as it is done with mini-grids or connection to the main grid. The viability gap for a pay-as-you-go business model should consider the difference between a regulated charge per the service being provided and the annuity of the cost of the solar kit plus the cost of maintaining service centers close to the customers which will provide repairs and maintenance when needed, and replacing and recycling exhausted batteries. Special deals might be offered, with extras such as provision of electric equipment and tools, replacement for lights and communication devices, power for productive uses (e.g. solar pumps) as well as, future upgrades of the initial supply kits. The financial sustainability of these business models will guarantee the mid and long-term permanence of the power supply in isolated rural zones, where local population will also require support and capacitation to take full advantage of the energy, economic and cultural transition posed by the generalization of electric supply in their lives.

8.2 Considerations regarding the financial aspects of the electrification process.

The electrification plan is inextricably associated to the complete Energy Sector Strategy Plan (ESSP), which in its present version has a total estimated cost of $3.12 billion, of which $2.73 billion correspond to electricity.

Electricity expenditure is largely driven by building new power stations and transmission lines. Regarding centralized generation, according to the ESSP, independent power producers (IPPs) will continue to be encouraged to finance and deliver generation projects through power purchase agreements (PPAs). This will reduce the immediate pressure on the GoR finances, attract internationally state-of-the-art technologies and reduce costs through competition. Similar approach can be applied to large individualized investments in the transmission network, as it is the case for transmission interconnections and major network reinforcements. Note that the cost of the PPA contracts must be passed through to the consumer tariffs. If the tariffs are not fully cost reflective, the difference will have to be reflected as a loss of the distribution activity of EUCL, absorbed by public funds and this deficit must be accounted for in any financial analysis of the regulated distribution utility.

After new generation capacity, expanding the transmission and distribution networks is the largest capital expenditure in the electricity subsector, typically financed from a mixture of sources, including Government budget, development partner's support and the private sector. Regarding large generation and transmission, and as it was indicated before (section 4.2), the success in attracting private investment for these two types of infrastructure will not depend that much of the definition of the business model itself and its regulation, as it will depend on external country-specific conditions such as legal security, sound governance, country risk, convertibility risk, and so on. The same applies to auctions for utility size renewables, which have been also successfully performed in Africa, as indicated before.

So far, good progress has been made in attracting investment in Rwanda. Rwanda ranked 56th out of 190 countries in the 2017 World Bank Doing Business report[35]. And its 2015 Human Development Index value was 0.500, slightly above the average for Sub-Saharan African countries[36]. Sustained economic growth is targeted in coming years.

The ESSP acknowledges the relevance of financial risk in the success of the electrification process. In its implementation plan, summarized in table 23 of the ESSP report, the most frequently mentioned risk for the diverse activities included in the electrification plan is "lack of finance results in project delays or cancellation".

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[35] World Bank Doing Business website (http://www.doingbusiness.org/data/exploreeconomies/rwanda).
[36] United Nations Development Programme, Human Development Report Office website (http://hdr.undp.org/en/countries/profiles/RWA).

The ESSP report asks for diversity in the financial resources to be tapped for the project. Given the volume of investment that is needed, even if it is assumed that generation and transmission needs will be fully covered by private investors, a substantial participation of private capital will be necessary to address the rest of the investment, as well as guarantees from DFIs backing the commitments of the GoR.

The EARP will continue to lead on-grid access. It is financed through a basket of funds from Government and development partners. Most of the non-Government funds are supplied in the form of grants or loans from donors with minimal interest.

The final regulation for off-grid electrification is still pending publication, but it is expected to be designed to attract private investment, with the possible participation of EDCL in the implementation of the standard mini-grid networks. Subsidies are needed to make off-grid supply – either by mini-grids or standalone systems – affordable to the end customers. A matter of concern is the compatibility of a multiplicity of developers, technologies, quality of service standards and tariffs, with a sound long-term vision of the power sector in Rwanda.

Standalone off-grid electrification will continue to be driven by the private sector, with companies operating in Rwanda and selling directly to households. The Renewables Electrification Fund, coordinated by the World Bank with funding from a number of development partners, may reduce the investment costs. The GoR can provide support to low-income households who would otherwise be unable to purchase a system. MININFRA and REG will seek to encourage the development of mini-grids where technically and economically feasible and will use appropriate financing arrangements.

Assessment of the financial commitments of the electrification plan.

The total cost of implementing the ESSP between 2018 and 2024, *once updated with the investment cost of NEP 2024*, is estimated at $3.28 billion. This is the total for the three subsectors, electricity, biomass and petroleum, with the total cost for the electricity subsector equal to $2.89 billion. Our detailed analysis of the part of the NEP 2024 considered in this report results in an increment of $158 million with respect to the estimation of the ESSP. Our detailed analysis of NEP 2024 has focused on the grid extension and off-grid least-cost electrification plan, and it has only increased the cost of the grid extension supply mode in 8.3% (with a total average cost of $648 per customer) with respect to the ESSP results. However, for mini-grids and standalone systems the cost is increased by 61% (though it averages only $152 per customer, due to the predominant component of solar kits).

The least cost electrification plan that we have developed for the NEP 2024, meant to achieve full electrification by 2024 and subject to the restrictions given by REG, has an overnight investment cost of $1,023 million, which can be broken down into $316 million for grid-standard extension, $448 million for grid-standard-densification, $200 million for grid-standard mini grids and $59 million for standalone systems, plus the corresponding total annual O&M costs of $23.7 million/year, which can be also broken down into grid extension ($7 million/year), mini-grids ($6 million/year), standalone systems ($0.7 million/year) and densification ($10 million/year). The densification investment and

O&M costs have been roughly estimated from known per-household connection costs[37] and estimated new connection needs. The calculations result in an estimated total cost (investment plus O&M) TOTEX annuity of $152 million/year in 2024, when customary depreciation rates and economic lives for the different pieces of equipment are considered.

The annual deficit or viability gap of the electrification plan can be estimated from the TOTEX annuity of each electrification mode, the upstream cost of energy and the estimated regulated tariffs for the different types of customers supplied under each mode for the considered year. For instance, with the present tariffs we can calculate a deficit of $23 million for the grid extension electrification mode. Depending on the assumptions made about the business models behind the development of mini-grids and the supply of standalone systems, the corresponding deficits can be also computed. The annual viability gap of the electrification plan would have to be added to the present or estimated future deficit associated to the supply of the already electrified customers to obtain the total annual deficit of the entire power sector.

We shall limit our discussion to the financial implications of the electrification plan NEP 2024. REG has to invest a total of $1,023 million during a period of 5 years (2020 to 2024), with some mix of equity and debt. Note that the typical value of public investment in the entire power sector of Rwanda during the last few years has been close to $90 million per annum. The required borrowing will have a macroeconomic impact on the financial situation of Rwanda as a country, obviously in combination with the global borrowing situation of the country in the energy sector (as indicated above) and in other sectors too.

Most private investments in the power sector will be directly or indirectly supported by governmental guarantees, with implications on the volume of sovereign debt in other macroeconomic indicators of the country. This topic is discussed in the following section.

8.3 A macroeconomic perspective.

As indicated by the International Energy Agency in its 2018 World Energy Outlook, reaching universal energy access in Africa may require an estimated ~$800bn investment. While significant private funding opportunities may appear in the future, public or publicly guaranteed financing may constitute a large part of this total amount and it will affect local sovereign creditworthiness. Therefore, the issue of sovereign indebtedness will be a key constraint when designing sustainable electrification strategies in Sub-Saharan African economies.

The objective of the Government of Rwanda (GoR) is to achieve full electrification by 2024. In this section we comment on the challenges that exist from a macroeconomic perspective and the issue of sovereign debt in particular exclusively in relation with the electrification plan NEP 2024, which, it must be remembered, is part of a wider energy plan (ESSP) between 2018 and 2024, whose investment cost, updated with the more accurate investment cost of our plan NEP 2024, is estimated

[37] These average connection costs encompass many different situations, ranging from cases where only a drop line to the closest LV line is needed, to cases where a new MV/LV transformer is also necessary, plus the meter and protections in all cases.

at $3.28 billion (including electricity, biomass and petroleum), with the total investment cost for the electricity subsector equal to $2.89 billion.

Recapping prior information, financing the electrification plan requires investing $1,023 million that will be spent over a period of 5 years (2020 to 2024) and incurring annual O&M costs of $24 million per year. From a purely regulatory perspective, as indicated above, the estimated TOTEX annuity is $152 million/year in 2024. And, making reasonable assumptions about the regulated tariffs, and assuming that all customers pay the bills, we estimate an annual deficit for electrification by grid connection of $23 million in 2024. More uncertain estimates can be made regarding the deployment of mini-grids and standalone systems. It is expected that the deficit will diminish with time, as tariffs will get closer to cost reflectiveness since the capacity to pay of customers will increase with economic growth and the per unit cost of electricity will decrease. This deficit can be termed a “regulatory deficit” (i.e. a deficit that happens when an orthodox accounting calculation of the annual cost and the annual regulated revenues is employed), but this is not the one that matters here if we want to examine the macroeconomic implications of the electrification plan.

In the first place, it is important to notice that distribution, even the extended one we are talking about here (with mini grids and SAS), is for the most part a regulated business and the regulated tariffs give a strong assurance that a fraction of the incurred costs will be recovered (the totality of the costs if – and only if – tariffs are cost reflective and all the customers pay the bills). The fraction of the investment costs that is not recovered, after paying the totality of the O&M costs, is the viability gap associated to the electrification plan, which needs to be paid by the GoR and must be guaranteed by some development financing institution (DFI), since otherwise it will be difficult attract a private investor. Guaranteeing the recovery of the viability gap, while it lasts, is our concern here.

Rather than using the “annuity of the regulatory deficit”, the examination of the macroeconomic impact on Rwanda of the electrification plan has to be based on the actual conditions of the financing approach that is available to REG for the plan. The conditions for repayment of the debt will be critical here: breakdown into different classes of debt, each one with an interest rate, a grace period, a time horizon for recovery, etc. Uncertainty has to be factored in. If there is a grace period in the repayment of the debt, during this period the annual O&M costs plus the annual return on the equity have to be covered by the annual revenues from the tariffs plus any subsidy that will be necessary to fill any gap. The grace periods of the loans should be related to the time when the tariffs as a whole are expected to reach cost-reflectivity. Otherwise, if the tariffs are not expected to reach cost reflectivity when the grace period expires, the gap to be covered with a governmental subsidy will be large, and it will be very difficult than any DFI, or any commercial bank, will be willing to guarantee the payment of the subsidy. A couple of business models can be examined now under this perspective.

Let us assume first that REG tries to do the electrification plan without the help of an external investor. Then, REG – or the GoR – will have to raise the capital to invest $1,023 million until 2024. If the GoR cannot obtain enough concessional loans, it would have to resort to commercial banks with a very high cost of capital. The GoR is presently negotiation an important concessional financial package for the energy sector. These are good news, but the amount that needs to be available for electrification purposes has to get close to the financial needs that have been presented here to minimize the need for additional support.

The alternative that is proposed in the Integrated Distribution Framework (see section 4.2 and annexes 1 and 2) is the partnership with an external investor under the format of a concession to manage REG for a long period of time. The external investor is assumed to be able to contribute with equity and to be able to get concessional loans and, if necessary, commercial loans at a more reasonable price. However, any external investor willing to get a concession to manage REG will demand some guarantee from a DFI that the subsidy will be paid in full and on time. And the DFI must trust that the Regulatory Authority and the Ministry will raise the tariffs progressively to get cost reflectiveness for most customer classes in a reasonable amount of time. And that the GoR will have sufficient economic resources and enough willingness to honour its commitment and pay the subsidy to REG every year, in full and on time.

An additional and significant complexity is that a concessionaire taking the responsibility of managing the distribution segment of REG will have to take care of all the other distribution activities that have been ignored when dealing with the electrification plan, i.e. the investments and O&M needed for all customers of REG that have already electricity supply. This must include the costs of refurbishing the existing network to reach any desired level of reliability, the cost of reinforcements and new developments in the existing network and investments in generation and transmission that might be necessary. All this will also require investments, O&M costs, and, with the existing tariffs and those tariffs to be expected in the near future, also subsidies, to be covered by the GoR. Again, any potential concessionaire with require that these governmental payments be somehow guaranteed by a DFI.

Besides political, social and technical constrains, the macro-economic feasibility of an electrification pathway must also be evaluated with debt sustainability analyses[38] that must be consistent with the pre-defined public financing schemes for universal energy access that have been adopted. This kind of analysis requires precise information about the current level of indebtedness of the country, which is necessary to evaluate the impact that the additional financial burden of the electrification plan would have from the macroeconomic standpoint, when adopting the integrated distribution framework, as explained above. The MIT team performed a preliminary analysis in 2017 and the diagnostic was favourable, since the impact of financing the electrification plan did not make Rwanda to exceed any of the thresholds that have been established to indicate risk to investors. Additional data would be now necessary to make a similar assessment. According to general indicators found in the literature, Rwanda continues in the upper level of attractiveness for doing business in the SSA region.

A complete analysis of the macroeconomic implications of the electrification plan would entail two successive evaluations. In the first place, the current macroeconomic situation of Rwanda should be examined to investigate the existence of any macroeconomic risk pre-dating the implementation of any electricity access strategy. Second, a new appraisal of Rwanda's sovereign creditworthiness

[38] See the IMF guidelines, as defined in *Guidance note on the Bank-Fund Debt Sustainability Framework for Low Income Countries* (Feb 2018).

would be necessaries to evaluate the macroeconomic impact of Rwanda’s electricity access strategy under two different *scenarios*: a grid-extension based model and the “integrated distribution framework” that has been recommended by the MIT team.

Section-9. Summary and Conclusions

Rwanda faces a challenge to achieve universal access to electricity, but the country has done its homework getting the power sector ready for a final push to accelerate the electrification process and towards moving Rwanda to a medium income status, ahead of most sub-Saharan African nations. However, an adequate strategy has to be devised to achieve this goal.

This final chapter of the report reviews the key aspects of the current situation of the power sector focusing on electricity access, recapitulates the contributions of the technical analysis of electrification planning, and offers some recommendations on a possible strategy to accelerate the process of achieving universal access.

9.1 A favourable starting point

The Gross Domestic Product per capita in Rwanda was $826 in 2018, which is equivalent to just 7% of the world's average. This low level of economic development can be partly attributed to infrastructure shortcomings, linked to high electricity costs that hinder socio-economic development and to lack of access that limits the transformation from an economy based on subsistence agriculture to a knowledge economy. Developing the energy sector is key to develop other sectors, such as manufacturing, agro-processing, housing, mining, tourism and IT services.

The electrification situation.

Rwanda has made great progress in electrification during the past decade. However, the electrification rate primarily reflects grid-connected users in urban areas and remains largely concentrated in the two top quintiles, with almost negligible coverage in the bottom 40 percent of the population. Electrification is primarily a rural challenge: 77 percent of the urban population is electrified, and their access is concentrated in the higher levels of service. By contrast, 84 percent of the rural population has no access to electricity and only very few are in the top levels. Off-grid solutions are more common in rural areas and they typically provide low levels of access.

The bulk power sector.

Rwanda lacks domestic, low-cost energy resources, and so far, lacks the electrical size that allows to make generation investments at scale, reducing the per unit energy costs. Rwanda has prioritized domestic solutions over electricity imports from neighbouring countries with cheaper supply, such as Ethiopia, Kenya, or Uganda. On top of the inherent disadvantage of limited domestic resources, investment planning was pursued without adhering to least-cost planning principles. Most contracts to develop capacity were procured through bilaterally negotiated deals rather than competitive procurement. Taken together, these decisions have led to excessively high electricity costs (around US$0.32 per Kilowatt hour (kWh) in FY2016/17) and a surplus of installed generation capacity estimated starting by 2020 under a BAU scenario, which could be compensated by the demand growth expected from additional customers to be connected to the grid according to the NEP 2024 targets. Despite the subsidies, the resulting tariffs for the end customers are high (US$0.20 per kWh on average), making electricity unaffordable for many, especially households and industry. Access to electricity remains largely concentrated in the two top quintiles of income of the population, with almost negligible coverage in the bottom 40 percent. Even at a subsidized rate, firms also pay a higher price of electricity compared to neighbouring countries, making access to electricity among the main constraints to scaling up private investment flows.

The good news is that the additional effort to expand generation capacity in the medium term to support a massive electrification effort by grid extension, if needed, will not be large despite the annual energy demand is expected to grow by a factor of 4 in 2024. And these future generation investments will be done under a least cost planning approach and allocated by competitive methods. This situation also calls for focusing on the development of transmission interconnections that will allow trade with other countries. Finally, and most important for electrification, any strong increments in electricity demand (as a result of growth in industrial and commercial loads, other productive electricity uses, as well as emerging technologies in electric transport, or electric cooking at households) will spread the capital costs of any future surplus of installed generation capacity, thus reducing the per unit energy price.

One additional concern is the exposure to climate change risk, because of the large share of hydro generation in the energy mix. Appropriate planning procedures must create a more secure energy mix by including complementary renewables and engaging in regional trades—thus mitigating these climate risks.

Fiscal impact of the power sector.
At present, tariff revenues collected by REG are insufficient to recover the operating costs of service provision to its customers. Rwanda's electricity supply is expensive due to limited domestic energy resources and noncompetitively procured generation capacity. Tariffs are among the highest in the region, but they are below cost recovery because the low incomes limit the consumers' ability to pay for electricity services. The gap is covered by budget transfers to REG. Even at a subsidized rate, firms pay a higher price of electricity compared to neighbouring countries, making access to electricity among the main constraints to scaling up private investment flows.

Absent a vigorous increment of demand as a result of an acceleration of the electrification plan, the estimated surplus of generation capacity after 2020 will create pressure on the tariff and – if the tariff remains below costs – on the need for Governmental subsidies. The new generators have high capital costs that should be recovered with cost-reflective tariffs, or with subsidies, if the tariffs are kept below costs. The World Bank has estimated[39] that this surplus capacity will result in a total subsidy requirement of around $1bn between now and 2025 assuming a rate of demand growth of around 8% per annum. Since REG is charging a very low price for the consumption of peat and methane from lake Kivu, increasing demand will result in a reduction of the per unit tariff to the end customers.

Policy and institutional reforms.
The World Bank staff estimated that, at the tariff prevailing until January 2017, electricity was affordable for the top 30 percent and unaffordable for the lowest 70 percent of the consumers.

[39] http://documents.worldbank.org/curated/en/321321512356422171/Rwanda-First-Programmatic-Energy-Sector-Development-Policy-Financing-Project

Electricity became even less affordable for households that only recently gained access to the grid and had to pay off their contribution to the connection fee.

To increase the affordability of electricity for low-income households, the electricity tariff was reviewed in 2016, with a new tariff regime put in place from January 2017. A number of important changes were made. First, the tariff revision in January 2017 reduced the cost of electricity by 51 percent for households with monthly consumption up to 15 kWh (the average monthly consumption of households in Rwanda was an estimated 35 kWh per month in 2016/17). Second, the new connection policy aims to make connections affordable for all consumer categories and introduces new payment options for the connection fee, including one with zero down payment targeted at low-income households. Both measures are meant to have significant, positive poverty and distributional effects. In August 2018, tariffs were adjusted again, blocks 1 and 2 stayed the same and block 3 increased by RWF 21 per kWh to RWF 210 per kWh (US$0.24 per kWh). Tariffs for selected non-household consumers that are not exposed to international competition—commercial customers, broadcasters, telecom towers and health facilities—have been brought closer to cost recovery.

Rwanda is a small, densely populated country that will ultimately be fully electrified through the national grid. However, grid extension to reach clusters with very low total demand is too expensive. Off-grid solutions, which provide lower-tier service but are more affordable, can provide an important interim solution for these households. The affordability challenge and the steep cost reductions in off-grid solar solutions have triggered the Government to reconsider its strategy for access expansion and put more emphasis on off-grid solar to provide access to households that have relatively basic electricity needs and would have difficulties affording even a subsidized connection fee for a grid connection. To implement the new targets, the Government has launched least cost electrification planning efforts – of which this report is the last example – and has put in place new procedures for simplified procurement of small mini-grids.[40]

Mini-grids first appeared in Rwanda's policy after the adoption of the National Energy Policy in 2004. Since then, through various plans and programmes, such as the National Electrification Plan, Energy Sector Strategic Plan and the Renewable Energy Fund, the role of mini-grids in achieving universal access has been elaborated and strengthened. RURA has developed a dedicated mini-grid regulatory framework, the first version of which was approved in August 2015. The rules apply to minigrid projects with generating capacity of up to 1 MW; projects with 100 kW or less are eligible for simplified and streamlined licensing, and mini-grids below 50 kW are exempt from licensing requirements. Licensees are free to set their own tariffs, subject to review by the regulatory authorities. The regulation provides several options to mini-grid operators in case the main grid arrives to their mini-grid site. Recognizing the crucial role of the private sector in ensuring universal access, RURA is working to develop a second-generation regulatory framework. The Rural Electrification Strategy lays out the government's role in creating an enabling environment for private developers by identifying eligible sites to be tendered out to private developers. This project has contributed to the definition of these sites. Even though Rwanda is one of the earlier adopters of mini-grids, the mini-grid sector currently includes only a handful of private sector developers. Several challenges need to be addressed to scale

[40] IRENA (2019). Policies and regulations for renewable energy mini-grids.

up deployment: delays in defining clear demarcations, need for capacity building of some developers, and, mainly, lack of financing, so that mini-grid development largely relies on donors.

Regarding standalone systems, mostly solar lanterns and solar kits, the Rwanda Standards Board issued and published in the Official Gazette the national standards consistent with the standards developed by the International Electrotechnical Commission (IEC) for solar systems and the MININFRA approved the Guidelines on Minimum Standards Requirements for Solar home systems to support off-grid standards enforcement.

Another significant development is the adoption of least cost planning for generation expansion, jointly with competitive procurement methods. Least-cost planning has also been followed in the development of the present electrification plan.

Governance.

Governance of Rwanda's power sector has historically been highly concentrated in the Government, with relatively little independent decision making, for example, in the utility. This benefits reform coordination and can speed up program implementation. However, with limited separation of commercial, regulatory, and political objectives in decision making, it carries risks of inefficiencies and non-adherence to business plans or regulatory mandates. To mitigate such risks, in 2013, with the support of the World Bank and other development partners, the Government restructured the key energy sector institutions, aiming at achieving regulatory independence, financial sustainability, and increased private sector engagement. REG was created to take over the electricity utility functions as well as carry out power sector planning and development. While the Government retains ownership of REG, its affiliated companies are governed under company law as opposed to public service law. Subsequent support focused on enhancing REG's operational efficiency and governance, including the competitive recruitment of key staff and senior managers of the sector institutions (for example, the CEO of REG). RURA is the sector regulator with a track record of independent tariffs decisions and utility performance reviews.

Business enabling environment and risk analysis.

Rwanda has been a leading reformer among African economies in Doing Business indicators[41], ranking second in Africa only after Mauritius in the business enabling environment in the country (for example, Rwanda is ranked 76 in starting a business out of 190 countries), but it is ranked 117 in getting electricity, with one of the highest electricity tariffs in the region.

According to recent reports by the WB[42], overall, while risks remain, Rwanda's macroeconomic policy framework is considered adequate by WB reviews and rating institutions. Rwanda's prudent macroeconomic policy has enabled the country to achieve high economic growth and macroeconomic stability in the past decade. Both monetary and fiscal policies have been implemented in a prudent manner. The World Bank/International Monetary Fund assessment of Rwanda's DSA indicates

[41] http://www.doingbusiness.org/data/exploreeconomies/rwanda#getting-electricity

[42] See World Bank (2017) First Programmatic Energy Sector Development Policy Financing, World Bank (2019) Lighting Rwanda. Rwanda Economic Update, and also our analysis in section 5.

continuation of low risk of debt distress. Rwanda's public sector debt has increased with an investment push in recent years but remains comfortable in absolute terms. Rwanda's domestic public debt has also increased to develop a broader domestic market in recent years but also remains low in absolute terms.

The Government is strongly committed to contain the fiscal impact of the electricity sector without slowing down its access program or compromising on consumer affordability, by reducing cost of service and losses as well as enhancing transparency. To ensure that cost and subsidies are handled in a transparent manner, the Government is committed to transition REG to fully IFRS-compliant financial statements and institutionalize their timely auditing and publication.

In the medium term, aside from some potential liquidity pressures when the 2013 eurobond is set to mature, the risks to the forecast are low. Under the baseline scenario, all but one debt burden indicators are projected to remain below the policy-dependent thresholds. The only breach occurs in 2023 when the present value of debt service-to-revenue ratio just exceeds its threshold, although that breach is temporary in nature (lasting one year) and relates to when the 2013 eurobond is set to mature. The present value of debt service-to-exports ratio also peaks in 2023, although with a small breach of the indicative threshold under the largest stress scenario—a shock to export growth. Other indicators remain well below their thresholds even under the most extreme stress scenarios.

Therefore, the overall conclusion is a reassuring one, despite some alarming warnings in the above-mentioned WB reports when focusing on the potential fiscal risks derived from the present generation expansion plan, where excessive costs might have been incurred leading to a possible capacity surplus with a substantial impact on tariffs[43]. Note that, should the electrification plan as proposed in this report happen, the estimated demand growth in the medium term would consume this hypothesized surplus of generation capacity and would require even additional generation capacity by the end of the plan in 2024. Promoting regional electricity trade via reinforced transmission interconnections would provide necessary flexibility to accommodate the uncertainty in demand growth, as well as to tap lower cost supply sources and better integrate variable renewables.

9.2 Takeaways from electrification planning

The National Electrification Plan of Rwanda 2024 has provided the roadmap to achieve universal access in Rwanda in the coming five years, detailing at village level the least-cost areas where the national grid needs to be extended at the end of this period, the location of least-cost mini-grid villages, and the areas where DC solar kits and other AC standalone systems should be supplied as a first, temporary, solution. NEP 2024 included the detailed design of the power systems required to supply each one of the 2.9 million new customers of the Rwandan power sector in 2024, providing the

[43] According to the previously mentioned WB reports, under business-as-usual circumstances (with an estimated demand growth of 8%), the envisioned sector expansion would imply significant fiscal risks for the Government, as the fiscal transfers needed to sustain operations in the sector, which are already at 1.4 percent of GDP, could increase significantly to over 4 percent. Most of the potential increase in subsidies comes from the generation power plants under development (totaling 205 MW, about the same as the total current installed capacity) that are scheduled to come online shortly after 2020. These additional costs will mainly take the form of capacity payments to unused capacity, if demand does not keep up with the new supply coming online.

GoR with an accurate evaluation of the total required investment ($1.023 billion), of which for grid extension ($316 million), densification ($448 million), grid-standard mini-grids ($200 million) and standalone systems (59 million), as well as the CAPEX and OPEX annuity associated to the new villages electrified with grid extension (CAPEX is $33 million/year, OPEX is $7 million/year and the cost of energy purchased upstream is $60 million/year), grid-standard mini-grids (CAPEX is $29 million/year and OPEX $6 million/year) and standalone systems (CAPEX is 19 million/year and OPEX $0.7 million/year). NEP also detailed the bill of materials for all the grid and off-grid network and generation components, broken down in 931 individual grid extension and 1,973 mini-grid projects, scheduled for their implementation from 2019 to 2024 according to the priorities for electrification of schools, health centers and productive loads, and the budget and operative constraints specified by EDCL.

Our detailed computer-based analysis with the REM model has been limited to the electrification of those customers which required to be supplied by grid extension that needed new MV distribution lines, with any necessary MV/LV transformers and LV lines to reach the end residential and C&I customers and to the off-grid solutions for customers located beyond the already electrified areas in service by the current MV central network. Customers to be connected by just densification, i.e. wired to existing nearby LV lines in already electrified villages and customers close to the existing MV lines, did not need of the REM analysis to determine their least cost electrification mode as grid extension. NEP 2024 has provided an initial rough estimation of the cost of the densification effort. However, an additional densification plan is required to analogously provide detail down to customer level of the implementation of these new connections and of the associated upstream reinforcements required in the existing distribution grid, and their potential impact at transmission and generation levels.

For the new grid-standard extension, the cost of the necessary upstream reinforcements in MV, HV needs from the established connection point will also need a detailed study to determine the upgrades required in lines and transformers, as well as any associated changes in the generation expansion plan. This is outside the scope of NEP 2024, but an initial estimate has been made, under the assumption that the price of energy withdrawn by the new grid extensions at the MV tap point needs to be cost-reflective of all the associated upstream costs (CAPEX and OPEX) including generation, transmission and high-level distribution. A detailed analysis for the different electrification scenarios will help determine and plan with required investments that will be needed in parallel with the implementation of NEP until 2024 and beyond, ascertaining the impact of the plan in upstream components of the electrification and energy strategy of Rwanda. In addition, an estimation of the cost of reinforcement and refurbishment of the existing networks to improve their reliability will be also needed.

In agreement with EDCL indications, the demand profiles and quality of service requirements for grid-standard customers (either connected to the central network or to decentralized generation in mini-grids) is equivalent, targeting a reliability as close to 100% as possible, which will allow the development of productive and commercial activities, as well as the provision of appropriate public services as mainly education and health. Under these conditions, it would be reasonable to apply the same tariff to grid extension and mini-grid supplied customers.

The last mile electrification, as detailed in Section 8.1 of the present report, represents a significant effort because of the typically high cost of supply of rural and low-consumption areas (either connected to the grid or off-grid). Considering that decentralized mini-grids (mostly solar or hybrid) incur in a much higher generation cost, because of the requirement of presently high cost batteries (though this cost will continue declining in the coming years), one of the outcomes of this study is to show the growing potential of mini-grid technologies as a least-cost solution in Rwanda for low-consumption rural villages far from the grid.

9.3 Strategic issues

Achieving full electrification in Rwanda by 2024 according to the plan proposed in this report is possible, but there are a number of issues that must be properly addressed. A least cost plan is available, which establishes the demarcation for grid extension, mini-grids and standalone systems, subject to some policy guidelines, as well as a trajectory of investments in time to reach the 2024 target. The major issues to be overcome are of a financial nature: i) how to attract the necessary capital in the volume that is required for full electrification by 2024, and ii) how to overcome the problem that the tariffs that is plausible to expect that will apply from now until 2024 will be insufficient to cover the total costs of supply. The insights that follow focus on the effort that would be necessary to complete the electrification process, leaving aside what will be required to supply the customers that are connected already and their demand growth.

The volume of overnight investment that is necessary has been estimated in $1,023 million for NEP 2024 ($316 for grid-standard-extension, $448 for densification, $200 for grid-standard-mini-grids and $59 million for standalone systems), which jointly with the operation and maintenance costs ($24 million/year) results in an estimated TOTEX annuity of $152 million/year in 2024, when customary depreciation rates and economic lives for the different pieces of equipment are considered. This volume of expenditure – in particular the volume of investment if the target year for universal electrification is 2024 – can be difficult to finance with public funds, given that the typical value of public investment in the entire power sector of Rwanda during the last few years has been close to $90 million per annum. Therefore, a substantial amount of private capital will be needed. Any private investor will require a rate of return of the invested capital in accordance with the perceived risk, which in turn will depend on the guarantees provided by some specialized entities – development financial institutions – or by any other means. Legal security, based on a sound regulatory approach, is of essence here. The annual subsidy that will be required to cover the systemic deficit in the revenues from the regulated tariffs to cover the total cost of supply is another matter of concern, even if it is expected that the deficit will decrease with time.

For any private investor in a regulated business, as it is the case of the distribution activity, it is critical for the regulated revenue (the “revenue requirement”) to be cost-reflective, including an adequate rate of return on the invested capital. A high confidence in that a cost-reflective revenue requirement will be paid to an investor in the distribution company– payment that is guaranteed by the Government with some level of support by some development bank – is necessary for the investor to make the decision to invest. This requires a solid agreement between the private investor, and the regulatory authorities – including the Government. The agreement would be more secure – from a legal standpoint – if it is based on a concession contract than on just the country regulation, which can be modified more easily. Annex 2 to this section of the report describes the types of concession agreements that are possible and some relevant experiences. Note that an orthodox approach to the remuneration of the distribution activity, with a cost of capital based on the economic lives of the physical assets, which could extend for 40 years of more in the case of transformers, poles or wires, will reduce the annuities to be charged to the customers significantly, with respect to remuneration schemes based on a quick cost recovery. Note, however, the distinction made in section 5.3 between the "orthodox regulatory accounting" and the actual financial needs, which depend on the specific conditions of the financial arrangements that are possible.

Since the current tariffs that apply to all customers´ categories are below costs, an explicit subsidy is needed until the future tariffs achieve cost reflectivity globally, subsidy that has to be covered by the Government. This will add to the uncertainty – and therefore the risk for the private investor, with implications on the cost of capital – unless sufficient guarantees are given that this essential component of the revenue requirement will be paid in full and on time every year until the agreed time when the subsidy will not be needed (most likely by an effective use of internal tariff cross-subsidization, whenever this is possible).

This "regulatory compact" will be facilitated – or made possible, actually – by a comprehensive commitment by the private investor, made explicit in the concession agreement, of a commitment to fulfill the electrification plan as scheduled, comply with a metering plan, improve the reliability of supply to meet some satisfactory standards of service, and to engage with the customers in a proactive way, supporting community and productive uses of electricity that will enhance the wellbeing and economic situation of the customers. See section 4.2 of this report and annexes 1 and 2 for a description of this comprehensive approach to electrification that we term the "Integrated Distribution Framework, IDF".

If the IDF approach is adopted as a guiding principle, tariff cross subsidization will be helped by two beneficial factors that may allow to raise the tariffs that need to be subsidized, therefore decreasing the amount of subsidy. On the one hand, the improvement in the reliability of supply and metering will make more acceptable a tariff rise and will minimize the non-paid bills and illegal connections. On the other hand, access to electricity – perhaps with some external support – should enable economic growth and therefore higher ability to pay a more cost-reflective tariff. The approach must include regularly adjusting tariffs for changes in cost, ability and willingness to pay and, over time, expanding the groups of electricity consumers that do not need tariff subsidies and are charged the full cost of service plus some extra for cross subsidization.

REG currently relies on Government support and donor financing to meet the Government's electricity supply and access targets. REG's capital expenditures, most of which are implemented by EDCL, are mostly covered by budget support in the form of grants from the Government, sourced from multilateral and bilateral developing partners. Access to commercial loans for REG's own projects has been very limited. For generation, Rwanda has been able to attract private finance for generation with REG as off-taker but only with the backing of sovereign guarantees for REG's payment to the private sector. According to the WB[44] the Government of Rwanda has invested around a billion USD in the

[44] World Bank Group (2019) Lighting Rwanda. Rwanda Economic Update. June 2019. Edition No. 14.

power sector, while 52% of generation capacity is already on private hands. The total guarantees provided by the Government to state owned enterprises in strategic sectors (including energy) reach 5% of GDP ($350 million), and the fiscal transfers needed to sustain the power sector alone are in the range of 1% to 1.5% of the GDP per year ($90 to $135 million).

Support from development financial institutions (DFIs) will be necessary to make the electrification plan financially viable. Grants or loans under concessional conditions will reduce the cost of capital of the electrification project. Additionally, a grace period in the return of the loan will help in two dimensions: i) it will give some time for the customers to improve their economic conditions now that are enabled with access to electricity and also to increase their willingness to pay once the reliability of supply has improved; ii) it will defer the repayments of the loan to a date beyond the year 2023, when the scheduled governmental subsidies will peak creating some temporary concern in the lending institutions, as indicated in section 6.1.

However, the most important component of the support from DFIs is the amount of guarantee that can be given to the investor regarding the dutifully payment of the subsidy while it is necessary. This is linked to the overall capability of the country in accepting further guarantees. An assessment of the impact of the electrification plan on debt sustainability has not been performed under the present conditions.

The core elements of the proposed electrification planning strategy rest upon not just putting in place an adequate plan and a decision-making framework but mostly on finding consensus among stakeholders, including the Government, development partners and private sector, on how to address fiscal risks and payment guarantees.

If the Government of Rwanda, REG and RURA decide that the entry in REG of a private investor as a concessionaire or under any other format is an acceptable approach, it remains to decide the responsibilities of the new investor in the management and investment in the distribution activity. Annexes 1 and 2 suggest a plausible business model and describe some interesting experiences and possible options, including the role of the enhanced REG in rural electrification. This seems to be a good time in Rwanda to make this kind of decisions, while reconsidering aspects of the regulation of mini-grids and the treatment of the PAYG companies offering electrification services with standalone systems. The broad umbrella of the Integrated Distribution Framework can offer attractive possibilities.

Annexure 1: The Integrated Distribution Framework (IDF) [45]

The IDF is a conceptual framework encompassing the four requirements that were presented in section 7.2. of this report, namely: inclusiveness, permanence, utilization of a mix of delivery modes, and also of the participation of external agents. The IDF brings specificity to the usual requirements that any entity participating in the electricity sector must have a viable underlying business model, and be part of a long term plan for system expansion and economic growth.

The IDF admits a range of business, regulatory and legal arrangements adapted to the specific characteristics of each country. At one extreme, the obligation to serve would remain with the incumbent disco – one or a few per country – which is compatible with the presence of one or more mini-grid developers (meeting some standards of service quality and grid compatibility) and one or more companies providing electricity services with standalone systems (solar kits or solar home systems for the most part, but also larger systems) within the disco's territory. This disco should be subject to some reforms aimed at turning it into a viable business, as discussed below. In addition to extending the grid, the incumbent disco would have a default obligation to provide off-grid supply with some required minimum level of performance for those customers in off-grid designated areas that are not supplied by independent developers. The disco would be also the supplier of last resort in the case of default by an independent off-grid developer.

At the other extreme, in a situation where the incumbent disco has not made significant progress in electrifying its territory, mini-grid developers could occupy some geographical area and with time become *de facto* concessionaires, once they meet some minimum conditions. At that point, mini-grids would operate as normal utilities, subject to regulated cost-reflective revenue requirements, subsidies, and tariffs to end customers. These independent utilities would coexist with the incumbent disco, which in parallel should be subject to some reforms to turn it into a viable business. Customary rules regarding exclusivity of supply within concession areas would apply, adapted to this particular situation. The options available to a mini-grid developer when "the grid arrives" should be clearly specified. All these utilities would compete to deliver services to still unelectrified customers under conditions established by the regulatory authorities.

Among the possibilities for external participation in the incumbent disco, partnering with the private sector is the most direct approach, with the possible (and desirable) involvement of capable local companies, mini-grid developers, and electricity services providers with standalone systems. The involvement of the private sector could take the form of a long-term concession, with responsibility for managing the company – including operations, planning, investment, metering, billing, and revenue collection –under a previously agreed remuneration scheme, including performance incentives. Other approaches to regenerate incumbent discos might exist, and ideas are welcome in this regard.

[45] See "The Global Commission to End Energy Poverty. Inception Report". MIT Energy Initiative for the Rockefeller Foundation. September 2019. www.endenergypoverty.org. See also I.J. Pérez-Arriaga, R.J. Stoner, R. Rahnama, S.J. Lee, G. Jacquot, E. Protzer, A. González-García, R. Amatya, M. Brusnahan, P. Dueñas, F.J. Santos. "A utility approach to accelerate universal electricity access in less developed countries: a regulatory proposal". Economics of Energy & Environmental Policy. vol. 8, 1, pp.33-50 March 2019.

The remuneration scheme for the incumbent disco, and for any mini-grids or providers of services with standalone systems, should recognize the different nature of “physical network assets and operation” (i.e., strict distribution network activity, or ‘carriage’) and “consumer interactions” (i.e. the retail activity, or ‘content’) components of the traditional distribution company[46]. For purposes of this discussion, the IDF approach applies to both the incumbent disco and to any mini-grids or providers of services with standalone systems that also become concessionaires.

A subsidy for any disco that expands access is needed if governments and regulatory authorities are not willing to apply local tariffs that reflect the actual costs. Distribution of electricity in rural areas with disperse and low demand has never been economically viable in any developed or developing country without subsidies – under diverse formats, ranging from tariff cross-subsidization to direct payments to the incumbent disco or territorial concessions under mutually agreed conditions. This applies both for on- and off-grid solutions. And this makes discos particularly dependent on legal security in their country.

There are multiple strategies for reducing the required volume of subsidies: planning to find the least-cost mode of electrification; improving consumer satisfaction and deploying advanced metering to drastically reduce illegal connections and unpaid bills; cross-subsidizing tariffs for lower-income households through other loads that can absorb some price increases, such as high-consumption residential, commercial, and industrial (C&I) customers; bringing back to the grid those commercial and industrial (C&I) customers who defected or were never connected because of poor reliability or excessive cross-subsidization; standardizing supply equipment and demand appliances with an emphasis on efficiency; creating activities around electricity access to stimulate additional residential demand, plus productive uses and community activities that need electricity; globally increasing useful demand and prosperity; and reducing per-unit supply cost.

Consumer engagement to change public perceptions and customers’ mindset with respect to the electricity supplier is a critical component of the IDF. Initial investments will be necessary to achieve satisfactory reliability and quality of service, which are necessary conditions for any attempt to introduce cost-reflective tariffs and address unpaid bills and illegal connections.

The IDF goes beyond mere connection to stimulate local economic development by facilitating its customers’ productive use of electricity, integrating the deployment of energy-efficient appliances with microfinance support, and developing spin-offs, either with the concessionaire itself or through integrated partnership programs with external providers. In a virtuous cycle, additional energy-intensive uses of electricity will increase the capacity factor of newly connected demand, reducing per-unit energy costs. In this regard, expanded electric cooking – with its health, environmental, and potential economic advantages – is an attractive policy proposition that deserves to be seriously examined.

The IDF will encourage the use of innovative technologies to efficiently provide high-quality electricity. For example, system design and pre-site preparation costs can be lowered substantially by the use of

[46] Further unbundling is also possible, as it is already happening with the companies of standalone systems.

geospatial planning tools, while operation management costs can be reduced by using remote-controlled management systems, smart meters, and pay-as-you-go schemes.

Adaptability of the IDF Concept.

We believe that the IDF concept can be adapted to the diverse circumstances of low-access countries with their range of power sector structures and regulatory regimes, and we have noted that many paths to creating an effective concession may be taken. Although we are not aware of any situation to date in which all the defining features of the IDF have been successfully combined, each feature has been implemented successfully *somewhere*, providing a rich base of experience from which to draw lessons.

The IDF can be adapted to the power sector structure of each country. For example, in countries with vertically integrated utilities, distribution unbundling is not necessary to implement the IDF, since only a clear definition of the rights and obligations of the concession is needed, along with, notably, agreement about the method of remuneration.

Even in those countries where near full electrification has been achieved, but reliability and service quality are still poor, the IDF concept offers useful guidance. The partnership of the incumbent distributor with an external investor can provide the resources needed to improve local reliability and quality of service with strategically located local generation and storage, facilitate productive uses of electricity and the microfinancing of appliances, and implement new approaches to customer engagement that are made possible by advanced technologies for metering, payment, and communication.

Electrification should be regarded as a dynamic process that depends on changing local conditions. In light of the speed with which they can be deployed, mini-grids and standalone systems are essential new weapons in the quest to provide universal electricity access. They can also serve to unlock latent community demand for electricity, thereby justifying subsequent investments in larger systems, and, ultimately, interconnection with the grid.

A key feature of the IDF concept is that the three available modes of electrification – grid extension, mini-grids, and standalone systems – are deployed within a single planning regime and placed on a level playing field. With notable exceptions (Rwanda would be an exception), these three modes of electrification, where they appear, have been deployed in a largely uncoordinated manner and with the involvement of different entities, which has tended to lead to competition rather than complementarity. Ideally, a comprehensive integrated planning methodology based on GIS technologies would identify the least-cost mix of electricity delivery modes; an IDF-compatible entity would be motivated by financial self-interest to ensure that the plan is implemented effectively; and dedicated policies and regulations would be implemented to address any issues arising from the interaction between on- and off-grid solutions, as well as tariff-setting.

Is the IDF financeable?

The IDF concept is sound from a regulatory and business-model standpoint. But the complexity created by the present, precarious condition of distribution companies in many low-access countries should not be underestimated. The ability to attract investment is the key challenge. Since rural electrification requires subsidies, the service provider runs the risk that the subsidy may be insufficient, or delayed – possibly indefinitely – with dire consequences. Some form of payment guarantee is needed from the national government in the first instance, underwritten by a willing financial institution. Experience so far has shown that such guarantees are not easily obtained in countries with dubious legal security, or with high sovereign debt – conditions that are common among low-access countries. Also, as indicated above, the situation is even more difficult for privatized distribution companies that may have high debt burdens, and little access to additional capital.

These financial challenges can be overcome only with cooperation among internal and external stakeholders, and a commitment to finding win-win outcomes. These stakeholders include:

- National governments, whose role in creating a stable and predictable investment environment with supportive policy and adherence to agreements with private investors cannot be overstated. Governments also play an indispensable role by implementing policies to accelerate and amplify the impact of energy system investments – for example, by funding and allocating subsidies among urban and rural consumers, productive and non-productive uses, and, in the case of the IDF, among on- and off-grid providers. In addition, governments must show leadership and political will in moving quickly to restore the financial viability of public and private distribution companies, and by ending ineffective bailouts.
- Regulators, whose role in regulatory reform and enforcement will also be crucial, notably to establish cost-reflective tariffs and ensure that providers are appropriately incentivized to meet aggressive access, cost, efficiency, and reliability benchmarks, and to ensure that direct and indirect subsidies are deployed fairly and effectively. Specifically, with respect to implementing IDF-like concessions, regulators must also benchmark and enforce cost-efficient planning, and institute backstopping mechanisms that ensure continuity of service should one or more parties to a concession fail to perform.
- Distribution companies, which must improve their operations and adhere to agreed financial and other performance metrics, and, in the case of the IDF, achieve access metrics that may call for the expanded use of off-grid technologies, either in their own businesses or by third parties operating within a shared concession.
- Off-grid firms, which have an unprecedented opportunity within the IDF to dramatically expand their businesses while also, through continuous innovation, playing an important role in accelerating rural access and creating value and opportunity for their customers in the long run.
- Development banks, which offer unrivalled stores of knowledge and expertise and which are longstanding stewards of concessionary and significant commercial financing on behalf of the global community. Development banks already fulfill a wide range of roles and responsibilities, and have active operations in many the low-access developing countries. They will be central to helping shape and adapt the IDF to the differentiated needs and situations of individual countries. Indeed, it is hard to see how the aim of achieving universal access by 2030 can be achieved without the engagement and leadership of development banks.

Private investors and developers, which can be expected that will remain engaged given the opportunities that will be created through cooperation across this wide range of stakeholders. Private investors and developers will also need to keep faith with those governments that agree to explore a necessary program of reform and aggressive action.

Annexure 2: Accelerating energy access: The potential of national utility concessions programs

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MIT Technology and Policy Program
Working Paper, August 2019

As national utilities still struggle to escape financially unsustainable business models and cycles of regular bankruptcy and bailouts, the new momentum in the energy access sector has sparked growing interest in the development of innovative governance models to restructure the distribution sector and accelerate electrification. In order to achieve SDG 7 and raise the required $49 billion per year, a target far exceeding current $9bn annual investments[47] and out of reach to public agencies, increased attention has been paid to business models able to attract private capital under socially, politically and economically sustainable terms.

A possible answer is to bridge the financing gap by leveraging the resources of the private sector through so-called "public-private partnerships" (or PPPs). Electricity concessions, constituting one particular form of PPPs at the interface between State-led programs and private sector-driven approaches, have been experienced in various forms - mostly in Sub-Saharan Africa – with more or less success. Hosier *et al.*[48] identifies more than 200 electricity concessions of varying nature and scope in about 15 Sub-Saharan African countries, from small mini-grids to national utility concessions. Twelve countries attempted to implement concessions and either cancelled existing concessions or abandoned implementation plans.

The success of utility concessions yields invaluable feedback on the potential of concessions to revive the distribution sector and achieve universal energy access. A detailed analysis of past experiences in concessions shows that if such approaches have already yielded very positive results in restoring financial visibility in previously financially ailing distribution utilities, utility concessions have had limited to no impact on energy access. However, recent studies show that concessions may also make unprecedented contributions towards energy access provided that electrification becomes fully part of flexible concession agreements prioritizing the financial sustainability of the distribution sector.

Electricity concessions, a promising middle ground between State-owned utility-led approaches and private sector-driven strategies

The World Bank defines a concession as "any arrangement in which a firm obtains from the government the right to provide a particular service under conditions of significant market power.".[49] While such arrangements "need not involve the private sector, since governments can award concessions to public enterprises," concessions are usually granted to privately owned firms for the

[47] SE4All (Sustainable Energy for All) Advisory Board's Finance Committee (2015), *Scaling up Finance for Sustainable Energy Investments: Report of the SE4All Advisory Board's Finance Committee, 2015*, Powerpoint presentation downloaded from SE4ALL website (July 5th, 2019).
[48] *Ibid*
[49] Kerf, Michel, R. David Gray, Timothy Irwin, Celine Levesque, Robert R. Taylor, and Michael Klein (1998), *Concessions for Infrastructure: A Guide to Their Design and Award*, World Bank, Washington, DC.

reasons mentioned above.

Concessions have mainly been implemented in two different forms. In the leasing model (or *affermage concessif*), the private contractor takes responsibility for the exploitation and maintenance of assets as well as bill recovery while the public sector retains ownership over all existing assets and remains responsible for new investments. Under strict concession agreements, the private contractor is responsible for exploiting, maintaining and expanding its assets according to pre-defined terms, with the obligation to return all assets to the public sector at the end of the concession period.

Hosler *et al.* classifies rural electrification concessions into four broad categories, namely solar home system concessions, mini-grid concessions, rural zonal concessions and national utility concessions, and provides unprecedented insight into the success factors for each concession model.

Solar concessions: an outdated framework?

The main purpose of solar home system concessions is to provide fast and flexible electrification solutions to populations hardly reachable by grid extension or mini-grids. In practice, experience has shown that the solar home system (SHS) concessional model, solely implemented in South Africa with very limited results, may not show much promise for private sector involvement in future electrification projects[50]. The natural competition in the solar sector, as well as the dynamism of fast-growing pay-as-you-go companies currently operating in more than 30 African countries, may soon render SHS concession agreements obsolete.

The SHS concession model could therefore hardly be recommended as a promising option. The level of subsidies and the difficulty of adapting these latter to different SHS and populations renders the administration of such problems hard to manage from a public perspective. Government actions should focus on establishing well-designed cross-subsidies systems between different electrification technologies while ensuring that regulators establish adequate frameworks for independent solar companies to install, maintain, and possibly finance SHS.

Mini-grid concessions: a high potential despite limited results to date

A mini-grid concession aims at providing service to settlements where demand is limited, and the costs of extending the national grid to the area either cannot be justified or cannot be undertaken in a timely manner. Most mini-grids remain small and operate in remote areas.

The development of most mini-grid concessions has long followed an informal, or “bottom-up” model[51]. Once adequate frameworks and subsidy models have been established by public agencies – most of the time by a consortium of Ministries and the local electrification agency or fund, local projects are proposed by local communities, evaluated and approved by public authorities. Interestingly, no national plans mention targeted areas as areas of specific interest for mini-grids and feasibility studies have exclusively remained at the charge of the local communities – or any form of

[50] Hosier *et al.* (2017), *Rural Electrification Concessions in Africa: What Does Experience Tell Us?*, World bank, Washington DC.

[51] Hosier *et al.* (2017), *Rural Electrification Concessions in Africa: What Does Experience Tell Us?*, World bank, Washington DC.

local contractor.

Tenenbaum *et al.* (2014)[52] has shown that while few African countries actively encouraged private mini-grids, adequate regulatory frameworks were still absent at the time, creating significant confusion, especially concerning subsidy regimes and the regime of connection to the grid. Despite the proclaimed objective of several African countries to actively support mini-grid concessions, adequate regulations and institutional frameworks remain elusive. An average 4-6 years elapsed between the development of national laws for mini-grid concessions and the award of the first concessions in Mali, Uganda, and Madagascar[53,54,55].

In practice, these small-scale mini-grid concessions have proven successful in attracting *local* private capital and skills. Most projects entailed private funding, that accounted for 10 to 60% of the total investment costs.

Mini-grid concessions have demonstrated very positive local impact despite their limited geographic scope. Most importantly, field studies have shown a dramatic involvement of local entrepreneurs and communities in the financing, installation, and maintenance of installations, unleashing local businesses, and productive businesses best suited to local contexts. The very local nature of mini-grids has proven well suited to local entrepreneurship and the involvement of local communities able to identify adequate generation models and operation/maintenance companies[56].

Several key challenges now hamper the large-scale development of mini-grids. In terms of financial viability, mini-grid concessions have demonstrated mixed results to date. Past experiences show that while most concessionaire usually raise adequate equity and debt to establish mini-grids and manage to recover their operation, current bottom-up models have limited the financial viability of these projects and ability to maintain and expand their asset base[57]. First, the small size of most mini-grids, preventing concessionaires from benefiting from economies of scale. Second, the bottom-up nature of mini-grid projects limits the ability of concessionaires to negotiate adequate cost-reflective tariffs, well-targeted subsidy schemes. Third, the unwillingness of local populations to pay higher prices compared to grid-based services. In Mali, most mini-grids within a close distance from the grid had to be purchased by the national utility and charge grid tariffs in order to avoid local unrests[58].

From a planning perspective, current bottom-up models suffer from the lack of coordination with larger-scale electrification projects and their structural inability to tap international funding sources.

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[52] Tenenbaum, Bernard, Chris Greacen, Tilak Siyambalapitiya, and James Knuckles (2014), *From the Bottom Up: How Small power Producers ad Mini-Grids Can Deliver Electrification and Renewable Energy in Africa.* World Bank, Washington, DC.
[53] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: Madagascar, Report to the World bank*, Castalia Advisory Group, Paris.
[54] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: Uganda, Report to the World bank*, Castalia Advisory Group, Paris.
[55] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: Mali, Report to the World bank*, Castalia Advisory Group, Paris.
[56] Hosier *et al.* (2017), *Rural Electrification Concessions in Africa: What Does Experience Tell Us?*, World bank, Washington DC.
[57] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: Mali, Report to the World bank*, Castalia Advisory Group, Paris.
[58] *Ibid*

Most importantly, mini-grids are developed independently from each other on an individual basis following local requests[59,60]. In the absence of detailed pre-feasibility studies, common management and ownership, and large-scale integrated planning, mini-grids are unlikely to benefit from economies of scale and adequate subsidy schemes. Mini-grids also generally develop without grid connection clauses, thereby threatening the viability of the projects while the grid arrives. What is more, the local nature of mini-grids usually prevents these latter from directly taping into international equity and debt financing, being limited to public funding through Ministries or eventual rural electrification agencies or funds (if any)[61].

Despite these obstacles, the positive impact of mini-grids in their areas of operation warrants paying utmost attention to the development of these business models to promote energy access in areas hardly reachable by the grid in the short or medium term. Improving access to international funding and private capital, developing well-targeted cross-subsidization schemes, implementing cost-reflective tariffs, adopting clear grid connection clauses and encouraging shared management and ownership would dramatically improve the impact of mini-grids and foster the scale-up of these business models out of the current pilot scale.

Territorial electrification concessions: an unsuccessful experience but key lessons to be learned

The territorial concession model has been implemented in Senegal as of the early 2000s in the aftermath of the much-celebrated Moroccan national electrification program PERG (*Plan d'Electrification Rurale Global* in French). In contrast to the State-owned utility-driven model adopted by Morocco, Senegal opted for a zonal concession approach granting rights to provide electrical services to external companies within preliminarily agreed upon delimitated areas. While this program may have yielded very limited results, key lessons about the structuring of concessions and the potential of zonal and national-scale concessions could be drawn from the Senegalese experience.

A decade after inception, the Senegalese territorial concession program yields important lessons about the design and implementation of concessions. First, that cooperation between concessionaires and local utilities is key. SENELEC proved unwilling to coordinate with contractors while extending its assets and did not sign off-take agreements to provide concessionaires with electricity, rendering grid extension-based projects unfeasible in more regions. Second, implementing large-scale concessions takes time and requires extensive experience from an institutional, financial, and technical perspective. Senegal was first in developing territorial concessions, and the connections took place nearly ten years after the inception of the program. Third, sustained political support is key in ensuring the design and implementation of concessions that run much beyond the typical 5-year political horizon.

The experience of Senegal in territorial concessions is mixed but yield important lessons that could pave the way for successful zonal concessions in the future, provided that adequate institutional,

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[59] *Ibid*

[60] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: Madagascar, Report to the World bank*, Castalia Advisory Group, Paris.

[61] Hosier *et al.* (2017), *Rural Electrification Concessions in Africa: What Does Experience Tell Us?*, World bank, Washington DC.

planning and regulatory measures are taken. The critical condition of local utilities, the recent development of fast-growing solar technologies and the advent of GIS-based technologies may now allow countries to further explore the potential of territorial concessions.

Utility-scale electrification concessions: a successful model yet to be opened to energy access

Four national utility concession programs have been implemented in Sub-Saharan and were still in operation in 2015 in Cameroon (ENEO), Côte-d'Ivoire (CIE), Gabon (SEEG) and Uganda (Umeme). All four were implemented with the idea of relieving the public sector from the burden of inefficient State-owned electricity utilities and drawing on private resources to revive ailing distribution sectors by improving sector performance and ensuring financial viability. ENEO, CIE, and SEEG are all privately-owned integrated utilities with substantial public ownership while Umeme is exclusively involved in the distribution sector. While the overall experience proved positive about the revitalization of previously financially unsustainable utilities, none of these concessions was implemented to accelerate energy access, and their impact on electrification might be limited to date[62]. However, the resilience and flexibility of the utility concession model leaves ample room for adjustments and integrating energy access into well-designed concession agreements without compromising on financial sustainability.

Interestingly, Hosler *et al.* records that nine other Sub-Saharan countries attempted – unsuccessfully to implement utility concession programs without abandoning the idea, thereby emphasizing the difficulty to implement efficient and financially sustainable programs. Most of these experiences remain undocumented. However, the limited amount of information available shows that most of these attempts failed at the inception stage during negotiations over tariff increases and the implementation of cost-reflective tariffs along with targeted subsidies.

Overview of currently operating utility concessions

All four concessions led to significant improvements in service quality and financial condition of the national power utilities. In the absence of any well-structured clauses about universal electrification, the impact of these concessions on energy access remains unclear.

In **Cameroon,** the utility concession was awarded to the privately-owned consortium AES SONEL (ENEO since 2014) for 20 years in 2001[63]. Annual performance targets operational efficiency, reduction of losses, and network extension have been met while the financial viability of the company has been consistently maintained over the past two decades[64]. Maintaining the concession in operation has required significant public involvement. ENEO's viability, guaranteed by cost-reflected tariffs that remain one of the highest in Sub-Saharan Africa, is further safeguarded by increasing public subsidies aiming at filling the gap between frozen electricity tariffs and rising operational costs[65].

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[62] Hosler *et al.* (2017), *Rural Electrification Concessions in Africa: What Does Experience Tell Us?*, World Bank, Washington DC.

[63] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: ENEO Concession Cameroon, Report to the World bank*, Castalia Advisory Group, Paris.

[64] *Rapports annuels* (2013 to 2017), ENEO, Douala

[65] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: ENEO Concession Cameroon, Report to the World bank*, Castalia Advisory Group, Paris.

Regarding **Côte d'Ivoire**, the concession was awarded to CIE (or *Compagnie Ivoirienne d'Electricité*) to operate the assets of the vertically integrated power utility for 15 years in 1990 and renewed for another 15 years in 2005[66]. As in Cameroon, energy access projects remain almost exclusively financed through public projects, thereby allowing CIE to focus on the operation, maintenance, and upgrade of its current assets and safeguarding CIE's long-term financial stability[67].

As for **Gabon**, the concession contract was awarded to SEEG (or *Société d'Energie et d'Eau du Gabon)* for 20 years in 1997. A decade of preparation of the institutional, financial, and operational aspects of the concession agreement have allowed the country to operate on a single contract without major revision for nearly 20 years[68]. SEEG's financial sustainability is ensured by the company's ability to charge annually revised tariffs in most regions and to benefit from public subsidies for "social customers". SEEG's electrification mandate is confined to its concession perimeter, which extends within 400 meters of the existing grid. Long-term investments in grid extension whose payback period exceeds the duration of the concession are the responsibility of the public sector, which then returns assets to the utility. This strategy has allowed the national utility to connect 98% of customers in urban areas.

Uganda's concession was awarded to Umeme Limited for 20 years in 2004. Umeme accounts for 95% of the country's distribution network, while small-size grid concessions account for the 37,000 customers[69]. The main objective of the concession was to relieve public finances by revitalizing of the distribution sector through loss reduction and increased bill recovery rates. Umeme's case is considered as one of the most successful concession experiences in Africa. According to Hosler *et al.* (2017), system losses fell from 38% in 2005 to 21% in 2014, and bill collection rates increased from 80% to 99.1% over the same period. However, this success may stem from the absence of cash-intensive rural electrification requirements in the concession agreement.

Umeme's responsibility in energy access is limited to its concession zone, which extends within 1km of the existing grid[70]. The extension of current lines to rural areas has suffered from competitive projects and limit the potential for large-scale electrification projects. The extension of the grid into rural areas is currently financed by public entities and assets are later transferred to local concessionaires, sometimes operating within Umeme's operation zone[71]. The fragmenting of the distribution sector resulting from public sector financed grid extension leads to significant duplication of efforts and may limit the potential for economies of scale.

Uganda's electrification rate thus follows a slow but steady upward trend, up from 9% in 2000 to 14%

[66] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: ENEO Concession Cameroon, Report to the World bank*, Castalia Advisory Group, Paris.
[67] Hosler *et al.* (2017), *Rural Electrification Concessions in Africa: What Does Experience Tell Us?*, World Bank, Washington DC.
[68] International Finance Corporation (2010), *Gabon: Société d'Energie et d'Eau*, Public-Private Partnership Stories, IFC, Washington DC.
[69] Castalia (2015), *Evaluation of Rural Electrification Concessions in sub-Saharan Africa, Detailed Case Study: Uganda, Report to the World bank*, Castalia Advisory Group, Paris.
[70] *Ibid*
[71] Hosler *et al.* (2017), *Rural Electrification Concessions in Africa: What Does Experience Tell Us?*, World Bank, Washington DC.

in 2016[72] and around a third of Umeme's new connections are made in rural areas[73].

The next frontier: integrating energy access into financially sustainable utility concession agreements

While the four national utility concession programs have proved successful in restructuring distribution utilities from periodically bailed out companies to financially sustainable structures able to meet stringent service quality targets, energy access has remained out of scope for all concession agreements and has experienced limited progress. However, past experiences show that concessionaires in Cameroon, Cote d'Ivoire, Gabon, and Uganda have proved willing to cooperate with governmentals provided that adequate supporting frameworks were implemented. A set of key lessons[74] could be derived from their experience and prove helpful in the design of future concessions best able to achieve universal energy access.

First of all, utility concessions were not designed to address the challenge of energy access but may prove resilient and flexible enough to accommodate universal electrification requirements. The experience of the four countries mentioned above shows that utilities were both willing and able to expand their concession area and engage into *well-targeted* electrification programs *within their area of action* provided that adequate guarantees, subsidies, and flexibility regarding the mode of electrification (through grid extension, mini-grids or SHS) were granted.

Second, proactive political support plays a key role in the design, implementation of resilient concessions. Such support will prove all the more important if energy access becomes part of concession agreements and foster further institutional, financial, and operational cooperation between public and private stakeholders. A major advantage of national utilities over smaller scale concessions is there negotiation power over public institutions and ability to set up more favorable conditions best able to support financially sustainable frameworks for action.

Lastly, a major challenge for the next decades will be to integrate a universal energy access mandate to concessions agreements without compromising on the financial health and increased performance of the concessionaire. Energy access targets should be defined in a holistic manner entailing both connections and quality of service.

National utility concessions have the potential to bring unprecedented disruption to the distribution sector by both reviving ailing distribution companies and empowering power companies to face daunting challenge of universal energy access – without compromising on performance and financial sustainability objectives. While most electrification efforts have historically focused on the limited concession zone surrounding the existing grid, national utility concessions have the geographic scope and resilience to engage into large-scale electrification programs best able to leverage all possible electrification technologies and modern planning methods under both bottom-up and top-down approaches.

[72] *Ibid*

[73] World Bank World Development Indicators (accessed on July 5th 2019)

[74] As determined by Hosler *et al.* (2017)

Implementation of National Electrification Strategy - Technical Recommendations and Preparation of Electrification Plan till 2024 for the National Electrification Plan in Rwanda

Section-10. Introduction- Technical Recommendations and Preparation of Electrification Plan

The government of Rwanda recognizes the vital role that electricity access plays in accelerating economic development through improving health and standards of living. Energy and particularly access to electricity is Government's key priority. Initiative to extend access to electricity involves a coordinated effort across all power sector participants to connect new customers, focusing also on powering productive activities. The institutional design established by REG – EDCL for Grid Service Area comprises of (a) The customers selected for a connection to the Rwandan Central Distribution Network and (b) The customers that will receive their electricity supply through an isolated grid-compatible microgrid. REG–EUCL will also take responsibility for the investment, implementation and maintenance of the microgrid networks as well as for the electricity retail business with the customer base (bill collection, quality assurance and customer management), taking care of the appropriate remuneration of the Independent Power Providers (IPPs) that will supply electricity to each microgrid. The least-cost achievement of Universal Access in Rwanda will also require the supply of DC Solar Kits for low-demand residential customers (below 50 Wp as defined by EDCL).

10.1 Key Roles and Responsibilities of various players in Rwanda's Power Sector

MININFRA: The Ministry has overall responsibility for formulating electric power policy and facilitating its implementation. In terms of electrification issues, the Ministry is responsible for policy development on increasing access to electrification. The Ministry also monitors and evaluates the performance and impact of electrification programs from a policy perspective.

Rwanda Energy Group (REG): Rwanda Energy Group is responsible for development, operation and maintenance of the power sector as per NST-1 targets through its subsidiaries Energy Development Corporation Limited (EDCL) and Energy Utility Corporation Limited (EUCL).

Energy Utility Corporation Limited (EUCL): The Energy Utility Corporation Limited (EUCL) is responsible for providing energy utility services in the Country through operations and maintenance of existing generation plants, transmission and distribution infrastructure and retail of electricity to end-users.

Energy Development Corporation Limited (EDCL): The Energy Development Corporation Limited (EDCL) is responsible for development of electrification strategy / electrification plan to meet EDPRS targets set by GoR through NST-1.

Rwanda Utility Regulatory Authority (RURA): RURA, in its mandate to regulate the Energy sector, is required to support the ongoing socio-economic transformation and poverty eradication through ensuring sufficient, reliable, affordable and sustainable energy supply. Initiate study to check the fund requirement on short, medium and long-term basis to achieve new electrification / improvement targets.

Private Partners: Private partners are responsible for development of standalone power systems / mini grids and extension of product / services to civilians to meet Off-grid connection targets. Their role is critical for achievement of national targets.

10.2 National Energy Policy (NEP)

The strategic framework for Rwanda's energy sector is established in the Energy Sector Strategic Plan (ESSP) and the National Energy Policy (NEP), these documents recognize the essential role of electricity access in accelerating economic development, as well as improving health outcomes and standards of living for people in Rwanda.

The financing and implementation of this Strategy will be undertaken in partnership with the private sector, where competition will help drive down costs and improve customer choice. This builds upon the significant private sector interest in both solar home systems and mini-grids in Rwanda and across Africa. In order to maximize impact, Government resources will be used in a targeted fashion to: i) help provide a basic level of electricity access to those with the lowest income; ii) reduce the risks perceived by the private sector in providing systems on finance through the establishment of a risk mitigation facility; and iii) provide social goods such as education, information dissemination and standards to support the private sector and protect customers.

The Rural Electrification Strategy can be considered as four distinct programmes:

1. Government will establish a mechanism to allow low-income households to access modern energy services through a basic solar system as a basic necessity.
2. Government will establish a risk-mitigation facility targeting the private sector such that solar products will be made available on financial terms that the population can afford.
3. Mini-grids will be developed by the private sector with Government playing a key role in identifying sites and establishing a framework through which these can become financially viable investments.
4. Government will continue to roll out the electricity network via EARP, focusing on connecting high consumption users and driving economic growth.

EDCL has conducted detailed feasibility study in phase-1 for developing least-cost option for power distribution using provision Reference Electrification Model (REM) developed and maintained by MIT/IIT-Spain.

10.3 Decision Criteria for least cost optimization mode by REM

Reference Electrification Model (REM) is designed as a toolbox with a number of functions, which can be used to support a variety of least cost optimization mode. The functions can be grouped into three categories:

- Fundamental algorithms - Solve a particular problem independently from the use case.
- Structuring functions - Performs simple operations such as comparisons or interpolations, which tend to be related to particular use cases.
- Auxiliary scripts/functions – It deals with file input/output.

The fundamental algorithms that have been developed includes the following 4 key functions:

- Clustering: group buildings in relevant units of comparison
- Off-grid supply design: Chooses the best off-grid supply components to meet an off-grid load
- Microgrid network design: Designs a distribution network for a microgrid using the Reference Network Model
- Grid-extension design: Designs a distribution network to connect a group of buildings to the existing distribution network.

The REM takes the decision in two major steps:

- Clustering using a bottom-up approach and
- Final decision on the best electrification mode for each cluster.

10.4 Least-cost optimization mode for access Universal Access in Rwanda Electrification Mode:

The technological design for each electrification mode, namely;

1) Connection to the existing grid;
2) single-building system;
3) Independent mini-grid,

Grid connection: *(Network expansion from the national power transmission system to new areas and communities)* • Layout of the grid extension. • Reinforcement requirements of the regional grid (network and generation) to accommodate the new consumption. • Reliability of the existing grid. • Applicable tariffs. • Grid codes.

Off-grid supply systems: *(An approach to access electricity in the areas with little no access to electricity, it comprises of generation through Solar, Hydro, Bio-mass, etc.)* • DC or AC grid layout and components. • Evaluating whether connection via standalone systems or via microgrids are preferred. • Evaluating tradeoffs between flexibility and cost for grid compatible microgrids for future interconnection. • Management scheme for the supply and the demand side in the microgrid. • Reliability of supply, which impacts the adopted solution for the supply technology (e.g. size of micro-hydro, solar panel or battery) and trade-offs between cost of supply and quality of level of service. • Utilization of local resources: solar, wind, mini-hydro or biomass, together with other feasible sources.

Solar Kits and Stand Alone Systems: Cost of distributed generation, according to the choice of supply: DC Solar Kits for isolated residential loads under 50 Wp.

10.5 Defining Project Titles

Grid connection:

- Grid-connected (on-grid) power supply / provision is defined as electricity supply which is fed by centrally generated electricity and uses a network of (high) medium and low voltage distribution grid system that exceeds one village.
- Grid extension is therefore a network expansion from the national power transmission system to new areas and communities.
- Grid-connected (on-grid) electrification comprises the connection of entire villages through network extension (grid extension), so the construction of new transmission

lines (transmission lines) as well as network densification measures need to be taken into consideration.

Off-grid supply systems:

- Decentralized power provision or off-grid system is understood as power generation in the village, such as on-site with renewable energy sources such as solar (particularly with photovoltaic), wind, micro hydro, geothermal; with a generator or Micro combined heat and power with adequate fuel reserves.
- *Off-grid electrification* is an approach to access electricity used in countries and areas with little access to electricity due to scattered or distant population.

Solar Kits and Stand Alone Systems:

- It is simply the DC Solar Kits for low-demand, isolated residential loads under 50 Wp as defined by EDCL.

After the clusters have been identified, the cost of the electrification options at different layers are calculated for each cluster as follows:

- For the grid-extension option:
  - Find the nearest viable connection points to the existing grid
  - Design the lowest cost distribution network to connect the buildings to the grid.
  - Calculate the final cost, considering
    - Cost of energy purchased from the grid
    - Network costs (investment, maintenance and losses)
    - Cost of non-served energy because of imperfect grid reliability
    - Administrative and connection costs.
- For the microgrid option:
  - Calculate the cost of generation.
  - Calculate the network cost.
  - Calculate the final cost, considering:
    - Generation costs (investment, operation, maintenance, and non-served energy).
    - Network costs (investment, maintenance and losses).
    - Administrative and connection costs.
- For the single-building option:
  - If the peak load of the customer is less than 50Wp, then this cost corresponds to that of the Solar Kit specified by EDCL.
  - If the consumption is higher, proceed as in the microgrid case, except for the network design and cost steps (no network present).

For implementation phase of the project, sensitivities around these values will be analysed.

Table 10-1: Summary of REM Re-run

Electrification 2024	Grid-Standard				Off-Grid				TOTAL
	Grid-Standard Electrified 2019	Grid-Standard Fill-in 2024	Grid-Standard Extension RCS	Grid-Standard Microgrids RCS	Off-Grid (SAS or MG) RCS	Off-Grid (only SAS) RCS	Off-Grid (Existing 2019)	Off-Grid (HRZ)	
Number of Customers 2024	990,037	746,669	431,366	316,838	281,533	181,264	388,827	533,538	3,870,072
Fraction of Customers 2024	25.58%	19.29%	11.15%	8.19%	7.27%	4.68%	10.05%	13.79%	100.00%
Overnight Investment (USD M$)	-	448	316.73	199.84	24.93	16.05	-	18.67	1,024.22
Fraction of Overnight Investment*	0.00%	43.74%	30.92%	19.51%	2.43%	1.57%	0.00%	1.82%	100.00%
Energy Consumption 2024 (GWh/yr)	997.13	752.02	467.81	52.88	43.98	28.32	9.53	13.07	2365.18
Fraction of Energy Consumption 2024	42.17%	31.81%	19.79%	2.22%	1.86%	1.20%	0.40%	0.55%	100.00%
Overnight Investment p.c.(USD/customer)		600.00	734.25	630.51	88.55	88.54		34.99	
Overnight Investment p.u.(USD/kWh)		0.60	0.67	3.81	0.57	0.57		1.43	
Ratio - Grid Standard : Off grid	64.21%				35.79%				

** Overnight investment: Overnight capital cost is a term used in the power industry to describe the cost of building a power plant overnight. The term is useful to compare the economic feasibility of building various plants. The overnight capital cost does not take into account financing costs or escalation, and hence is not an actual estimate of construction cost.*

10.6 Project Definitions;

- Implementation plan has been prepared for two category separately i.e. (i) Grid Extension & (ii) Micro Grid.
- Implementation plan has been framed considering province as a package which is further divided into several districts, however EDCL needs to redefine the package if required.
- Province wise implementation plan has been divided into yearly packages with uniform distribution of Capex and will be achieved by the year 2023-24
- For Grid Extension following works has been considered;
    - Laying of new MV line using ACSR conductor of sizes 120mm^2 and 70mm^2 based on the peak load requirement in the project area.
    - Supply and Installation of Distribution Transformers of various rating i.e. 25 kVA, 50 kVA, 100 kVA, 160 kVA and, 200 kVA, etc.
    - Laying of new LV line using Aerial Bunch Conductor / Twisted Cable of sizes i.e. 3x70 mm^2, 3x50 mm^2 and 3x35 mm^2 based on the peak load requirement in the project area
- For Micro Grid following works has been considered;

- Supply and Installation of Solar Photo voltaic system of various sizes i.e. 200 kWp, 100 kWp, 80 kWp, 50 kWp, 40 kWp, 30 kWp and, 25 kWp based on the peak load requirement in the project area.
- Laying of LV line using Aerial Bunch Conductor / Twisted Cable of sizes i.e. 3x70 and Cable 3x50 mm^2 based on the peak load requirement in the project area.

10.7 Criteria for prioritization of implementation plan

- Productive customers were identified from industrial and commercial categories and prioritized according to their energy consumption.
- Extensions/villages considering productive customers having strategic importance for the country were selected in the first year of implementation.
- Rest of the extensions/villages were considered in the succeeding years considering productive customers having higher energy consumption.
- All extensions/villages with productive customers will be electrified in the first 3 years i.e. by the end of financial year 2023-2024.
- Rest of all extensions/villages having only residential customers were selected in last two years of implementation plan according to their energy consumption.
- Capital expenditure for each year has been kept almost constant for ensuring availability of funds.

Table 10-2: Province wise summary – Grid Extension

Total no. of Provinces	Total no. of Districts	Total nos. of Extensions	Total nos. of Villages	Total nos. of Customers	Total nos. of DTs	Total Cost of DTs	Total Length of MV Line	Total Cost of MV Line	Total Length of LV Line	Total Cost of LV Line
Nos.	Nos.	Nos.	Nos.	Nos.	Nos.	Million USD	Kms	Million USD	Kms	Million USD
1	2	3	4	5	6	7	8	9	10	11
Eastern Province	7	195	446	88,741	326	$ 1.86	279.62	$ 10.88	2,911.40	$ 46.08
Kigali	3	141	383	36,472	169	$ 0.93	62.44	$ 4.35	922.57	$ 15.42
Northern Province	5	122	368	73,048	209	$ 1.20	156.12	$ 6.48	2,071.21	$ 35.74
Southern Province	8	184	529	115,317	388	$ 2.29	386.28	$ 14.03	4,103.23	$ 71.63
Western Province	7	289	694	117,788	412	$ 2.33	280.93	$ 13.51	3,466.46	$ 61.95
Grand Total	**30**	**931**	**2420**	**431,366**	**1504**	**$ 8.61**	**1,165.39**	**$ 49.26**	**13,474.87**	**$ 230.83**

Table 10-3: Province wise summary – Grid Extension

Total Cost of Customer connections	CAPEX project (Total)	OPEX (Network) project (Total) $ per year	OPEX (Management) project (Total) $ per year	OPEX (Generation) project (Total) $ per year	OPEX project (Total)
Million USD	Million USD	Million USD	Million USD	Million USD	Million USD
12	13	14	15	16	17
$ 5.77	$ 64.59	$ 0.49	$ 0.80	$ 29.45	$ 30.74
$ 2.37	$ 23.08	$ 0.15	$ 0.33	$ 1.13	$ 1.60
$ 4.75	$ 48.17	$ 0.34	$ 0.66	$ 2.96	$ 3.95
$ 7.50	$ 95.45	$ 0.75	$ 1.04	$ 9.75	$ 11.54
$ 7.66	$ 85.45	$ 0.62	$ 1.06	$ 15.63	$ 17.31
$ 28.04	**$ 316.73**	**$ 2.34**	**$ 3.88**	**$ 58.93**	**$ 65.15**

Table 10-4: Implementation Plan - Coverage of Customers – Grid Extension

Type of Customers	Total Customers	Year 2021-22	Year 2022-23	Year 2023-24	Year 2024-25	Year 2025-26
Airport	1	1	0	0	0	0
Cell office	152	32	44	76	0	0
Coffee washing station	10	0	4	6	0	0
Health center	6	2	2	2	0	0
Health post	10	3	5	2	0	0
IDP Model Village (avg.)	21	7	10	4	0	0
Irrigation pumping	10	4	6	0	0	0
Markets	26	4	11	11	0	0
Milk collection center	2	0	2	0	0	0
Mining	37	16	20	1	0	0
Pre-primary school	39	3	11	25	0	0
Primary school	107	35	31	41	0	0
Secondary school	46	15	15	16	0	0
Sector Office	6	4	2	0	0	0
Tea Factory	4	3	1	0	0	0
Technical Schools	1	1	0	0	0	0
Telecom Tower	59	42	17	0	0	0
VTC	9	8	1	0	0	0
Water pumping stations	8	2	6	0	0	0
Residential 10W	201,709	35,122	38,288	45,784	36,101	46,414
Residential 50W	229,103	33,816	45,508	46,641	55,732	47,406
Total	**431,366**	**69,120**	**83,984**	**92,609**	**91,833**	**93,820**

Table 10-5: Prioritization Criteria for year on year electrification – Grid Extension

<u>Year on Year investment required (Million USD)</u>					
CAPEX project (Total) ($)	Year 2021-22	Year 2022-23	Year 2023-24	Year 2024-25	Year 2025-26
$ 316.73	**$ 63.31**	**$ 63.42**	**$ 63.56**	**$ 63.25**	**$ 63.19**
<u>Year on Year Energy supplied (GWh)</u>					
Total Energy consumption	Year 2021-22	Year 2022-23	Year 2023-24	Year 2024-25	Year 2025-26
467.68	**251.41**	**166.59**	**17.25**	**17.14**	**15.43**

Year on Year Customers					
Total customers	Year 2021-22	Year 2022-23	Year 2023-24	Year 2024-25	Year 2025-26
431,366	69,120	83,984	92,609	91,833	93,820
Year on Year Extensions covered					
Total Extensions	Year 2021-22	Year 2022-23	Year 2023-24	Year 2024-25	Year 2025-26
931	107	181	150	222	271
Year on Year Villages covered					
Total Villages	Year 2021-22	Year 2022-23	Year 2023-24	Year 2024-25	Year 2025-26
2420	383	553	462	518	504

Table 10-6: Province wise summary – Micro Grid

Total no. of Provinces	Total no. of Districts	Total nos. of Extensions	Total nos. of Villages	Total nos. of Customers	Total nos. of PV Arrays	Total Length of LV Line	Total Cost of PV Array	Total Cost of LV Line	Total Cost of Customer connections
Nos.	Nos.	Nos.	Nos.	Nos.	Nos.	Kms	Million USD	Million USD	Million USD
1	2	3	4	5	6	7	8	9	10
Eastern Province	7	769	764	121,367	769	3,640.48	$ 5.29	$ 58.13	$ 7.70
Kigali	3	73	73	9,433	73	292.55	$ 0.43	$ 4.88	$ 0.60
Northern Province	5	267	263	42,362	267	1,283.17	$ 1.83	$ 23.23	$ 2.69
Southern Province	8	396	390	65,470	396	2,176.7	$ 3.00	$ 38.03	$ 4.14
Western Province	7	468	468	78,206	468	2,330.79	$ 3.45	$ 41.45	$ 4.98
Grand Total	**30**	**1,973**	**1,958**	**316,838**	**1,973**	**9,723.69**	**$ 14.00**	**$ 165.72**	**$ 20.12**

Table 10-7: Province wise summary – Micro Grid

CAPEX project (Total)	OPEX (Network) project (Total) $ per year	OPEX (Management) project (Total) $ per year	OPEX (Generation) project (Total) $ per year	OPEX project (Total) $ per year
Million USD	Million USD	Million USD	Million USD	Million USD
11	12	13	14	15
$ 71.11	$ 0.25	$ 1.60	$ 0.36	$ 2.21
$ 5.91	$ 0.02	$ 0.13	$ 0.03	$ 0.18
$ 27.76	$ 0.11	$ 0.56	$ 0.12	$ 0.79
$ 45.17	$ 0.17	$ 0.85	$ 0.21	$ 1.23
$ 49.88	$ 0.19	$ 1.02	$ 0.23	$ 1.43
$ 199.84	**$ 0.73**	**$ 4.17**	**$ 0.96**	**$ 5.85**

Table 10-8: Implementation Plan - Coverage of Customers – Micro Grid

Type of Customers	Total Customers	Year 2021-22	Year 2022-23	Year 2023-24	Year 2024-25	Year 2025-26
Cell office	83	83	0	0	0	0
Coffee washing station	10	10	0	0	0	0
Health center	4	4	0	0	0	0
Health post	2	2	0	0	0	0
IDP Model Village (avg.)	1	1	0	0	0	0
Markets	3	3	0	0	0	0
Milk collection center	1	1	0	0	0	0
Mining	1	1	0	0	0	0
Pre-primary school	35	35	0	0	0	0
Primary school	83	83	0	0	0	0
Secondary school	30	30	0	0	0	0
Sector Office	2	2	0	0	0	0
Residential 10W	161,651	33,529	31,781	32,880	31,716	31,745
Residential 50W	154,932	32,483	34,125	30,284	29,960	28,080
Total	**316,838**	**66,267**	**65,906**	**63,164**	**61,676**	**59,825**

Table 10-9: Prioritization Criteria for year on year electrification – Micro Grid

Year on Year investment required (Million USD)					
CAPEX project (Total) ($)	**Year 2021-22**	**Year 2022-23**	**Year 2023-24**	**Year 2024-25**	**Year 2025-26**
$ 199.84	**$ 41.91**	**$ 42.35**	**$ 39.68**	**$ 38.96**	**$ 36.94**
Year on Year Energy supplied (GWh)					
Total Energy consumption	**Year 2021-22**	**Year 2022-23**	**Year 2023-24**	**Year 2024-25**	**Year 2025-26**
52.72	**12.39**	**11.28**	**9.91**	**9.82**	**9.33**
Year on Year Customers					
Total customers	**Year 2021-22**	**Year 2022-23**	**Year 2023-24**	**Year 2024-25**	**Year 2025-26**
316,838	**66267**	**65906**	**63164**	**61676**	**59825**
Year on Year Extensions covered					
Total Extensions	**Year 2021-22**	**Year 2022-23**	**Year 2023-24**	**Year 2024-25**	**Year 2025-26**
1,973	**311**	**323**	**351**	**416**	**572**
Year on Year Villages covered					
Total Villages	**Year 2021-22**	**Year 2022-23**	**Year 2023-24**	**Year 2024-25**	**Year 2025-26**
1,958	**306**	**322**	**350**	**412**	**568**

10.8 Procurement Philosophy

- **Right Product**- in terms of meeting technical specifications, quality & quantities, that minimizes the environmental impact;
- **Right in Time**- in terms of meeting user's requirements, ensuring minimum inventory carrying cost & avoiding stock outs;

- **Right Price**- best in competitive environment & to ensure minimum inventory carrying costs;

The procurement flow will be performed as per government law and approved REG procurement Policies and Procedures

10.9 Project Monitoring Governance Structure

A tentative Organogram for NES is proposed considering the existing posts as per Annexure-D. The proposed structure is for the execution of this project only for a limited period now EDCL has an option to source this particular staff from an internal department or may outsource the staff from the outside market for the entire project period.

Further, we have considered the existing manpower for most of the positions however for the project management and monitoring at the site, we have recommended additional manpower for this project which can be filled by either an internal source from the department or can be outsourced from the outside market (total additional 81 nos. of resources are required out of which 62 nos of project engineers, technicians and computer operator will be required for project monitoring)

This project not only has a huge volume of work associated but also has strategic importance for the whole of Rwanda and needs to be executed in due timelines and with utmost quality & safety.

Link to Annexure-D:
https://drive.google.com/file/d/1KFZi1WNSuzZgYXA8hHVHYxxbKnUNcvkC/view?usp=sharing

10.10 Three tier Quality Control Mechanism (QCM)

In order to ensure proper Quality of materials as well as in installations in Electrification Scheme, three tier Quality Control Mechanism (QCM) has been drafted. This Quality Control Manual established three tier QCM. The basic framework of the three tier QCM is stipulated below:

<u>**Tier -I**</u>

- Concern department in EDCL will nominate appropriate officer in organisation for inspection of material & installation to ensure quality assurance for first tier monitoring & quality control.
- It shall include preparation of detailed monitoring & Quality Assurance Program, which should ensure quality checks as below:
    - Inspections of all material as per Drawings/Technical Specifications,
    - Inspection of works at mid & final stage of installation.
    - All works to be inspected as per Filed Quality Plan (FQP), and
    - 100% verification of customer connections.

<u>**Tier -II**</u>

- EDCL shall nominate officials from Design Engineering Department and Quality Assurance Department for inspection of material & installation in second tier Quality Control Mechanism.
- The second tier Quality control shall ensure quality checks in appropriate no. of material inspection and installation inspections not less than 10% of total inspections.

<u>**Tier -III**</u>

- The third tier Quality Control Mechanism will be an **optional stage**.
- Some Funding Agencies may recommend a quality auditing Report from an Independent Quality Auditor.

10.11 Field Quality Plan

- Following Field Quality Plan has been drafted to ensure quality in workmanship:
    a. Conductor, Earth wire & AB Cable erection (HT &LT)
    b. Cable
    c. Civil Works
    d. Poles (30kV& LV), Pole earthing and Guy erection
    e. Erection of 30kV pole accessories
    f. Isolator, AB switch/DO fuse
    g. Lightening Arrestor
    h. Painting
    i. Customer Connection
    j. DTR Structure and Components
    k. DC System

10.12 Material Quality Plan

- Following Material Quality Plan has been drafted to ensure quality in workmanship and material:
    a. XLPE Aerial Bunched Cable
    b. LT PVC Un-Armoured Cable
    c. Air Break Switch
    d. Disc Insulators
    e. ACSR Conductor
    f. Drop Out Fuse
    g. PSC Concrete Poles
    h. LTDB for Distribution Transformer Substation
    i. Pole Top Distribution Box
    j. Distribution Transformers
    k. Lightening Arrestor

10.13 Quality Management System

- The objective of the Quality Management System is to lay down clear guidelines for all contractor which would facilitate them to observe all statutory rules and regulations, comply with applicable standards of regulating authority.
- The contractor will appoint Quality supervisor, engineer / manager for the project work.

10.14 Duties of Quality Representative:

a. Installation Quality training of 3hrs/employee/month and half day of quality training to all new employees joining the Contractor will be conducted by the Contractor.
b. Quality Talk before start of work at site.

c. Ensuring the availability of materials required for ensuring quality
d. Ensuring the adherence to standard quality procedures of EDCL
e. Quality inspections / audits as per the process of EDCL
f. Submission of Field Quality Plans for Major works & Working in close coordination with Inspection & Quality Assurance Group of EDCL.
g. Reporting of major Non Compliances in Quality to Engineer In-Charge and QA Group of EDCL immediately after its occurrence.
h. Ensuring compliance with installation quality and other laws as may be applicable and providing for Quality assurance.

10.15 Flow of Funds – Monitoring of Energy Development Fund (EDF)

The Flow of Funds related to Electrification Projects will be performed and monitored as per the approved REG Financial Management Policies and Procedures.

10.16 Project Execution – Safety Aspects

1. Safety Precautions
    a. Contractor shall prepare and submit safety plan as per the prevailing guidelines and practises to EDCL for approval,
    b. The contractor shall ensure compliance to the safety plan during execution of the works,
    c. The Contractor shall observe all applicable regulations regarding safety at Site,
    d. Appointment of the safety officer for ensuring safety during execution of the project,
    e. Conducting periodic safety audits, and
    f. Unless otherwise stated, the Contractor shall, from the commencement of work on site until taking over, provide:
        - Fencing, lighting, guarding and watching of the Works, and
        - Temporary roadways, footways, guards and fences which may be necessary for the accommodation and protection of Employer / his representatives and occupiers of adjacent property, the public and others.

10.17 Project Closure

Project closure will be done as per the prevailing practises of EDCL including the following requirements.

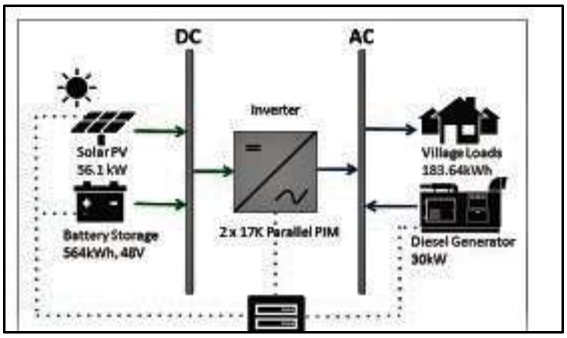
- Confirm work is done as per the requirements
- Complete procurement closure
- Gain formal acceptance from all departments
- Complete final performance reporting as per guidelines under the project
- Index and archive records - Collected documents are finalized. Final versions of the project management plans and all necessary documents about the project are archived in the company records.
- Hand-over of project to EDCL
- Energization of the project

Section-11. Guidelines for Supply, Installation, Operation & Maintenance of Solar PV Microgrid Systems

11.1 Overview of solar microgrid system

A solar microgrid is a small-scale solar powered grid that can operate independently to supply energy for limited number of customers in a village or a hamlet. A solar microgrid generally consist of a solar PV array, a battery bank, charge controller or control system, inverter (in case of AC supply), cables for power distribution and safety devices.

Figure 11-1: Typical diagram of solar microgrid



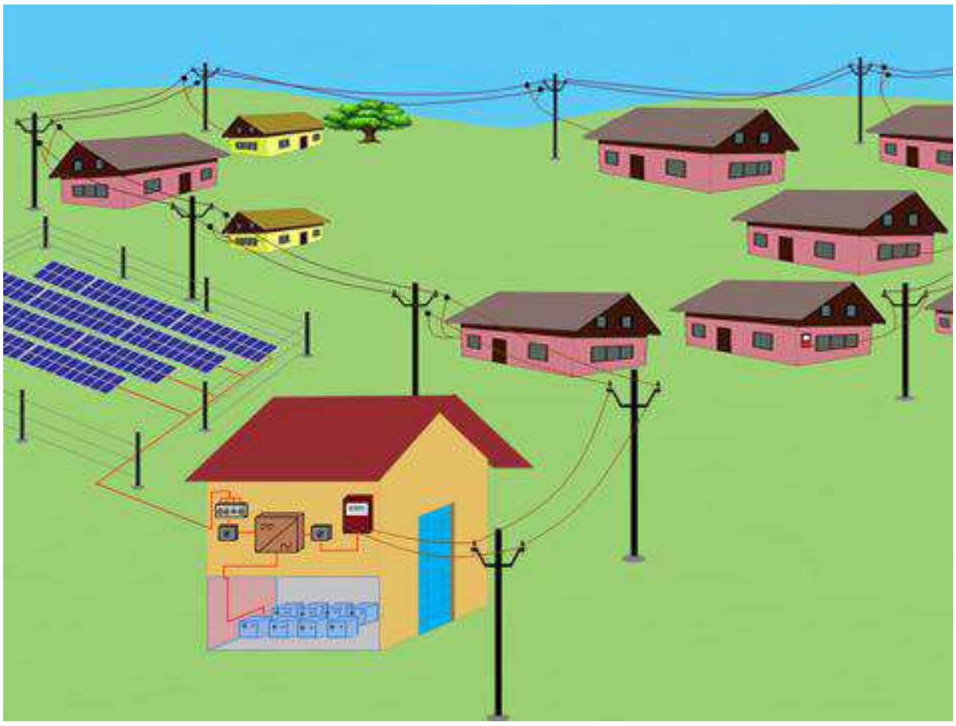
Size of a microgrid system depends on the number of customers and corresponding energy demands. Capacity of a microgrid system can be as small as 100W to supply basic lighting load for few adjacent households or even more than 200kW to supply residential and commercial load in a village.

The IEC62257 Part 9-1:2008: Micro power systems technical specifications covers low voltage AC, three-phase or single-phase, with rated capacity of the power plant at the electrical output less than, or equal to, 100kVA.

The voltage levels covered under this IEC technical specification are:

a. Low Voltage (LV) AC systems at voltage level of 120-240V single phase /208-415V three phase at 50Hz or 60Hz
b. Extra low voltage (IELV) DC systems less than 120V DC

Figure 11-2: ***A conceptual schematic of solar microgrid system***



11.1.1Components of a solar microgrid system PV Module – variations on size/wattages

PV modules are the device that captures the Sun's energy and converts it into electricity. There are a wide variety of modules available today which differ in the type of silicon used, the manufacturing process and the product quality. The vast majorities of commercially available PV modules are made from silicon and differentiate into three main varieties; mono-crystalline, polycrystalline and thin-film solar cells. The different types of PV modules vary significantly by cost, efficiency and appearance. The choice is highly dependent on the application, however the most important thing is to ensure that they are compliant to the relevant codes and standards as will be discussed.

Table 11-1: Rated Capacity at STC (Wp)

Rated Capacity at STC (Wp)	Isc	Imp	Voc	Vmp	Length (mm)	Width (mm)	Weight (kg)
50Wp	3.04	2.8	21.77	17.89	608	666	4.6
100Wp	6.11	5.57	21.84	17.99	1152	666	8
200Wp	8.1	7.48	32.65	26.74	1486	982	15.5
250Wp	8.71	8.18	37.55	30.58	1639	982	17.45
300Wp	8.74	8.05	45.1	37.28	1956	992	27

Figure 11-3: Major equipment's required for Photovoltaic power plant

11.1.2Battery storage – type and classifications

In a standalone PV system, battery storage is required if electrical loads are required to operate at night time or during extended periods of cloudy or overcast weather when the PV array by itself cannot supply enough power. The primary functions of a storage battery in a PV system are:

a. Energy Storage Capacity and Autonomy
b. Voltage and Current Stabilization
c. Supply Surge Currents

The number of days the battery storage capacity is available to operate the electrical loads directly from the battery, without any energy input from the PV array is called days of "autonomy" in a standalone PV system. For common, less critical PV applications, autonomy periods are typically designed for between 2 – 6 days. For critical applications involving essential loads or public safety autonomy periods may be greater than 10 days. In general, electrical storage batteries are broadly classified as Primary and Secondary Batteries. Primary batteries are not used in PV systems because they cannot be recharged. A secondary battery can store and deliver electrical energy and can also be recharged by passing a current through it in an opposite direction to the discharge current.

Figure 11-4: Different types of batteries

		
Flooded Electrolyte LA battery	VRLA battery	Lithium Ion battery

The batteries that are commercially available and viable for use in photovoltaic system include:

- Flooded Lead Acid Batteries
- Valve Regulated Lead Acid (VRLA) Batteries
- Nickel Cadmium (NiCd)
- Nickel metal Hydride (NiMH)
- Lithium Ion (Li-ion)

There are several types of lead-acid batteries manufactured. The following sections describe the types of lead-acid batteries commonly used in PV systems.

11.1.2.1 Flooded Lead-Acid Batteries

Flooded lead-acid batteries are the most common lead-acid batteries. They contain vents which allow the resulting hydrogen gas from electrolysis escape. As a result, the electrolyte level will fall over a period of time, and must be monitored and topped up with water, preferably demineralised water. The hydrogen gas produced is highly flammable. Care must be taken to ensure that there is adequate ventilation above and around flooded batteries.

11.1.2.2 Valve Regulated Lead-Acid (VRLA)

Valve regulated lead acid (VRLA) batteries are also known as captive electrolyte batteries and as the name implies, the electrolyte is immobilized in some manner and the battery is sealed under normal operating conditions. Under excessive overcharge, the normally sealed vents open under gas pressure through a pressure regulating mechanism. Electrolyte cannot be replenished in these battery designs; therefore they are intolerant of excessive overcharge. VRLA batteries are available in two different technologies: **Absorbed Glass Mat (AGM)** and **Gelled Electrolyte**.

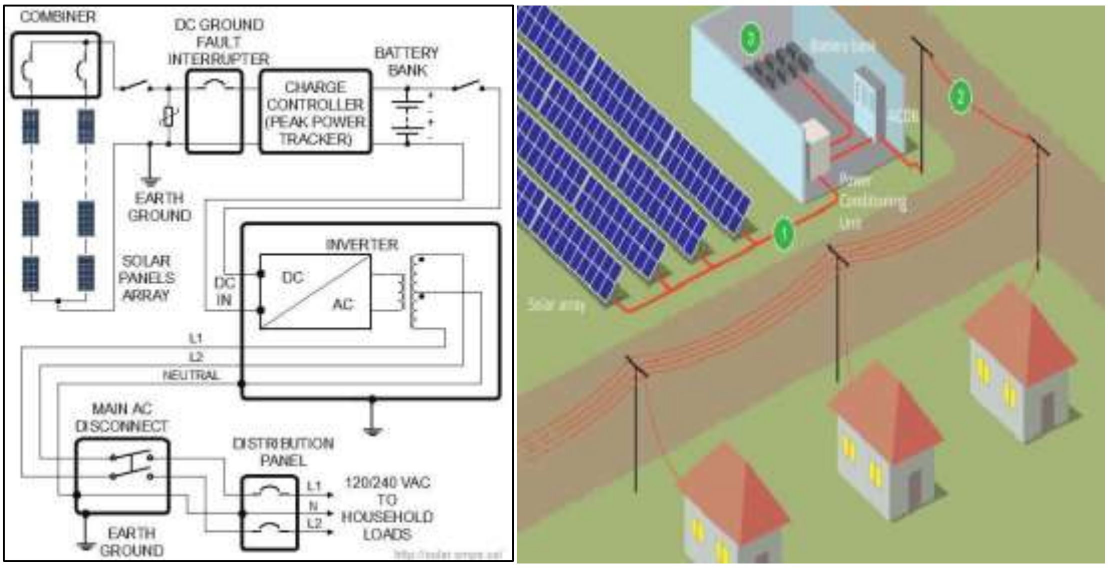
11.1.2.3 Lithium Ion Batteries

Lithium ion batteries are an emerging technology and have a number of advantages over other batteries, especially lead acid batteries. They are generally smaller and lighter for the same capacity, are faster at charging and are less susceptible to degradation due to charging and discharging. However, lithium ion batteries have a very high up-front cost and they can be sensitive to extreme temperature and voltages.

11.1.3Inverters & other electronic equipment

The photovoltaic array and battery produce DC current and voltage. The purpose of an inverter is to convert the DC electricity into a form suitable for AC electrical appliances and/or exportable to the AC grid. The typical low voltage (LV) supply into a domestic dwelling or small commercial building will be either 230V AC single phase or 415V AC three phase. Higher voltages may be supplied to larger commercial buildings which will then have transformers for stepping down to 230V or 415V.

Figure 11-5: Single Line Diagram for Standalone PV system



Stand-alone inverters or off-grid inverters, are very different from grid-connected inverters. Stand-alone inverters do not include the same MPPT function as grid-connected inverters because in stand-alone systems, the PV array is not usually connected to the inverter but is wired through a system controller to the batteries as shown in the figure above.

The inverter in a stand-alone power system takes its power from the batteries to supply the AC circuit(s). The system controller (voltage regulator) itself can be a MPPT. The advantage of the MPPT controller is to optimise the battery charging. This function has no impact on whether the inverter itself will supply power to any AC circuits. Stand-alone inverters are typically voltage-specific, i.e. they are manufactured to operate from a specific nominal battery voltage e.g. 12V, 24V, 48V or 120V DC.

In a grid-connected PV system, the PV array is directly connected to the grid-connected inverter. The grid-connected inverter is the device which delivers the solar power to the AC power grid. The PV array is configured so that it operates within specific range of DC voltages to suit the grid-connected inverter's specifications. The inverter will convert the solar DC power to an AC sine wave that matches the AC supply in voltage and frequency to which it is connected.

Grid-connected inverters cannot independently produce a grid equivalent AC sine wave: the inverter must see and reference the grid to be able to operate. If the AC grid is not present, the inverter will simply not function.

11.1.4Charge controller

Battery charge regulation and control of the energy produced by the PV array is a critical function in PV systems. The most important functions of battery charge regulators and system controls are listed below.

a. Prevent Battery Overcharge
b. Prevent Battery Over discharge
c. Provide Load Control Functions
d. Provide Status Information to System Users/Operators
e. Interface and Control Backup
f. Energy Sources
g. Divert PV Energy to an Auxiliary Load
h. Serve as a Wiring Centre

11.1.5Other Equipment

In addition to the PV modules, battery, inverter and charge controller there are other components required in a solar PV microgrid system; these components are referred to as Balance of Systems (BoS)/other equipment.

Other equipment includes:

- **Solar Array Mounting System:** The equipment used to safely secure the PV modules to the mounting surface or ground.
- **Cabling**: Both DC and AC cabling is required to connect components.
- **Array Junction Box:** This may or may not be required depending on the PV array. It is used to combine the different array strings.
- **Protection and Disconnect Switches:** These components ensure the safety of the system.
- **Lightning Protection:** May or may not be required (depending on criteria in IEC62305-2/IEC 62305-3) to protect the system from lighting strikes.
- **Metering:** Measures the quantity of electricity generated by solar or quantity of electricity consumed by a customer.
- **System Monitoring:** Shows the system owner exactly how much electricity their system is producing and can be helpful in detecting a problem within the system.
- **Signage:** PV systems installed requires various signs to ensure safety.

11.2 Technical Specifications

11.2.1Technical Specifications

SPV modules and BOS including power conditioners/inverter, charge controller/ MPPT units, storage batteries, cables used in SPV power generation plant should strictly have minimal technical requirement/ standards as per IEC Standards.

Table 11-2: Technical Specifications – Solar PV System

ITEM	DESCRIPTION
SPV Module	• The photovoltaic modules should be Crystalline Silicon with a total array capacity as specified in the below.

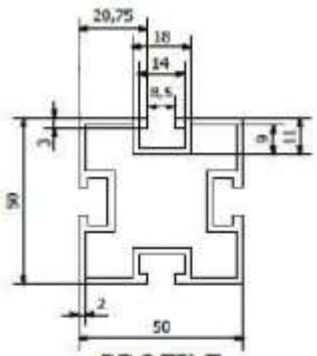
ITEM	DESCRIPTION
	• The Photovoltaic modules must be qualified as per IEC 61215 (revised) and in addition, the modules must conform to IEC 61730-1 requirements for construction & Part-2 requirements for testing, for safety qualification. • The PV modules must be tested and approved from authorised Testing and Calibration Laboratories. • The supplier shall provide performance guarantee for the PV modules used in the power plants must be warranted for their output peak watt capacity, which should not be less than 90% at the end of 10 years and 80% at the end of 25 years. • The efficiency of the PV modules should be minimum 15%.The fill factor should be more than 70%. • There should be a Name Plate fixed inside the module which will give: a. Name of the Manufacturer or Distinctive Logo. b. Model Number c. Serial Number d. Year of manufacture e. EDCL logo • RFID tag to be provided for proper traceability of the modules.
Battery Bank	The battery bank should be of Lithium Ion or lead acid type, connected in series/ parallel to form required battery bank for various capacities of systems as specified in below • The Batteries Cells should be conforming to relevant international standards (IEC). • It will be staged in racks duly painted with acid resistant paint to cover less space.
Power Conditioning Unit with inbuilt charge controller(Smart Hybrid system)	The Power conditioning unit with inbuilt charge controller of capacity & ratings as specified below for various capacity of Solar Power Plants should convert DC power in to AC power, must confirm to standards IEC 61683. The PCU will have following features: • MOSFET/ IGBT based MPPT / PWM charging • Wide input voltage range • Output voltage 230 V+ 2% of modified/ pure sine wave for single phase PCU & 440 V + 2% for three phase PCU. • Output frequency: 50 Hz+0.5 Hz • Capacity of PCU/ Inverter is specified at 0.8 lagging power factor. • THD: less than 3% • Efficiency: >85% for 5 KW &> 90 % for 10 KW capacity of PCU at full load. • Ambient Temp 50 degree Celsius (max.) • Operating humidity 95% maximum • Protections: a) Over voltage (automatic shut down) b) Under voltage (automatic shut down) c) Overload d) Short circuit (circuit breaker & electronics protection against sustained fault). e) Over Temperature f) Battery, PV reverse polarity

ITEM	DESCRIPTION
	• Indications: a) - Array on b) - MPPT/ PWM charger on c) - Battery connected, charging d) - Inverter ON e) - Load on solar/ battery f) - Grid charger on g) - Load on Grid h) - Grid on • Display parameters a) - Charging current b) - Charging voltage c) - Voltage of PV panels d) - Output voltage e) - Grid voltage f) - Inverter loading g) - Output frequency • Cooling: Air cooled, it shall include adequate internal cooling arrangements (exhaust fan and ducting)
Junction boxes	• The junction boxes shall be dust and water proof and made of thermoplastic the terminals will be connected to copper lugs or bus-bar of proper sizes. The junction boxes will have suitable cable entry points fitted with the cables. Suitable markings shall be provided on the lugs or bus-bars for easy identification at cable ferrules will be fitted at the cable terminations points for identification. Each main junction box shall be fitted with appropriate rating reverse blocking diode. The junction boxes shall be of reputed make. • The junction boxes shall have suitable arrangement for the following: a) Combine groups of modules into independent charging sub-arrays that will be wired into the controller. b) Provide arrangement for disconnection for each of the groups. c) Provide a test point for each sub group for quick fault location. d) To provide group array isolation. e) The rating of the JBS shall be suitable with adequate safety factor to inter connect the Solar PV array. f) The Junction boxes shall be dust, vermin and water proof and made of thermo plastic or metallic and shall have protection minimum as per IEC62208 and IP 65 type, Class II protection
Structure for module frame	**Module mounting structure** (MMS) should be of anodised aluminium for mounting of SPV modules at site. The panel frame structure should be capable of withstanding a minimum wind load of 150 KM per hour, after grouting and installation. MMS should be sturdy & designed to assist SPV Modules to render maximum output. The hardware (fasteners) used for installation of SPV Modules & MMS should be of suitable Stainless Steel (SS 304). Each MMS should be with minimum four legs grouted on pedestals of minimum 300X300X250 mm with

<table>
<tr><th>ITEM</th><th>DESCRIPTION</th></tr>
<tr><td></td><td>
anchoring/ chipping & chemical sealing of foundation based on RCC roof. Foundation bolts of stainless /GI steel should be at least 300 mm long.

Its size should be with reference to the specifications of the selected make SPV modules. Anti-Theft Nut Bolts of SS (with washers) should be used for mounting modules for better theft proofing.

<u>Aluminium structure should meet the following minimum specifications:</u>
A. Structure Assembly Main Components:
1. Purlin
2. Leg & Base Plate
3. Rafter (with cleat)

B. Component Details:
1. Purlin/Rafter:


PROFILE
• Cross section Length: 50mm, Cross section Width: 50mm, Thickness: 02 mm
• Component Length – As per PV modules table designed
• Tolerance: ±5%

Cleat:
• Cross sectional length – 135mm, Cross sectional width – 50mm, Thickness – 5mm
• Tolerance: ±5%

2. Leg & Base Plate
(a) <u>Base Plate:</u>
• Cross sectional Length: 75mm, Cross sectional Height: 75mm, Thickness: 5mm
• Component Length: 150mm with two holes on base area for fixing of J Bolts
• Tolerance: ±5%

(b) <u>Leg attached to base plate</u>
• Cross sectional length – 50mm, Cross sectional width – 50mm, Thickness – 5mm
</td></tr>
</table>

ITEM	DESCRIPTION
	• Component Length – 3808mm ((or as per site requirement of tilt angle and may vary with the required height of structure) with two holes on bottom area for fixing with base plate and one hole on top are for fixing of Rafter • Tolerance: ±5% **Foundation:** The CC foundation shall have to be designed on the basis of the weight of the structure with module and minimum wind speed of the site, i.e. 150 Km/hour. Normally, each MMS should be with minimum four legs grouted on pedestals of proper size. However, for sheds CC work will not be required, the structure shall be grouted to withstand the required wind velocity. In that case aluminium structure of suitable strength may be used.
Connecting cables	Sizes of the PVC insulated copper cables depends on the rating of the PV system for: • Module interconnections • Module parallel interconnection • Array or AJB to PCU • Battery to PCU • PCU to load / change over switch
Indoor wiring	All indoor wiring is to be done in a casing capping system. As and when required flexible pipe may also be used.
Load connection	The supplier shall also ensure that main points of the building should be connected keeping in view the capacity of the plant.
Lighting protection	Suitable nos. of lighting arrestors shall be provided in the array field for the protection.
Earthling protection	Each array structure and all metal casings of the plant etc. shall be earthed properly.
Tool Kit and Spares	One necessary tools kit and spares will have to be provided by the supplier
Energy meter	Supplier shall provide energy meter to measure the DC power in KWphrs being fed to the plant.

11.2.2Technical specification for solar photo voltaic modules & cells

Mono/multi-crystalline Silicon solar photo-voltaic modules:

11.2.2.1 The SPV modules must conform to the latest edition of any of the following IEC standards for SPV module design qualification and type approval:

a. Crystalline silicon terrestrial SPV modules - IEC 61215
b. Thin film terrestrial SPV modules - IEC 61646
c. Concentrator SPV modules &assemblies - IEC 62108
d. For the SPV modules to be used in a highly corrosive atmosphere throughout their lifetime, they must qualify to IEC 61701
e. Solar PV Mono/Multi crystalline Module should be of high efficiency (>15% Multi, >17% Mono)
f. In addition, the modules must conform to IEC 61730 Part 1-requirements for construction & Part 2- requirements for testing.

11.2.2.2 Other details of technical specification solar photo voltaic modules

a. The panel should be supplied with a plastic coated thermal sticker to be affixed at the back side of SPV Module which contains the matter in English about warning against illegal use of SPV module.

b. Protective devices against surges at the SPV module shall be provided. Low voltage drop bypass diodes shall be provided.

c. PV modules must be tested and approved by one of the IEC authorized test centres.

d. The module frame shall be made of corrosion resistant materials, preferably having anodized aluminium.

e. The Bidder shall carefully design and accommodate requisite numbers of the modules to achieve the rated power in his Bid.

f. Other general requirement for the PV modules and subsystems shall be the following:

   1. The rated output power of any supplied module shall have tolerance of ± 3%.
   2. The peak-power point voltage and the peak-power point current of any supplied module and/or any module string (series connected modules) shall not vary by more than two (2) percent from the respective arithmetic means for all modules and/or for all module strings, as the case may be.
   3. The module shall be provided with a junction box with either provision of external screw terminal connection or sealed type and with arrangement for provision of by-pass diode. The box shall have hinged, weather proof lid with captive screws and cable gland entry points or may be of sealed type and IP-65 rated.
   4. IV curves at STC should be provided by Bidder.

g. Identification and traceability

   1. Each SPV module must use a RF identification tag (RFID). RFID shall be mandatorily placed inside the module laminate. RFID must contain the following information:
      - Name of the manufacturer of SPV Module
      - Name of the manufacturer of solar cells
      - Month and year of manufacture (separately for solar cells and module)
      - Country of origin (separately for solar cells and module)
      - I-V curve for the module
      - Peak Wattage, Im, Vm and PF for the module.
      - Unique Serial No and Model No of the module.
      - Date and year of obtaining IEC SPV module qualification certificate.
      - Name of the test lab issuing IEC certificate.
      - Other relevant information on traceability of solar cells and module as per IEC.

11.2.2.3 Warranties: Material Warranty-

a. Material Warranty is defined as: The manufacturer should warrant the Solar Module(s) to be free from the defects and/or failures specified below for a period not less than five (5) years from the date of sale to the Bidder

b. Defects and/or failures due to manufacturing

c. Defects and/or failures due to quality of materials

d. Non- conformity to specifications due to faulty manufacturing and/or inspection processes. If the solar Module(s) fails to conform to this warranty, the manufacturer will repair or replace the solar module(s).

11.2.2.4 PCU/ Inverter

a. As SPV array produces direct current electricity, it is necessary to convert this direct current into alternating current and adjust the voltage levels to match the grid voltage. Conversion shall be achieved using an electronic Inverter and the associated control and protection devices. All these components of the system are termed the "Power Conditioning Unit (PCU)". In addition, the PCU shall also house MPPT (Maximum Power Point Tracker), an interface between Solar PV array & the Inverter, to the power conditioning unit/inverter should also be DG set interactive. The power conditioning unit should also have provision of charge controller in case of systems with battery backup.
b. Three Phase PCU/inverter shall be used with each power plant system.
c. PCU/inverter shall be capable of complete automatic operation including wake-up, synchronization & shutdown.
d. The output of power factor of PCU inverter is suitable for all voltage ranges or sink of reactive power, inverter should have internal protection arrangement against any sustainable fault in feeder line and against the lightning on feeder.
e. Built-in meter and data logger to monitor plant performance through external computer shall be provided.
f. The power conditioning units / inverters should comply with applicable IEC standard for efficiency measurements and environmental tests as per standard codes IEC 61683 and IEC 60068-2(1,2,14,30).
g. The charge controller (if any) / MPPT units environmental testing should qualify IEC 60068-2(1, 2, 14, 30. The junction boxes/ enclosures should be IP 65(for outdoor)/ IP 54 (indoor) and as per IEC 529 specifications.

11.2.2.5 Data acquisition system/ plant monitoring

a. Successful Bidder shall install appropriate Time-of-Day (ToD) meter at Site to keep record of 15- minute time block-wise generation and supply of electricity. For this purpose, the standard and specifications of the meter shall be at par with those recommended by EDCL suitable for generation and supply from plants of the size of Project.
b. The meter should have capacity to store 15-minute time block-wise data on generation and supply for 40-45 days and day-wise data on generation and supply for 6 months in such a form as to help Engineer download it using MRI.
c. There should be an easily accessible emergency stop switch.

11.2.2.6 Protection and safety

a. Specifically, the inverter should be three phase static solid state type power conditioning unit. Both AC & DC lines shall have suitable MCB/MCCB and Contractors to allow safe start up and shut down of the system. PCU should have protections for overload, surge current, high Temperature, over / under voltage and over / under frequency & reverse polarity. The complete operation process & safety instructions should be printed on the sticker & suitably pasted on the PCU. The inverter shall have provision for input & output isolation (automatic & manual).

b. Each solid state electronic device shall have to be protected to ensure long life of the inverter as well as smooth functioning of the inverter. Inverter should have safety measures to protect inverter from reverse short circuit current due to lightening or line faults of distribution network.

c. PCU should be suitably placed in control room on a suitable wooden or concrete platform with complete safety measure as per norms.

11.2.2.7 Battery Bank

1. The tubular VRLA/GEL batteries must meet the requirements of Ministry of New and Renewable Energy programme. The battery bank capacity shall be of different capacities as specified in the price schedule, of tubular VRLA/GEL Battery of 2 volt cells. The general specifications shall be as under:
    a) The battery bank shall consist of required number of deep-discharge electrochemical storage cells, suitably interconnected as required. Parallel connections of storage cells will be discouraged.
    b) The cells shall be capable of deep discharge and frequent cycling with long maintenance intervals and high columbic efficiency. Automotive or car batteries shall not be accepted.
    c) The nominal voltage and capacity of the storage bank shall be selected and specified by the supplier in the Bid.
    d) The self-discharge rate of the battery bank or individual cell shall not exceed four (4) percent per month.
    e) The permitted maximum Depth of Discharge (DOD), shall not be more than 80%.
    f) The cells shall include explosion proof safety vents.
    g) Suitable number of corrosion resistant storage racks shall be supplied to accommodate the cells tester and other accessories. The rack design shall be such that minimum space is required, without any way obstructing the maintenance requirements. For metallic racks, standards specified for control panel enclosures and other metallic shall govern.
    h) All the connectors should be insulated except for the end portions.
    i) Charging instructions shall be provided along with the batteries.
    j) A suitable battery rack with interconnections & end connector shall be provided to suitably house the batteries in the bank.
    k) The batteries shall be suitable for recharging by means of solar modules via incremental / open circuit regulators.
    l) Battery interconnecting links shall be provided for interconnecting the battery in series and in parallel as needed and shall be Lead coated heavy duty copper strips.
    m) Connectors for inter cell connection (series / parallel) shall be maintenance free screws. Front covers shall be provided for each battery bank.
    n) The operating range will be 0ºC to +55/60°C.
    o) AH Efficiency: >95% and WH Efficiency: >85%
    p) Recombination Efficiency shall be >98%

q) Self-Discharge of battery shall be <0.5% per week at 27ºC.

2. The minimum rating of battery voltage (V) and Ah at C10 rate of discharge of different villages shall depends on their type of consumers, their consumption pattern, etc.

11.2.2.8 Battery Rack

Battery rack should be of matured treated Salwood duly painted single tier or two tier (if required) or epoxy coated MS structure (for VRLA GEL Cells) with rubberized coating on battery runners. Placement of battery should be such that maintenance of the battery could be carried out easily. The non-reactive acid proof mat should be provided to cover the entire floor space covering the battery rack. Battery rack should compulsorily be placed on the appropriate rubbers pads to avoid the contact of racks with the floor, and to protect wooden rack particularly from termite.

11.2.2.9 Array structure

1. Hot dip galvanized MS mounting structures may be used for mounting the modules/ panels/arrays. Each structure should have angle of inclination as per the site conditions to take maximum insolation. However, to accommodate more capacity the angle inclination may be reduced until the plant meets the specified performance ratio requirements.
2. The Mounting structure shall be so designed to withstand the speed for the wind zone of the location where a PV system is proposed to be installed (for minimum wind speed of 150 km/ hour). Suitable fastening arrangement that do not require drilling in roof tops should be adopted to secure the installation against the specific wind speed.
3. The mounting structure steel shall be galvanized in compliance of latest relevant standard.
4. Structural material shall be corrosion resistant and electrolytically compatible with the materials used in the module frame, its fasteners, and nuts and bolts. Aluminium structures also can be used, that can withstand the wind speed of respective wind zone. Necessary protection towards rusting need to be provided, either by coating or anodization.
5. The fasteners used should be made up of stainless steel. The structures shall be designed to allow easy replacement of any module. The array structure shall be so designed that it will occupy minimum space without sacrificing the output from the SPV panels
6. Regarding civil structures the Bidder need to take care of the load bearing capacity of the roof and need to arrange suitable structures based on the quality of roof.
7. The total load of the structure (when installed with PV modules) on the terrace should be less than 60 kg/m2.
8. The minimum clearance of the structure from the roof level should be 300 mm

11.2.2.10 Lightning and over voltage protection

1. The SPV power plants shall be provided with lightning & overvoltage protection. The main aim in this protection shall be to reduce the over voltage to a tolerable value before it reaches the PV or other sub system components. The source of over voltage can be lightning, atmosphere disturbances etc. The entire space occupying the SPV array shall be suitably protected against Lightning by deploying required number of Lightning Arrestors. Lightning protection should be provided as per IEC 62305 standard. The protection against induced high-voltages shall be

provided by the use of Metal Oxide Varistors (MOVs) and suitable earthing such that induced transients find an alternate route to earth.

11.2.2.11 Surge Protection

1. Internal surge protection shall consist of three MOV type surge-arrestors connected from +ve and –ve terminals to earth (via Y arrangement).

11.2.2.12 Earthing protection

1. Each array structure of the PV yard should be grounded/ earthed properly. In addition the lighting arrester/masts should also be earthed inside the array field. Earth Resistance shall be tested in presence of the representative of Department as and when required after earthing by calibrated earth tester. PCU, CAD and DC DB should also be earthed properly.
2. Earth resistance shall not be more than 5 ohms. It shall be ensured that all the earthing points are bonded together to make them at the same potential.

11.2.2.13 Array Junction Box (JAB)

This shall consist of suitable polycarbonate / powder coated metal casting. Array junction box allows several photovoltaic strings (from 8 to 32) to be connected in parallel. The total DC power is then distributed to the photovoltaic inverter. It includes photovoltaic string protection, overvoltage protection and a DC output switch disconnector. In this box/boxes, a separate arrangement, consisting of SPDs and DC connector of suitable specifications for array, shall be made to help it with stand respective flow of current.

11.2.2.14 DC Distribution Board (DCDB)

DCDB shall be provided with the purpose of providing the option for isolating the battery bank. There shall be copper bus bars of suitable rating and can either be independent or integrated in PCU.

11.2.2.15 AC Distribution Board (ACDB)

1. This shall consist of box of suitable powder coated metal casting. One feeder per phase shall be provided in ACDB with MCB of suitable capacity installed at each feeder in the ACDB. One electronic energy meter, single / three phase (as per requirement) of good quality shall also be installed in ACDB suitable placed to measure the consumption of power from SPV Power Plant. Proper rating MCB shall be installed at every feeder (in case of single phase output also, there shall be three feeders) to protect feeders from the short circuit current as per the requirement of the site & instructions of EDCL. A separate dedicated feeder from conventional line to PCU as well as ACDB should also be installed, as per EDCL's instruction.

2. A separate changeover switch of proper rating should also be suitably installed in the ACDB to isolate the existing connected load from solar system and cater the power to the existing load from convention power (Mains) in case of emergency. ACDB should be connected between PCU and Load.

11.2.2.16 Battery Protection Panel (BPP)

This shall consist of box of suitable powder coated metal casting. BPP should be installed to make provision to isolate the battery bank. Proper rating HRC fuse and MCCB/isolator for DC application should be suitably installed. BPP should be connected between battery bank and DCDB. This can be integrated in the PCU.

11.2.2.17 Danger Boards

Danger boards should be provided as and where necessary as per RE Act/RE Rules as amended up to date, as per the instructions of EDCL and affixed at various appropriate locations.

11.2.2.18 Cables/ wires

1. Cables of appropriate size to be used in the system shall have the following characteristics:
    a) Shall meet IEC 60227, IEC 60502 standards
    b) Temp. Range: –10°C to +80°C.
    c) Voltage rating 660/1000V
    d) Excellent resistance to heat, cold, water, oil, abrasion, UV radiation
    e) Flexible
    f) Sizes of cables between array interconnections, array to junction boxes, junction boxes to Inverter etc. shall be so selected to keep the voltage drop (power loss) of the entire solar system to the minimum. The cables should be insulated with a special grade PVC compound formulated for outdoor use.
    g) Cable Routing/ Marking: All cable/wires are to be routed in a GI cable tray and suitably tagged and marked with proper manner by good quality ferule or by other means so that the cable easily identified.
    h) The Cable should be so selected that it should be compatible up to the life of the solar PV panels i.e. 25 years.
    i) The ratings given are approximate. Bidder to indicate size and length as per system design requirement. All the cables required for the plant provided by the Bidder. Any change in cabling sizes if desired by the Bidder/approved after citing appropriate reasons. All cable schedules/layout drawings approved prior to installation.
    j) Multi Strand, Annealed high conductivity copper conductor PVC type ‘A’ pressure extruded insulation or XLPE insulation. Overall PVC/XLPE insulation for UV protection Armoured cable for underground laying. All cable trays including covers to be provided. All cables conform to latest edition of IEC
    k) Description Standard Number Cables General Test and Measuring Methods, PVC/XLPE insulated cables for working Voltage up to and including 1100 V, UV resistant for outdoor installation IEC 69947.
    l) The size of each type of DC cable selected shall be based on minimum voltage drop however; the maximum drop shall be limited to 1%.
    m) The size of each type of AC cable selected shall be based on minimum voltage drop however; the maximum drop shall be limited to 2%.

11.2.2.19 Junction Boxes (JBs)

All the JBs/ enclosures for inverters/ charge controllers/ luminaries should be IP 54(for outdoor)/ IP 21(for indoor) shall be as per IEC 529 Junction Boxes for Cables from Solar Array. The junction boxes shall be made up of FRP (Hensel make or equivalent make)/PP/ABS (with prior approval of EDCL) with dust, water and vermin proof. It should be provided with proper locking arrangements.

11.2.2.20 Power distribution network

Supply, installation and commissioning of Power Distribution Network (PDN) at the site, which shall operate on the electrical power produced by the SPV Power plant, shall fulfil the below mentioned requirement as per standards/ specifications mentioned therein:

a) Installation of domestic connection to every household shall be through service pole as per the standard electrical fittings. It shall use cable of aluminium wire PVC insulated sheathed and single core cable (6 sq.mm) of reputed make.
b) Installation of appropriate load limiting switch / fuse for controlling domestic / street lighting connections, as per requirement of the site.
c) Supply, installation & grouting of poles as per EDCL norms for overhead distribution network of cables at village/site. All poles should be numbered by oil paint in the specified format of EDCL. Two numbers of MS sign boards (each of 2’ x 2.5’ size) has to be supplied, painted (in the same manner as pole painting instructions) & clamped on the poles of the PDN as per EDCL’s instructions.
d) Supply, installation & commissioning of cabling from pole to pole & pole to house. Cabling between pole to pole/ pole to house can also be done as per Bidder’s design with prior approval of EDCL.
e) Supply & installation of earthing kits, stay wire sets with complete set for poles etc. as per norms where ever required.

Note - All cables should be of copper, tested for general test and measuring method and PVC insulated cables as per IEC 60227 and IEC 60502. All the materials to be consumed in the power distribution network should be of best quality confirming to specification and should be with prior approval of EDCL.

11.2.2.21 Operation & Maintenance

Operation & maintenance of SPV Power Plant along with PDN system installed at site has to be done for a period of five (5) years from the date of commissioning of the Project. Successful bidders have to submit the O&M report to EDCL every two months with necessary details of plant.

11.2.2.22 Other Features

Any minor equipment and material may not be specifically mentioned in this specifications but are required to make the system complete in a every respect in accordance with technical specification shall be deemed to have been covered under the scope of this specification and shall be provided by the tenderer / supplier within the quoted price.

11.2.3Codes and Standards

The BoS items / components of the SPV power plant must conform to the latest edition of IEC/ equivalent International Standards recognized by RSB as specified below:

Table 11-3: Codes and Standards

BoS item / component	Standard Description	Standard Number
Power Conditioning Unit Inverter	Efficiency Measurements Environmental Testing	IEC61683 IEC60068 2 (1, 2, 14, 30)
Charge controller/ MPPT units*	Environmental Testing	IEC60068 2 (1, 2, 14, 30)
Storage Batteries	General Requirements & Methods of Test VRLA Tubular GEL type	IEC 61427
Cables	General Test and Measuring Methods PVC insulated cables for working voltages upto and including 1100 V-Do-, UV resistant for outdoor installation	IEC 60227
Switches / Circuit Breakers / Connectors	General Requirements Connectors-safety AC/DC	IEC 60947 part I, II & III/ EN 50521
Junction Boxes/ Enclosures for inverters/ charge controller	General Requirements	IP54 (for outdoor) / IP/21 (for indoor) as per IEC 529

*In case if the Charge controller is in-built in the inverter, no separate IEC 62093 test is required and must additionally conform to the relevant national/international Electrical Safety Standards wherever applicable

11.3 Installation & commissioning

11.3.1 Site survey & planning

The installer shall gather all design documents and engineering drawings of the system including site layout, system schematic, single line diagrams, drawings for structure and foundations, distribution systems, module and battery interconnection drawings, control system drawing, etc. The installer shall also have information (data sheet) on the major components such as modules, controls, inverter, and batteries and must be familiar with the instruction manual for installation of such equipment.

The first step of installation is to visit the site and finalize the layout of the equipment. If the site layout is already given, this should be verified at site identifying actual locations for the installation of equipment and verify the distances and dimensions.

11.3.2Occupational Health & Safety Assessment:

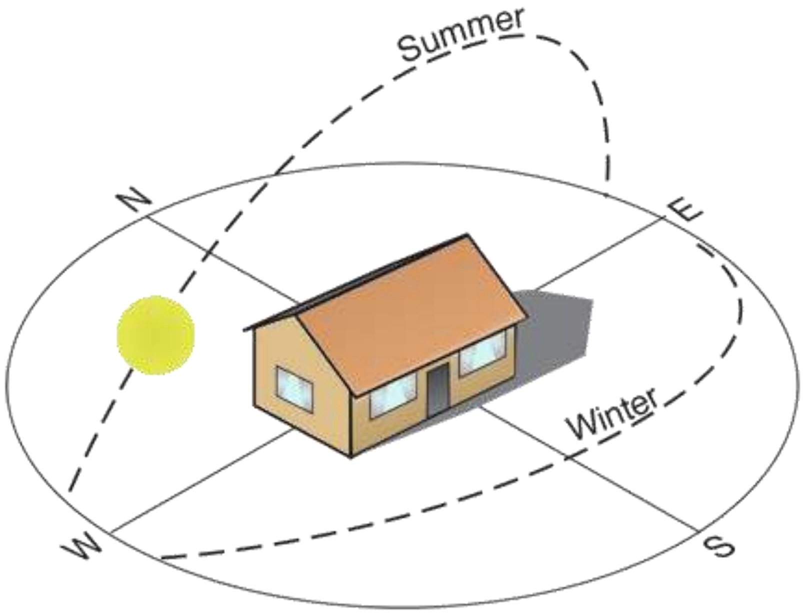
Prior to starting any on-site work it is recommended that the installer undertake an on-site risk assessment. This requires:

- The identification of all possible risks;
- Determination of the work practices that will be undertaken to remove the risk, or to minimize the risk if it cannot be removed altogether; and
- Communicating with all the staff working on-site about these risks and how they will be removed or minimized.

11.3.3Solar Array Location

For a solar photovoltaic system, it is crucial that the solar array is installed at a location that is free from any shading throughout the day. Finding a shadow free location for placement of array is usually not an issue for remote sites, where ample space and options for locating may be available. Shadow during winter season is much longer than the shadow during summer season due to change in earth's altitude. There may be shadow from nearby trees and houses or even shadow from mountains, which is not very far from the site. Sometimes, shadow in the early morning and late afternoon cannot be avoided due to very low altitude of sun. In such situations, arrays must be placed in such a way that there is no shading between the hours of best insolation, usually from 8 a.m. to 4 p.m., on the day with the longest shadows, December 21 in the Northern Hemisphere.

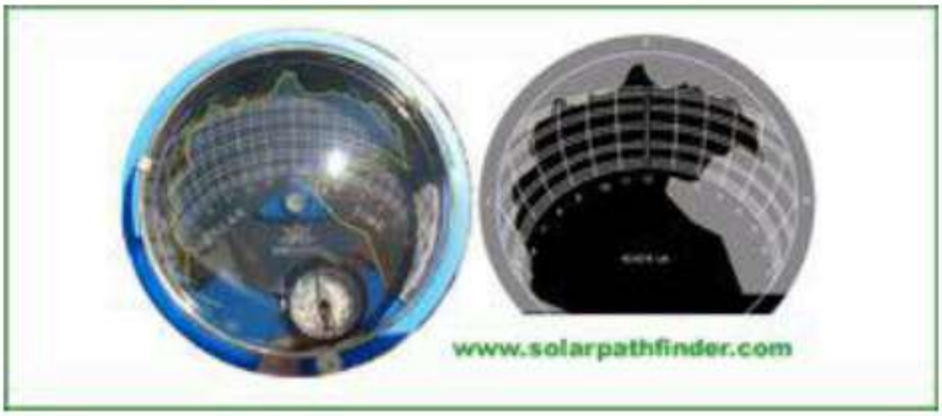
Figure 11-6: Placement of Solar arrays considering summer and winter sun positions



11.3.3.1 Using Solar Pathfinder

The most accurate and convenient way to place the array away from any tall object that can possibly cause shadow is to use the solar pathfinder. When you use a solar pathfinder there is no need to measure distance or height of any objects that can create shadow at any point of time during the year. Just placing the solar pathfinder in the potential array location, you will understand if there is any shadow. If there is any shadow image seen in the pathfinder, move away from that point to the direction where the shadow can be avoided. Solar pathfinder should be located at the four corners of the array to ensure that the complete array is shadow free.

Figure 11-7: ***Shadow analysis using a solar pathfinder and sun path diagram***

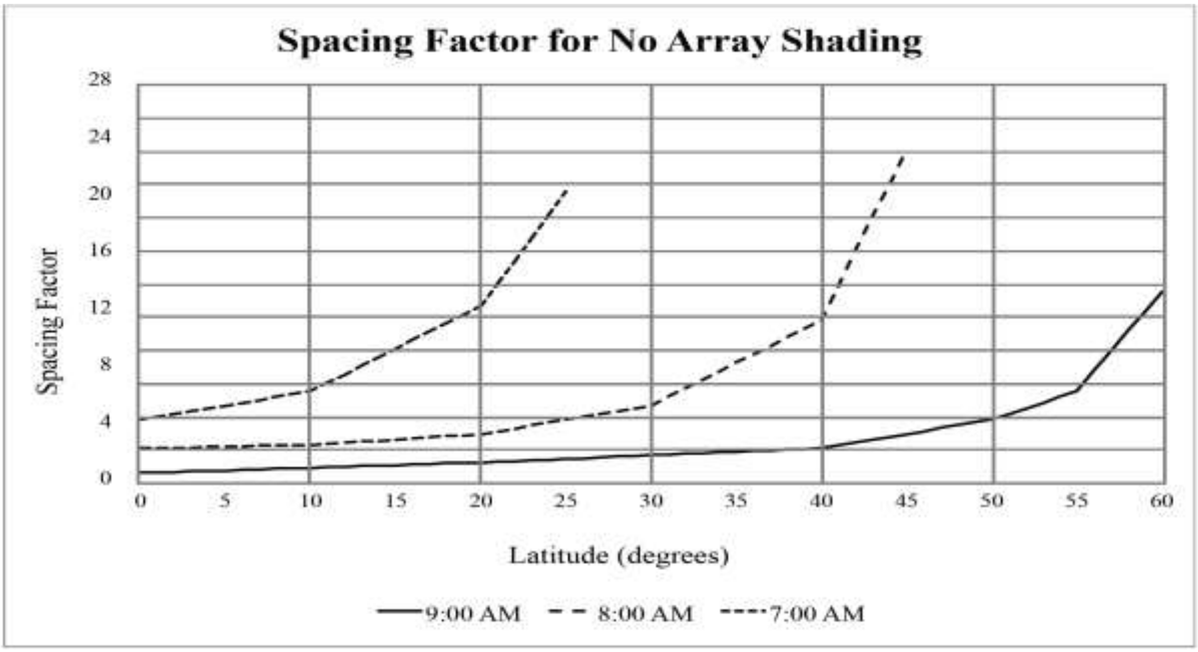


If you do not have access to a solar pathfinder, use the following calculations to ensure that the array will be located away from potential shading. However, these methods require some measurement, calculation and good assumptions to decide whether the array will be shadow free for all days of the year.

11.3.3.2 Using Spacing Factor Graph

One easy approach is to use the "spacing factor graph" given in the figure below. This graph will help in deciding where to place an array for no winter shading. Read up from the latitude of the site to the curve for the hour when no shadows are to reach the array (again usually 8 a.m. to 9 a.m.). Then read across to find the Spacing Factor. Multiply this factor times the height of the object to calculate the distance the array must be placed away from the object.

Figure 11-8: Graph to determine array spacing factor



The proper distance depends on the latitude, time, and the height of the nearest tall object. With the help of graph, now calculate the minimum distance from object to the array using the following formula.

$$Distance\ from\ object\ to\ array = Object\ Height\ x\ Spacing\ Factor$$

11.3.3.3 Applying Rule of Thumb

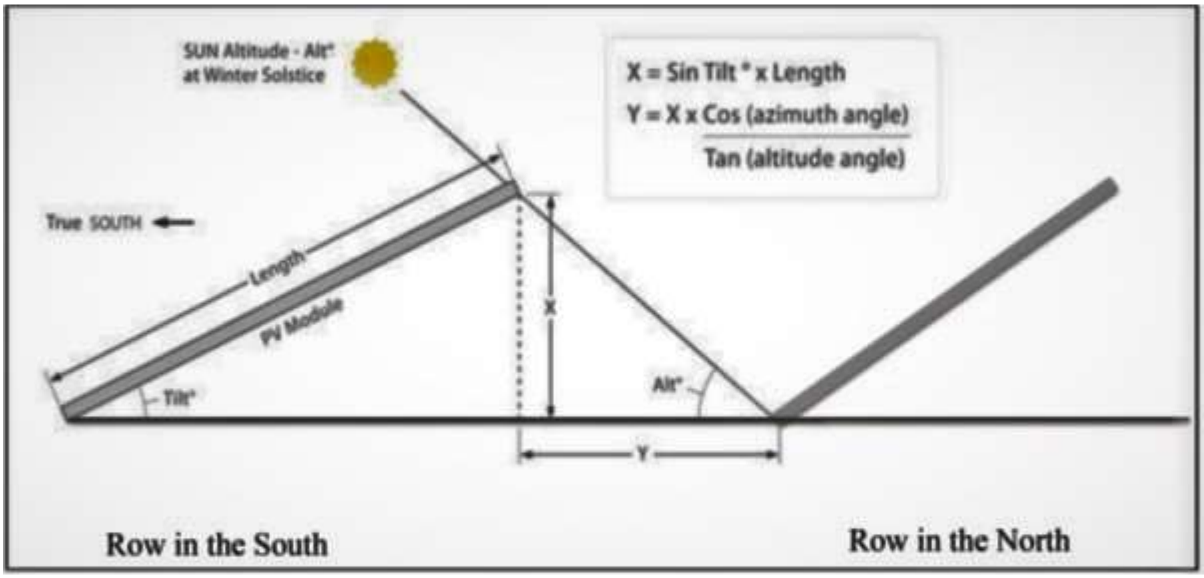
The general rule of thumb is to locate the array at a distance away from the object that is at least twice the height of the object. This will ensure that the object will not cast a shadow for 4 hours either side of solar noon.

11.3.3.4 Space between two Rows

When PV modules are installed in multiple rows, consideration must be given to the fact that one row of modules does not cast a shadow on the row behind. Calculations need to be done to find the minimum distance between PV Array rows to avoid winter mid-day shading. This can be calculated using basic trigonometry as shown in the figure below.

$$Row\ spacing\ (Y) = (X)\ x\ \frac{Cos\ (azimuth\ angle)}{Tan\ (altitude\ angle)}$$

Figure 11-9: Calculating the minimum distance between rows



Example:

The PV array is located in Kigali: Latitude 1.97°S and Longitude 30.10° E. The row spacing should avoid shading at solar noon on August 30.

Azimuth = 21.95°

Altitude = 78.16° at solar noon on August 30

$$Y = X\ x\ \frac{Cos\ (21.95^\circ)}{Tan\ (78.16^\circ)} = X\ x\ \frac{(0.93)}{(4.77)} = X\ x\ 0.195$$

If height of the row is 1m, distance between two rows shall be 1m x 0.195 = 0.195m

11.3.4Other Equipment Location

The next step of site survey is to determine the location of the control equipment, inverter, battery bank, earth pits and cable route.

- Controls and inverter should be placed in such a way that access is controlled.
- Switches are to be located in a place which is easily accessible. Batteries should be installed in a separate room closed to the inverter /control room and access to the room should be controlled.
- Batteries to be located in cool and dry and well ventilated place.

11.3.5Tools for Installation

Some tools for installing and maintaining photovoltaic power systems are listed below.

Table 11-4 Tools and equipment's required for Installation

Sl. No.	Tools and equipment's for Installation
1	First aid kit
2	System service logbook
3	Datasheet & O&M manual
4	This manual
5	Paper/Pencil
6	Multi-meter, digital voltmeter, with at least 10A current capability, spare batteries
7	Clamp on DC ammeter
8	Wrenches: Specific sizes, for all mounting bolts; Adjustable, for unexpected on-site problems; Vice-Grips for variable and heavy duty
9	Compass and Sun Pathfinder
10	Screw Drivers: flat Blade, in sizes for all mounting hardware; Phillips, in sizes for all mounting hardware; Small jewellery size, for adjusting controls
11	Linesman pliers, nose pliers
12	Nut drivers 1/4in and 5/16in
13	Measuring tape (25m)
14	Tilt Angle indicator, or plumb line and protractor
15	Hydrometer
16	Safety goggles
17	Rubber gloves
18	Electrical Tape
19	Wire Crimping, Stripping and Cutting Tool (s)
20	Miscellaneous for connections: Split bolts, wire nuts, lugs, solder-less connectors
21	A hand drill or DC operated electric drill
22	DC soldering iron
23	Hacksaw
24	Utility knife
25	Hammer
26	Ladder

11.3.6Installation Processes

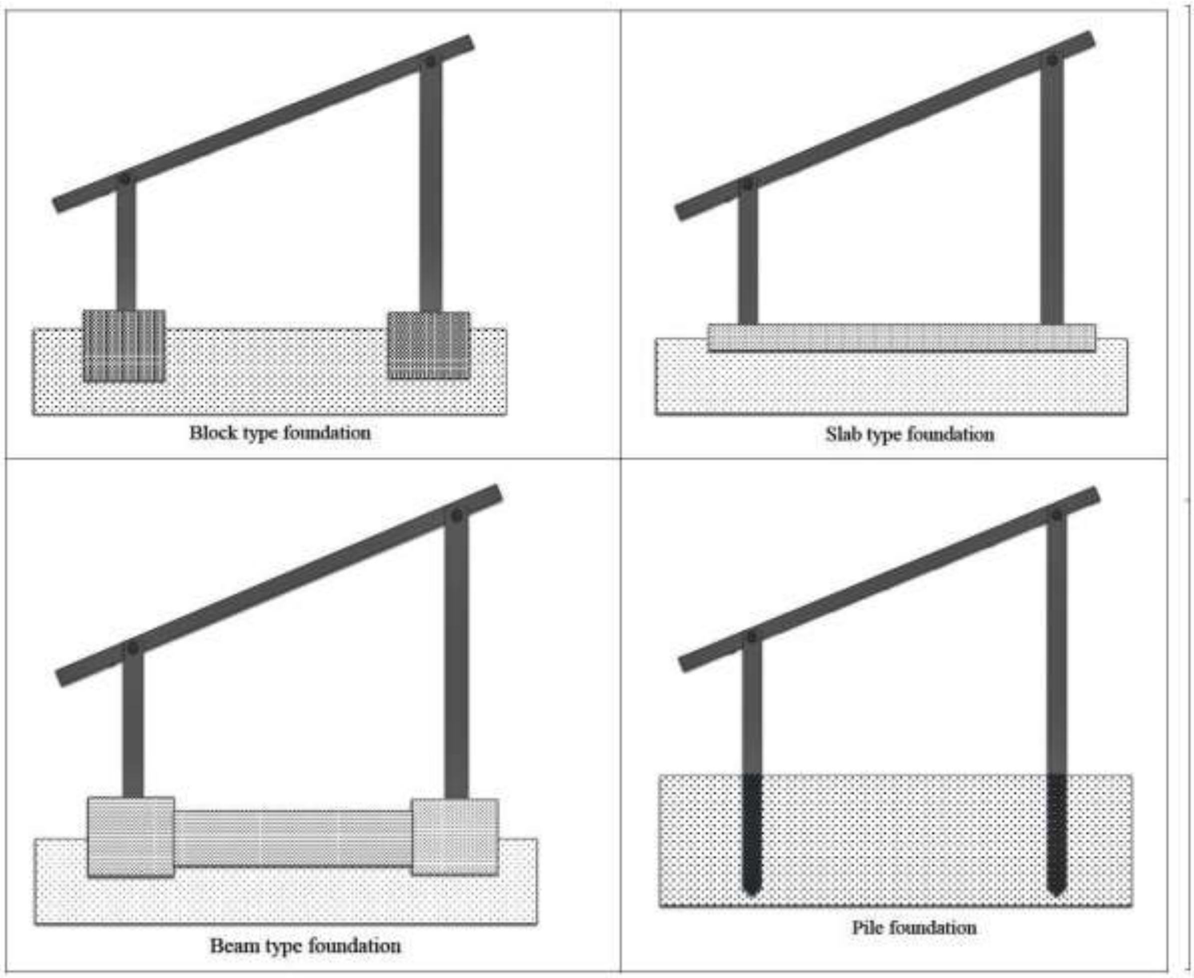
11.3.6.1 Foundation and Structural Alignment

The most critical element of foundation and structure installation is alignment. The points where the mounting structure is to meet the foundation must be level, and the mounting bolts must be spaced correctly. It is very important to take the measurements carefully, both for spacing and for flatness. The orientation of the foundation must face true south.

11.3.6.2 Type of foundations for mounting structure

Foundation for array mounting structure may be different for different sites, type and load bearing capacity of soil, wind velocity, waterlogging possibility and type of mounting structure. Conceptual drawing of foundation type generally used to hold PV array structure are presented below:

Figure 11-10: Various types of foundations for mounting structure



11.3.6.3 Installation of Mounting Structure

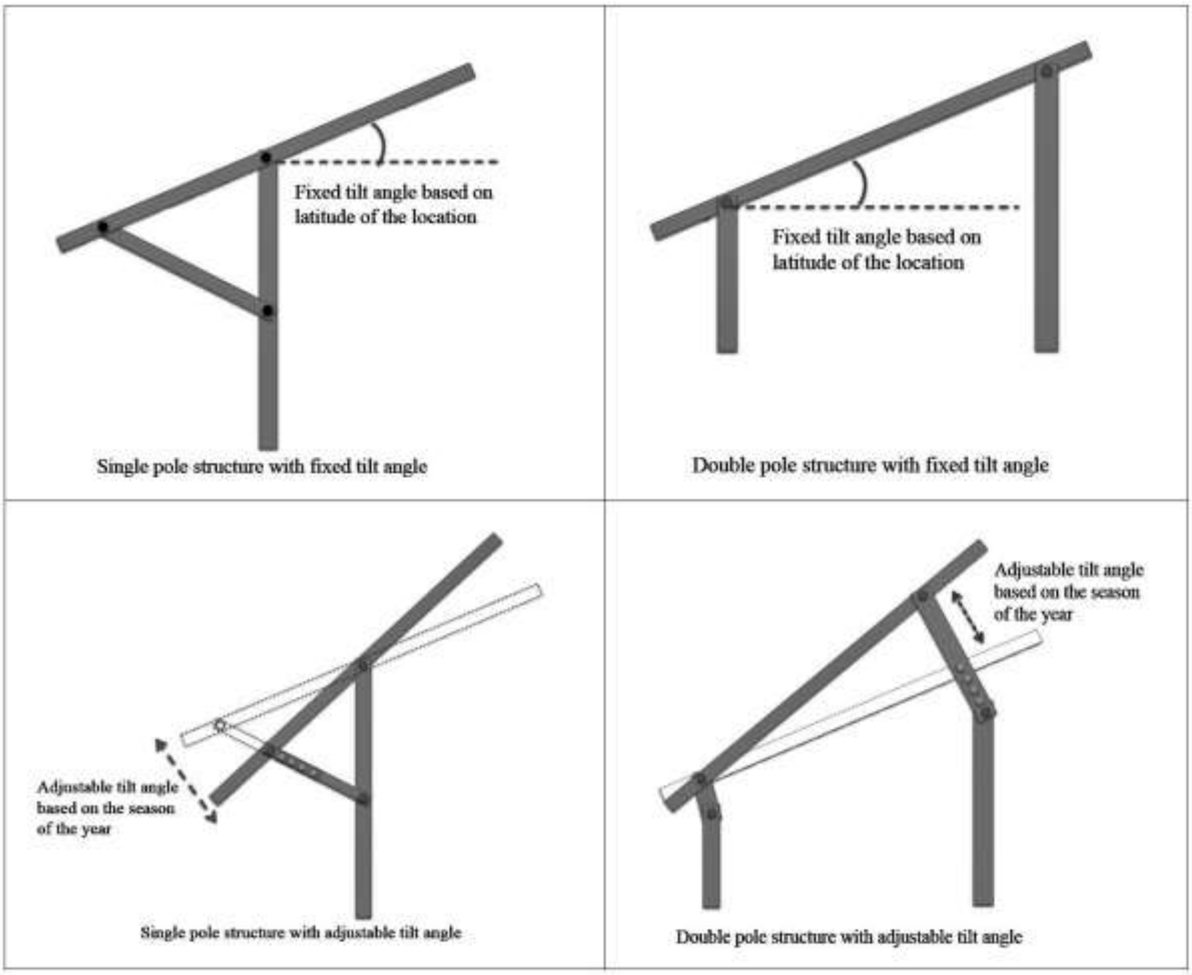
Generally, PV arrays for solar microgrid system are installed in the ground as there is ample of space available in rural area and finding an appropriate roof for installation of PV arrays may not be easy.

The ground mounting system has the following advantages:

(1) It is easier to have seasonal or daily tracking provision in a ground mounted structure
(2) Easy cleaning and maintenance access of PC array
(3) Better air flow keep the modules cool hence will have better performance
(4) Easy maintenance of structure, cable tray, electrical connectors and cable etc.
(5) Easy to expand PV array capacity if required

Array mounting structure could be of different types depending upon site, system capacity maintenance plan, type of soil, wind velocity, waterlogging possibility etc. Conceptual drawing of few commonly used array structures are presented below:

Figure 11-11: Various angles for Installation of Mounting Structure



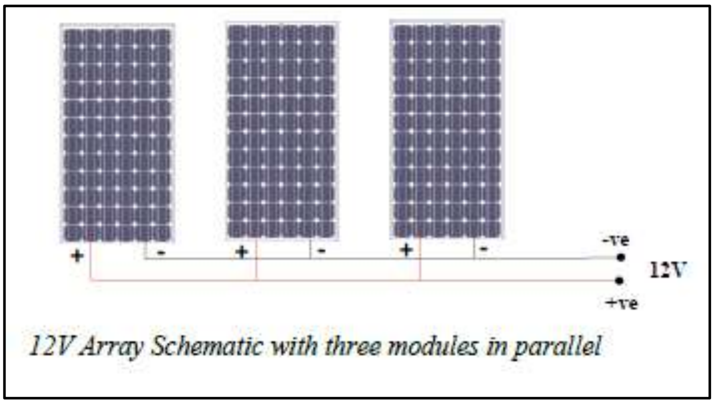
11.3.6.4 Array Installation and Wiring

Once the mounting structure is in place, modules are placed on to it and fixed properly. Modules are pre-wired with MC4 connector before fixing to the structure. Modules are connected together in series and parallel as per design. It is necessary to draw the module interconnection diagrams before connecting them in series or parallel. This can be done in two steps, first for clarity as a theoretical schematic, and then actual details as they would be installed. Examples of module interconnection for 12V, 24V and 48V array configuration are presented below.

11.3.6.4.1 12 Volt Array Wiring

The schematic arrangement of a 12V array involves placing the modules side by side, with all the positive terminals connected in parallel. The current from each module adds to give the total array current, while voltage of the entire array is the same as the voltage of one module. The schematic below shows three numbers of 12V modules connected in parallel.

Figure 11-12: 12 V array Schematic with three modules in parallel



The installed wiring of 12V array modules would have all the positive connected together in parallel, and all the negative connected together in a bus bar of a junction box or with the help of a MC4 multi-branch connector as shown in the figures below.

Figure 11-13: Two 12 V modules are connected in parallel in a junction box

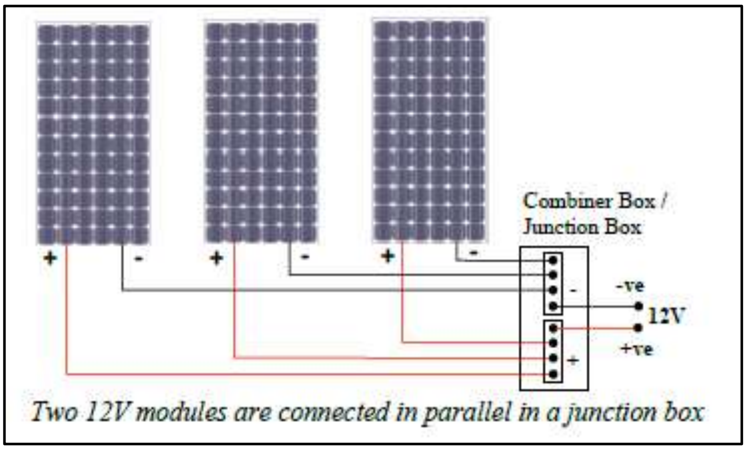
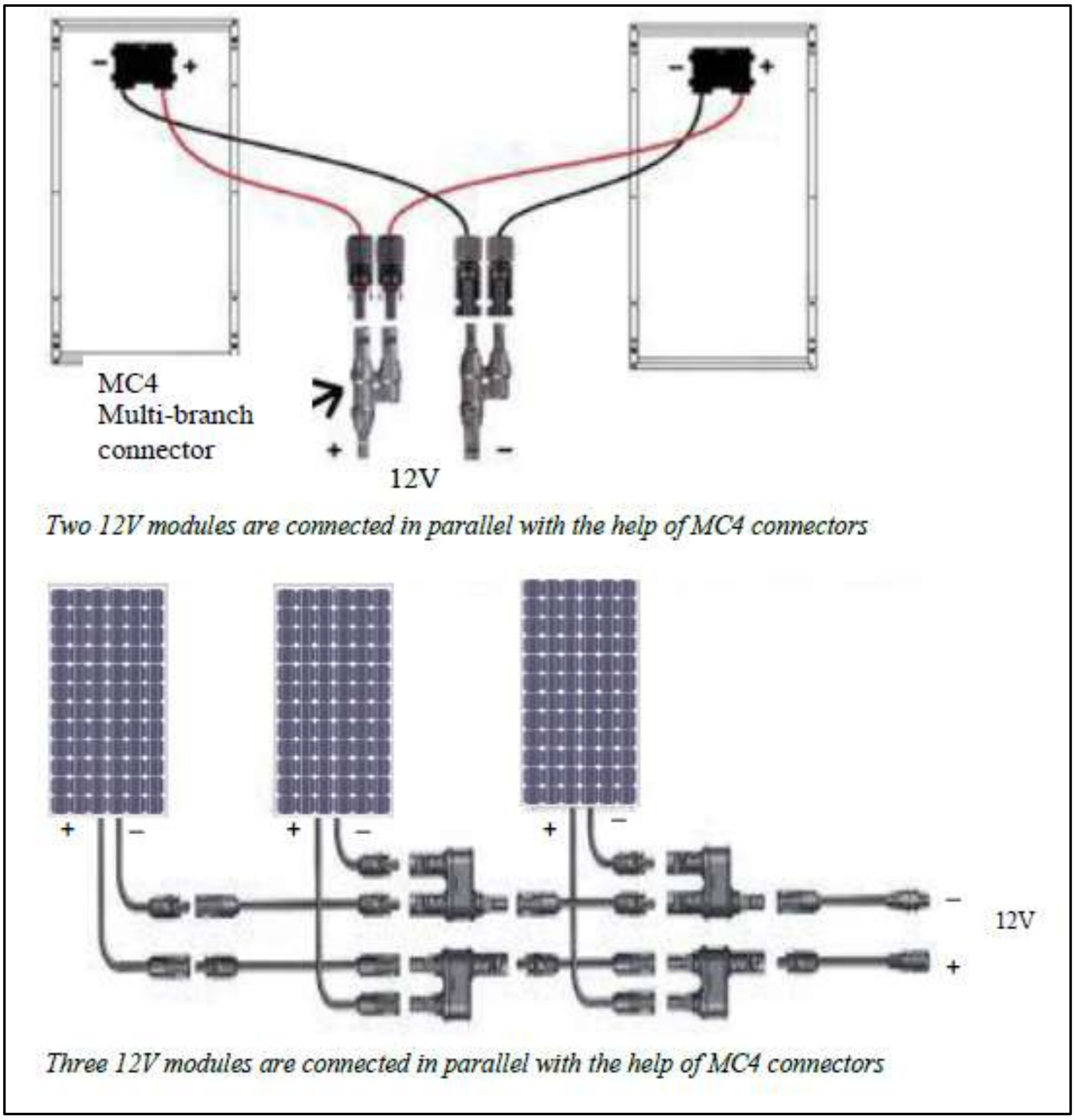


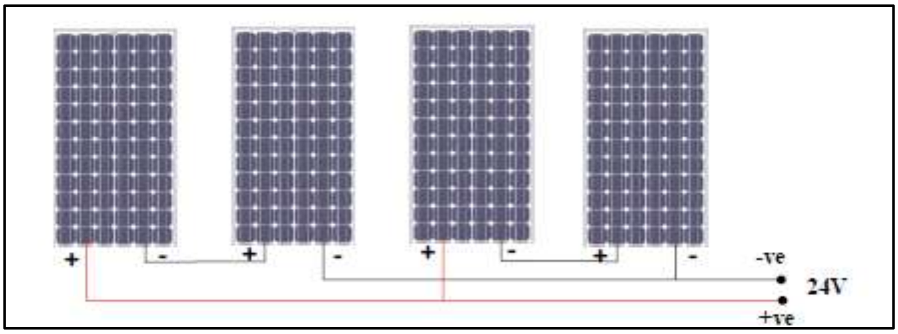
Figure 11-14: Two and three 12 V modules are connected in parallel with the help of MC4 connectors



11.3.6.4.2 24 Volt Array Wiring

For a 24V array, two modules are connected in series (string). Any number of such strings can then be connected in parallel to give the required current. A schematic view of a 24V array is shown below. In this example, two 12V modules are connected in series string to produce 24V and two such strings are connected in parallel to get required current.

Figure 11-15: two 12V modules are connected in series string to produce 24V



24 Volt Array Wiring Schematic

In actual field installation, two 24V strings will be connected in parallel in a common bus bar of a combiner box/ junction box or with the help of a MC4 multi-branch connector as shown in the figure below.

Figure 11-16: ***Two modules in series string and two strings in parallel connected through a junction box***

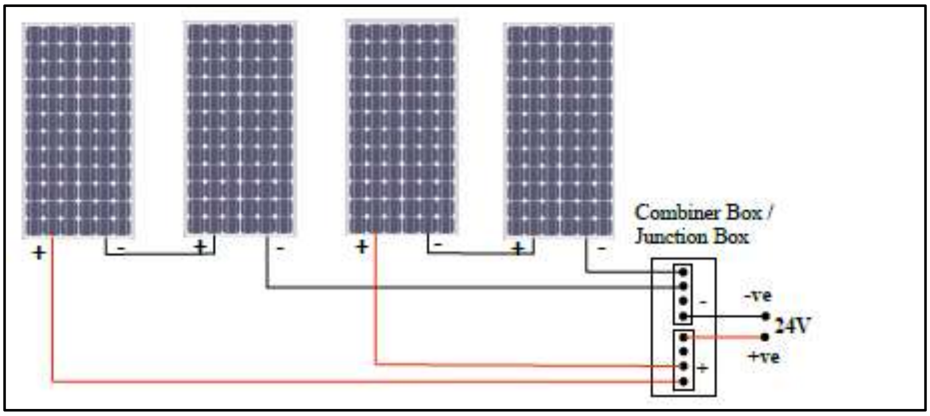


Figure 11-17: Two modules are connected in series with the help of MC4 connectors

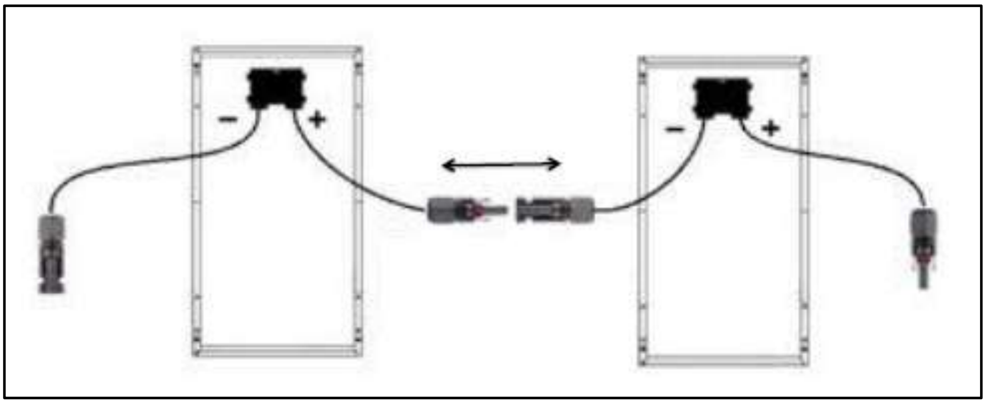
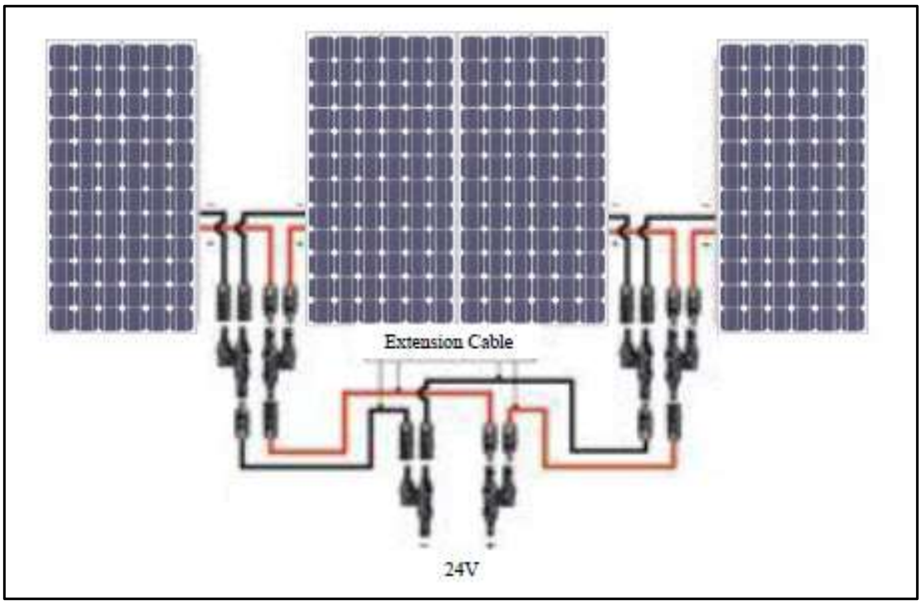


Figure 11-18: Two modules are connected in series and two strings are connected in parallel with the help of MC4 connectors



11.3.6.4.3 48 Volt Array Wiring

In the case of 48V system, we need four modules connected in series. Strings of four modules can be combined in parallel to give final array current. Example in the figure below shows two strings of 48V are connected in parallel.

Figure 11-19: 48 Volt Array Schematic with 4 modules connected in series and two strings connected in Parallel

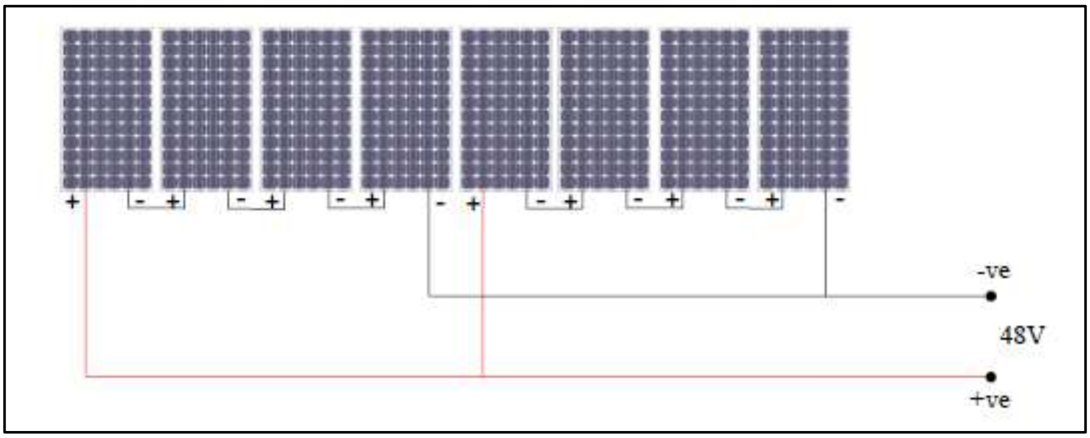


Figure 11-20: Four modules are connected in series string and two strings are connected in parallel through a junction box

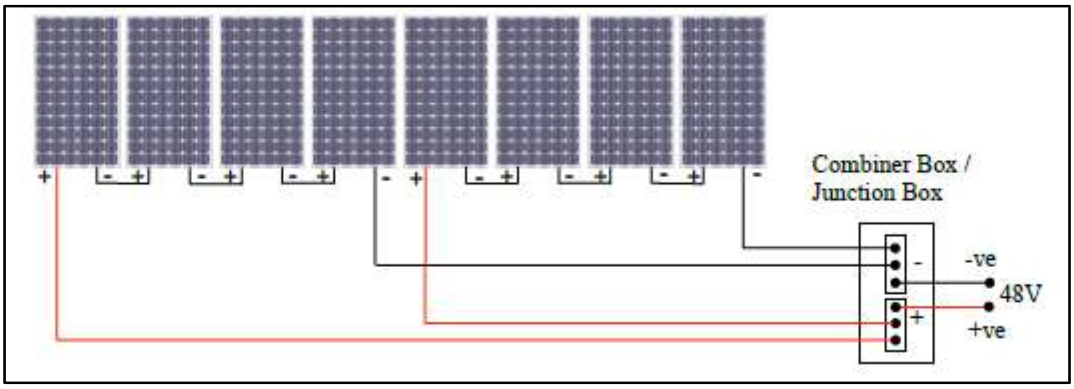
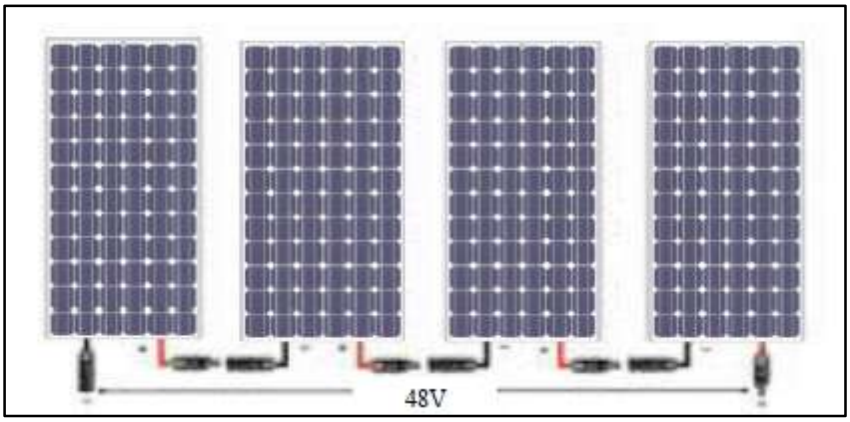


Figure 11-21: Four modules connected in series string with the help of MC4 connectors



11.3.6.5 Battery Installation

It is essential to check the following before installation of batteries:

- Review battery safety procedures
- Do not mount the batteries directly on a concrete floor. Mount onto wooden or other non-conducting rails.
- Make sure the batteries are fully charged and that the electrolyte level is at manufacturer's recommended level.
- Check all cell voltages and write down on a status sheet for later comparison.
- Handle batteries with extreme care and use the tools carefully. The greatest danger will occur if wires are hastily connected, or if tools are dropped onto the bare battery terminals.
- All connections should be "walked through" a few times, perhaps with another installer present to confirm, before actual wiring is done.
- Make sure to place a sign at the batteries warning unauthorized personnel about the dangers.

11.3.6.6 Battery Wiring:

Similar to solar modules, batteries are connected in series and parallel to achieve required voltage and capacity. To operate at a higher voltage, batteries are connected in series. Examples of wiring of battery bank at different voltage configurations and capacity are shown below.

11.3.6.7 PCU/ Inverter

As SPV array produces direct current electricity, it is necessary to convert this direct current into alternating current and adjust the voltage levels to match the grid voltage. Conversion shall be achieved using an electronic Inverter and the associated control and protection devices. All these components of the system are termed the "Power Conditioning Unit (PCU)". In addition, the PCU shall also house MPPT (Maximum Power Point Tracker), an interface between Solar PV array & the Inverter, to the power conditioning unit/inverter should also be DG set interactive. The power conditioning unit should also have provision of charge controller in case of systems with battery backup.

11.3.7Disposal

The regulator in charge of E-waste management and the importer shall work together to ensure adequate disposal of solar photovoltaic parts after they served their purpose.

11.4 Scope of work for Contractors

11.4.1Broad scope of work

The broad scope of work would include design, supply, installation, commissioning of the mentioned rating of Solar PV Power Plant in the Bill of Material and providing manpower for O&M services of Solar PV Power Plant for at least 1 (One) year from the date of handing over. This would inter-alia include;

1. Supply of the complete systems, including all necessary components, subcomponents, spares, consumables, tools & tackles etc. as per technical specifications given elsewhere in this document.
2. Erection and commissioning of the supplied systems at the specified site.
3. Providing the control room near the building along with necessary partition with glass and aluminium frame structure works.
4. Providing pedestals if required for mounting of the PCUs and control panels.
5. All structural drawings to be got approved from the Employer.
6. Any other work urgently required as per site conditions.
7. The selected contractor shall provide detailed Operation & Maintenance Manual in English and local language for all the systems.
8. Fabrication, supply and the installation of suitable support for the PV panels and other components whichever is required with the accessories.
9. Civil work (grouting) for PV structure and foundation for control room.
10. SPV Power Plant shall be installed as per the specifications provided in the technical offer.
11. Provide electrochemical marking (embossing) on each solar module frame which will show name of manufacturer, year of installation and capacity of solar module.
12. Supply and installation of control equipment's required for the system.
13. Training to the users for operation and maintenance of the system.
14. Any additional works not covered above, but necessary for the functioning of the system and required as per specification incorporated. The items of minor nature, which are not mentioned, shall be incorporated by the Contractor.
15. Regarding actual work to be carried out at the site, Contractor needs to execute the work in coordination with EDCL.

16. The Contractor shall provide the necessary training to identified representative of the Employer and Owner for proper daily operation and maintenance of installed systems after being taken over by Employer.
17. All cabling and load connections should be carried by the Contractor with proper synergy with the existing electrical systems of the project site.
18. The Contractor will provide sufficient LED Signages powered by solar.
19. The Contractor shall quote for Comprehensive Maintenance Contract for 1 years from the date handing over of the project.
20. The CMC period shall be 1 years from the date handing over of the project. The Contractor need to visit the installation monthly and carry out regular servicing of installed systems and submit monthly performance reports of installed systems to the Project Manager of the Project.
21. During the visit, contractor shall check the complete solar panels for any deficiency. If any deficiency is noticed, the same shall be rectified within 24 hours.
22. At the event of any fault occurred shall be duly communicated to the firm through mobile/email by EDCL in charge or concerned of EDCL which has to be attended within 24 hours and communicated to Employer/Owner.
23. The contractor shall have to appoint well qualified technicians to attend faults and provide maintenance services of all the solar panels to be installed for next 1 (One) year from the date of Handing Over/Taken Over.
24. Sufficient quantity of required spare parts shall always be available with their employed qualified technicians for prompt service.
25. Any minor equipment and material may not be specifically mentioned in this specifications but are required to make the system complete in a every respect in accordance with technical specification shall be deemed to have been covered under the scope of this specification and shall be provided by the tenderer / supplier within the quoted price.
26. Any other activity required for keeping the contracted solar panels operational for maximum time shall also be ensured by the firm.

11.4.2Quality and Workmanship

Solar PV modules are designed to last 25 years or more. It is therefore essential that all system components and parts, including the mounting structures, cables, junction boxes, distribution boxes and other parts also have a life cycle of at least 25 years. Therefore, all works shall be undertaken with the highest levels of quality and workmanship.

11.4.3Warranty and Maintenance

1. The PV modules will be warranted for a minimum period of 25 years from the date of supply. (Output wattage should not be less than 90% at the end of 10 years and 80% at the end of 25 years).
2. The mechanical structures, electrical components including evacuation infrastructure and overall workmanship of the Solar PV Rooftop power plant system must be warranted for a minimum of 5 years from the date of commissioning and handing over of the system.

3. The Comprehensive Maintenance (within warranty period) shall be executed by the firm themselves or through the authorized dealer/ service centre of the firm in the concerned district.
4. Necessary maintenance spares for five years trouble free operation shall also be supplied with the system.
5. The contractor/ bidder shall be responsible to replace free of cost (including transportation and insurance expenses) to the purchaser whole or any part of supply which under normal and proper use become dysfunctional within one month of issue of any such complaint by the purchaser.
6. The service personnel of the Successful Bidder will make routine quarterly maintenance visits. The maintenance shall include thorough testing & replacement of any damaged parts. Apart from this, any complaint registered/ service calls received / faults notified in the report generated by the IVRS should be attended to and the system should be repaired/ restored/ replaced within 4 days.
7. Normal and preventive maintenance of the SPV Power Plant systems will also be the duties of the deputed personnel during quarterly maintenance visits.
8. During operation and maintenance period of the SPV Power Plant systems, if there is any loss or damage of any component due to miss management/miss handling or due to any other reasons pertaining to the deputed personnel, what-so-ever, the supplier shall be responsible for immediate replacement/rectification. The damaged component may be repaired or replaced by new component

Table 11-5: Warranties and/or guarantees for solar rooftop systems

Sl. No	System/component	Warranty (Years)	Performance Requirement	Workmanship / Replacement Guarantee (Years) with an equivalent standard
1.	Roof top solar PV system	5	Minimum CUF of 13% (annual basis) Power plant Performance Ratio minimum 70%	-
2	Solar Modules	25	Minimum 90% power output at the end of 10 years & minimum 80% power output at the end of 25 years	10
3	Inverter	5	Warrants the products including functioning of built-in options and against defect of material	5
4	Power Evacuation and Metering Equipment	-	NA	10
5	Balance of Systems	-	NA	10 (parts and workmanship)
6	Power Plant Installation	-	NA	10

Sl. No	System/component	Warranty (Years)	Performance Requirement	Workmanship / Replacement Guarantee (Years) with an equivalent standard
7	PV Array Installation	25	Structural Breakage and Corrosion	-

11.4.4Data Acquisition System / Plant Monitoring

1. Data Acquisition System shall be provided for each of the solar PV plant.
2. Data Logging Provision for plant control and monitoring, time and date stamped system data logs for analysis with the high quality, suitable PC. Metering and Instrumentation for display of systems parameters and status indication to be provided.
3. Solar Irradiance: An integrating Pyrano meter / Solar cell based irradiation sensor (along with calibration certificate) provided, with the sensor mounted in the plane of the array. Readout integrated with data logging system.
4. Temperature: Temperature probes for recording the Solar panel temperature and/or ambient temperature to be provided complete with readouts integrated with the data logging system.
5. The following parameters are accessible via the operating interface display in real time separately for solar power plant:
    a. AC Voltage.
    b. AC Output current.
    c. Output Power
    d. Power factor.
    e. DC Input Voltage.
    f. DC Input Current.
    g. Time Active.
    h. Time disabled.
    i. Time Idle.
    j. Power produced
    k. Protective function limits (Viz-AC Over voltage, AC Under voltage, over frequency, Under frequency ground fault, PV starting voltage, PV stopping voltage.
6. All major parameters available on the digital bus and logging facility for energy auditing through the internal microprocessor and read on the digital front panel at any time) and logging facility (the current values, previous values for up to a month and the average values) should be made available for energy auditing through the internal microprocessor and should be read on the digital front panel.
7. PV array energy production: Digital Energy Meters to log the actual value of AC/ DC voltage, Current & Energy generated by the PV system provided. Energy meter along with CT/PT should be of 0.5 accuracy class.
8. Computerized DC String/Array monitoring and AC output monitoring shall be provided as part of the inverter and/or string/array combiner box or separately.
9. String and array DC Voltage, Current and Power, Inverter AC output voltage and current (All 3 phases and lines), AC power (Active, Reactive and Apparent), Power Factor and AC energy (All 3 phases and cumulative) and frequency shall be monitored.
10. Computerized AC energy monitoring shall be in addition to the digital AC energy meter.

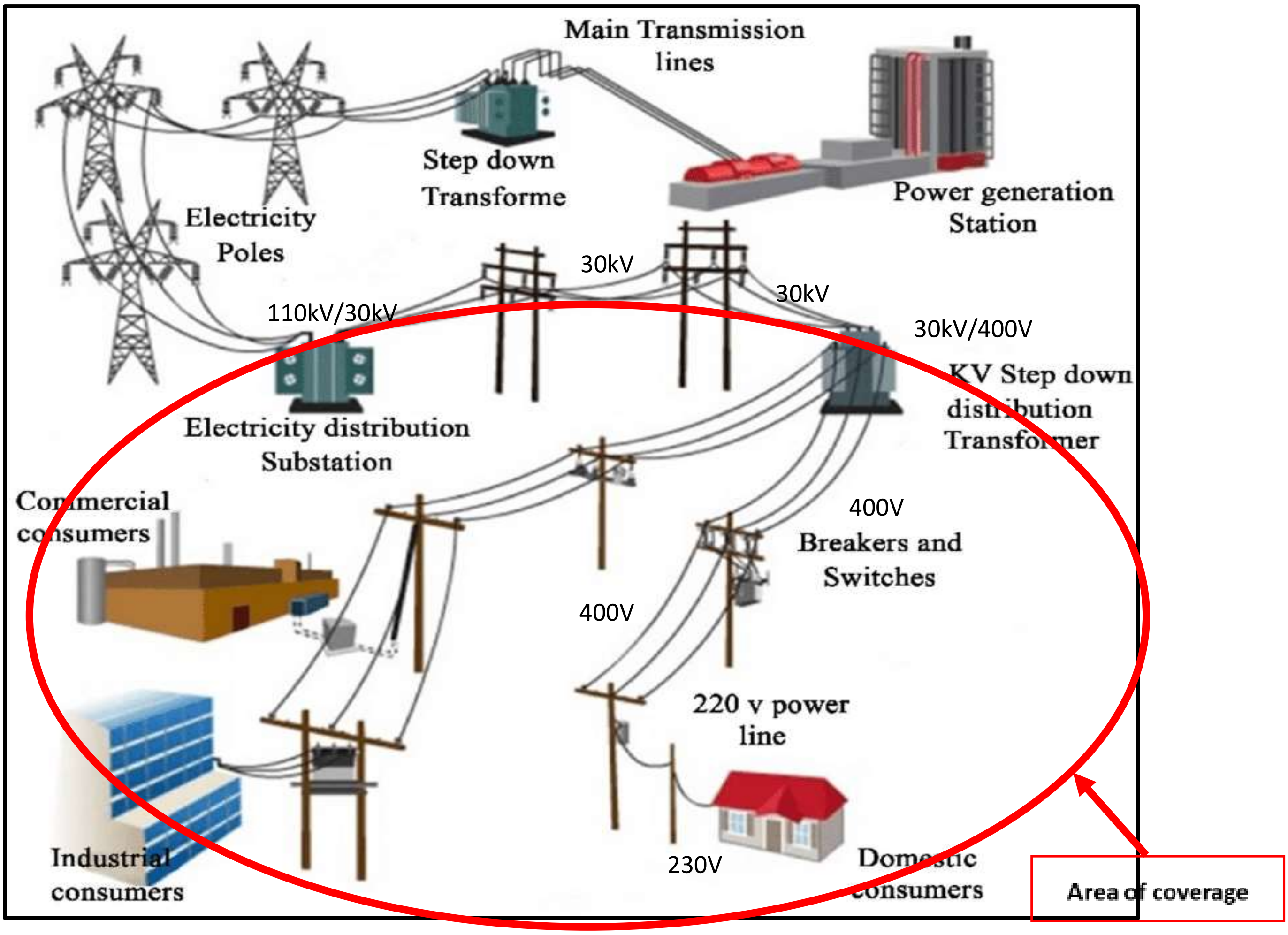
11. The data shall be recorded in a common work sheet chronologically date wise. The data file shall be MS Excel compatible. The data shall be represented in both tabular and graphical form.
12. All instantaneous data shall be shown on the computer screen.
13. Software shall be provided for USB download and analysis of DC and AC parametric data for individual plant.
14. Provision for instantaneous Internet monitoring and download of historical data shall be also incorporated.
15. Remote Server and Software for centralized Internet monitoring system shall be also provided for download and analysis of cumulative data of all the plants and the data of the solar radiation and temperature monitoring system.
16. Ambient / Solar PV module back surface temperature shall be also monitored on continuous basis.
17. Simultaneous monitoring of DC and AC electrical voltage, current, power, energy and other data of the plant for correlation with solar and environment data shall be provided.
18. Remote Monitoring and data acquisition through Remote Monitoring System software at the owner / EDCL location with latest software/hardware configuration and service connectivity for online / real time data monitoring / control complete to be supplied and operation and maintenance / control to be ensured by the bidder.
19. Any minor equipment and material may not be specifically mentioned in this specifications but are required to make the system complete in a every respect in accordance with technical specification shall be deemed to have been covered under the scope of this specification and shall be provided by the tenderer / supplier within the quoted price.

Section-12. Overview and Scope of Work for Grid Extension

12.1 Overview of Power Network

The key of successful power delivery to the load center is to design and implement a reliable and stable distribution network. Power provision to individual customer's premises can be enhanced through a proper and efficient electrical power distribution system. Typically a grid connected distribution network consists of substations, primary feeder (MV lines), Distribution Transformers (DT's), and distributor (LV lines) and service mains (Customer connections).

Figure 12-1: Typical diagram of Electrical Power Network



12.2 Scope of work

As shown in the above Figure 12-1, the scope of project is to construct the distribution network below 110/30kV electricity distribution substation up to the last mile connectivity in the un-electrified villages. The detailed scope of work includes the following major works;

1. Supply, Erection, Testing & Commissioning of all materials as per relevant IEC/RS for the following works;
    a. Laying of medium voltage line (30kV line & 15 kV where necessary),
    b. Installation of distribution transformers,

c. Installation of low voltage lines (0.400 kV), and
d. Energising the customer’s household.

Table 12-1: Rating of equipment used for implementation of project

Distribution Transformers		Medium Voltage lines (30kV & 15 kV where necessary)		Low Voltage lines (400V)		Customer Connections	
Rating	**Quantity (Nos.)**	**Rating**	**Quantity (KMs)**	**Rating**	**Quantity (KMs)**	**Rating**	**Quantity (KMs)**
15 kVA	563	ACSR Steel 120	27.84	Twisted cable 3x70	226.86	Customer Connections	431366
25 kVA	515	ACSR Steel 70	1137.55	Twisted cable 3x35	13248.01		
50 kVA	365						
100 kVA	58						
160 kVA	3						

12.2.1New Medium Voltage Lines

12.2.1.1 Survey

Mapping of route of proposed new 30 kV & 15 kV where necessary line by foot survey in project areas to be performed mentioning various milestones. While surveying, existing electrical infrastructure in the area should also be mapped. Line alignment (single line diagram) on political map with fair correctness, be prepared.

12.2.1.2 Support (pole):

Following type of supports are envisaged for new 30 KV overhead lines-

- MV light use (S140) (wooden pole)
- MV medium (S190) (wooden pole)
- MV stout (S255)(wooden pole)
- 12m Sectional Steel Tubular pole for special use as per Construction standards (650 - 800 daN)
- 12m Concrete pole for special use as per Construction standards
- 14m Sectional Steel Tubular pole for special use as per Construction standards
- Wooden Pole for H-poles structure for extra-long spans (S190)

12.2.1.3 Fabricated steel items:

Fabricated steel items like MV Anchoring cross arm 2.5m &2bolt, MV Anchoring cross arm 2.5m &2bolt, with braces & 3 Bolts (2*M16x50mm, 1*M16x350mm), MV Anchoring cross arm 3m & 2bolt etc. shall be made of MS Channels, MS angle, MS flats as per relevant Rwandan Standards. Fabricated steel structure items shall be hot dip galvanized and cleaned till good surface finish.

12.2.1.4 Hardware:

MS Nuts, bolts and washers (Galvanized) shall be used for tying of overhead structure items like cross arms, top clamps, brackets, clamps, bracing, strain plates etc.

12.2.1.5 Stay Set:

Stay Structure including Stay collar, tension screw, stay wire, base plate, guy grip, stay insulator, Strut pole Structure (Type S140), and Overhead (FLYING) Stay Structure shall be used at all turning locations, conductor dead end location, double pole structure, triple pole structure, four pole structure to nullify the tension of conductor. At dead end locations, stay sets shall be used in pairs in separate foundations. Erection of storm guys at suitable location in straight line may also be provided.

12.2.1.6 Earthing:

Following earthing arrangements are envisaged for new 30 kV lines:

- Earthing of Link structure
- Earthing of all Steel poles (galvanized steel tape, earth rods)

GI flats and GI wires must be properly dressed, bundled and fixed on supporting structure at 1 to 2 feet intervals.

12.2.1.7 Insulator and hardware –

30 KV polymer Disc/Pin insulator with suitable hardware fittings shall be used. Insulator should be tied properly using binding wire and tape/helical form fitting. In road crossing and line crossing locations bridling cross arms and pin insulator shall be used.

12.2.1.8 ACSR Conductor:

Following ACSR Conductors are envisaged for new 30 kV lines:

- ACSR Steel 120
- ACSR Steel 70

Care should be taken while drawing conductor from the drum. Proper roller should be used while handling conductors during erection. Proper sag should be maintained using sag chart table. While tensioning, care should be taken to avoid tension on pin insulator. Therefore, proper alignment of line to be ensured. Conductor joint should not be in the middle span but may be planned nearer the support.

12.2.1.9 Pole numbering:

Each support pole should be numbered properly labelled with indication marks (number or digits). 40/50 mm height digits/words should be used for this purpose.

12.2.1.10 Anti-climbing device:

Galvanized barbed wire shall be used on each 30 kV support. Galvanized barbed wire should be properly dressed and crimped at termination. While wrapping the wire on support, proper tension should be maintained.

12.2.1.11 Danger board:

Each MV support should be provided with a danger board with pole clamps as per approved drawing. Danger board should be in bi-lingual languages (local language and English). Clamp for danger board, nut-bolts and washers shall be painted with two or more coats of red-oxide and aluminium paints respectively till smooth surface before installation.

12.2.1.12 Outdoor 30 kV & 15kV wherever necessary AB Switch:

30kV link stick operated Air Break Switch 600A including cross arm (pole excluded), AB Switch shall be installed at cut points and at suitable locations as per instructions of Project Manager.

12.2.1.13 Support foundation:

Cement concrete in mixture 1 part cement, 1.5 part coarse sand, 3 part 40mm size aggregate stone chips (1:1.5:3) shall be used in all the types of 30 kV line supports.

12.2.1.14 Tree-cutting/trimming of tree:

The Contractor shall count, mark and put proper numbers with suitable quality of paint at his own cost on all the trees that are to be cut/trim to obtain required tree clearance.

12.2.1.15 Statutory clearances:

During execution of 30 KV Line work, all statutory clearances shall be ensured for ground clearance, line-to-line clearance, road crossing clearance, horizontal and vertical clearances from buildings/objects etc. All road crossings and line crossings shall be guarded as per specifications. Conductor joint should not be provided in mid span length. Instead, it should be nearer to the support.

12.2.2 Distribution Transformers

12.2.2.1 Survey of Distribution Transformer Substations:

A detailed survey of existing village shall be performed showing population residing in the un-electrified area/existing electrified area of village, best location of installation of a new distribution transformer substation and the capacity of transformers to be selected for installation.

12.2.2.2 Types of support are envisaged for Distribution Transformer Substation:

- Steel Poles 12m for 3 Phase Transformer of all ratings
- Concrete Poles 12m for 3 Phase Transformer of all ratings

12.2.2.3 Fabricated steel items:

Fabricated steel items like MV Anchoring cross arm 2.5m &2bolt, MV Anchoring cross arm 2.5m &2bolt, with braces & 3 Bolts (2*M16x50mm, 1*M16x350mm, 1*M16x300mm), MV Anchoring cross arm 3m & 2bolt etc. shall be made of MS Channels, MS angle, MS flats as per relevant Rwandan Standards. Fabricated steel structure items shall be hot dip galvanized and cleaned till good surface finish.

12.2.2.4 Hardware:

MS Nuts, bolts and washers (Galvanized) shall be used for tying of overhead structure items like cross arms, top clamps, brackets, clamps, bracing, strain plates etc.

12.2.2.5 Stay Set:

Stay Structure including Stay collar, tension screw, stay wire, base plate, guy grip, stay insulator, Strut pole Structure (Type S140), and Overhead (FLYING) Stay Structure shall be used at all turning locations, conductor dead end location, double pole structure, triple pole structure, four pole structure to nullify the tension of conductor. At dead end locations, stay sets shall be used in pairs in separate foundations. Erection of storm guys at suitable location in straight line may also be provided.

12.2.2.6 Distribution Transformer:

Following type of distribution transformers are standardized in the project:

- 25kVA 30/0.4kV Transformer-three phase
- 50kVA 30/0.4kV Transformer-three phase
- 100kVA 30/0.4kV Transformer-three phase
- 160kVA 30/0.4kV Transformer-three phase

12.2.2.7 ACSR Conductor:

ACSR Steel as per the requirement is to be used for connection between overhead lines to transformer studs/bushing.

12.2.2.8 Distribution box and Power Cabling:

Distribution boxes to be erected at least from 1m from ground, electrically connected with the existing system, properly earthed, and labelled. The test report of pre-commissioning checks should be prepared and submitted.

12.2.2.9 Earthing:

MV earthing

- Generally, overhead earth conductor shall be installed on the lines. However, where the shield wire was not installed, alternative lightning protection will be installed.
- Where the shield wire exists, it should be earthed at every set of links, switchgear, power transformer locations and at a sufficient number of additional points with made or existing electrodes to total not less than four grounds in each 1.6 km of the entire line.
- On lines where the shield wire was not installed, the earthing system shall comply with the
- following requirements:
    - MV networks are earthed through surge arresters at each transformer installation, and at each additional set of surge arrestors on the network.
    - Surge arresters must be installed at every set of links, switchgear and transformer.
    - No section of the line longer than 3km must be without protection by surge arresters. On long rural lines where there are no transformers or switchgear, surge arresters must be installed every 3km of line length.
- On the Transformer installation, the following items are all commonly earthed to ground.
    - MV Surge arrestors or/and shield wire
    - Transformer bed
    - Transformer earth stud

- LV DB metal enclosure

- All copper earth work on the transformer installation is done with 25mm² Stranded Copper wire or 25 mm² steel wire in high theft areas where copper is stolen.
- Transformer MV installation is earthed at the transformer structure with 25mm² copper earth spikes.

Earthing is done with a continuous earth wire in a 1m deep 3m long trench from the transformer pole. Additional earthing must be installed if the grounding resistivity is not low enough.

- The total earth resistance of the LV network shall not exceed 10 Ω.
- The MV earthing resistance at the transformer shall not exceed 5 Ω.
- If the desired earthing is not measured, additional earthing must be installed.
- Every metallic pole must be earthed according to the level of voltage of the line

12.2.2.10 Insulator and hardware:

30 KV polymer Disc/Pin insulator with suitable hardware fittings shall be used. Insulator should be tied properly using binding wire and tape/helical form fitting. In road crossing and line crossing locations bridling cross arms and pin insulator shall be used.

12.2.2.11 Substation numbering:

Each Substation should be numbered properly labelled using yellow base and black indication marks (number or digits). 40/50 mm height digits/words should be used for this purpose.

12.2.2.12 Anti-climbing device:

Galvanized barbed wire shall be used on each sub-station support. Galvanized barbed wire should be properly dressed and crimped at termination. While wrapping the wire on support, proper tension should be maintained.

12.2.2.13 Danger board:

Each support should be provided with a danger board with pole clamps as per approved drawing. Danger board should be in bi-lingual languages (local language and English). Clamp for danger board, nut-bolts and washers shall be painted with two or more coats of red-oxide and aluminium paints respectively till smooth surface before installation.

12.2.2.14 Support foundation:

Cement concrete in mixture 1 part cement, 1.5 part coarse sand, 3 part 40 mm size aggregate stone chips (1:1.5:3) shall be used in PCC Pole, steel tubular poles and H-Beam support foundation.

12.2.2.15 30KV or 15 kV wherever necessary AB Switch:

30kV link stick operated Air Break Switch 600A including cross arm (pole excluded), AB Switch shall be installed on distribution transformer substation. B Class GI pipe shall be used (without any joints) for operation of switch. AB Switch structure and handle must be earthed using 8 SWG GI wire.

12.2.2.16 30 KV or 15 kV wherever necessary Drop Out Fuses:

30 kV, 3-ph, Drop Out fuse units (set of 3 units) along with Support Insulators, Base Channel, fuse barrel etc. shall be used for all capacity Distribution Transformer Substations. DO Fuse structure shall be earthed using 8 SWG GI wire.

12.2.2.17 Lighting Arrester:

Distribution Class LAs on each phase shall be provided in the sub-station with base steel structure, terminals bi – metallic connectors and earth connectors. LAs are to be connected with separate earth connection.

12.2.3 New LV Line

12.2.3.1 Survey:

Mapping of route of proposed new LV line by foot survey in rural areas be performed mentioning various milestones. While surveying, existing electrical infrastructure in the locality should also be mapped. Line alignment (single line diagram) on political map with fair correctness, be prepared.

12.2.3.2 Type of cable:

The LT line between distribution transformer LVDB and customer shall be on LT Areal Bunched cables of following sizes:

- 3*70mm^2 +54.6mm^2 ABC
- 3*35mm^2 +54.6mm^2 ABC

12.2.3.3 Support for LT overhead Line:

- 9m Wood pole for LV Line
  - LV light use (S140)
  - LV medium (S190)
  - LV stout (S255)

12.2.3.4 Fabricated steel items:

Fabricated steel items like clamps, stay clamp, etc shall be made of MS Channels, MS angle, MS flats as per relevant Rwandan standards. While fabricating, good quality electrical cutting tools and drill machine shall be used to ensure no sharp edges and perfect holes.

12.2.3.5 Hardware:

MS Nuts, bolts and washers (Galvanized) nuts, bolts & washers shall be used for tying of overhead structure wherever required.

12.2.3.6 Galvanized Stay Set

Stay Structure including Stay collar, tension screw, stay wire, base plate, guy grip, stay insulator, Strut pole Structure (Type S140), and Overhead (FLYING) Stay Structure shall be used at all turning locations, cable dead end locations to nullify the tension of the cable.

12.2.3.7 Earthing arrangements:

Earthing

The Multiple Earthed Neutral (MEN) system must be used for LV earthing.

Men System for LV

- The LV is not earthed at the Transformer Structure.
- The LV is earthed on the first pole away from the transformer and every five poles for each LV feeder and Spur off feeder.

LV earthing general

- LV down earthing is done with $16mm^2$ stranded copper conductor, stapled or saddled to the pole at least every 400mm.
- LV down earthing can be done with 25 mm^2 steel wire in high theft areas where copper is stolen.
- Bi-metal PG clamps must be used for connecting the earth to the overhead ABC conductor.
- The earth wire shall be stapled to the pole down to the ground level of the pole and from there coiled around the pole down to the bottom. An additional 1m earth wire shall be coiled under the base of the pole.
- The metallic enclosure of the LV DB on the transformer installation is earthed to the MV side. All LV bus bars inside the DB, including the neutral bus bar are insulated (1000V) from the case of the DB.
- Over all LV Earthing resistance must be lower than 10 Ohm.
- The main incoming cable from the transformer must be connected to a 10 kA LV surge arrestor that must be earthed to the LV Neutral.

12.2.3.8 Distribution box:

Single phase or three phase distribution box shall be provided for extending power supply to LT customers. Distribution Box (DB) shall be mounted on LT pole with MS clamp of 40x3 mm size duly painted. DB shall be earthed using 8 SWG GI wire. The distribution box shall be installed only at locations where customer connections are provided.

12.2.3.9 Support foundation:

Cement concrete in mixture 1 part cement, 1.5 part coarse sand, 3 part 40 mm size aggregate stone chips (1:1.5:3) shall be used in steel tubular Concrete poles and LT line supports.

12.2.3.10 Tree-cutting/trimming of tree:

The Contractor shall count, mark and put proper numbers with suitable quality of paint at his own cost on all the trees that are to be cut/trim to obtain required tree clearance.

12.2.3.11 Statutory clearances:

During execution of LT Line works, all statutory clearances shall be ensured for ground clearance, line-to-line clearance, road crossing clearance etc.

- The earthing point of distribution transformer should be extended to the single phase beneficiary premises having en-route earth connection at every 6th supports. The earth conductor is to be connected with earth point provided in the premises of single phase customers. The bearer wire shall be earthed at every sixth pole.
- Bearer wire of LT AB cable shall be anchored through eyehook or dead end (anchor) clamps.
- Extra length of continuous AB cable along with messenger / bearer wire shall be properly dressed and clamped.

12.2.4 Customer Connection from Service Pole

12.2.4.1 General arrangement:

- Service connections are of the overhead type, connecting directly from the pole to the house and fixed onto the house's roof structure or the wall by means of a suitable tension clamp with eye bolt or pigtail bolt, bearing in mind that the service connections would also have to support the communications cable of the split pre-payment meter.
- Metering shall be done through split pre-payment meters where the metering unit will be situated on the pole and the customer keyboard would be situated at external wall (not exposed to sunlight and rain) of the customer dwelling.
- The minimum distance of Service cable to ground should not be lower than 3 meters (normal terrain) and 6 meters (crossing the road). When this vertical clearance is not respected, intermediate pole between the last LV pole and the house must be inserted. The intermediate pole (9m, 6m or 4m) shall be provided with suitable clamps and in case of metallic pole, it must be earthed.
- Ready boards may be supplied to selected low income customers in Villages where materials for wiring are scarce.

Section-13. Quality Control Plan for systematic monitoring of electrification works.

13.1 Quality Management System

13.1.1 Objective

The objective of the Quality Management System is to lay down clear guidelines for all contractor (including their associates, staff and agents) which would facilitate them to observe all statutory rules and regulations, comply with applicable standards of regulating authority for Technical Standards for Construction of Distribution Network & measures relating to safety and electric supply & Relevant Standard Drawings & Installation Standards etc. thus, ensuring good Execution Quality in all Installations in EDCL for all stakeholders of our network.

13.1.2 Scope

All contracts related to physical Electrical & Civil works in any installation will be subject to the provisions of this document.

13.1.3 General Guidelines

Contractor shall comply with **Statutory Requirements related to Installation Quality** and submit the "Installation Quality Undertaking" as per *annexure 1.*

The contractor will appoint Quality supervisor, engineer / manager for the project work. The Contractor shall make all necessary arrangements for getting their workforce trained and competency checked from the Engineer In-charge of EDCL before deployment in the field. Quality Representative of contractor will formally become the nodal point for quality concerns for EDCL & shall have dual reporting i.e. to EDCL QA group & Contractor. Contractor will be required to provide all applicable infrastructure and power to ensure smooth working of the quality representative to maintain a sound quality management system. Quality representative will not be assigned any other activity at site apart from the works related to quality management. EDCL will be auditing the facilities provided to the BA's quality team time to time. He shall be responsible for providing the MIS and/or any other relevant information, as and when desired, within the stipulated time frame as per the requirements of EDCL. Any non-conformance to quality will lead to the negative marking or issue of Quality violation challan/ tokens which shall affect the performance evaluation of Contractor.

13.1.4 Requirements from the Quality Representative(s) of the contractor:

Quality Supervisor/Representative: It is mandatory that educational qualification of Quality supervisor be Diploma (Electrical engineering) and he has a working experience on electrical system / network of at least 5 years or Graduate (Electrical engineering) with working experience on electrical system / network of at least 2 years having formal experience of the quality systems will be an added advantage.

13.1.5 Duties of Quality Representative:

1. Installation Quality training of 3hrs/employee/month and half day of quality training to all new employees joining the Contractor will be conducted by the Contractor.
2. Quality Talk before start of work at site.

3. Ensuring the availability of materials required for ensuring quality.
4. Ensuring the adherence to standard quality procedures of EDCL.
5. Quality inspections / audits as per the process of EDCL.
6. Submission of Field Quality Plans for Major works & Working in close coordination with Inspection & Quality Assurance Group of EDCL.
7. Reporting of major Non Compliances in Quality to Engineer In-Charge and QA Group of EDCL immediately after its occurrence.
8. Ensuring compliance with installation quality and other laws as may be applicable and providing for Quality assurance.

The Contractor shall not deploy any person at work place / site without quality Induction Training. It is desired that quality representative of the Contractor to impart the general quality training to each employee of duration 4 hours per month. The training will be organized at Contractor level and the record to be sent to engineer in-charge and QA group of EDCL every month.

All new Contractor supervisors have to necessarily undergo half day Quality training and Competency assessment at EDCL.

List of Quality Assurance Guidelines, EDCL Approved Drawings & Installation Standards as applicable to works should be available at site Supervisor for reference by executing team, EIC, Inspection & Quality Group.

Inspections & Quality Audit: The Contractor shall get the required Quality inspection / audit conducted by his technical team comprising of quality representative. The quality representative of Contractor shall inform and educate for the reduction of Non Compliances observed to employees, supervisor and engineer as well as the engineer in-charge and QA group of EDCL.

The Contractor has to provide monthly "Performance Report – Quality" to engineer in-charge and QA group EDCL along with training details. Refer Annexure-2 for more details.

13.1.6Quality Violation/Best Practices

EDCL can implement Execution Quality Index (EQI) to measure the performance of project in which every project is rated based on various parameters.

- The Engineer In-Charge or QA group will conduct surprise & normal audits of the work / project and if any non-conformance is found the same will be booked and entered in the format "Quality Violation Record". The flow of the information is given below:

Table 13-1: Monitoring Process for Best Practices & Non Compliances in Installation Quality

Action	Responsibility
Report for Non compliances & Best Practices observed has been filled and counter foil sent to QA team for information. The main report is to be given to Contractor supervisor / Engineer in-charge.	Engineer In-charge/ QA / Any authorized EDCL official.

Action	Responsibility
Entry of the Major Non compliances & Best Practices in the master record and sending the information to concerned Manager, HoG, HoD,	QA Group
MIS with CAPA of major Non compliances & Best Practices to be shared with all concerns. The data shall be used for Quality Initiatives in EDCL	I&QA Group

EDCL can implement Execution Quality Index(EQI) to measure the performance of project in which every project is rated based on various parameters related to quality of Project planning & execution. EDCL expects all contractors to support EDCL in improvement of Installation Quality. Contractors shall ensure Zero Defect Installation in Projects. Best contractors shall contractors shall be eligible for “Best Contractor in Installation Quality” as decided by competent authority.

13.2 Execution Quality Index– A Tool for Measuring Project Performance

13.2.1Abstract

Power Distribution sector need to strengthen by augmentation of Lines & Transformers to cater to the load growth. For effective completion of Projects, there is a need to monitor the performance of Projects in a holistic manner. The performance of any project is characterized by its quality, Cost & Time of execution. In addition, the quality of Project execution also affects the safety of men & material associated with the utilization of assets created during & after project execution. Considering these challenges, EDCL can adopt a single index i.e. Execution Quality Index (EQI) to measure the Project Performance on various parameters i.e. Time, Cost, Budget, Quality & Safety.

13.2.2Introduction:

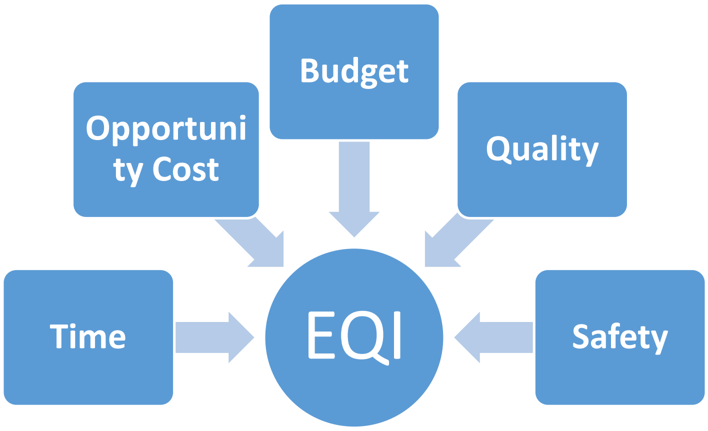
Power sector especially Electric Distribution had been going through a bad phase. Governments felt the need to strengthen the Distribution sector by augmentation of Lines & Transformers to cater to the load growth. In order to achieve it, a lot of improvement projects have been planned for completion as per schedule within statuary guidelines through designated agencies. For effective completion of Projects, there is a need to monitor the performance of projects in a holistic manner. Every utility has different parameters to judge the project performance.

In an environment where power distribution utilities across the Africa are reeling under heavy losses and experiencing acute power shortages, the key performance factor has been the optimal and effective deployment of technology interventions through a comprehensive roadmap.

Now, the performance of any project is characterized by its quality, Cost & Time of execution. In addition, the quality of Project execution also affects the safety of men & material associated with the utilization of assets created during & after Project execution. Since all these factors affects the utility in one or other way, it is important to monitor the Projects in holistic manner to ensure internal & external customers satisfaction. Utilisation of assets starts after energization of installations duly certified by Third Party official. In addition, Performance Assurance guidelines by Regulator specifies the maximum cycle time compliance & compensation.

Based on upcoming challenges, utility can adopt a single index i.e. Execution Quality Index (EQI) to measure the Project Performance on various parameters mentioned below.

EQI = 0.2 T+ 0.2 C + 0.2 B + 0.2 Q + 0.2 S



Where;

Execution Time Index (T) – Ratio of Duration of execution of Project starting from date of Approval of scheme & date of Capitalization by Finance group (Lesser the delay in scheduled capitalization time, higher is the index).

Cost Performance Index (C) – Relative Measure of opportunity cost of Project Delay measured as interest of 10% per annum on capitalization amount per month on a period of delay of project from scheduled completion time(Higher the delay in capitalization of Scheme, there will be exponential effect on the factor, lower is the index).

Budget Deviation Index (B) – Ratio of Deviation in Budgeted scheme amount wrt Actual execution Amount as compared to that of Budgeted scheme amount (lesser the deviation higher the Index).

Quality Compliance Index (Q) – Indicative of % of Non-Compliances (NCs) observed in Quality of Installation out of total NCs possible in a Scheme as per checklist (Lesser the %NCs higher the Index).

Safety Compliance Index (S) - Adherence to Safety Standards characterized by no. of Non Compliances in Safety Audit of Installation in a Scheme (Lesser the safety related non compliances higher the Index).

13.2.3Methodology:

The detailed Calculation Methodology of all indexes discussed above along with EQI is explained below.

Usually major steps in any Capex Process consists of following steps

EDCL Capex Process – Major Steps

1. Capex Scheme Proposal
2. Approval by Regulator/Management as applicable
3. Budget Allocation
4. Award of Contract
5. Project Execution
6. In House Inspection & Third Party Clearance
7. Technical Closure (TECO) of Project

8. Financial Closure & Capitalization of Project

In a utility, following issues have been observed in Project Management cycle

1. Some projects out of sample have been completed after scheduled completion date effecting timely utilization of capitalised asset & loss of revenue. Moreover, customer satisfaction has been effected due to delay in electricity connection. It is to be noted that the Capex Projects in EDCL have been approved by regulator who specifies the schedule of completion of projects which have to be adhered.
2. Scheme estimated amount is approved with a defined scope of work however deviations are observed (major in some cases) in final execution value of scheme due to change in cost, inaccuracy or change in scope of work at site. Due to deviations, the amendment takes time which affects the process. Also, Excess budget gets unutilized sometimes.
3. The no of non-compliances observed in quality of projects installations is also very important to comply with statuary guidelines & reduce the burden associated with O&M cost which gets increased due to rework in bad quality installations.
4. Similarly, there are unreported safety incidents which happened to be major & needs to be shared across organization. Safety of men & materials during execution is utmost important. Unsafe installations are hazard for general public & employees.

13.2.4Action Plan:

1 Brainstorming with all stakeholders
2 Decentralized Seekh Sessions/Meetings with Projects & Safety Group on Concept of EQI
3 Data Retrieval, Analysis & Release of EQI Reports of Projects
4 Reach Out Sessions with all members of Projects
5 Reach Out Sessions with Safety Group
6 Reach Out Session with all contractor
7 Feedback for improvement in EQI of Projects
8 Inclusion of EQI & Other Sub indexes in Functional BSC, Departmental & Individual KRAs of all concern including contractors Performance Evaluation
9 CAPA for EQI Report on sub-indexes to analyse & scale up OFIs & Best Practices
10 EQI Report for WIP Schemes – A Proactive Approach
11 Subsequent Rounds of Reach Out Sessions with POs & Vendor Supervisors
12 Interdepartmental Coordination to improve Processes etc. if any based on Feedback from all concern

13.2.5Results:

The monthly results can be released for various type of Projects separately. The formats of results have been mentioned in Annexure-2. The results consists of the following:

1. Detailed Report of all closed schemes indicating sub-indexes & EQI for all schemes
2. Summary of EQI & sub-indexes based on Geographical Area, Type of Schemes, contractor etc.
3. Trend Analysis of EQI
4. Impact of EQI on Financial, Quality & safety Parameters
5. Corrective & Preventive Action for sharing OFIs & Best Practices

The projects having EQI>=0.8 is rated as Green, between 0.5 to 0.8 as Yellow & Below 0.5 as Red. The concept of EQI can also be extended to ongoing projects by evaluating the current performance in terms of Time & Balance capitalization amount as a lead indicator for improvement in overall performance of the project

13.2.6Conclusions (Sample):

1. **Execution Time Index**
    a. Schemes having Execution time index less than 0.5 indicates that Scheme were capitalized with double time as compared to that of scheduled duration of scheme. The benefits associated with use of assets have been delayed to that extent.
2. **Cost Performance Index**
    a. Cost Performance Index of 0.58 indicates that the capitalization amount of Rs. 100(Approx.) in these schemes could have resulted in receipt of Return on Equity & Additional Revenue earlier as scheduled vis-à-vis actual now. The effective Project cost escalated to Rs.172 (approx.) due to delay as per calculation methodology.

3. **Budget Deviation Index**
    a. The Budget deviation index of less than 0.5 indicates more than 15% deviation in the approved scheme cost vs actual capitalized cost. The reasons should be analysed & necessary CAPA should be taken since it involves lot of rework & disturbs budget allocation process.
4. **Quality Compliance index**
    a. QCI of 0.9 signifies that on an average 20 defects are being observed in a scheme out of 100 defects which can happen in a scheme.
5. **Safety Compliance Index**
    a. SCI of 0.8 signifies that on an average 2 non compliances are being observed at site during execution.

13.2.7Benefits accrued:

Financial:

1. Increase in EQI will result Timely utilization of Capitalized Asset.
2. Improvement of Execution time index can result in savings for expected loss of interest on Capital employed for Project.
3. Timely Revenue finally hitting bottom line (Revenue for 06days)
4. Reduced Cost of Rework – High O&M Cost due to Non compliances in Installation quality
5. Proper Budget Allocation
6. Reduction in Amendments

Quality:

1. Reduction in Non Compliances in Installation Quality - Less O&M Cost
2. Network Reliability
3. Alignment with Capex Process
4. Process Quality – Linkage of EQI with Functional BSC, Departmental & Individual KRAs, Contractor Performance Evaluation

Safety
1. Capturing of Safety Observations in Projects
2. Safety Talks & CAPA

General:
1. Timely Completion of Projects leading to Internal & External customers
2. Reward & Recognition – Contractor Satisfaction
3. Effective Management Reporting
4. Concept of EQI for WIP Projects to have lead indicator

13.2.8Corrective Action Preventive Action:

1 **Execution Time Index**
   a. Continuous Monitoring of Schemes – Timely Reminders
   b. Right of Way (RoW) Permission from Road Owning Agencies
   c. Contractor Capacity & Capability Assessment

2 **Budget Deviation Index**
   a. Accuracy in Scheme Scope of Work
   b. Deviation in Estimation cost & Actual Cost per activity

3 **Cost Performance Index**
   a. Categorization of Schemes based on Cost benefit analysis

4 **Quality Compliance Index**
   a. Penalty clause in Contracts with Contractor for Non Compliances observed during Inspection of installations
   b. Compliance to Standards during execution
   c. Contractor Capacity & Capability Assessment
   d. Continuous Monitoring & Inspections
   e. Reward & Recognition

5 **Safety Compliance Index**
   a. Safety Visit for every Project Site
   b. Reward & Recognition

Overall, Execution Quality Index is holistic way of measuring performance of any project wrt quality of installation, Cost performance & Time of execution. The concept can be scaled up & replicated in all utilities & other organizations with minor modifications.

With the implementation of EQI, EDCL is committed to change the view of looking the Project execution in a different way in line with changing requirements.
Another First in EDCL - Adoption of Best Practices in Power Distribution Systems.

13.3 Vendor Performance Evaluation Criteria

13.3.1Process:

Post award and execution of contracts (after receipt of NDC against a PO/RC), contractors shall be evaluated based on the performance achieved by them on the following two approaches on a half yearly basis:

Approach – 1:

A. For Supply Contractor

Contractor Performance Score generated against preparation of GRN/SES for Timeliness & Quantity of material supplied

B. For Service Contractor

Table 13-2: Contractor Performance Measurement

S. No.	Parameter	Criteria for Scoring while preparing SES	Performance Measurement	Score Band		
1	Quality of Services	Consider whether Contractor meets the quality standards of executing the services as stipulated in the contract like Rework during installation and commissioning (first time right performance), Quality of documentation, etc.	Exceeded Requirements			
			Meets Requirements			
			Meets Minimum Requirements, substantial Improvement desirable			
			Did not meet the requirements			
2	Responsiveness	Consider whether the bidder submits the invoices on time Consider whether all the services as envisaged in the contract are being performed by the Contractor and whether the Contractor effectively communicates addressing your concerns, issues in a time bound manner	Exceeded Requirements			
			Meets Requirements			
			Meets Minimum Requirements, substantial Improvement desirable			
			Did not meet the requirements			

- The above scores shall be assigned by the Project Manager after completion of works.

Approach – 2:

Scores to be calculated as per the inputs received on performance of Contractor from respective groups. Please refer Table 5.1, 5.2 and 5.3.

Table 13-3: Contractor Performance Evaluation Mechanism for Supply Contracts

Sl. No.	Focus Area	Methodology	KPI	Responsibility Centre
1	Quality	Procurement Quality department acts as a nodal point to collect information on quality related issues from site in-	Quantum of quality issues	PQ group to maintain this data and provide the

Sl. No.	Focus Area	Methodology	KPI	Responsibility Centre
		charge, checks the gravity of issues and same information is used for scoring the vendor. Quantum of quality issues along with their severity (H, M, L) shall be communicated to Contracts by PQ on an half yearly basis. H - High: Work disruption due to the issue and material taken back by vendor for rectification and new material replaced at site. M - Medium: Partial Work disruption due to the issue but rectification done at site and material reused. L - Low: Quality issue reported but material continued in usage. No disruption in work.	reported along with severity	same to Contracts on half yearly basis. PQ group shall coordinate with all concern groups for the same
2	Safety	Inputs to be provided by Safety Group based on the following: 1. No. of Safety issues reported because of material quality/workmanship ....'S' 2. No. of Accidents reported because of inferior product quality/workmanship (Fatal or Non-fatal).... 'A'	No. of safety incidents	Safety group to maintain and provide the data as suggested

Table 13-4: Contractor Performance Evaluation Mechanism for Service Contracts

S. No.	Focus Area	Methodology	KPI	Responsibility Centre
1	Safety	Inputs to be taken from Safety Group on the following: 1. No. of Safety Violations (No Accident but violation in use of PPE, PTW etc.) 2. No. of Accident reported (Fatal or Non-fatal)	No. of safety incidents	Safety group to maintain and provide the data as suggested
2	Statutory Compliance	Contractor to be penalized in terms of performance based on their past track record with respect to statutory compliances stipulated timelines	No. of statutory non -compliances	BA-Legal Cell to maintain and provide the data as suggested
3	Timeliness	Contractor to be penalized in terms of performance based on their past track record with respect to LD deductions	%age LD deduction	Finance to provide the data

Table 13-5: Contractor Performance Evaluation Mechanism for Composite Contracts

S. No.	Focus Area	Proposed Methodology	KPI	Responsibility Centre
1	Quality	Procurement Quality department acts as a nodal point to collect information on quality related issues from site in-charge, checks the gravity of issues and same information is used for scoring the vendor.	Quantum of quality issues reported along with severity	PQ group to coordinate with all concern groups to maintain this data, and provide the

S. No.	Focus Area	Proposed Methodology	KPI	Responsibility Centre
		H - High: Work disruption due to the issue and material taken back by vendor for rectification and new material replaced at site or vendor needs to be replaced with another. M - Medium: Partial Work disruption due to the issue but rectification done at site and material reused or manpower reshuffled at site and operations continued. L - Low: Quality/ Service issue reported w.r.t. material/ services but usage continued. No disruption in work.		same to Contracts on half yearly basis.
2	Safety	Inputs to be taken from Safety group on the following: 1. No. of Safety Violations (No Accident but violation in use of PPE, PTW etc.) 2. No. of Accident reported (Fatal or Non-fatal)	No. of safety incidents	Safety group to maintain and provide the data as suggested
3	Statutory Compliance	Contractor to be penalized in terms of performance based on their past track record with respect to statutory compliances stipulated timelines	No. of statutory non -compliances	BA-Legal Cell to maintain and provide the data as suggested
4	Timeliness	Contractor to be penalized in terms of performance based on their past track record with respect to LD deductions	%age LD deduction	Finance to provide the data

13.3.2Classification of Contractor

Table 13-6: Classification of Contractor

Score	Classification of BA	Action to be taken
Score >= 80	Class I	To be continued in the approved vendor list without any requirement of re-registration
60 < Score <= 80	Class II	To be reviewed for registration continuation with EDCL once in two years
30 < Score <= 60	Class III	To be warned by a letter and if three consecutive times the supplier falls in Class III, then demote to Class IV
Score <= 30	Class IV	To be deleted from Approved Vendor List and case forwarded to screening committee for sending the Contractor on holiday

13.3.3Steps for Project Execution Flow:

1. Allocation of person Project Officer for the scheme/Project after receipt of Contract
2. Decision if Contract will be Turnkey or Non Turnkey
3. Apply Right of Way (ROW) Permission if applicable and get the estimation from land owning agency
4. Deposit the estimate and get the ROW permission
5. Receipt of Purchase Order/Contract Agreement from Contracts
6. Kick-off meeting & Site Visit with Vendor after award of PO
    a. Finalization of Safety Requirement at Site
    b. Finalization of Project Schedule
    c. Field Quality Assurance Plan
    d. Organogram of Contractor & Manpower details
    e. Obtain All Risk Insurance Policy from Contractor

f. Material & Drawing List
g. Any other Important point

7. Detailed Survey with Vendor for Scope Finalisation
8. Detailed Engineering of Project for Materials Specifications, Drawings & Design by Engineering Group
9. Mobilization of resources at site as per schedule for Execution at site
10. Coordination for Materials Inspection & Issue of Despatch Clearance
11. Execution of work /Delivery of Material at site
12. Stage Inspections at Regular Intervals of Installations in Progress especially Foundations, Earthing, Cable Laying etc.
13. Weekly Review Meeting with Contractor
14. Mid-term financial review of the project w.r.t Budget allocated (Monthly Basis)
15. Request for Amendment if Scheme amount is having with deviation in the overall cost. Amendment to be sought as per DoP, Work at site to resume only after the PO is amended or take the Management Approval to continue work
16. Release of amended PO with deviation
17. Completion of work as per order/requirements
18. Apply for In House Inspection Team of Quality Assurance Group
19. Point wise Compliance to Punch points observed during Inspection of Installations
20. Inspection by Third Party Agency/Regulator etc.
21. Pre Commissioning Tests on Equipment/Network
22. Energize the Equipment's and Handing Over- Taking over od Assets to User
23. Return dismantled materials and Joint Measurement of works executed
24. Material Reconciliation after returning of all excess/dismantled material
25. Up-dation of Network, Equipment As built drawing in GIS
26. Send final Order amendment measurement to Audit for verification. After verification Fwd. to contracts for PO amendment
27. Final Bill processing after release of PO amendment
28. Final Bill Certification of Vendor
29. Final Bill Cleared by Finance
30. If all PO's Final bills booked against the scheme/Project Then Activate Technical & Financial Closure of Project

13.4 Three Tier Quality Control Mechanism

13.4.1Overview of methodology

In order to ensure proper Quality of materials as well as in installations in Electrification Scheme, three tier Quality Control Mechanism (QCM) has been drafted. This Quality Control Manual established three tier QCM. The basic framework of the three tier QCM is stipulated below:

(i) Tier-I

A. Concern department in EDCL will nominate appropriate officer in organisation for inspection of material & installation to ensure quality assurance for first tier monitoring & quality control.

B. It shall include preparation of detailed monitoring & Quality Assurance Program, which should ensure quality checks as below:
   i. Inspections of all material as per Drawings/Technical Specifications,
   ii. Inspection of works at mid & final stage of installation.
   iii. All works to be inspected as per Filed Quality Plan (FQP), and
   iv. 100% verification of customer connections.

(ii) Tier-II

A. EDCL shall nominate officials from Design Engineering Department and Quality Assurance Department for inspection of material & installation in second tier Quality Control Mechanism.
B. The second tier Quality control shall ensure quality checks in appropriate no. of material inspection and installation inspections not less than 10% of total inspections.

(iii) Tier-III

A. The third tier Quality Control Mechanism will be an **optional stage**.
B. Some Funding Agencies may recommend a quality auditing Report from an Independent Quality Auditor.

13.5 Information Flow Procedure

1. Turnkey Contractor shall furnish all records of Quality of material/equipment and inspection report of Field checks performed during execution/installation by him to EARPQCC. The record must include at least followings:
   a) Manufacturing Quality Plans (IEC/REG Standards) of equipment/material
   b) FQP
   c) List of sub-vendors
   d) Acceptance tests report of equipment
   e) Type tests reports of equipment
   f) Routine tests reports of equipment
   g) Field inspections reports as per FQP

13.6 Guidelines for Quality Control during construction

1. Documents required - The supervision and inspection shall be carried out based on the following documents to be provided by the EARP :-
   a. Approved route map with pole schedule.
   b. Quality assurance plan agreed upon by the EDCL and the executing agency (contractor)
   c. Contract documents/Letter of award & special conditions of the contract
   d. Technical specifications of the turnkey contract, for supply and erection of all equipment and materials.
   e. Sanctioned Detailed Project Report (DPR) for the project district with all revisions/ modifications.
   f. Relevant drawings/ blue prints, area distribution maps and schematic diagrams.
   g. EDCL Specifications and Construction Standards –

h. Booklet of the Amendments to EDCL Specification and Construction Standards.
i. Rwandan Electricity Rules (RER)
j. PERT network

2. Project Monitoring & Supervision
   a. Physical verification: Physical verification has to be carried out in project villages, in each sanctioned project, in which electrification works & Customer services have been reported by the EDCL to have been completed or carried out.
   b. Monitoring teams: The project is to be monitored by a dedicated monitoring team. The verification will be based on the village wise progress reported which will be provided periodically at the end of each month by EDCL.
   c. Monitoring Report of the Third Party Agency
      The third party inspection agency will report the progress & quality of works as per the Monitoring & Inspection Report Formats provided in these guidelines. These formats cover the following:
      1. Project Parameter
      2. Highlights of major project monitoring observations of the project
      3. Village snap shots of each village visited covering
         a. Physical performance in the village
         b. Workmanship and construction standards
         c. Quality of materials & equipment in the village
         d. Adherence to Rwandan Electricity Rules
         e. Photographs of deficiencies & defects requiring rectification in the village

3. Supervision of quality of material used & works executed and construction standards adopted during construction.
   a. Supervision - The supervision & inspection of quality of materials & equipment used and works executed and construction standards adopted during construction, should be guided by the relevant portions/ sections of following guidelines and documents in the sequence they are mentioned here-under, for the type of works being undertaken as per the turnkey contract:-
      (i) Approved Drawings.
      (ii) The technical specifications, of the turnkey contract, for supply and erection of all equipment and materials, including the scope of works etc.
      (iii) EDCL Specifications & Construction Standards and amendments to EDCL Specification and Construction Standards.
      (iv) Rwandan Electricity Rules (RER)
   b. The important EDCL specifications for major & key material/ equipment and the relevant IEC standards/ specifications their code numbers generally applicable to projects being implemented under the electrification scheme, which need to be kept in consideration during the course of monitoring/ supervision/ inspection.

4. Adherence to Rwandan Electricity Rules (RER)
   The implementing agency shall adhere to the conditions stipulated in the relevant sections of Rwandan Electricity Rules in regard to construction, erection and commissioning of electric supply lines (overhead and underground) as well installations, systems and equipment, apparatus etc. for generation, transmission, supply and use of electrical energy as per the purpose and objects of the Rwandan Electricity Act.

13.7 Annexure-1: Quality Undertaking

I____________________________s/o__________________R/o_______________________(AUTHORIZED REPRESENTATIVE/PARTNER/DIRECTOR/PROPREITOR) of M/S ____________ (name of company/firm)__ having its office at (Complete address of Company), authorized vide power of attorney dated ------/Board resolution dated----/letter of authority dated----, hereinafter referred to as **Contractor** which expression shall, unless it be repugnant to or inconsistent with the meaning or context thereof, be deemed to include its heirs, executors, administrators, and assigns do hereby affirm and undertake as under :

1. The present undertaking shall remain in force from the date of execution of contract awarded by EARP and shall be valid till the date of termination of the said contract by either parties. The undertaking is binding on me (contractor) as well as my sub-contractor and its employees, representatives etc.
2. That I(the contractor) will be responsible and liable to comply and abide by all the Quality rules, instructions and regulations as may be specified and laid down by EDCL so as enable EDCL to achieve its goal of Zero Defects in Installations.
3. That the Contractor shall be fully responsible for ensuring competence towards Quality of its employees, representatives, agents as well as of its subcontractor's employees, at all times during the discharge of their respective obligations under the contract including any methods adopted for performance of their tasks / work.
4. That the Contractor shall engage adequate and competent Quality – Supervisor / Engineer / Manager / Skilled persons at site as per the Qualification and experience mentioned in Tender document.
5. That the Contractor shall engage the competent Site – Supervisor with each group of workers for good quality workmanship, proper co-ordination of material and site work as per contract.
6. That the Contractor and its subcontractors shall abide by all the Quality guidelines as per relevant Guidelines, Installation Quality management Document and other guidelines issued from time to time by EDCL during the contract period.
7. That in case the Contractor and/or any of its Subcontractor fail to ensure the compliance as required in terms of this undertaking the Contractor shall keep and hold EDCL / its directors / officers / employees indemnified against any / all losses / damage / expense / liability / fines / compensation / claims / action / prosecutions or the like which might be suffered by EDCL or to which EDCL might get exposed to as a result of any breach /wilful negligence /deliberate default on the part of the Contractor /Subcontractor in complying with the same.

(Signature with Stamp)

13.8 Annexure-2: General Conditions

A Contractor awarded a contract work of Project in area of a region will be required to fulfil the following conditions:

- Contractor shall provide Quality Policy & Quality objectives of its company.
- Contractor shall comply with all statutory requirements like: applicable acts, regulations, codes of practice, Standards, etc.
- Contractor shall abide by regulatory Guidelines & Installation Standards of EDCL.
- Contractor shall provide its organization structure & responsibilities in terms of Quality Management to EDCL.
- Contractor shall document the Field Quality Plans, work practices and procedures in terms of Quality Management during execution at site.
- Contractor shall ensure quality training and induction program for the employees
- Contractor shall conduct quality audits & inspections as per EDCL procedures provided by QA group.
- Contractor shall ensure periodic inspection of Tools & Instruments to ensure its serviceability & accuracy as per the specification given by EDCL.
- Contractor shall ensure the adherence to standard operating procedures or guidelines laid down by EDCL.
- Contractor shall ensure reporting of any Non Compliance in Quality to engineer in-charge and QA team of EDCL.
- Contractor shall provide performance and MIS report to engineer in-charge and QA Group monthly. Based on any performance in Installation quality, Performance evaluation of Contractor shall be done.
- Contractor shall ensure to depute a Quality representative for managing a complete Quality management system in the area.

13.9 Annexure-3: Field Quality Plan

					Table 13-7: Field Quality Plan-- Conductor, Earth wire & AB Cable erection (HT &LT)					
Contractor/Sub Contractor/ Agency Name & Address:					**Item: Conductor, Earth wire & AB Cable (HT & LT)**					
					System: Conductor, Earth wire & AB Cable					
Sub-System: 1 Conductor(AAAC,AAC,ACSR) erection										
Sl. No	**Main Activity & Operation**	**Characteristics / Instruments**	**Class of Check**	**Type of Check**	**Quantum of check-Contractor/** EARP**QCC**	**Quantum of check -TPIA/EDCL/ Independent Quality Auditor**	**Reference Document**	**Acceptance norms**	**Format of record**	**Remarks**
1	**Receipt and storage**	1) Receipt at stores	C	Visual check	100%	Random	Delivery challan	Correlation of the lot received with the delivery challan/mdcc descriptions	Stores register	Components which are inspected and cleared by EARP shall only be accepted on Receipt
		2) Visual inspection	C	Visual check	100%	Random		Drums found damaged during transit are stacked separately	Stores register	
		3) Storage	C	Visual check	100%	Random	Standard practice	Drums are stored on hard surface area	Stores register	
2	**Erection of conductor**	1) Handling of the conductor	C	Visual	100%	Random	Utility specification or as per acceptance norms	Conductor should not be dragged on the ground		Scratches or damages to the strands would occur if not handled properly
		2) Sequence of conductor erection	C	Visual	100%	Random	Utility specification or as per acceptance norms	Sequence of running out shall be from top to bottom, i.e.. The top conductor shall run out first, followed by the side conductors		

		3) Stringing of the conductors	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	Any damages to the strands shall be repaired with repair sleeves		
		4) Mid span jointing	**B**	Visual	100%	Random	Utility specification or as per acceptance norms	Compression type not more one joint per sub conductor per span		All joints and splices should be 15 meters away from the pole
		5) Binding the conductor to the insulator	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	As per the EDCL specifications		
		6) Erection at Road Crossings	**B**	Visual	100%	Random	Utility specification or as per acceptance norms	Guarding shall be provided at major crossings		The ground clearances at road crossings shall be as per relevant rules
		7) Anti-climbing devices	**B**	Visual	100%	Random	Utility specification or as per acceptance norms	Approved drawings		
		8) Danger Boards	**B**	Visual	100%	Random	Utility specification or as per acceptance norms	Approved drawings		

3	**Tensioning and Sagging**	1) Measurement of sagging	**B**	Visual	100%	Random	As per sag-tension charts			Tensioning and sagging operations are carried in calm weather, when rapid changes in temperature are not likely to occur
4	**Clipping**	1) Clipping the conductor in position	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	Manufacturer's recommendation		
		2) Jumpering at section and angle towers	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	Jumpers formed to parabolic shape		To ensure maximum clearance to equipment
Sub-System:2 Erection of Aerial Bunched Cable										
4	**Receipt and Storage**	1) Receipt at stores	c	Visual	100%	Random	Delivery challan/ mdcc	Correlation of the lot received with the delivery challan/ mdcc descriptions	Stores register	Components which are inspected and cleared by EARP shall only be accepted on receipt
		2) Visual inspection	c	Visual	100%	Random		Drums found damaged during transit are stacked separately	Stores register	
		3) Storage	c	Visual	100%	Random	Standard practice	Drums are stored on hard surface area	Stores register	

5	**Fixing of Eye Hook and Sus-pension / Dead End Clamps**	a) Eye Hook with pole through bolt								
		1) Check the threading's over the through bolt	C	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	
		2) Fix the through bolt into the pole	C	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	
		3) Check the alignment of bolt with the pole	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	
		B) Eye Hook with Eye Hook Clamp								
		1) Check the dimensions of the clamp and fix the clamp to the pole	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	
		2) Check the alignment of clamp with the pole	**C**	Visual	100%	Random	Utility specification or as per	As per approved drawing	Site register	The clamp should be exactly perpendicular to pole

							acceptance norms			
		c) Check the alignment of the eye hooks along the line	**C**	Visual	100%	Random	standard practice	Hooks shall be erected at same Elevation	Site register	where ever hooks are misaligned there should be replaced before conduct ring
		d) Fixing of suspension clams / dead end clamps	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	
6	**Erection of Cable**	1) Handling of the cable	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	Cable should be carefully handled to avoid and damage		Cable surface shall be free from faults, flaws etc.
		2) Sequence of cable erection	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	Sequence of running out shall be from top to bottom, i.e.. the top cable shall run out first, followed by the side cables		
		3) Fix the messenger wire of AB cable to clamps(Suspension/ Dead End Clamp)	**C**	Visual	100%	10%	Utility specification or as per acceptance norms	PIA specification/ as per approved drawing		
		4) Check the tightness of	**C**	Visual	100%	Random	Utility specification or	As per the standard practice		

		cable with clamps					as per acceptance norms			
		5) Check the Ground clearances after Erection of the AB cable	**C**	Visual	100%	Random	Utility specification or as per acceptance norms			The minimum ground clearances should be maintained
Sub-System:3 Erection of Earth wire										
7	**Receipt and Storage**	1) Receipt at stores	C	Visual check	100%	Random	Delivery challan	Correlation of the lot received with the delivery challan	Stores register	Components which are inspected and cleared by EARP shall only be accepted on receipt
		2) Visual inspection	C	Visual check	100%	Random		The surface of earth wire should be free from flaws and dust	Stores register	
		3) Storage	C	Visual check	100%	Random	Standard practice	earth wire should be stored in dry areas	Stores register	
8	**Erection of Earth wire**	1) Handling of the Earth wire	C	Visual	100%	Random	Utility specification or as per acceptance norms	Earth wire should be carefully handled to avoid any damage		Scratches or damages to the surface would occur if not handled properly
		2) Erection of Earth Knob	C	Visual	100%	10%	Utility specification or as per acceptance norms	Sequence of running out shall be from top to bottom, i.e. the top earth wire shall run out first, followed by the side earth wires		Check the clearance between earth knob and pin insulators and the components shall

										be erected as per drawing and as per spec
		3) StringiIng of the Earth wires	C	Visual	100%	Random	Utility specification or as per acceptance norms	All joints shall be compression type		Ground clearances should be maintained
Class of check: A – Critical, B – Major, C—Minor Name/ Signature of the sub-contractor/ Erection Agency										

Table 13-8: Standard Field Quality Plan for Cable

PROJECT / UTILITY : **CONTRACT No.** **CONTRACTOR :** **PACKAGE:**		**ITEM : ERECTION WORK** **SUB SYSTEM : CABLES** **STANDARD FIELD QUALITY PLAN FOR CABLE**							
		DATE							
Sr. No.	**Characteristics / Items**	**Type of Check**	**Instruments**	**Class**	**Quantum of check-Contractor/ EARQCC**	**Quantum of check - TPIA/REG/ Independent Quality Auditor**	**Reference documents & Acceptance Standard**	**“Format Of Records”**	**Remarks**
1	2	3	4	5	6		7	8	9
1	**Receipt & Storage**								
1.1	Receiving inspection (Completeness of documents, test certificates, etc.)	V	-	B	100%	Random	Delivery Challan	MRC	
1.2	Unloading	V	-	B	100%	Random	Instruction Manual	-	

1.3	Visual examination	V	-	B	100%	Random	Packing list / Instruction Manual	-	
1.4	Proper storage	V	-	B	100%	Random	Instruction Manual	-	
1.5	End Sealing (Cable ends are sealed by PVC cap to avoid ingress of moisture)	V	_	B	100%	Random		Site Record	
2	**Pre Installation**								
2.1	Unloading of Drums								
A	Check for drum mounting - cable wheel/ jack	V	-	B	100%	Random		Site Record	
B	Check for cable unwinding - cable wheel/ jack	V	-	B	100%	Random		Site Record	
C	Check for proper unrolling - Cable Wheel/ Jack	V	-	B	100%	Random		Site Record	
D	Check for cable end sealing	V	-	B	100%	Random		Site Record	
2.2	Availability of bricks at site for buried cables	V	-	C	100%	Random		Site Record	
2.3	Excavation of trench for U/G cable laying	V	-	C	100%	Random	Utility specification or as per acceptance norms	Site Record	
2.4	Sand Cushioning for buried cables	V	-	C	100%	Random		Site Record	
2.5	Ascertaining cable route and length	V	-	B	100%	10%	Cable Route	Site Record	
2.6	Conformity with cable schedule	V	-	B	100%	Random	Cable Schedule	Site Record	
2.7	Insulation resistance checking – Megger (500 V for LT & 1000V for Cables upto 30kV)	Electrical	Megger	A	100%	10%		Site Record	
2.8	Proper route maintaining during cable laying	V	-	B	100%	Random	Cable Route	Site Record	
2.9	identification and dressing of cables	V	-	B	100%	Random	Standard Practice	Site Record	
2.10	Use of trefoil clamps for single core cables	V	-	B	100%	Random	Standard Practice	Site Record	
2.11	Proper verticality of multicore cables	V	-	B	100%	Random	Standard Practice	Site Record	
3	**Installation**								

3.1	Removal of wooden planks from cable drum	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.2	Check cable is not dragged on hard ground	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.3	Check size of cable & cutting of cable length	V	-	B	100%	10%	Utility specification or as per acceptance norms	-	
3.4	Check the separation between different types of cables laid nearby.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.5	Check the laying of cables as per cable schedule.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.6	Check the cable tray are earthed as per the drawing.	V	-	B	100%	10%	Utility specification or as per acceptance norms	-	
3.7	Check the cable glands, lugs, ferrules, cable tag/ marker are provided as per requirement.	V	-	B	100%	10%	Utility specification or as per acceptance norms	-	
3.8	Check the cable drum/ cable to be laid for any external damage.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.9	Check the availability and functionality of the rollers.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.10	Check there are no damage / twisting of cables during laying.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	

3.11	Check that cables are protected from the sharp bends while laying.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.12	Check that the power cables are separated from the control cables.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.13	Check the phase matching at both end after each joint.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.14	Check cable tags are provided at required intervals/required places and both end as per cable schedule.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.15	Check the cables are dressed, clamped and supported properly as per the drawing.	V	-	B	100%	Random	Utility specification or as per acceptance norms	-	
3.16	Insulation Resistance Check	Electrical	Meggar	B	100%	10%	Utility specification or as per acceptance norms	Site Record	
3.17	Check whether some extra length (1.5 mtr.) is kept in each cable run for future use	Physical	-	B	100%	Random	Utility specification or as per acceptance norms	Site Record	
3.18	Check that all wall openings/ pipes/ sleeves are sealed to avoid seepage of water	Physical	-	B	100%	Random	Utility specification or as per acceptance norms	Site Record	
3.19	check that buried cables are covered with sand layers and by protective bricks	Physical	-	B	100%	Random	Utility specification or as per acceptance norms	Site Record	
3.20	Ensure that the location of underground cable joints are identified.	Physical	-	B	100%	Random	Utility specification or as per acceptance norms	Site Record	

Contractor’s Signature Name & Sign of Approving Authority

Legends :A – Critical, B – Major, C—Minor, TC : Test Certificate, V : Verify, EIC : Engineer In Charge

Table 13-9: Field Quality Plan for Civil Works									**DATE :**	
1	**Documents and Drawing**									
1.1	Check that the instruction manuals for all equipment have been received.		Physical		100%	Random	Bill of Material		Office record	
1.2	Check that the approved civil foundation plan of equipment are available.		Physical		100%	Random	Bill of Material		Office record	
2	**Civil works for equipment foundations**									
2.1	**Earth Work**									
2.1.1	**Before excavation**									
2.1.1.1	Check the pegs conditions as per line and alignment w.r.t. existing structure	Measure Tape	B	Visual	100%	Random	As per site EIC	As per site EIC	Office record	
2.1.1.2	Checking of pit marking as per drawing.	Measure Tape	B	Visual	100%	Random	Foundation plan	Foundation plan		
2.1.2	**Excavation work**									

2.1.2.1	Checking of pit marking / location	Measure Tape	B	Physical	100%	Random	Foundation Plan	Foundation Plan	Site record	
2.1.2.2	Check the dimension of pit at bottom (Lx Bx D)	Measure Tape	B	Physical	100%	Random	Foundation Plan	Foundation Plan	Site record	
2.1.2.3	Check the type of soil, if BC soil is confirmed follow the instruction on drawing for stone soling	Measure Tape	B	Physical/ Hammer-ing crobar	100%	Random	Foundation Plan	Foundation Plan	Site record	
Sr. No.	**Activity and Operation**	**Characteristics / Instruments**	**Class of Check**	**Type of Check**	**Quantum of check - contrac-tor/EARPQCC**	**Quantum of check - TPIA/REG/ Independent Quality Auditor**	**Reference Documents**	**Acceptance Norms**	**“Format Of Records”**	**Remarks**
2.1.2.4	Check the type of soil, if Non BC soil is confirmed follow the drawing.	Measure Tape	B	Physical/ Hammer-ing crobar	100%	Random	Foundation Plan	Foundation Plan	Site record	
2.3	Shuttering									
2.3.1	Check the shuttering board which are made to shape with steel tape including cleaning proper surface preparation.	Measure tape	B	Visual	100%	Random	Foundation Plan	Foundation Plan	Site record	
2.3.2	Placement of shuttering boards including supports, tie rod etc.	Tackling equipment	B	Visual	100%	Random	Foundation Plan	Foundation Plan	Site record	Required as per site condition
2.3.3	Measurement, line and level with steel tape & water level.	Steel tape & water level	B	Visual	100%	Random	Foundation Plan	Foundation Plan	Site record	
2.3.4	Check placement, alignment & embedment of anchor bolts,	Measure tape	B	Visual	100%	Random	Foundation Plan	Foundation Plan	Site record	

	Check no oil on inserts (For foundation bolts)									
2.3.5	Check bolt setting with templates.	Measure tape	B	Visual	100%	Random	Foundation Plan	Foundation Plan	Site record	
2.4	Cement									
2.4.1	Cement - Received from Sup-Plier	Review of TC/ As per IS	A	Visual	One of consignment	Random	Utility specification or as per acceptance norms	Manufacturer's Test Certificate	Site Record	
2.4.2	Setting Time & Compressive strength	Review of TC/ As per IS	A	Visual	One of consignment	Random	Utility specification or as per acceptance norms	Manufacturer's Test Certificate	Site Record	
2.5	Reinforced Steel									
2.5.1	Visual Examination to ensure free from cracks, surface flaws, imperfect edges and dimensional checks		B	Visual	100%	Random	Utility specification or as per acceptance norms & Approved Drawings	Approved Draw-ings	Site Record	
2.5.2	Cutting, Bending, placing of reinforced steel bars & lapping	Tackling Equipment	B	Visual	100%	Random	Approved Drawings	Approved Draw-ings	Site Record	
2.6	Concreting									
2.6.1	Mixing of cement (OPC, 53 Grade, ISI mark), sand & coarse aggregate as per ratio 1:4:8/1:2:4/1:5:8/ 1:1.5:3	Tackling equipment	B	Visual	100%	Random	As per instructions of manufacturer's	As per instructions of manufacturer's	Site record	

2.6.2	Check workability of concrete	Tackling equipment	B	Visual	100%	Random	As per instructions of manufacturer's	As per instructions of manufacturer's	Site record	
2.6.3	Placing concrete, poking and compacting.	Tackling equipment	B	Visual	100%	Random	As per instructions of manufacturer's	As per instructions of manufacturer's	Site record	
2.6.4	Testing of concrete cubes for compression strength. 7 Day or 28 Days.	Compression machine	A	Third party lab test	One set per substation	Random			Site record	
2.6.5	Check whether curing period of the foundation is completed.		C	Visual	100%	Random	Visual check for min 7 days	Visual check for min 7 days	Site record	
2.6.6	Check the backfilling and compaction is completed upto ground level.	Tackling equipment	A	Visual	100%	Random	Foundation Plan	Foundation Plan	Site record	
2.7	Masonary work									
2.7.1	Check the proportion, mixing & placement of mortar.	Tackling equipment	B	Visual	Random	Random	Foundation Plan	Foundation Plan	Site record	
2.7.2	Plumb & alignment	Tackling equipment	B	Visual	Random	Random	Foundation Plan	Foundation Plan		
2.7.3	Curing		B	Visual	100%	Random	Visual check for min 7 days	Visual check for min 7 days	Site record	
2.7.4	Control brick height " In day work"	Measure tape	B	Visual	100%	Random	Foundation Plan	Foundation Plan		
2.8	Plastering work									
2.8.1	Plastering thickness and even-ness		B	Visual	Random	Random	Visual check	Visual check		

2.8.2	Mortar mix / proportion	Tackling equipment	B	Visual	Random	Random	Foundation Plan	Foundation Plan	Site record	
2.8.3	Check the placement, thickness of plaster, line & level of plaster	Tackling equipment	B	Visual	Random	RANDOM	Foundation Plan	Foundation Plan	Site record	
2.8.4	Curing		B	Visual	100%	RANDOM	Visual check for min 7 days	Visual check for min 7 days	Site record	

Legends :
"Class of check:
A -- Critical -- to be witnessed by PIA site and surveillance by PIA, CC.
B – Major -- To be witnessed by Contractor and PIA site
C—Minor -- To be witnessed by Contractor and Surveillance by PIA site"
TC : Test Certificate
V : Verify
W : Witness
EIC : Engineer In Charge

					Table 13-10: Field Quality Plan-- Poles (30/15 kV& LT), Pole Earthing and Guy erection		
					Item: Poles(30/15kV& LT)		
Contractor's Name:						DATE:	
Sub Contractor/ agency Name & Address:							
					Sub-system: POLE ERECTION ,EARTHING, GUY ERECTION		

									PAGE:	
Sl.No	**Main Activity & Operation**	**Characteristics / Instruments**	**Class of check**	**Type of check**	**Quantum of check- Contractor/ EARPQCC**	**Quantum of check - TPIA/REG/ Independent Quality Auditor**	**Reference document**	**Acceptance norms**	**Format of record**	**Remarks**
1	**Receipt and storage**	1) Receipt at stores	C	Visual	100%	Random	Supplier tc	Correlation of the lot received with the tc	Supplier tc	Poles which are inspected and cleared by PIA shall only be accepted on receipt
		2) Visual inspection	C	Visual	100%	Random		Broken, damaged poles shall be stacked separately	Site register	
		3) Proper storage	C	Visual	100%	Random	Utility specification or as per acceptance norms	"1)Poles shall be stacked in such a manner that broad side is vertical. 2)each tier in the stack is supported on wooden sleepers located at 1.2mtr apart, wooden supports aligned in vertical line. "	Site register	
2	Transportation of poles	Transportation	**C**	Visual	100%	-	Utility specification or as per acceptance norms	"1)Poles shall be transported with broad faces placed vertically		

								2)Supports are located at 1.2mtr apart throughout the length of the pole”		
3	Pre installation	Availability of approved drawings all constructional material.	**C**	Visual	100%	Random Check	Utility specification or as per acceptance norms	“1)Ensure approve drawings for installation of the poles are available at work place 2)Ensure all construction material like boulders, sand , Cement , stone chips are also available at work place “	Site register	
		availability of route survey map at work place	**C**	Visual	100%	100%	Route survey report		Site register	
4.Insalation of poles										
4.1	Excavation of pit	4.1.1) manual excavation / con- trolled blasting	C	Visual	100%	Random	Utility specification or as per acceptance norms	Pit longitudinal axis should be in the direction of the line	Site register	“Controlled blasting is permitted in case of hard or rocky soils (in case of inhabited location drilling/ chipping to be resorted to)”

		4.1.2)size of pit	C	Dimensional	100%	Random	Utility specification or as per acceptance norms	0.6m x 1.2m (or) 0.6dia x 1.5m depth	Site register	In hard rock locations one mtr. deep hole and dia of 1.2 times the bottom dimension of the pole.
		4.1.3) planting depth in ground	C	Dimensional	100%	5%	Utility specification or as per acceptance norms	1.5 m above precast slab	Site register	in case of black cotton & wet soils planting depth increased by 0.2 mtr
4.2	Base foundation	base concrete	C	Measurement	100%	5%	Utility specification or as per acceptance norms	M-15 grade size 0.45m x 0.45m x 0.075 m	Site register	Equivalent size stone plate can also be used where ever found economical
4.3	Pole erection	4.3.1) pole erection	C	Visual	100%	Random	Utility specification or as per acceptance norms	"1)Poles shall be lifted to the pit with the help of wooden supports 2)The pole shall be kept in vertical position with the help 25mm manila ropes."		
		4.3.2) Alignment & verticality in both directions	C	Spirit level	100%	Random	Utility specification or as per acceptance norms		Site register	

		4.3.3) Back filling	C	Visual	100%	Random 10%	Utility specification or as per acceptance norms	With brick bats and compacted in layers	Site register	Temporary anchors shall be removed only after the pole is set in the foundation after compacting the soil.
		4.3.4) Concreting of foundations	C	"Measure ment"	100%		Utility specification or as per acceptance norms		Site register	At all tapping points, dead end poles, at DT locations, at all points as per EDCL construction drawing at 1 km.
		5.1) Coil type earthing	C	Visual	100%	5%	Utility specification or as per acceptance norms		Site register	
6	Coil type Earthing installation	a) Excavation of pit size (dia-600 x 1500 mm)	C	Visual/ dimension al	100%	Random	Utility specification or as per acceptance norms		Site register	
		b)Install earthing spiral	C	Visual	100%	Random	Utility specification or as per acceptance norms			Ensure the spiral wire is 4mm GI wire
		c) Fill the pit with alternate	B	Visual	100%	Random	Utility specification or as per			

		layers of 300mm with charcoal and salt upto 1.2 mtr.of depth from bottom of the pit.					acceptance norms			
		d) Connection between the spiral wire and pole earth wire	C	Visual	100%	Random	Utility specification or as per acceptance norms			
		6.1) Pipe/ rod type earthing	C	Visual	100%	5%	Utility specification or as per acceptance norms		Site register	At both sides of railway, road, drain, telecom, river crossings
7	Pipe type earthing installation	a) Excavation of pit size by 0.6m dia x 2.7m depth	C	Visual	100%	Random	Utility specification or as per acceptance norms		Site register	
		b) Install 40 dia GI pipe with 12 dia holes in the pit.	C	Visual	100%	Random	Utility specification or as per acceptance norms			
		c) fill the pit with	B	Visual	100%	Random	Utility specification			

		alternate layers of 300mm charcoal and salt.					or as per acceptance norms			
		d) Connection between the pipe and pole with 8mm SWG wire	C	Visual	100%	Random	Utility specification or as per acceptance norms			
8	Stay / Guy Erection	8.1) Location for the guy sets	C	Visual	100%	5%	Utility specification or as per acceptance norms			The guy sets are erected at angle locations , dead end locations , t- off points , steep gradient locations, double pole structures.
		8.2) Excavation of pit size 0.5m x 0.5m x 1.6m	C	Dimension al	100%	5%	Utility specification or as per acceptance norms			
		8.3)Sizing of anchor plate	C	Dimension al	100%	5%	Utility specification or as per acceptance norms			
		8.4)Grouting of anchor plate and	C	Dimension al	100%	5%	Utility specification or as per			If guy wire is found hazardous it should be protected with

		anchor rod with earth filling					acceptance norms			asbestos pipe fill with concrete
		8.5)Angle be-tween stay wire and pole	B	“Measurm ent”	100%	5%	Utility specification or as per acceptance norms			
		8.6)Erection of guy insulator	C	Visual	100%	50%	Utility specification or as per acceptance norms			Guy insulators are erected at height of 3050 mm from the ground.
		8.7) Erection turn buckle	C	Visual	100%	50%	Utility specification or as per acceptance norms			Turn buckle are mounted half way in the working position, thus giving the max. movement for tightening and loosening
Class of check: A -- Critical B -- Major C—Minor Name/ Signature of the Sub-Contractor/ Erection Agency										

	Table 13-11:Field Quality Plan--Erection of 30/15 kV pole accessories			
Contractor’s Name:	**Item: Erection of 30/15 kV pole accessories**			
Sub Contractor/ Agency Name & Address:				

		Sub-system: G.I components, insulators, hardware fittings, Danger boards, anti-climbing devices, Guarding		DATE:	
				PAGE:	

MS galvanized components

Sl.No	Main Activity & Operation	Characteristics/ instruments	Class of check	Type of check	Quantum of check - Contractor/EA RPQCC	Quantum of check - TPIA/REG/ Independent Quality Auditor	Reference document	Acceptance norms	Format of record	Remarks
1	**Receipt and Storage**	1) Receipt at stores	C	Visual check	100%	Random		Correlation of the lot received with tc	Stores register	Components which are inspected and cleared by PIA shall only be accepted on receipt
		2) Visual inspection	C	Visual check	100%	Random		Damaged and galvanization defective components are to be stacked separately	Stores register	
		3) Proper storage	0	Visual check	100%	Random	Utility specification or as per acceptance norms	All G.I. components should be stacked on wooden sleepers and the storage area shall	Stores register	

								be free from water logging		
2	**Fixing of MS components**	1) v- cross arm with cross arm back clamp	**C**	Visual check	100%	10%	Utility specification or as per acceptance norms	As per approved drawing	Site register	Cross arms are to be fixed at the Markings provided on the poles
		2) Horizontal alignment of cross arms with pole	**C**	Water level	100%	10%	Approved drawing	Approved drawing		
		3) Top cleat with back clamp	**C**	Visual check	100%	10%	Utility specification or as per acceptance norms	As per approved drawing	Site register	Top cleats are to be fixed at the Markings provided on the top of the pole
		4) Vertical alignment of top cleat with pole	**C**	Water level	100%	10%	Approved drawing	Approved drawing		
		5) Tightening MS components with nuts, bolts and washers	**C**	Erection check	100%	10%	Approved drawing	The components should be fixed rigid enough to with stand all the forces	Site register	
Insulators with pins										

3	**Receipt and Storage**	1) Receipt at stores	C	Visual check	100%	Random	Utility specification or as per acceptance norms	Correlation of the lot received with the chp descriptions	Site register	Components which are inspected and cleared by PIA shall only be accepted on receipt
		2) Visual inspection	C	Visual check	100%	Random		The surface of the insulators are to be thoroughly checked and cleaned, threading of the insulator thimble to be checked	Stores register	Damaged insulators are to be stacked separately
		3) Proper storage	C	Visual check	100%	Random	Standard practice		Stores register	
4	**Fixing of insulators**	1) Check threading over the pins and insulator thimbles and check the alignment of pin with insulator	C	Visual check	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	site register	At ground level this preassembly check is done for proper assembly
		2) Assembling the GI pin and insulators	C	Visual	100%	Random	Approved drawing	Approved drawing		

		3) Fixing the pin insulator to the cross arms and pole top bracket	C	Visual check	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	On all the poles in the straight line pin insulators shall be used. Disc insulators are used at dead end and angle locations
		4) check the clearances between the insulators	b	Dimensional	random	Random	Utility specification or as per acceptance norms	Approved drawing		For checking the clearances suitable template/ jigs are to be used
Class of check: A -- Critical B -- Major C-- Minor										
							Name/ Signature of the Sub-contractor/ Erection Agency			

Table 13-12:Field Quality Plan for Isolator, AB switch/DO fuse					**ITEM :**		**Erection Work**		
					SUB SYSTEM :		**ISO/AB Switch/ DO Fuse**		
					DATE :				
Sr. No.	**Characteristics / items**	**Type of Check**	**Instruments**	**Class**	**Quantum of check - contractor/EA RPQCC**	**Quantum of check - TPIA/REG/ Independent Quality Auditor**	**Reference documents & Acceptance Standard**	**"Format of records"**	**Remarks**
1	2	3	4	5	6		7	8	9
1	**Receipt & Storage**								

1.1	Receiving inspection (Completeness of documents, test certificates, instruction manual etc.)	V	-	B	100%	Random	Delivery Challan	MRC	
1.2	Unloading	V	-	B	100%	Random	Instruction Manual	-	
1.3	Visual examination for damage & defects	V	-	B	100%	Random	Packing list / Instruction Manual	-	
1.4	Proper storage	V	-	B	100%	Random	Instruction Manual	-	
2	**Pre Installation**								
2.1	Availability of instruction manual and drawing, lifting arrangement	V	-	B	100%	Random	List of approved drawing / Instruction Manuals	-	
2.2	Availability of all materials	V	-	B	100%	Random	Packing list, Approved drawing & Bill Of Material	-	
2.3	Foundation (If required)	V	-	B	100%	Random	Civil foundation drawing	-	
2.4	Verticality of support structure	V	-	B	100%	50%	GA/ Structural drawing	-	
3	**Installation**								
3.1	Rating plate details	V	-	B	100%	Random	instruction manual	Site record	
3.2	Check for proper slinging & lifting	V	-	B	100%	Random	Instruction Manual	-	
3.3	Check for the tightness of base bolts & other	V	-	B	100%	50%	Instruction Manual	-	

	bolted joints preferably by torque wrench.								
3.4	Check level & alignment of the base, housing assembly and flanges.	V	-	B	100%	50%	Instruction Manual	-	
3.5	Ensure proper erection of poles, main blade & drive assembly as per approved drgs.	V	-	B	100%	50%	Instruction Manual	Site record	
3.6	Check for the alignment of isolator and verticality of isolator / AB switch / DO Fuse.	V	-	B	100%	50%	Instruction Manual	Site record	
3.7	Check for the clearance between live part to earth.	V	-	B	100%	50%		-	
3.8	Check for no vibration or rotation of contacts of insulators during isolator operation. (Electrical & Mechanical)	V	-	B	100%	50%	Instruction Manual	-	
3.9	Check for the provision of earthing and earth connection.	V	-	B	100%	50%	Instruction Manual	-	
3.10	Check operation of the isolator by rotating one of the insulator stack manually and adjust the length of the crossed	V	-	B	100%	50%	Instruction Manual	-	

	tandem assembly to ensure proper engagement of contacts during closing.								
4	**Pre Commissioning**								
4.1	Check for visual damage to any parts including porcelain isolator.	V	-	B	100%	50%	Instruction Manual	TC	
4.2	Check manual / operation and inter locks.	V	-	B	100%	50%	Instruction Manual	TC	
4.3	IR Value a. Between each pole to earth.	Test	Megger	B	100%	50%	Instruction Manual	TC	
4.4	Ground connections	V	-	B	100%	50%	Instruction Manual	TC	
4.5	Check continuity	Electrical	Multi-meter	B	100%	50%	Instruction Manual	Site Record	
Legends : Class of check: A – Critical, B – Major, C—Minor, TC : Test Certificate, MRC : Material Receipt Certificate, V : Visual, EIC : Engineer In Charge									

Table 13-13:Field Quality Plan for LA						**ITEM :**			**Erection Work**
						SUB SYSTEM :			**Lightning Arrestor**
Sr. No.	**Characteristics / items**	**Type of Check**	**Instruments**	**Class**	**Quantum of check - contractor/EARPQCC**	**Quantum of check - TPIA/ REG/ Independent Quality Auditor**	**Reference documents & acceptance Standard**	**"Format of records"**	**Remarks**
1	2	3	4	5	6		7	8	9

1 **Receipt & Storage**									
1.1	Receiving inspection (Completeness of documents, test certificates, instruction manual etc.)	V	-	B	100%	Random	Delivery Challan	MRC	
1.2	Unloading	V	-	B	100%	Random	Instruction Manual	-	
1.3	Visual examination for damage & defects	V	-	B	100%	Random	Packing list / Instruction Manual	-	
1.4	Proper storage	V	-	B	100%	Random	Instruction Manual	-	
2	**Pre Installation**								
2.1	Availability of instruction manual and drawing, lifting arrangement	V	-	B	100%	Random	List of approved drawing / Instruction Manuals	-	
2.2	Availability of all materials	V	-	B	100%	Random	Packing list, Approved drawing & Bill Of Material	-	
2.3	Verticality of support structure	V	-	B		50%	GA/ Structural drawing	-	
3	**Installation**								
3.1	Rating plate details	V	-	B	100%	Random	Instruction manual	Site record	
3.2	Check cleanliness of surfaces of the arrester and check Megger value.	Test	Megger	B	100%	10%	Instruction manual	-	
3.3	Check base of the surge arrestor.	V	-	B	100%	50%	Instruction manual	-	
1	2	3	4	5	6		7	8	9

3.4	Check the tightness of equipment base with structure.	V	-	B	100%	50%	Instruction manual	-	
3.5	Ensure that the explosion vent of the LA is away from adjacent critical equipment.	V	-	B	100%	50%	Instruction manual	-	
3.6	Check earthing provision and connection tightness.	V	-	B	100%	50%	Instruction manual	-	
3.7	Check clearance between live parts to earth part.	V	-	B	100%	50%	Instruction manual	-	
3.8	Check overall alignment of LA.	V	-	B	100%	50%	Instruction manual	-	
3.9	Mounting height of LA	Measure	-	B	100%	Random	Instruction manual	Site record	
4	**Pre Commissioning**								
4.1	IR Value test	Test	Megger	A	100%	10%	Instruction manual	TC	
4.2	Check for resistance of ground connection.	Test	-	B	100%	10%	Instruction manual	TC	
4.3	Earth continuity test	Test	Earth Megger	B	100%	10%	Instruction manual	TC	
4.4	Final Document review	V	-	B	100%	Random	instruction manual /final document list	TC	
Contractor’s signature					Name & Sign of Approving Authority				
Legends : Class of check: A – Critical, B – Major, C—Minor, TC : Test Certificate MRC : Material Receipt Certificate, V : Visual, EIC : Engineer In Charge									

Table 13-14: Field Quality Plan for Painting						ITEM :		Erection Work	
						SUB SYSTEM :		Painting	
						DATE :			
Sr. No.	**Characteristics / Items**	**Type of Check**	**Instruments**	**Class**	**Quantum ofcheck contractor/EAR PQCC**	**Quantum of check - TPIA/ REG/ Independent Quality Auditor**	**Reference documents & Acceptance Standard**	**“Format of records”**	**Remarks**
1	**2**	**3**	**4**	**5**			**7**	**8**	**9**
1	**Receipt & Storage**								
1.1	Receiving inspection	V		C	100%	Random	Delivery Challan & Specification	MRC	
1.2	Proper storage	V		C	100%	Random	5%	Site Records	
2	**Painting**								
2.1	De rusting from struc - tutres & other rusted part of the equipment	V	Wire Brush, emery paper	B	100%	Random	As per EIC	-	
2.2	Red oxide zinc chromate paint on steel structures - Two Coats	V	Paint brush	B	100%	Random		Site Records	
2.3	Synthetic enamel paint - Two Coats or more coats	V	Paint brush	B	100%	Random		Site Records	

2.4	Aluminium Paint - Two Coats or more coats	V	Paint brush	B	100%	Random		Site Records
2.5	Final document review	-	-	B	100%	Random	Final document list	Site Records
Contractor’s Signature					Name & Sign of Approving Authority			
Legends : Class of check: A – Critical, B – Major, C—Minor, TC : Test Certificate, MRC : Material Reciept Certificate, V : VISUAL								

					Table 13-15: Field Quality Plan Customer Connection					
					Item: Erection of Customer Connection					
					Sub-system:					
Sl.No	**Main Activity & Operation**	**Characteristics / Instruments**	**Class of check**	**Type of check**	**Quantum of check - contractor/ EARPQCC**	**Quantum of check - TPIA / REG /Independent Quality Auditor**	**Reference document**	**Acceptance norms**	**Format of record**	**Remarks**
Section 1 : Bought out items of Customer Connection										
1	**Receipt and Storage**	1) Receipt at Stores	C	Visual check	100%	Random	Approved BOM and approved drawing	Approved make of the item	Stores register	
		2) Visual inspection	C	Visual check	100%	Random		Damaged and defective components are to be replaced with good one	Stores register	The meter board shall be of teak wood quality or hard wood

		3) Proper storage	C	Visual check	100%	Random	Standard practice	Standard practice	Stores register	
Section : 2 Fixing of boards and accessories									
2	**Fixing of boards and accessories**	1) Identifying and marking the positions where the components are to be erected	C	Visual check	100%	Random	As per specification	As per approved drawing	Site register	Clearance shall be maintained as per approved drawing and as per specification
		2) Fixing the service supports and guys	C	Visual check	100%	Random	As per specification	As per approved drawing	Site register	The surface of all supports should be cleaned .
		"3) Fixing of the wooden boards (meter board and switch board)"	**C**	Dimensional	100%	Random	As per specification	As per approved drawing	Site register	
		4) Fixing of all other accessories	**C**	Visual Check	100%	Random	As per specification	As per approved drawing	Site register	
Section : 3 Stringing of Service Cable									
3	**Stringing of service cable**	1) Handling of the cable	C	Visual check	100%	Random	As per specification	Cable should not be dragged on the ground	Site register	Cable surface shall be free from faults, flaws etc.
		2) Sequence of cable erection	C	Visual check	100%	Random	As per specification	Sequence of running out shall be from top to bottom, i.e.. the top cable shall run out first, followed by the side cables	Site register	

		3) Fix the G.I wire of service cable to clamps	C	visual check	100%	Random	As per specification	Specification / as per approved drawing	Site register	
		4) Check the tightness of service cable with clamps	C	Visual check	100%	Random	As per specification	As per the standard practice	Site register	
		5) Check the ground clearances after erection of the service cable	C	Visual check	100%	Random	As per specification		Site register	The minimum ground clearances should be maintained
Section : 4 Earthing arrangement										
4	**Earthing arrangement**	1) Local earthing of customer house hold	C	Visual check	100%	Random	Standard practice		Site register	
		2) Earthing of GI support wire	C	Visual check	100%	Random	Standard practice		Site register	
Section : 5 Charging of Customer Connection										
5	**Charging of customer connections**	1) check the continuity of connection	c	Test	100%	Random	Standard practice	Standard practice	Site register	
		2) connection of service line to the pole	c	Visual check	100%	Random	Standard practice	Standard practice	Site register	Take line clear on pole from which service line to be tapped
		3) Charging of	c	Visual check	100%	Random	Standard practice	Standard practice	Site register	Check for any abnormalities

		service connection								at the board
Class of check: A – Critical, B – Major, C-- Minor										
Name/ Signature of the Sub-Contractor/ Erection Agency										

					Table 13-16:Field Quality Plan DTR Structure and Components					
					Item: DTR Structure and Components					
					Sub-system: Erection Transformer Structure					
Section - I : MS galvanized components										
Sl. No	**Main Activity & Operation**	**Characteristics/ Instruments**	**Class of check**	**Type of check**	**Quantum of check-contractor/ EARPQCC**	**Quantum of check - TPIA/REG/ Independent Quality Auditor**	**Reference document**	**Acceptance norms**	**Format of record**	**Remarks**
1	Receipt and Storage	1) Receipt at stores	C	Visual	100%	Random	Delivery challan	Correlation of the lot received with the delivery challan / mdcc descriptions	Site register	Components which are inspected and cleared shall only be accepted
		2) Visual inspection	C	Visual	100%	Random		Damaged and galvanization defective components are to be stacked separately	Stores register	
		3) Proper storage	C	Visual	100%	Random	Utility specification or as per	All G.I. components should be stacked on wooden sleepers and the storage area shall be	Stores register	

							acceptance norms	free from water logging		
2	Fixing of MS components	1) Check the alignment of two poles	C	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	Both the poles should be parallel to each other and should be planted at same depth
		2) Fix the top channel	C	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	Check the alignment of the top channel with the pole
		3) Fix the fish plate	C	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	These fish plate should be placed rigidly and holes are to be checked
		3) Fix the belting angles with belting angle back Clamp	C	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	Angles should be fixed from specified from ground

		4) Horizontal alignment of the belting angle with poles	C	Dimensional	100%	Random	Approved drawing	Approved drawing	Site register	
		5) Fix the bracing angles with bracing angle clamp	C	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	The bolts and nuts shall be tight enough to hold the bracing to the pole
		6) Alignment of the bracing angle with belting angles	C	Dimensional	100%	Random	approved drawing	Approved drawing	Site register	The angle between the two bracing should be 900 and should be rigid enough to bear the forces
3	**Stay / Guy erection**	8.1) Location for the guy sets	C	Visual	100%	50%	Utility specification or as per		Site register	As per approved drawing the number of stays are to be erected

							acceptance norms			
		8.2) Excavation of pit size 0.5m x 0.5m x 1.6m	C	Dimensional	100%	Random	Utility specification or as per acceptance norms		Site register	
		8.3)Sizing of anchor plate	C	Dimensional	100%	Random	Utility specification or as per acceptance norms		Site register	
		8.4)Grouting of anchor plate and anchor rod with earth filling	C	Dimensional	100%	50%	Utility specification or as per acceptance norms		Site register	If guy wire is found hazardous it should be protected with asbestos pipe fill with concrete
		8.5)Angle between stay wire and pole	B	"Measurement"	100%	50%	Utility specification or as per acceptance norms		Site register	
		8.6)Erection of guy insulator	C	Visual	100%	50%	Utility specification or as per acceptance norms		Site register	Guy insulators are erected at height of 3050 mm from the ground.

		8.7) Erection turn buckle	C	Visual	100%	50%	Utility specification or as per acceptance norms		Site register	Turn buckle are mounted half way in the working position , thus giving the max. movement for tightening and loosening
		8.8) Ensure the rigidness of the structure	C	Visual	100%	Random	Standard practice	Approved drawing	Site register	
Section - II : Fixing of insulators										
4	**Receipt and Storage**	1) Receipt at stores	C	Visual	100%	Random	Delivery challan	Correlation of the lot received with the delivery challan / mdcc descriptions	Site register	Components which are inspected and cleared by PIA shall only be accepted on receipt
		2) Visual inspection	C	Visual	100%	Random		The surface of the insulator is to be thoroughly checked and cleaned, the threading of the insulator is to be checked	Stores register	Damaged insulators are to be stacked separately
		3) Proper storage	C	Visual	100%	Random	Standard practice		Stores register	
5	**Fixing of insulators**	1) Check threading over the pins and insula-tors and check the alignment	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	

		of pin with insulator								
		2) Assembling the GI pin and insulators	**C**	Visual	100%	Random	Approved drawing	Approved drawing		
		3) Fix the pin insulator over the fish plates	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	Pin insulators shall be tightened rigidly to with stand the load.
		4) Check the clearances between the insulators	**B**	Dimensional	Random	Random	Utility specification or as per acceptance norms	Approved drawing		For checking the clearances suitable template/ jigs are to be used
		5) Now fix the respective disc insulators with disc insulator clamps	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	As per approved drawing	Site register	Depending on type of location T&C or B&S are to be used as per approved drawing
		6) Check the clearances between the insulators	**B**	Dimensional	Random	Random	Utility specification or as per	Approved drawing		For checking the clearances suitable template/ jigs are to be used

							acceptance norms			
Section - III : Fixing of 30/15 kV HG Fuse										
6	**Receipt and Storage**	1) Receipt at stores	C	Visual	100%	Random	Delivery challan	Correlation of the lot received with the delivery challan	Stores register	Components which are inspected and cleared shall only be accepted on receipt
		2) Visual inspection	C	Visual	100%	Random		Damaged and defective equipment shall be stacked separately	Stores register	Major damaged material shall be discarded.
		3) Proper storage	C	Visual	100%	Random	Utility specification or as per acceptance norms	The HG Fuse components shall be stored on wooden platform of 300mm depth	Stores register	
7	**Fixing of HG Fuse set**	1) Rating plate details	C	Visual	100%	10%	Standard practice	Approved drawings	Stores register	
		2) Check level & alignment of the base, housing assembly & flangs	C	Visual	100%	10%	Standard practice	Instruction manual	Site register	
		3) Check for the clearance between	B	Visual	100%	Random	Standard practice	Instruction manual / approved drawing\	Site register	

		live part to earth								
Section - IV : Erection and Commissioning of Line Sectionalizers / AB Switch										
8	**Receipt and Storage**	1) Receipt at stores	C	Visual	100%	Random	Delivery challan	Correlation of the lot received with the delivery challan	Stores register	Components which are inspected and cleared shall only be accepted on Receipt
		2) Visual inspection	C	Visual	100%	Random		Damaged and defective equipment shall be stacked separately	Stores register	Major damaged material shall be discarded.
		3) Proper storage	C	Visual	100%	Random	Standard practice	The AB Switch components shall be stored on wooden platform of 300mm depth	Stores register	
9	**Fixing of line Sectionalizers/ AB Switch**	a) Installation								
		1) Rating plate details	C	Visual	100%	10%	Standard practice	Approved drawing	Site register	
		2) Check for proper sling and lifting	C	Visual	100%	Random	Standard practice	Instruction manual	Site register	
		3) Check tightness of base bolts and other	C	Visual	100%	Random	Standard practice	Instruction manual	Site register	

		bolted joints by torque wrench								
		4) Check level & alignment of the base, housing assembly & flanges	**C**	Visual	100%	10%	Standard practice	Instruction manual	Site register	
		5) Ensure Proper erection of poles, main Blade & drive assembly as per approved drawings	**C**	Visual	100%	Random	Standard practice	Approved drawing	Site register	
		6) Check for the alignment and verticality of Sectionalizers	**C**	Visual	100%	10%	Standard practice	Instruction manual / approved drawing\	site register	
		7) Check for the	**B**	Visual	100%	Random	Standard practice	Instruction manual / approved drawing\	Site register	

		clearance between live part to earth								
		9) Check for no vibration or rotation of contacts insulators during isolator operation	**C**	Visual	100%	10%	Standard practice	Instruction manual	Site register	
		10) Check for the provision of earthing and earth connection	**C**	Visual	100%	50%	Standard practice	Approved drawing	Site register	
		11) Check Operation of the isolator by rotating one of the insulator stack manually and adjust the length of the	**B**	Visual	100%	50%	Standard practice	Instruction manual / approved drawing\	Site register	ensure the entire structure should be rigid and check the rigidness by operating the AB Switches

		crossed tandem assembly to ensure proper engagement of contacts during closing.								
10	**Pre Com-missioning**	1) Check for visual damage to any parts including porcelain isolator	**C**	Visual	100%	Random	Standard practice	Instruction manual / approved drawing\	Site register	
		2) Check manual / operation and inter locks	**B**	Visual check	100%	10%	Standard practice	Instruction manual / approved drawing\	Site register	
		3) IR value between earth to pole	**B**	Visual check	100%	10%	Standard practice	Instruction manual / approved drawing\	Site register	
		4) Ground connections	**C**	Visual check	100%	Random	Standard practice	Instruction manual / approved drawing\	Site register	
		5) Check continuity	**B**	Visual check	100%	10%	Standard practice	Instruction manual / approved drawing\	Site register	

Section - V : Erection & Commissioning of DTRS										
11	**Receipt and Storage**	1) Receipt at stores	C	Visual	100%	Random	Delivery challan	Correlation of the lot received with the delivery challan / mdcc descriptions	Stores register	Transformers and accessories including las which are inspected and cleared shall only be accepted on receipt
		2) Visual inspection	C	Visual	100%	Random	Approved drawing	Damaged components shall be staged separately	Stores register	Major damaged material shall be discarded.
		3) Proper storage	**C**	Visual	100%	Random	Utility specification or as per acceptance norms	The transformers and the accessories shall be stacked on dry levelled and raised platform. all pipe work conservators, radiators should be stored with their blanking plates in position heaters in the marshelling box should be kept enerzized to avoid condensation	Stores register	
12	**Erection of Transformers**	1) Ensure the rigidness of the structure over which transformer is to be erected	**C**	Visual	100%	50%	Standard practice	As per approved drawing	Site register	
		2) Lifting of	**C**	Visual	100%	Random	As per	“Verticality of the	Site register	

		The transformers					manufacturer instruction manual	transformers shall be maintained HV / LV orientation of the transformer shall be checked”		
		3) Ensure proper sitting of the trans-former over the structure	**c**	Visual	100%	10%	standard practice	There should not be any movement of the transformer and transformer shall be fixed rigidly to the structure	Site register	The bolts and nuts shall be tight enough to hold the transformer without any shake
		4) HV / LV position	**C**	Visual	100%	Random	As per manufacturer instruction manual	As per approved drawing	Site register	Air clearance should be as per approved drawing
		5) Other accessories like Las, bushings, connectors etc. are erected	**C**	Visual	100%	50%	As per manufacturer instruction Manual	As per approved drawing	Site register	Air clearance should be as per approved drawing
13	**Pre commissioning checks**	1) Insulation resistance	**A**	Test	100%	10%	Utility specification or as per acceptance norms		Site register	A 5 kV Megger preferably motor operated should be used for measuring higher values. Bushings are thoroughly cleaned before taking IR values.

										IR values between windings and between windings to earth are checked. while checking these values, no external lines or lightning arresters should be in circuit.
		2) Oil dielectric strength test	**A**	Test	100%	10%	As per instruction manual	Samples from top and bottom of transformer are tested, if required	Site register	
		3) General checks								
		a) All oil valves are in correct position, closed or opened as required	**C**	Visual	100%	Random	As per instruction manual		Site register	
		b) All air pockets are cleared	**C**	Test	100%	Random	As per instruction manual		Site register	
		c) Thermometer pockets are filled with oil	**C**	Test	100%	Random	As per instruction manual		Site register	

		d) Oil is at correct level in the transformer	**B**	Test	100%	Random	As per instruction manual		Site register	
		e) Earthing connections are done	**C**	Test	100%	50%	As per instruction manual		Site register	
		f) Arcing horn gaps on bushings are properly adjusted	**C**	Test	100%	10%	As per instruction manual		Site register	
14	**Enerzisation**	Charging the trans-former	**A**	Visual	100%	10%	As per instruction manual	No abnormality such as vibration of the parts, hum noise should be absorbed	Site register	Abnormalities if noticed should be corrected after few hours of enerzisation at no load.
Section - VI : Earthing of DTR station										
15	**Identification of the earth pits and earthing equipment**	1) Identify the location where the earthing is to be done	A	Visual	100%	10%	As per approved drawing	Refer utility construction standards	Site register	
		2) identify the trans-former neutral terminal, la terminal and	A	Visual	100%	10%	As per approved drawing	Refer utility construction standards	Site register	

		other accessories								
16	**Pipe type earthing installation of DP structure**	1) Excavation of pit size	C	Visual	100%	Random	As per approved drawing	Refer utility construction standards	Site register	
		2) Install 40 dia GI pipe with 12 dia holes in the pit	C	Visual	100%	10%	As per approved drawing	Refer utility construction standards	Site register	
		3) Fill the pit with alternate layers of 300 mm char coal and salt	**A**	Visual	100%	10%	As per approved drawing	Refer utility construction standards	Site register	In case of the ordinary soils where pipe could hamoured in, treatment of the pit with charcoal and salt is not necessary
		4) Connections between the pipe and pole with 8mm SWG wire	**C**	Visual	100%	10%	As per approved drawing	Refer utility construction standards	Site register	
		5) Connect the equipment to be	**C**	Visual	100%	10%	As per approved drawing	there should not be any loose connections	Site register	

		earthed and the pipe earthing terminals with GI wire								
17	Testing of earth resistivity	testing of earthing	**A**	Test	100%	10%	Standard practice	Instruction manual	Site register	
Section - VII : Erection of Danger Boards and Anti-climbing devices										
18		1) Fixing of danger boards	C	Visual	100%	50%	Instruction manual	Approved drawings	Site register	
		2) Erection of anti-climbing devices - barbed wire	C	Visual	100%	50%	Instruction manual	Approved drawings	Site register	
Section - VIII : Erection and Commissioning of LT Distribution Boxes										
19	Installation	1) Receipt at stores	C	Visual	100%	5%	Delivery challan	Correlation of the lot received with the delivery challan	Stores register	Components which are inspected and cleared shall only be accepted on receipt
		2) Visual inspection	C	Visual	100%	5%	Approved drawing	Damaged components shall be stacked separately	Stores register	Major damaged material shall be discarded.
		3) Proper storage	C	Visual	100%	5%	Utility specification or as per	The transformers and the accessories shall be stacked on dry levelled	Stores register	

							acceptance norms	and raised platform. all pipe work conservators, radiators should be stored with their blanking plates in position heaters in the marshelling box should be kept enerzized to avoid condensation		
		4) Erection of LT Distribution boxes	C	Visual	100%	10%	Standard practice	As per approved drawings	Site register	
		2) Erection of anti-climbing devices - barbed wire	C	Visual	100%	50%	Instruction manual	Approved drawings	Site register	
Section - IX : Erection and Commissioning of HT distribution boxes										
19	**Installation**	1) Receipt at stores	C	Visual	100%	5%	Delivery challan	Correlation of the lot received with the delivery challan	Stores register	Components which are inspected and cleared shall only be accepted on receipt
		2) Visual inspection	C	Visual	100%	5%	Approved drawing	Damaged components shall be stacked separately	Stores register	Major damaged material shall be discarded.
		3) Proper storage	C	Visual	100%	5%	Utility specification or as per	The transformers and the accessories shall be stacked on dry levelled	Stores register	

							acceptance norms	and raised platform. all pipe work conservators, radiators should be stored with their blanking plates in position heaters in the marshelling box should be kept energized to avoid condensation		
		4) Erection of LT Distribution boxes	C	Visual	100%	10%	Standard practice	As per approved drawings	Site register	
		5) Earthing of LTDB	B	Visual	100%	10%	Standard practice	As per approved drawings	Site register	Cover of the box is also to be earthed by way of flexible copper link of suitable dimension
	Class of Check A-Critical B-Major C-Minor									
	Name/ Signature of the Sub-Contractor/ Erection Agency									

Table 13-17:Field Quality Plan for DC System						**ITEM :** **SUB SYSTEM :** **DATE :**		**Erection Work** **DC System**
Sr. No.	**Characteristics / Items**	**Type of Check**	**Instruments**	**Class**	**Quantum/ Frequency**	**Reference documents &**	**“Format Of Records”**	**Remarks**

						Acceptance Standard		
1	2	3	4	5	6	7	8	9
1	**Receipt & Storage**							
1.1	Receiving inspection (Completeness of documents, test certificates, instruction manual etc.)	V	-	B	100%	Delivery Challan	MRC / Check List / DC / 06	
1.2	Unloading	V	-	B	100%	Instruction Manual	-	
1.3	Visual examination for damage & defects	V	-	B	100%	Packing list / Instruction Manual	-	
1.4	Proper storage	V	-	B	100%	Instruction Manual	-	
2	**Pre Installation**							
2.1	Availability of instruction manual and drawing, lifting arrangement	V	-	B	100%	List of approved drawing / Instruction Manuals	-	
2.2	Availability of all materials	V	-	B	100%	Packing list, Approved drawing & Bill of Material	-	
2.3	Completion of civil / ventilation requirement of battery room.	V	-	B	100%	Control room detail	-	
3	**Installation - Battery**							
3.1	Rating plate details	V	-	B	100%	Instruction manual	Site record	
3.2	Check availability of safety devices, water and first aid box.	V	-	B	100%	BOM / Specification	-	

3.3	Check installation of batteries and rack as per approved layout.	V	-	B	100%	Instruction Manual	-	
3.4	Check the specific gravity of the electrolyte prior to pouring in the cells.							
3.5	Check for availability of electrolyte level up to required level and there is no leakage.	V	-	B	100%	Instruction Manual	-	
3.6	Check alignment and level of each cell	V	-	B	100%	Instruction Manual	-	
3.7	Check for tightness inter cell connection and application of grease.	V	-	B	100%	Instruction Manual	-	
3.8	Check for provision of earthing and tightness of earthing connection. Ensure cell are not earth anywhere.	V	-	B	100%	Instruction Manual	-	
3.9	Check all cell no. are properly fixed and are visible.	V	-	B	100%	Instruction Manual	-	
3.10	The cabling from Battery Charger to first, last and tap cells is completed.	V	-	B	100%	Instruction Manual	-	
3.11	Check all the cells are connected in correct polarity.	V	-	B	100%	Instruction Manual	-	
3.12	Painting of battery stand	V	-	B	100%	Instruction Manual	-	
4	**Installation - Battery Charger**							
4.1	Rating plate details	V	-	B	100%	Instruction manual	Site record	
4.2	The quantity, ratings, type and make of the devices are as per	V	-	B	100%	Instruction Manual	-	

	the BOM as given in approved drawings.							
4.3	No physical damages are there in any devices of the panels and replacement of damaged parts.	V	-	B	100%	Instruction Manual	-	
4.4	The inter panel Earth bus connections and connection to the earthing grid are tightened properly.	V	-	B	100%	Instruction Manual	-	
4.5	Fuses provided are of rating as shown in the approved drawings.	V	-	B	100%	Instruction Manual	-	
4.6	Check that the labeling of devices is as per the approved drawings.	V	-	B	100%	Instruction Manual	-	
4.7	Check the wiring is completed as per the approved drawings.	V	-	B	100%	Instruction Manual	-	
4.8	External cabling and termination with glands is completed as per the Cable schedule.	V	-	B	100%	Instruction Manual	-	
4.9	Cable tags, ferrules for cores are provided as per cable schedule.	V	-	B	100%	Instruction Manual	-	
4.10	Dressing and clamping of cables is done properly.	V	-	B	100%	Instruction Manual	-	
4.11	Check the phases sequence of the Mains supply to the battery charger.	V	-	B	100%	Instruction Manual	-	

4.12	Check functioning of all relays/meters/selector switches etc.	V	-	B	100%	Instruction Manual	-	
4.13	All alarms & annunciations, indications are functioning properly.	V	-	B	100%	Instruction Manual	-	
4.14	Check the Float & Boost charger operation, set the O/P voltage (if reqd).	V	-	B	100%	Instruction Manual	-	
4.15	Check the current limiting feature of charger & set the current limit (if reqd).	V	-	B	100%	Instruction Manual	-	
4.16	IR Value check	Measure	-	A	100%	Instruction Manual		
5	**Pre-Commissioning**							
5.1	Check that all the assembly activities are completed.	V	-	B	100%	Instruction Manual	TC	
5.2	The cabling from Battery Charger to first, last and tap cells is completed.	V	-	B	100%	Instruction Manual	TC	
5.3	Check the polarity of the DC connection from Battery charger to Battery.	Test	Multimeter	B	100%	Instruction Manual	Site Record	
5.4	Check that the charging & discharging cycle is completed as per guidelines of manufacturer to prove battery AH capacity at 10 hr discharge rate.	V	-	A	100%	Instruction Manual	TC	
5.5	Recharge	Electrical	-	B	100%	Instruction Manual	Site record	
5.6	Final document review	V	-	B	100%	Approved panel	TC	

						drawing / Final document list		
Contractor's Signature							Name & Sign of Approving Authority	
Legends : "Class Of Check: A – Critical, B -- Major, C—Minor, TC : Test Certificate, MRC : Material Receipt Certificate, V : Visual, EIC : Engineer In Charge								

13.10 Annexure-4: Material Quality Plan

Table 13-18: MQP for 30/15 KV HT XLPE AERIAL BUNCHED CABLE (3X35+70)

Manufacture's Name & Address:				**Manufacturing Quality Plan**	
				ITEM: 30/15 KV HT XLPE AERIAL BUNCHED CABLE (3X35+70)	
Sl. No	Component & operation	Characteristics	Class	Type of Check	Quantum of Check
1	2	3	4	5	6
1	Aluminum Rod	a) Diameter	Major	Measurement	One sample from each lot
		b) Tensile Strength	Major	Test	do
		c) Elongation	Major	Test	do
		d) Resistivity / Conductivity	Major	Electrical Test	do
2	Alloy Rod	a) Diameter	Major	Measurement	One sample from each lot
		b) Tensile Strength	Major	Test	do
		c) Elongation	Major	Test	do
		d) Resistivity / Conductivity	Major	Electrical Test	do
3	XLPE Com- pound	a) Hot set	Critical	Test	One sample from each lot
		b) Tensile Strength	Major	Test	do
		c) Elongation	Major	Test	do
		"d) Volume Resistivity (Insulation Resistance)"	Major	Electrical Test	do
		e) Thermal Ageing Shelf Life-One Year Contamination & Voids	Critical	Test	do
4	Messenger Wire	a) Diameter	Major	Measurement	One sample from each lot
		b) Tensile Strength	Major	Test	do
		c) Elongation	Major	Test	do
5	"Wire Drawing (Aluminum/ Alloy)"	a) Dimension	Major	Measurement	10%
		b) Tensile Strength	Major	Test	do
		c) Wrapping test	Major	Test	do
		d) Surface Finish	Major	Visual	do

6	"Stranding Phase/ Messenger Wire"	a) Dimension	Major	Measurement	100%
		b) No./ Diameter of Wire	Major	Visual	do
		c) Sequence	Major	Visual	do
		d) D.C Conductor Resistance	Major	Electrical Test	do
		e) Surface Finish	Major	Visual	do
		f) Lay length, compact & ovality	Major	Visual	do
		g) Direction of lay	Major	Visual	do
		h) Tensile Strength	Major	Test	One sample from each lot
		i) Elongation	Major	Test	do
		j) UTS	Major	Test	do
7	Insulation	a) Type of component	Major	Visual	100%
		b) Diameter of conductor / core Thickness	Major	Measurement	do
		c) Thickness	Major	Measurement	100%
		d) Colour	Major	Visual	do
		e) Identification Ridge	Major	Visual	do
		f) Surface Finish	Major	Visual	do
		g) Embossing	Major	Visual	do
		h) Curing	Major	Visual	do
		i) Hot set test	Major	Test	1 spool
		j) Tensile Strength	Major	Test	do
		k) Elongation	Major	Test	do
		l) Volume Resistivity	Major	Electrical Test	do
		m) Spark Test	Major	Electrical Test	do
8	Laying Up	a) Core Sequence	Major	Visual	100%
		b) Laid Up diameter	Minor	Measurement	do
		c) Length	Major	Measurement	do
9	Copper Tape	a) Dimension of Tape	Major	Measurement	100%
		b) Surface finish	Minor	Visual	do

		c) Overlap in cop- per tape	Major	Visual	do
		d) Continuity	Major	Electrical Test	do
10	Outer Sheath	a) Type of component	Major	Visual	100%
		b) Colour of Sheath	Major	Visual	do
		c) Embossing	Minor	Visual	do
		d) Surface finish	Minor	Visual	do
11	Routine test	a) Conductor resistance	Major	Electrical Test	100%
		b) High Voltage	Major	Electrical Test	Do
		c) Partial Dis- charge Test	Major	Electrical Test	Do
12	All Type Tests as per NESCL Technical Specification	Type Tests	Major	Electrical Test	Sample
	Acceptance test on Cable	a) Conductor resistance	Major	Electrical Test	As per sampling plan of IEC
		b) Test for thick- ness & Dimension of insulation including eccentricity & ovality	Major	Test	do
		c) Thickness of sheath	Major	Test	do
		d) Hot set test for insulation	Major	Test	do
		e) Partial dis- charge test	Major	Electrical Test	do
		f) Tensile strength & elongation at break for insulation & sheath	Major	Test	do
		g) High voltage test	Major	Electrical Test	do
		h) Insulation Resistance (V. R)	Major	Electrical Test	do
		k) Wrapping Test	Major	Test	do
		l) Tensile Strength for Aluminum	Major	Test	do
13	Acceptance test on messenger wire	a) Breaking Load Test	Major	Test	As per sampling plan of IEC
		b) Elongation	Major	Test	As per sampling plan of IEC
		c) Resistance Test	Major	Test	As per sampling plan of IEC
14	Packing & Marking		Major	Visual	Random

Table 13-19: MQP for LT PVC Un-Armoured Cable

MANUFACTURE'S NAME & ADDRESS:				MANUFACTURING QUALITY PLAN	
				ITEM: LT PVC Un-Armoured Cable	
				SUB-SYSTEM:	
Sl. No	Component & operation	Characteristics	Class	Type of Check	Quantum of Check
1	2	3	4	5	6
1	Aluminum Rod	a) Dimension	M/A	Physical	One sample from each lot
		b) Tensile Strength	M/A	Physical	do
		c) Elongation	M/A	Physical	do
		d) Resistivity / Conductivity	M/A	Electrical	do
2	"PVC for insulation (Type-A)"	a) Thermal Stability	M/A	Physical	One sample from each lot
		b) Tensile Strength	M/A	Physical	do
		c) Elongation	M/A	Physical	do
		"d) Volume Resistivity (Insulation Resistance)"	M/A	Electrical	do
3	"PVC for Sheath (Type-ST1)"	a) Specific Gravity	M/A	Physical	One sample from each lot
		b) Thermal Stability	M/A	Physical	do
		c) Tensile Strength	M/A	Physical	do
		d) Elongation	M/A	Physical	do
4	Wooden Drum	Dimension	M/I	Measurement	As per relevant IEC
5	Wire Drawing	a) Dimension	M/A	Measurement	10%
		b) Tensile Strength	M/A	Physical	do
		c) Wrapping test	M/A	Physical	do

6	Insulation (Extrusion)	a) Thickness	M/A	Measurement	100%
		b) Surface Finish	M/A	Visual	do
		c) Spark Test	M/A	Electrical	do
		d) Colour	M/A	Visual	do
		e) Tensile Strength	M/A	Physical	do
		f) Elongation	M/A	Physical	do
7	Outer Sheath	a) Surface Finish	M/A	Visual	100%
		b) Sheath Thick- ness	M/A	Measurement	do
		c) Diameter Over outer sheath	M/A	Measurement	do
		d) Tensile Strength	M/A	Physical	do
		f) Elongation	M/A	Physical	do
		f) Embossing	M/A	Visual	do
8	Routine test	a) Conductor Resistance	Critical	Electrical	100%
		b) High Voltage	Critical	Electrical	do
9	Type Test	Type Tests	Critical	Electrical	Sample
10	Acceptance test	a) Conductor resistance	Critical	Electrical	As per sampling plan of IEC
		b) Test for thick- ness of insulation & sheath	Critical	Physical	do
		c) Tensile strength & elongation test for Insulation & Sheath	Critical	Physical	do
		d) High voltage test	Critical	Electrical	do
		e) Annealing (for Copper)	Critical	Electrical	do
		f) Wrapping for Aluminum	Critical	Electrical	do
		g) Tensile for Aluminum	Critical	Electrical	do
		h) Insulation Resistance (V. R)	Critical	Electrical	do
11	Packing & Marking		Major	Visual	Random

Table 13-20: MQP for 30/15 kV A B switch

Manufacturer's Name And Address :			Manufacturing Quality Plan	
			Item :30/15 kV A B switch	
Sl. No	Component & Operations	Characteristics	Class	Type of Check
Section : 1 Raw Materials				
1.	Copper Flats	Visual Examination	Major	PH
		Dimension	Major	PH
		Tensile Strength	Major	ME
		Chemical Composition	Major	CH
		Bend Test	Major	ME
		Resistivity / Conductivity	Major	E
2	Aluminium Flats	Visual Examination	Major	PH
		Dimension	Major	PH
		Tensile Strength	Major	ME
		Bend Test	Major	ME
		Resistivity / Conductivity	Major	E
		Chemical Composition	Major	CH
3	MILD STEEL SECTIONS	Visual Examination	Major	PH
		Dimension	Major	PH
		Tensile Strength	Major	ME
		Chemical Composition	Major	CH
		Bend Test	Major	ME
4	CONTACT SPRIGS	Visual Examination	Major	PH
		Dimension	Major	PH
		Functional check	Major	PH
		Fitment/ Springs	Major	PH
5	FASTN- ERS	Visual Examination	Major	PH
		Dimension	Major	PH
		Wedge Test	Major	ME

		Hardness	Major	ME
		Galvanizing	Major	CH
6	GI PINS	Visual	Major	PH
		Dimension	Major	PH
		Galvanization Checks	Major	CH
7	INSULATOR	Visual	Major	PH
		Dimension	Major	PH
		High Voltage Test	Major	E
		Temperature Cycle	Major	E
		Mechanical Strength/ Failing load Test	Major	ME
		Puncture Test	Major	E
		Porosity Test	Major	PH
		Galvanizing test	Major	CH
8	AL. ALLOY	Chemical Composition	Major	CH
9	ZINC	Chemical Composition	Major	CH
10	GI TUBES	Visual	Major	PH
		Dimension	Major	PH
		Chemical Analysis	Major	CH
		Tensile Strength	Major	ME
		Elongation	Major	ME
		Bend Test	Major	ME
		Galvanizing	Major	CH
11	WELDED/ FABRICATED M.S. COMPONENT	Visual Examination	Major	PH
		Dimension	Major	PH
		Fitment/ Assembly	Major	PH
12	FABRICATION OF COPPER CONTACTS	Visual Examination	Major	PH
		Dimension	Major	PH
		Fitment / Assembly	Major	PH
13	HOT DIP GALVANIZING	Visual Examination	Major	PH

		Appearance	Major	PH
		Uniformity	Major	CH
		Mass of zinc	Major	CH
14	Terminals Connector	Visual Examination	Major	PH
		Dimension	Major	PH
		Tensile	Major	ME
		Resistance	Major	E
		Temperature Rise	Major	E
		Short Time Current test	Major	E
15	Electroplating	Visual Examination	Major	PH
		Thickness of plating	Major	PH
16	Assemblies/ Subassemblies	Visual Examination	Major	PH
		Dimension	Major	PH
		Verification of components	Major	PH
		Functional check	Major	PH
17	PACKING	Visual	Major	PH
18	TYPE TEST – GO AB SWITCH	All type tests as per relevant IS & Technical Specifications	Major	TTR
19	ROUTINE TEST- GO AB SWITCH	1) Power Frequency Voltage Dry Test 2) Measurement of Resistance of main circuit 3)Operating Test	Major	Routine Checks
		Visual Examination	Major	Physical
		Dimension	Major	Physical
		Verification of component	Major	Physical
		Operational check	Major	Physical
		Measurement of Resistance on main circuits	Major	Electrical
		Power Frequency withstand voltage test	Major	Electrical

Table 13-21: MQP for 30/15 kV DISC INSULATORS

		Manufacture's Name & Address:		**Manufacturing Quality Plan**	
				ITEM: 30/15 kV DISC INSULATORS	
Sl. No	Component & operation	Characteristics	Class	Type of Check	Quantum of Check
1	2	3	4	5	6
Section:1 Raw Material Inspection					
Section: 1.1 Raw Material for Body					
1	Quartz Powder	a) Inspection / colour	Major	Visual	1 Kg/20 MT part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		c) fired colour	Major	Visual	Do
		d) Sintering/ fired behavior	Major	Visual	Do
		"e) Chemical analysis SiO2 Fe2 O3 LOI at 1000oc"	Major	Test	Sampling Once in 3 month/ 300 MT
2	Feldspar powder	a) Inspection / colour	Major	Visual	1 Kg/20 MT part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		c) fired behavior/Sintering	Major	Visual	Do
		"d) Chemical analysis K2O+Na2O K2O Na2O Fe2O3 LOI at 1000OC"	Major	Test	Sampling Once in 3 month/ 300MT
3	China clays	a) Inspection	Major	Visual	1 Kg/20 MT or part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		c) Fired colour	Major	Visual	Do
		d) Dry shrink- age	Major	Test	Do
		e) Total shrink- age	Major	Test	Do
		"f) Chemical analysis	Major	Test	Once in 3 month/ 300MT

		Al2 03, Fe2 03, Tio2, LOI at 1000oc”			
4	Ball clay	a) Inspection/ colour	Major	Visual	1 Kg/20 MT or part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		c) Fired colour	Major	Visual	Do
		d) Dry shrink- age	Major	Test	Do
		e) Total shrink- age	Major	Test	Do
		“f) Chemical analysis Tio2, Al2 03, Fe2 03, LOI at 1000oc”	Major	Test	Once in 3 month/ 300MT
Section: 1.2 Raw Material for Glaze					
5	Iron oxide	a) Inspection/ colour	Major	Visual	1 Kg/05 MT or part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		c) Fired colour of 1% iron oxide in feldspar powder	Major	Visual	Do
		“d) Chemical analysis Fe2O3 content “	Major	Test	Sampling Once in 6 month/ 10 MT
6	Manga- nese di- oxide	a) Inspection/ colour	Major	Visual	1 Kg/05 MT or part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		c) Fired colour of 2% manga- nese dioxide in feldspar powder	Major	Visual	Do
		“d) Chemical analysis MnO2 content “	Major	Test	Sampling Once in 6 month/ 10 MT
7	Chromium oxide	a) Inspection/ colour	Major	Visual	1 Kg/05 MT or part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		c) Fired colour of 3% chromium oxide in feldspar powder	Major	Visual	Do
		“d) Chemical analysis Cr2O3 content “	Major	Test	Sampling Once in 6 month/ 10 MT
8	Calcite powder	a) Inspection/ colour	Major	Visual	1 Kg/05 MT or part thereof
		b) Residue retained on 200 mesh	Major	Test	Do
		Fired characteristic	Major	Visual	Do
		“d) Chemical analysis CaO Fe2O3 SiO2“	Major	Test	Sampling Once in 6 month/ 10 MT

9	Cement	a) Inspection	Major	Visual	0.01% of total quantity received
		b) Compressive strength	Major	Test	Do
		c) Expansion (Autoclave)	Major	Test	Do
10	Cork sheet	a) Thickness	Major	Visual	5Nos/ 5000 Nos
		b) specific gravity	Major	Test	Do
11	Ball Pin & Tongue Pin	a) Inspection (Black & Galvanizing stage)	Major	Visual	100%
		b) Gauge checking (black & Galvanizing stage)	Major	Test	100%
		c) Dimension (black & Galvanizing stage)	Major	Test	“Lot sample 1-1000 5 1000+ 10”
		d) Mechanical failing load test (black & Galvanizing stage)	Major	Test	“Lot sample 1-1000 3 1000+ 5”
		e) Yield strength, Tensile Strength & % Elongation on test bar	Major	Test	Do
		f) Hardness	Major	Test	Do
		g) Galvanizing	Major	Test	“Lot sample 1-10000 3 1000+5”
		“h) Chemical Analysis Carbon Manganese Silicon Sulphur Phosphorous”	Major	Test	Each con- signment
		i) Heat Treatment	Major	Test	100%
		j) M.P.I	Major	Test	100%
12	M.C.I. Cap (Socket/ Clevis)	a) Inspection (Black & Galvanizing stage)	Major	Visual	100%
		b) Gauge checking (black & Galvanizing stage)	Major	Test	100%
		c) Dimension (black & Galvanizing stage)	Major	Measurement	“Lot sample 1-1000 5 1000+ 10”
		d) Mechanical failing load test (black & Galvanizing stage)	Major	Test	“Lot sample 1-1000 3 1000+ 5”
		e) Galvanizing	Major	Test	Do
		f) Tensile Strength on test bar	Major	Test	Do
		g) 0.2% Proof stress on test bar	Major	Test	“Lot sample 1-1000 3 1000+ 5”

		h) Elongation on test bar	Major	Test	Do
		i) Hardness	Major	Test	Do
		"j) Chemical Analysis Phosphorous"	Major	Test	Each consignment
		k) M.P.L	Major	Test	100%
		l) Micro Structure	Major	Test	1 No/Lot
13	Security Clip (W/R Clip)	a) Inspection	Major	Visual	100%
		b) Dimension	Major	Measurement	"Lot sample 1-1000 3 1000+ 5"
		c) Chemical Analysis i) Phosphorous	Major	Test	Each consignment
		ii) Stainless W/R clip	Major	Test	Do
14	Cotter Pin (for T& C Cap)	a) mechanical failing load test	Major	Test	"Lot sample 1-1000 3 1000+ 5"
		b) Galvanizing	Major	Test	Do
15	Brass split Pin (for Tic Cap)	Chemical Analysis	Major	Test	Do
16	Wet grinding of ceramic body	a) Inspection	Major	Visual	Each charge
		b) Residue retained on 200 mesh	Major	Test	Do
		c) Litre Weight	Major	Test	Do
17	Glaze Preparation	a) Residue retained on 300 mesh	Major	Test	Each charge
		b) Litre Weight	Major	Test	Do
18	Pug mill's clay blank	a) De airing checking	Major	Test	Every 30 Mins
19	Properties of unfired porcelain	a) Dry MOR	Major	Test	Sampling Once in 3 month
		b) Linear shrinkage	Major	Test	Sampling Once in month
20	Shaping	a) Making cavity check (Dimension)	Major	Measurement	Once in every shift
		b) Finishing dimension	Major	Measurement	Do
		c) Moisture	Major	Test	Once daily
21	Drying	a) Hot rooms temperature	Major	Visual	Once in a day
		b) moisture content	Major	Test	3 samples per day
22	Properties of fired porcelain	a) Fired M.O.R	Major	Test	Sampling Once in 3 month
		b) porosity	Major	Test	All cars of every shuttle kiln & any one unloaded car of tunnel kiln

		c) Bulk density/ Water absorption	Major	Test	daily & each kiln
23	Glazing (Brown glaze)	a) Inspection	Major	Visual	100%
		b) Sp. gravity	Major	Test	Every hour
		c) Moisture %	Major	Test	3 samples per day
24	Temperature during firing of green wares		Major	Visual	Every hour
25	Sorting of fired insulator	a) Inspection	Major	Visual	100%
		b) Dimension	Major	Measurement	5 Nos/day
26	Routine electrical Test on Shell (Power frequency test)		Major	Test	100%
27	Hydraulic proof load test on shell (if applicable)		Major	Test	100%
28	Routine electrical (power frequency) & Mechanical Test	a) Routine Mechanical test	Major	Test	100%
		b) Routine Electrical test	Major	Test	100%
		Routine Mechanical Test on Assembled insulators	Major	Test	100%
29	Packing Crate	a) Inspection	Major	Visual	100%
		b) Dimension	Major	Test	"Lot sample 1-1000 5 1000+ 10"
30	Acceptance test on assembled insulators	a) Dimension checking	Major	Measurement	
		b) Temperature cycle test	Major	Test	
		c) Puncture Test	Major	Test	
		d) Galvanizing test	Major	Test	
		e) Electro-mechanical failing load test	Major	Test	
		f) Porosity test	Major	Test	
31	Routine Tests	a) Visual Examination	Major	Test	
		b) Electrical Tests	Major	Test	
		c) Mechanical tests	Major	Test	

32	Type Test *	a) Visual Examination	Major	Visually	
		b) Verification of Dimensions	Major	Measurement	
		c) Visible dis- charge test	Major	Test	
		d) Impulse with- stand voltage test	Major	Test	
		e) Wet power frequency with- stand voltage test	Major	Test	
		f) Temperature cycle test	Major	Test	
		g) Puncture test	Major	Test	
		h) Porosity test	Major	Test	
		i) Galvanizing test	Major	Test	
		J) Electro-mechanical failing load test	Major	Test	
		k) Thermal Mechanical Performance Tests	Major	Test	

Table 13-22: MQP for ACSR CONDUCTOR Size

		Manufacture's Name & Address:		**Manufacturing Quality Plan**	
				"ITEM :ACSR CONDUC- TOR Size"	
Sl. No	Component & operation	Characteristics	Class	Type of Check	Quantum of Check
1	2	3	4	5	6
Section:1 Raw Material Inspection					
Section: 1.1 Raw Material for Body					
1	Aluminum Wire Rod	1.Chemical	Minor	Chemical	ONE SAMPLE FROM 4 MT OR PART THEREOF
		2. Diameter Of Aluminum Rod	Minor	Measurement	ONE SAM- PLE FROM EACH COIL
		3.Breaking Load / Tensile Test	Minor	Mechanical	DO
		4.Resistivity Test	Minor	Electrical	DO
		5.Elongation Test	Minor	Mechanical	DO

		6. Cleanliness & Surface Smoothness	Minor	Visual	100% ON EACH COIL
2	Galvanised Steel Wire	1. Chemical Analysis	Minor	Chemical	THREE SAMPLES PER HEAT
		2.Diameter Galvanized Steel Wire	Critical	Measurement	ONE SAM- PLE FROM EACH COIL
		3.Breaking Load / Tensile Test	Critical	Mechanical	DO
		4.Elongation Test	Critical	Mechanical	DO
		5. Torsion Test	Critical	Mechanical	DO
		6. Wrapping Test	Major	Mechanical	DO
		7. Preece Test	Major	Chemical	DO
		8. Weight Of Zinc Coating	Major	Chemical	DO
3	Aluminium Drawn Wire	1. Surface Finish & Winding	Major	Visual	100% ON EACH SPOOL
		2. Dia Of Drawn Wire	Critical	Measurement	ONE SAM- PLE FROM EACH COIL
		3. Breaking Load / Tensile Test	Critical	Mechanical	ONE SAM- PLE FROM EACH SPOOL
		4. Resistance Test	Major	Electrical	DO
		5.Wrapping Test	Major	Mechanical	DO
4	Steel Stranding	1. Lay Ratio / Direction & Compact- ness	Major	Measurement	ONE SAM- PLE FROM EACH SPOOL
5	Conductor Stranding	1. Lay Ratio / Direction & Compact- ness			
		A).Inner Aluminum Layer	Minor	Measurement	ONE SAM- PLE FROM EACH SPOOL
		B).Outer Aluminum Layer	Minor	Measurement	ONE SAM- PLE FROM EACH SPOOL
		2) Smooth- ness / Surface Scratches	Minor	Visual	100%
		3) Joints	Major	Visual	100%
6	Acceptance Test On Finished Conductor	Lay Ratio	Minor	Measurement	ONE SAM- PLE FROM EACH 10 DRUMS
7	Acceptance Test On Aluminum Test On Aluminum Wire Of Finished Conductor	1.Diameter	Major	Do	DO
		2.Breaking Load / Tensile Test	Major	Mechanical	DO
		3.Resistance	Major	Electrical	DO
		4.Wrapping Test	Major	Mechanical	DO

		5.Surface Finish	Major	Visual	DO
		6.Ductility Test	Major	Mechanical	DO
8	Acceptance Test Of Galvanised Steel Wire Of Finished	1. Diameter	Major	Measurement	ONE SAM- PLE FROM EACH 10 DRUMS OR PART THEREOF
		2.Breaking Load / Tensile Test	Major	Mechanical	DO
		3.Elongation	Major	Do	DO
		4.Torsion Test(Either Test Of 3 Or 4)	Minor	Do	DO
		5.Wrapping Test	Minor	Do	DO
		6.Preece Test	Minor	Chemical	DO
		7.Weight Of Zinc Coating	Minor	Chemical	DO
		8.Adhesion Test	Minor	Mechanical	DO
9	Length Measurement Of Finished Conductor	Check For Joints Surface Finished And Length Measurement	Major	Visual/ Mechanical	DO
10	Sealing At Both Ends By The Inspecting Authority				
11	Wooden Drums	Dimensions	Major	Measurement	DO
12	Packing & Des- patch Check For Identification & Packing	1. Proper Packing	Major	Visual	100%
		2. Manufacturer Name	Major	Visual	100%
		3. Size & Code	Major	Visual	100%
		4. Gross Weight	Major	Visual	100%
		5. Tare Weight	Major	Visual	100%
		6. Net Weight	Major	Visual	100%
		7. Length Of Conductor	Major	Visual	100%
		8. Painting	Major	Visual	100%

Table 13-23: MQP for 30/15 KV D O FUSE

		Manufacture’s Name & Address:	
Sl. No	Component & operation	Characteristics	Class
1	2	3	4
1	Copper Flats	Visual Examination	Major
		Dimension	Major
		Tensile Strength	Major
		Chemical Composition	Major
		Bend Test	Major
		Resistivity / Conductivity	Major
2	Aluminium Flats	Visual Examination	Major
		Dimension	Major
		Tensile Strength	Major
		Bend Test	Major
		Resistivity / Conductivity	Major
		Chemical Composition	Major
3	MILD STEEL SECTIONS	Visual Examination	Major
		Dimension	Major
		Tensile Strength	Major
		Chemical Composition	Major
		Bend Test	Major
4	CONTACT SPRIGS	Visual Examination	Major
		Dimension	Major
		Functional check	Major
		Fitment/Springs	Major
5	Fasteners	Visual Examination	Major
		Dimension	Major
		Wedge Test	Major
		Hardness	Major
		Galvanizing	Major

6	Gi Pins	Visual	Major
		Dimension	Major
		Galvanization Checks	Major
7	Insulator	Visual	Major
		Dimension	Major
		High Voltage Test	Major
		Temperature Cycle	Major
		Mechanical Strength/Failing load Test	Major
		Puncture Test	Major
		Porosity Test	Major
		Galvanizing Test	Major
8	Al. Alloy	Chemical Composition	Major
9	Zinc	Chemical Composition	Major
10	GI TUBES	Visual	Major
		Dimension	Major
		Chemical Analysis	Major
		Tensile Strength	Major
		Elongation	Major
		Bend Test	Major
		Galvanizing	Major
11	Welded/ Fabricated M.S., Component Welded/ Fabricated M.S. Component	Visual Examination	Major
		Dimension	Major
		Fitment/Assembly	Major
12	Fabrication Of Copper Contacts	Visual Examination	Major
		Dimension	Major
		Fitment /Assembly	Major
13	Hot Dip Galvanizing	Visual Examination	Major
		Appearance	Major
		Uniformity	Major

		Mass of zinc	Major
14	Terminals Connector	Visual Examination	Major
		Dimension	Major
		Tensile	Major
		Resistance	Major
		Temperature Rise	Major
		Short Time Current test	Major
15	Electroplating	Visual Examination	Major
		Thickness of plating	Major
16	Assemblies/ Subassemblies	Visual Examination	Major
		Dimension	Major
		Verification of components	Major
		Functional check	Major
17	Packing	Visual	Major
18	Type Test – Do Fuse	All type tests as per relevant IS & Technical Specifications	Major
19	Routine Test-Do Fuse	1) Dielectric Tests 2) Temperature Rise Tests at rated current	Major
		1) Visual Examination	Major
		2) Dimension	Major
		3) Verification of component	Major
		4) Dry Power Frequency withstand voltage test	Major
		5) Temperature Rise Tests at rated current	Major
		6) Test for composition and mechanical strength of Aluminum used	Major

Table 13-24: MQP for PRE-STRESSED CEMENT CONCRETE POLES

	Manufacture's Name & Address:	**Manufacturing Quality Plan**
		ITEM : PRE-STRESSED CEMENT CONCRETE POLES
		SUB-SYSTEM:

Sl. No	Component & operation	Characteristics	Class	Type of Check
1	2	3	4	5
1	High tensile Pre-stressing Cold Drawn Indented wire	a) Dimensions	Major	Measure
		b) Chemical Analysis	Major	Test
		c) Tensile strength	Major	Test
2	GI Wire for Earthing	a) Chemical Composition	Major	Test
		b) Zinc Grade	Major	Test
		c) Zinc Coating	Major	Test
		d) Galvanizing	Major	Visual
3	Cement 43Grade, OPC	a) Chemical Composition	Major	Test
		b) Physical Test	Major	Test
		c) Setting Time	Major	Test
		d) Compressive Strength	Major	Cube Test
4	Aggregates	Size	Major	Sieve Analysis
		Crushing Strength	Major	Mech
5	Steel Stirrups	a) Physical	Major	visual
		b) Chemical	Major	Test
6	Manufacturing	a) Check Casting Moulds for Dimensions, soundness, supports, alignment and Cleanliness	Major	Measure
		b) Pre-stressing of HT wires	Major	Measure
		c) Concrete Mix M420	Major	Cube Test
		d) Casting	Major	Visual
		e) Position, Nos. and Dimensions of Lifting Hooks	Major	Visual
		f) De-moulding and De-tensioning	Major	Physical
		g) Curing	Major	Physical
7	Final Product Testing	a) Dimensional check for overall length, cross-sectional Dimensions and uprightness	Critical	Measure

		b) Transverse Strength Test	Critical	Test
		c) Test for Cover	Critical	Test
8	Marking Above The Planting Depth	Project name	Major	Visual
		Month & Year of Manufacture		
		Transverse Strength of pole		
		Makers Serial No. and Mark		
		Coloured indelible depth marker at 1.5 mtrs, from bot- tom to verify planting depth		
9	Pre-Shipment	a) Stacking	Major	Visual
		b) Handling/ Transportation	Major	Visual
		c) Physical Inspection	Major	Visual/ Physical

Table 13-25: MQP for LTDB for Distribution Transformer Substation

		Manufacture's Name & Address:		**Manufacturing Quality Plan**	
				Item: LTDB For Distribution Transformer Substation	
				SUB-SYSTEM:	
Sl. No	Component & operation	Characteristics	Class	Type of Check	Quantum of Check
1	2	3	4	5	6
Section:1 Raw Material Inspection					
Section: 1.1 Raw Material for Body					
1	Ms Sheet	1) Visual Examination	Major	Visual	Random
		2) Dimension	Major	Measurement	Random
2	Aluminium Bus Bar	1) Visual Examination	Major	Visual	Random
		2) Dimension	Major	Measurement	Random

		3) Chemical Analysis	Major	Test	Random
3	Mccb	1)Rating And Make	Major	Visual	Random
		2) Routine Tests			
		I) Mechanical Operation Test	Major	Test	100%
		Ii)Calibration Test	Major	Test	100%
		Iii) Dielectric Tests	Major	Test	100%
4	Routine Test	A) Visual Check	Major	Visual	100%
		B) Verification Of Component Rating	Major	Visual	100%
		C) Other Check			
		i) Easy Accessibility And Maintenance	Major	Visual	100%
		ii) Colour Coding Provided By Coloured Tapes	Major	Visual	100%
		iii) Bus Bar Dimensions	Major	Measurement	100%
		iv) Degree Of Protection Check By Paper	Major	Test	100%
		D) Dimension Check	Major	Measurement	100%
		E) Insulation Resistance Tests	Major	Electrical Test	100%
		F) Mechanical Operation Tests	Major	Mechanical Test	100%
		G) Bus Bar Sup- port And Clearance	Major	Measurement	100%
		H) Continuity Of Circuits And Function	Major	Electrical And Mechanical Test	100%
		I) Painting	Major	Measurement	100%
		J) Overload Release Setting Of The Mccb	Major	Electrical Test	100%
5	Type Test*	All Type Test As Per Is: 13947 & Is:8623	Critical	Visual / Measurement/Electrical/ Mechanical	Plant Standard
6	Acceptance Test	A) Visual Check	Major	Visual	Sample as per relevant IEC
		B) Verification Of Component Rating	Major	Visual	Sample as per relevant IEC
		C) Other Check			

		i) Colour Coding Provided By Coloured Tapes	Major	Visual	Sample as per relevant IEC
		ii) Bus Bar Dimensions	Major	Measurement	Sample as per relevant IEC
		iii) Degree Of Protection Check By Paper	Major	Test	Sample as per relevant IEC
		iv) Easy Accessibility And Maintenance	Major	Test	Sample as per relevant IEC
		D) Dimension Check	Major	Measurement	Sample as per relevant IEC
		E) Insulation Resistance Tests	Major	Electrical Test	Sample as per relevant IEC
		F) Mechanical Operation Tests	Major	Mechanical Test	Sample as per relevant IEC
		G) Bus Bar Sup- port And Clearance	Major	Measurement	Sample as per relevant IEC
		H) Continuity Of Circuits And Function	Major	Electrical And Mechanical Test	Sample as per relevant IEC
		I) Painting	Major	Measurement	Sample as per relevant IEC
		J) Overload Release Setting Of The Mccb	Major	Measurement	Sample as per relevant IEC

Table 13-26: MQP for Pole Top Distribution Box

	Manufacture's Name & Address:	**Manufacturing Quality Plan**	
		Item: Pole Top Distribution Box	
		SUB-SYSTEM:	

Sl. No	Component & operation	Characteristics	Class	Type of Check	Quantum of Check
1	2	3	4	5	6
Section:1 Raw Material Inspection					
Section: 1.1 Raw Material for Body					
1	Polycarbonate Raw Material	1) Visual Examination	Major	Visual	Random
		2) Dimension	Major	Measurement	Random
2	Aluminium Bus Bar	1) Visual Examination	Major	Visual	Random
		2) Dimension	Major	Measurement	Random
		3) Chemical Analysis	Major	Test	Random
3	Mccb If Applicable	1)Rating And Make	Major	Visual	Random
		I) Mechanical Operation Test	Major	Test	100%
		Ii)Calibration Test	Major	Test	100%
		Iii) Dielectric Tests	Major	Test	100%
4	Routine Test	A) Visual Check	Major	Visual	100%
		B) Verification Of Component Rating	Major	Visual	100%
		I) Easy Accessibility And Maintenance	Major	Visual	100%
		Ii) Colour Coding Provided By Coloured Tapes	Major	Visual	100%
		Iii) Bus Bar Dimensions	Major	Measurement	100%
		Iv) Degree Of Protection Check By Paper	Major	Test	100%
		D) Dimension Check	Major	Measurement	100%
		E) Insulation Resistance Tests	Major	Electrical Test	100%
		F) Mechanical Operation Tests	Major	Mechanical Test	100%
		G) Bus Bar Support And Clearance	Major	Measurement	100%
		H) Continuity Of Circuits And Function	Major	Electrical And Mechanical Test	100%

		I) Painting	Major	Measurement	100%
		J) Overload Release Set- ting Of The Mccb	Major	Electrical Test	100%
5	Type Test*	All Type Test As Per Is: 13947 & Is:8623	Critical	Visual / Measurement/ Electrical/ Mechanical	Plant Standard
6	Acceptance Test	A) Visual Check	Major	Visual	Sample as per relevant IEC
		B) Verification Of Component Rating	Major	Visual	Sample as per relevant IEC
		C) Other Check			
		I) Colour Coding Provided By Coloured Tapes	Major	Visual	Sample as per relevant IEC
		Ii) Bus Bar Dimensions	Major	Measurement	Sample as per relevant IEC
		Iii) Degree Of Protection Check By Paper	Major	Test	Sample as per relevant IEC
		Iv) Easy Accessibility And Maintenance	Major	Test	Sample as per relevant IEC
		D) Dimension Check	Major	Measurement	Sample as per relevant IEC
		E) Insulation Resistance Tests	Major	Electrical Test	Sample as per relevant IEC
		F) Mechanical Operation Tests	Major	Mechanical Test	Sample as per relevant IEC
		G) Bus Bar Support And Clearance	Major	Measurement	Sample as per relevant IEC
		H) Continuity Of Circuits And Function	Major	Electrical And Mechanical Test	Sample as per relevant IEC
		I) Painting	Major	Measurement	Sample as per relevant IEC
		J) Overload Release Set- ting Of The Mccb	Major	Measurement	Sample as per relevant IEC

Manufacture's Name & Address:									
SR. NO.	COMPONENT OPERATIONS & DISCRIPTION TEST	TYPE OF CHECK	APPLICABLE CODES Agency						
			Code 1	Code 2	Code 3	Code 4	Code 5	Code 6
1.01	M.S.MATERIAL FOR TANK							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/ Z		N
b)	Dimensional	Meas.	B	K	P	W/Z	E	N
c)	Mechanical Prop.	Meas.	B	K	P	W/ Z		N
d)	Chemical Composition	Meas.	B	K	P	W/ Z		N
1.02(a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z		N
b)	Dimensional	Meas.	B	K	P	W/Z		N
c)	Mechanical Prop. & Hardness	Meas.	B	K	P	W/Z	E	N
d)	Chemical Composition	Meas.	B	K	P	W/Z		N
e)	Galvanization	Meas.	B	K	P	W/Z		N
1.03(a)	GASKETS (Rubber Bonded Cork Sheet) Visual & Check for Expiry date	Visual	A/ B	J/ K	P/S	W/Z		N
b)	Dimensional	Meas.	B	K	P	W/Z	E	N
c)	Hardness, Compressibility, recovery factor compression set & tensile strength	Meas.	B	K	P	W/Z		N
d)	Flexibility & Chemical test (PH, Chloride & Sulphate content)	Meas.	B	K	P	W/Z		N
1.04(a)	BUSHING WITH METAL PARTS Visual	Visual	A/ B	J/ K	P/S	W/ Z		N
b)	Dimensional	Meas.	B	K	P	W/Z		N
c)	Oil Leakage Test	Meas.	B	K	P	W/Z	E	N
d)	Routine Test	Meas.	B	K	P	W/Z		N
e)	Type Test	Meas.	B/ D	K/ L	U/ V	W/Z		Y
1.05(a)	TEMPERATURE INDICATOR (if Applicable) Visual	Visual	A/ B	J/ K	P/ S	W/ Z		N
b)	Dimensional	Meas.	B	K	P	W/ Z	E	N
c)	HV Test (2 KV for 1 Minute) IR Test	Meas.	B	K	P	W/ Z		N
d)	Calibration & Operation (Alarm, Trip)	Meas.	B	K	P	W/ Z		N
1.06(a)	TAP SWITCH (if applicable) Visual	Visual	A/ B	J/ K	P/ S	W/ Z	E	N

b)	Dimensional	Meas.	B	K	P	W/ Z		N
c)	Operational test	Visual	B	K	P	W/ Z		N
1.07 (a)	BUCHHOLZ RELAY (if applicable) Visual	Visual	A/ B	J/ K	P/ S	W/ Z		N
b)	Dimensional	Meas.	B	K	P	W/ Z		N
c)	Routine test including Float Operation, Porosity, Gas Volume, loss of oil, surge test & element test	Meas.	B	K	P	W/ Z	E	N
d)	H.V. Test (2 KV for 1 Minute) with IR test	Meas.	B	K	P	W/ Z		N
e)	Type tests	Meas.	B/ D	K/ L	P/ V	W/ Z		N
1.08	SILICA GEL BREATHER FILLED WITH SILICA GEL (if Applicable)							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z	E	N
b)	Dimensional	Meas.	B	K	P	W/Z		N
c)	Oil Leakage /Pressure Test	Visual	B	K	P	W/Z		N
1.09	CRGO LAMINATION							
a)	Visual	Visual	A/ B	J/ K	U	W/Z		Y
b)	Thickness	Meas.	A/ B	J/ K	U	W/Z		Y
c)	Burr Level & bend Properties	Meas.	D	L	V	W/Z	E	Y
d)	Specific Loss	Meas.	D	L	V	W/Z		Y
e)	Magnetization Characteristics/ Permeability	Meas.	D	L	V	W/Z		Y
f)	Stacking factor	Meas.	D	L	V	W/Z		Y
g)	Ageing test	Meas.	D	L	V	W/Z		Y
1.10(a)	PAPER COVER/INSULATED COPPER CONDUCTOR (PICC) Visual	Visual	A/ B	J/ K	P/ S	W/Z		N
b)	Dimensional (Conductor/Overall/Covering Overlap)	Meas.	A/ B	J/ K	P/ S	W/Z	E	N
c)	Resistivity/ Conductivity	Meas.	B	K	P	W/Z		N
d)	Mechanical Properties (Tensile Strength, elongation etc.)	Meas.	B	K	P	W/Z		N
1.10B	PAPER COVER/INSULATED ALUMINIUM CONDUCTOR (PIAC)							
a)	Visual	Visual	A/ B	J/ K	P/S	W/Z		N
b)	Dimensional (Conductor/Overall/Covering Overlap)	Meas.	A/ B	J/ K	P/S	W/Z	E	N
c)	Resistivity/ Conductivity	Meas.	B	K	P	W/Z		N
d)	Mechanical Properties (Tensile Strength, elongation etc.)	Meas.	B	K	P	W/Z		N

1.10C	ENAMEL COVER/INSULATED COPPER/ALUMINUM CONDUCTOR (EICC/EIAC)							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/ Z		N
b)	Dimensional (Bare Size/Covered Size)	Meas.	A/ B	J/ K	P/ S	W/ Z		N
c)	Resistivity/ Conductivity	Meas.	B	K	P	W/ Z		N
d)	Mechanical Properties (Tensile strength/ Elongation etc)	Meas.	B	K	P	W/ Z		N
e)	Springness	Meas.	B	K	P	W/ Z	E	N
f)	Flexibility & Adherence	Meas.	B	K	P	W/ Z		N
g)	Heat Shock	Meas.	B	K	P	W/ Z		N
h)	Break down Voltage	Meas.	B	K	P	W/ Z		N
i)	Temperature Index	Meas.	B/D	K/L	P/V	W/ Z		N
1.11	Kraft Insulating Paper							
a)	Dimensional/Thickness, density, air, resistance, moisture content & ash content	Meas.	B	K	P	W/ Z		N
b)	PH Value & aqueous extract conductivity	Meas.	B	K	P	W/ Z		N
c)	Bursting Strength	Meas.	B	K	P	W/ Z		N
d)	Elongation & Tensile Strength	Meas.	B	K	P	W/ Z		N
e)	Di electric Strength	Meas.	B	K	P	W/Z		N
f)	Heat Stability (Type Test)	Meas.	B	K	P	W/Z		N
1.12	VALVES							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z		N
b)	Dimension	Meas.	B	K	P	W/Z	E	N
c)	Body leakage test	Meas.	B	K	P	W/Z		N
d)	Flap/Seat & Lever operation/spindle operation (if applicable)	Visual	B	K	P	W/Z		N
1.13	TRANSFORMER OIL							
a)	Appearance	Visual	A/ B	J/ K	P/ S	W/ Z		N
b)	Density at 29.5 deg C	Meas.	B	K	P	W/ Z		N
c)	Viscosity, Kinematics at 27 deg C	Meas.	B	K	P	W/ Z	E	N
d)	Interfacial Tension at 27 deg C	Meas.	B	K	P	W/ Z		N
e)	Flash Point	Meas.	B	K	P	W/ Z		N
f)	Pour Point	Meas.	B	K	P	W/ Z		N

g)	Neutralization Value (i) Total Acidity (ii)Inorganic Acidity/Alkalinity	Meas.	B	K	P	W/ Z		N
h)	Corrosive Sulpher CopperStrip corrosion at 140 deg C for 19hrs	Meas.	B	K	P	W/ Z		N
i)	Electric Strength (B.D.Voltage)	Meas.	B	K	P	W/ Z		N
j)	Dielectric dissipation Factor at 90 deg C(Tan Delta)	Meas.	B/D	K/L	P/V	W/ Z		N
k)	Resistivity at 90 deg C	Meas.	B/D	K/L	P/V	W/ Z		N
l)	Resistivity at 27 deg C	Meas.	B/D	K/L	P/V	W/ Z		N
m)	Oxidation Stability (i) Neutralization Value (ii) Total Sludge	Meas.	B/D	K/L	P/V	W/ Z		N
n)	Presence of oxidation Inhibitor	Meas.	B/D	K/L	P/V	W/ Z		N
o)	Water Content (PPM)	Meas.	B	K	P	W/ Z		N
p)	Accelerated ageing at 115deg C for 96 hrs..	Meas.	B	K	P	W/ Z		N
1.14)	INSULATING PRESS BOARD							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/ Z		N
b)	Dimension/Thickness	Meas.	B	K	P	W/ Z		N
c)	Density	Meas.	B	K	P	W/ Z		N
d)	Shrinkage in air	Meas.	B	K	P	W/ Z		N
e)	Tensile Strength/Compressibilty	Meas.	B	K	P	W/ Z		N
f)	Elongation	Meas.	B	K	P	W/ Z	E	N
g)	Dielectric Strength/Electrical Strength	Meas.	B	K	P	W/ Z		N
h)	Ash Content	Meas.	B	K	P	W/ Z		N
i)	Moisture Content	Meas.	B	K	P	W/ Z		N
j)	Conductivity of aqueous extracts PH Value.	Meas.	B	K	P	W/ Z		N
k)	Reaction with Hot oil/oil absorption	Meas.	B	K	P	W/ Z		N
l)	Cohesion with Piles	Meas.	B	K	P	W/ Z		N
1.15	VARNISH (If applicable)							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z	N	N
b)	Viscosity	Meas.	B	K	P	W/Z		N
1.16	PRIMER							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z	N	N
b)	Shade	Meas.	A/ B	J/ K	P/ S	W/Z		N

1.17	PAINT							
a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z	N	N
b)	Shade	Meas.	B	K	P	W/Z		N
c)	Viscosity	Meas.	B	K	P	W/Z		N
1.18	INSULATING MATERIALWOOD (IF APPLICABLE)							
a)	Visual & dimensional	Visual, Meas.	A/ B	J/ K	P/ S	W/Z	E	N
b)	DielectricStrength	Meas.	B	K	P	W/Z		N
c)	Reaction of hotoil	Meas.	B	K	P	W/Z		N
1.19	BIMETALIC TERMINAL CONNECTOR (if applicable)							
a)	Visual & dimensional	Visual/ Meas.	A/ B	J/ K	P/ S	W/Z	E	N
b)	Acceptance Test	Meas.	B	K	P	W/Z		N
c)	Type test	Meas.	B/D	K/L	U/V	W/Z		N
1.20								
a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z	E	N
b)	Dimensions	Meas.	A/ B	J/ K	P/ S	W/Z		N
1.21	PRESSURE RELIEF DEVICE (If applicable)							
a)	Visual check	Visual	A/ B	J/ K	P/ S	W/Z	E	N
b)	Dimensions	Meas.	B	K	P	W/Z		N
c)	Leakage test	Visual	B	K	P	W/Z		N
d)	Bursting pressure	Meas.	B	K	P	W/Z		N
1.22	EARTHING TERMINAL (if applicable)							
a)	Visual	Visual	A/ B	J/K	P/S	W/Z	N	N
b)	Dimensions	Meas.	A/ B	J/ K	P/ S	W/Z		N
1.23	RATING AND TERMINAL MARKING PLATE							
a)	Visual	Visual	A/ B	J/K	P/S	W/Z	N	N
b)	Dimensions	Meas.	A/ B	J/ K	P/ S	W/Z		N
1.24	LIFTING LUGS							
a)	Visual	Visual	A/ B	J/ K	P/ S	W	E	N
b)	Dimensions	Meas.	A/ B	J/ K	P/ S	W		N

c)	DP Test	Meas.	A/ B	J/ K	P/ S	W			N
1.25	PLAIN ROLLER (if applicable)								
a)	Visual	Visual	A/ B	J/ K	P/ S	W		E	N
b)	Dimensions	Meas.	A/ B	J/ K	P/ S	W			N
1.26	AIR RELEASE PLUG (If applicable)								
a)	Visual	Visual	A/ B	J/ K	P/ S	W			N
b)	Dimensions	Meas.	A/ B	J/ K	P/ S	W		E	N
c)	Oil Leakage	Meas.	A/ B	J/ K	P/ S	W			N
d)	Air release check	Visual	A/ B	J/ K	P/ S	W			N
1.27	MAGNETIC OIL LEVEL GAUGE (if applicable)								
a)	Visual	Visual	B	K	P	W/Z			N
b)	Operation (alarm)	Meas.	B	K	P	W/Z		E	N
c)	HV Test	Visual & meas	B	K	P	W/Z			N
d)	IR	Meas.	B	K	P	W/Z			N
e)	Leak Test	Meas.	B	K	P	W/Z			N
1.28	RADIATORS								
a)	Visual	Visual	A/ B	J/ K	P/ S	W/Z			N
b)	Dimensions	Meas.	B	K	P	W/Z		E	N
c)	Leak Test	Meas.	B	K	P	W/Z			N
d)	Painting checks shade, thickness & Adhesion	Visual & meas	B	K	P	W/Z			N
2.01	TRANSFORMERTANK CONSERVATOR & ACCESSORIES INCLUDING PIPE WORK								
a)	Welder Qualification & welding procedure specification.	Review	D	L	V	W/Z			N
b)	Visual & Dimensions	Visual/ Meas.	A	J	S	W/Z			N
c)	DP test	Visual/ Meas.	A	J	S	W/Z		E	N
d)	Air pressure test/ Leakage test	Visual.	A	J	P	W/Z			N
e)	Type test	Meas.	A	J	U	W/Z			Y
f)	Painting Checks - shade, thickness & adhesion	Visual Meas.	A	J	S	W/Z			N
2.02	FRAME PARTS								
a)	Visual & Dimensions	Visual Meas.	A	J	S	W/Z			N

b)	Painting Checks - shade, thickness & adhesion	Visual Meas.	A	J	S	W/Z		N
2.03	MARSHALLING BOX (Surface cleaning by 7 tank chemical process) If applicable							
a)	Visual check (including workmanship of internal arrangements, ferruling, labeling, access etc. dimensions, paint shade thickness and adhesion test)	Visual.	A/ B	J/ K	P/ S	W/ Z		N
b)	Dimensions	Meas.	A/B	J/K	P/ S	W/ Z		N
c)	Terminal arrangement/ferruling/labeling	Meas.	A/ B	J/ K	P/ S	W/ Z		N
d)	Paint thickness, shade & paint adhesion	Visual.	A/ B	J/ K	P/ S	W/ Z		N
e)	Routine test (H.V. tests, IR test, wiring & Functional check, interlock, make & type of components.)	Meas.	A/ B	J/ K	P/ S	W/ Z		N
g)	Type test	Meas.	B/ D	K/L	U/ V	W/Z		Y
2.04	CORE & FRAME ASSEMBLY							
a)	Visual, Dimension	Visual	A	J	U	W/Z		Y
b)	Check of quality of Varnish Used (if applicable)	Meas.	A	J	S	W/Z		N
c)	Core Loss/Iron loss & check for any hot spot	Meas.	A	J	S	W/Z		N
d)	H.V.Test (Flash Test) (if applicable)	Meas.	A	J	S	W/Z		N
2.05	WINDING							
a)	Inside & Outside Diameter	Meas.	A	J	S	W/Z		N
b)	Dimension of Coil	Meas.	A	J	S	W/Z		N
c)	Insulation Arrangements	Visual.	A	J	S	W/Z		N
d)	Transposition (if applicable)	Visual.	A	J	S	W/Z		N
e)	Joints Checks	Visual.	A	J	S	W/Z		N
f)	Brazing Procedure & Brazer's qualification	Visual.	A	J	S	W/Z		N
2.06)	CORE & COIL ASSEMBLY							
a)	Axial & Radial Insulating arrangement/ Clearance	Meas.	A	J	S	W/Z		N
b)	Position of lead out	Visual.	A	J	S	W/Z		N
c)	HV&LV Connection to the Bushing/tightness of Joints	Visual.	A	J	S	W/Z		N
d)	Assembly of Tap Switch (if applicable)	Visual.	A	J	S	W/Z		N
e)	Visual/Finishing of Insulation on brazed joints.	Visual.	A	J	S	W/Z		N

f)	Clamping of Lead	Visual.	A	J	S	W/Z		N
g)	Flash Test (HV Test) for Core Clamp/Core Bolt & Frame (If applicable as per Design)	Meas.	A	J	S	W/Z		N
h)	Ratio test	Meas.	A	J	S	W/Z		N
i)	Polarity & Vector Group	Meas.	A	J	S	W/Z		N
j)	No Load currents	Meas.	A	J	S	W/Z		N
2.07	DRYING OF CORE & COIL ASSEMBLY							
a)	Temperature of oven	Meas.	A	J	S	W/Z		N
b)	Time duration of Drying	Meas.	A	J	S	W/Z		N
c)	IR Check of winding for end of Drying Cycle	Meas.	A	J	S	W/Z		N
2.08	TANKING INCLUDING OIL IMPREGNATION							
a)	Clamping of winding	Visual.	A	J	S	W/Z		N
b)	Job locking	Visual.	A	J	S	W/Z		N
c)	Visual	Visual.	A	J	S	W/Z		N
d)	Dimensions	Meas.	A	J	S	W/Z		N
e)	Level of Vacuum	Meas.	A	J	S	W/Z		N
f)	Start & end of Oil Filling under Vacuum	Visual.	A	J	S	W/Z		N
2.09	COMPLETE TRANSFORMER ASSEMBLY							
a)	Dimension Measurement of Air clearance & completeness	Meas.	A	J	S	W/Z		N
b)	Mounting of Fitting & accessories	Meas.	A	J	S	W/Z		N
c)	Earth Continuity connection	Visual.	A	J	S	W/Z		N
d)	Painting Checks, Shade, thickness & adhesion	Meas. Visual	A	J	S	W/Z		N
3.1	ROUTINE TESTS							
a)	Ratio Test	Meas.	A	J	U	Y		Y
b)	Vector Group test/ Polarity	Meas.	A	J	U	Y		Y
c)	Winding Resistance test	Meas.	A	J	U	Y		Y
d)	Insulation resistance/Meggar test	Meas.	A	J	U	Y		Y
e)	Impedance voltage/Load loss	Meas.	A	J	U	Y		Y
f)	Measurement of No- load loss and exciting current	Meas.	A	J	U	Y		Y

g)	High Voltage test	Meas.	A	J	U	Y		Y
h)	Measurement of magnetizing current	Meas.	A	J	U	Y		Y
i)	Magnetic balance test	Meas.	A	J	U	Y		Y
j)	Repeat no-load loss measurement	Meas.	A	J	U	Y		Y
k)	Di-Electric test, as applicable (Induced over voltage test, separate source voltage test etc.)	Meas.	A	J	U	Y		Y
l)	Test on Transformer Oil	Meas.	A/ D	J/ L	S/ V	W/Z		Y
m)	Dye Penetration test, Jacking test & Leakage test on complete transformer assembly.	Meas.	A	J	U	Y		Y
n)	Visual, Dimensional checks, air clearance & Paint checks on complete Transformer assembly (paint checks, shade, thickness & adhesion)	Visual Meas.	A	J	U	Y		Y
o)	Marshalling Box (if applicable	Meas.	A	J	U	Y		Y
i)	Visual Check & Paint Check-Shade Thickness & Adhesion	Visual Meas.	A	J	U	Y		Y
3.02	TYPE TEST & SPECIAL TESTS	Meas.	A/D	J/L	U	Y		Y
4.01	Pre-shipment check interchangeability of components of similar transformers & for mounting dimensions	Visual	A	J	S	W		N
4.02	Verification of completeness of accessories	Visual	A	J	S	W		N
4.03	Check for soundness of packing of accessories and fitting like radiators, bushings, explosion vent, dehydration breather, buchholz relay, conservator etc.	Visual	A	J	S	W		N
4.04	Verification of CIP/MICC reference on packing cases	Visual	A	J	S	W		N

Code 1 – Indicates place where testing is planned to be performed A- At equipment's manufacturer itself B- At component manufacturer's work C- At authorized distributor's place D- At independent lab E- At turnkey contractors location F- Not specified	**Code 2 –** Indicates who has to perform the test i.e. Testing agency. J – The equipment manufacturer K – The component manufacturer L - The third party M – The turnkey contractor
Code 3 – Indicates who shall witness the tests i.e. witnessing agency	**Code 4 -** Review of test Reports/ certificates

P – Component manufacturer itself Q – Component manufacturer and equipment Manufacturer R- Component manufacturer, Equipment Manufacturer and contractor S - Equipment manufacturer itself T – Equipment manufacturer and contractor U – Equipment manufacturer , Contractor V – Third party itself	W –By equipment manufacturer during raw material /bought out component inspection. X- By contractor during product/process Inspection. Y – By EDCL during product/process inspection. Z - By contractor and / or EDCL During product/process inspection
Code 5- Whether specific approval of sub-vendor / component make is envisaged. E – Envisaged N – Not envisaged	**Code 6 -** Whether test records is required to be Submitted after final inspection for issuance of CIP/MICC Y - Yes , N- No

Table 13-28: MQP for Lightening Arrestor

S.l. No.	Component	Characteristics	Class	Type of check	Quantum Of Check
1	**2**	**3**	**4**	**5**	**6**
Section: I Bought out Components					
1	Porcelain Bushing	a) Major Dimension	Major	Physical	2 Samples/Lot
		b) Visual Examination	Major	Physical	100%
		c) Porosity	Major	Physical	1 Samples/Lot
		d) Electrical Routine Test	Critical	Electrical	100%
		e)Temp. Cycle Test	Major	Physical	2 Samples/Lot
		f) Pressure test	Minor	Visual	100%
2	Aluminium Casting for S.A (End Fittings)	a) Major Dimension	Major	Physical	2 Samples/Lot

S.l. No.	Component	Characteristics	Class	Type of check	Quantum Of Check
1	**2**	**3**	**4**	**5**	**6**
		b) Visual Examination	Major	Physical	100%
		c) Chemical Analysis	Major	Chemical	1 test piece for every 2000 Kgs/cast
		d) Tensile test on test Bar	Major	Mech	
		e) Elongation test on test Bar.	Major	Mech	
3	FRP Tubes/ Rods	a) Major Dimension	Major	Physical	100%
		b) Visual Examination	Major	Physical	2 Samples/Lot
		c) Leakage Currernt test	Critical	Electrical	2 Samples/Lot
		d) Voltage withstand test.	Critical	Electrical	2 Samples/Lot
4	Gaskets/ 'O' Rings (Rubber Component - Neoprene)	a) Dimension	Major	Physical	2 Samples/Lot
		b) Hardness	Major	Mech	2 Samples/Lot
		c) Compression test	Major	Mech	2 Samples/Lot
		d) Accelerating Ageing	Major	Mech	2 Samples/Lot
		e) Tensile & Elongation test	Major	Electrical	2 Samples/Lot
5	Sulphur Cement	a) Compression Strength	Major	Physical	As per relevant IEC
		b) Flexural Strength	Major	Physical	As per relevant IEC

S.l. No.	Component	Characteristics	Class	Type of check	Quantum Of Check
1	**2**	**3**	**4**	**5**	**6**
		c) Water Absorption	Major	Physical	As per relevant IEC
		d) Bond Strength	Major	Physical	As per relevant IEC
		e) Tensile Strength	Major	Physical	As per relevant IEC
		f) Chemical Analysis	Major	Chemical	As per relevant IEC
6	Pressure Release Diaphragm	a) Visual Check	Major	Physical	100%
		b) Dimensions	Major	Physical	1 Samples/Lot
		c) Chemical Analysis	Major	Chemical	1 Samples/Lot
		d) Mechanical Test	Major	Mech	1 Samples/Lot
7	Spring	a) Major Dimension	Major	Physical	2 Samples/Lot
		b) Visual Examination	Major	Physical	100%
		d) Mechanical properties	Major	Mech	1 Samples/Lot
8	Grading Rings/ Corona Rings & Terminal Connector	b) Visual Examination	Major	Physical	100%
		a) Major Dimension	Major	Physical	1 Samples/Lot
9	Insulating Base	b) Visual Examination	Major	Physical	100%
		a) Major Dimension	Major	Physical	1 Samples/Lot

S.l. No.	Component	Characteristics	Class	Type of check	Quantum Of Check
1	**2**	**3**	**4**	**5**	**6**
		c) Electrical withstand Test	Major	Physical	10 Samples/Lot
Section –II : Manufacturing Item - Inhouse (Metal Oxide Block)					
10	Metal Oxide Blocks	a) Visual Examination	Major	Physical	100%
		b) Dimensions test	Major	Physical	10 Samples/Lot
		c) Power frequency reference Voltage test. {dc Milli Amps Test}	Critical	Electrical	100%
		d) Residual Voltage test	Critical	Electrical	100%
		e) ENERGY handling {line Discharge} Class test	Critical	Electrical	3 Samples/batch
		f) High Current Test	Critical	Electrical	3 Samples/batch
		g) Thermals tability test	Critical	Electrical	3 Samples/batch
		H) Watt Loss Or Resistive Current {Accelerated Ageing test}	Critical	Electrical	3 Samples/batch
Section – III : Routine test on Surge arresters and Surge monitors.					
1A	Routine test on complete Arrester	a) Seal leak test	Major	Physical	100%
		b) Insulation resistance	Major	Electrical	100%
		c) Power frequency Reference Voltage test	Major	Electrical	100%
		d) Leakagae current test.	Major	Electrical	100%
		e) P.D Test	Major	Physical	100%

S.l. No.	Component	Characteristics	Class	Type of check	Quantum Of Check
1	**2**	**3**	**4**	**5**	**6**
		f) Lighting impulse Residual Voltage test at Nominal Discharge current.	Major	Electrical	100%
		g) Visual Examination	Major	Physical	100%
		h) Dimension	Major	Physical	3 samples
		i) Verticality check	Major	Physical	1 Sample/lot
1B	Routine Test on Surge Monitor	a) Visual Examination	Major	Physical	100%
		b) Dimension	Major	Physical	100%
		c) operation test	Major	Electrical	100%
Section – IV: Acceptance test on Surge arresters and Surge monitors.					
2A	Acceptance Test on Surge arrester	a) Power frequency Reference Voltage test	Critical	Electrical	Cube rootof qty offered
		b) Lighting impulse Residual Voltage test at Nominal Discharge current.	Critical	Electrical	
		c) P.D Test	Critical	Electrical	
		d) Galvanizing test on Ground terminal bracket. (zinc coating thickness)	Major	Physical	1 Sample
		e) Visual Examination	Major	Physical	100%

S.l. No.	Component	Characteristics	Class	Type of check	Quantum Of Check
1	**2**	**3**	**4**	**5**	**6**
		f) Dimension	Major	Physical	1 Sample
2B	Acceptance test on Surge Monitor	a) Visual Examination	Major	Physical	100%
		b) Dimension	Major	Physical	1 Sample
		c) operation test	Major	Electrical	1 Sample

Section-14. Procurement Guidelines for efficient procurement of material and services.

14.1 Introduction

a. All the guidelines for procurement of goods and services shall be as per the framework of EDCL Purchase Procedure and Delegation of Powers issued from time to time.
b. The guidelines will be applicable in respect of all procurement of services and goods in the Corporate Office, Zonal Offices, Project Offices, Sub Offices and Other Offices of EDCL.
c. In case of difference in guidelines & DOP, DOP shall prevail.

14.2 Procurement Philosophy

a. Right Product- in terms of meeting technical specifications, quality & quantities, that minimizes the environmental impact;
b. Right in Time- in terms of meeting user's requirements, ensuring minimum inventory carrying cost & avoiding stock outs;
c. Right Price- best in competitive environment & to ensure minimum inventory carrying costs;

And of course procurement from the right source is of paramount importance, as it leads to above objectives, cumulatively.

14.3 Procurement Policy

- **Transparency, fairness and fraud prevention** is important to ensure accountability and proper utilization of funds
- **Equal opportunity** ensures that the suppliers/sellers have equal opportunity to compete
- **Economy and Efficiency** means that goods and services to be procured at a their true worth
- **Effectiveness** means that the goods and services procured will help to achieve project goals & objectives

14.4 Fundamentals of procurement

In order to ensure the above, following things are desired in contract document for efficient procurement of material and services in execution of large electrification projects;

- All guidelines in the contract document needs to be flawless and comprehensive,
- Contract document should contain all the possibilities, implications and challenges that may impact the timelines of the project,
- There shall be proper mechanism for ensuring quality team,
- Roles and responsibilities needs to be define in the contract document
- For ensuring safety, proper safety guidelines needs to be describe to achieve 100% compliance to the guidelines,
- The Contract document shall contain the following important sections to be the part of the document;
    - Invitation for Bids (IFB)

- Instruction to Bidders (ITB)
- Bid Data Sheets (BDS)
- General Conditions of Contract (GCC)
- Special Conditions of Contract (SCC)
- Scope of Works (SoW)
- Bill of material (BoM)
- Sample Forms and Procedures

- The consultant have gone through the GoR procurement law, further, we have not recommended any changes in the law, and instead, some minor additions were recommended as part of framework contract which was not in practice currently at EDCL. These were:
  - Framework contract can be placed based on the estimated quantities and Separate release orders may be issued from the Framework contract for districts as per the implementation plan.
    - Since there were many clusters of villages for grid extension and micro grids it is recommended to award works on 2-3 different vendors in one province to have flexibility in execution within the conditions of existing laws.
    - Framework contract should have the flexibility of variation of quantities as per the requirement of the project within the conditions of existing laws.
- To achieve competitive prices negotiations may be carried out with qualified bidder as per the Rwanda procurement law and negotiation can be carried out through manually driven process or utilising technology enabled platforms i.e. e-reverse auction (details has been attached as an annexure-C)

Further, the procurement flow will be performed as per government law and approved REG procurement Policies and Procedures.

ANNEXURE-C

E-Reverse Auction as per Article 75 (Negotiations with selected consultant) of the Official Gazette no. Special of 07/09/2018

a. E-Reverse Auction(e-RA) Auction may be used as an effective negotiation tool for the large volume of work having a higher value of the contract.
b. E-Reverse Auction aims to enable negotiations to be engaged in using technology that allows a faster pricing process, a more objective way of selecting bidders, and greater transparency of market prices. However, EDCL reserve the right to use this tool or may use manual negotiations.

e-Reverse Auction Guidelines:

These Guidelines are intended to guide about e-Reverse Auction processes, awarding criteria, and confidentiality requirements, and to the binding nature of bids made at e-Reverse Auction.

The aim of e-Reverse Auctions is to enable negotiations to be engaged in using technology that allows a faster pricing process, a more objective way of selecting bidders and greater transparency of market prices. EDCL and bidders are expected to follow the standards set forth in these Guidelines.

1. Reverse Auctions are carried out under the framework of rules as defined by EDCL and all bidders participating in Reverse Auction shall understand/accept and give an undertaking for compliance with the same to the EDCL in the prescribed format (clause no.14.5.2).
2. Any bidder not willing to submit such an undertaking shall be disqualified for further participation with respect to the said procurement.
3. Reverse Auction shall be carried out amongst the bidders who have quoted within lowest price + 15% of the evaluation criteria price. However, in case no other bidders fall within +15% of L-1 quoted prices then reverse auction can take place up to lowest price + 25% or as decided by EDCL shall be allowed to participate in the online Reverse Auctioning.
4. The overall lowest price quoted by the bidder will be considered as Reserve Base Price during reverse auction, further the item wise price of all items shall be arrived from the overall lowest quoted price in the same ratio as quoted by the bidders earlier in the financial bid and all the technically qualified bidders will be considered at the same platform.
5. Decrement value to be kept for conducting Reverse Auction shall range from 0.50% to 5% of the Reserve Base Price converted to the nearest round figure, depending upon the value of the bid.
6. Preferably the time duration kept for conducting Reverse Auction process is for at least 3-4 hours with the incremental time duration of 30 minutes from the time of last quote considering that the bidder may be provided sufficient time for quoting their best lowest rates. The window may be extended to accommodate 30 minutes, if required, response time. The auction will terminate either at the scheduled end time or as extended as per requirement till there is no response during the incremental time duration. However, EDCL reserves the right to modify the process with pre-information to bidders, if required.
7. The eligible bidders can participate in the online Reverse Auction from any place of their choice and need not to visit EDCL office for this purpose.
8. The User ID and password for online reverse auction will be provided at the time of bidder registration.
9. The Reserve Base Price for Reverse Auction will be informed after the Opening of Price Bid. This shall be the lowest rate received against the initial price bids submitted by participating bidders.
10. EDCL shall make all efforts to rectify the problem(s) leading to system failure during the online reverse auction. However, in case the system could not be restored within the reasonable time period as deemed fit by EDCL, the reverse auction event shall be suitably extended/ shall be restarted again after rectification by giving a new schedule for the same, which shall cover the left over time period as per the original schedule. On restart of reverse auction, the last R1 price received during reverse auction at which the reverse auction event got terminated, shall be the starting price.
11. Where necessary, EDCL will facilitate training for participation in Reverse Auction either on its own or through the service provider for the Reverse Auction to familiarize the vendors/bidders with Reverse Auction process.

12. Any vendor/bidder not participating in training shall do so at his own risk and it shall not be open for him to make any complaint/grievance later.
13. The Reverse Auction may be conducted by EDCL through a service provider specifically identified/appointed/empanelled by EDCL.
14. In case of Reverse Auctions conducted by EDCL through a Service Provider, the EDCL shall enter into a separate agreement clearly detailing the role and responsibilities of the service provider hosting the web portal for the Reverse Auction. The Service Level Agreement (SLA) by EDCL with the service provider is an arrangement for smooth and fair conduct of the Reverse Auction.
15. Every successive bid by the bidder / vendor being decremented bid shall replace the earlier bid automatically and the final bid as per the time and log-in ID shall prevail over the earlier bids.
16. No two bids can have identical price from two different vendors. In other words, there shall never be a “Tie” in bids.
17. All bidders will be able to view during the auction time the current lowest price in the portal. Bidder shall be able to view not only the lowest bid but also the last bid made by him at any point of time during the auction.
18. Names of bidders/ vendors shall be anonymously screened in the Reverse Auction process and vendors will be given suitable dummy names. After completion of Reverse Auction, the service provider / auctioneer shall submit a report to EDCL with all details of bid, the original names of the bidders and the L-1 bidder.
19. The successful vendor/ bidder shall be obliged to provide a Bill of Material at the last bid price at the close of auction.
20. EDCL decision on award of Contract shall be final and binding on all the Bidders.

ACCEPTANCE FORM FOR PARTICIPATION IN REVERSE AUCTION EVENT
(To be signed and stamped by the bidder)

The following terms and conditions need to be accepted by the bidder on participation in the bid event:

1. EDCL shall provide the user id and password to the authorized representative of the bidder. (Authorization Letter in lieu of the same shall be submitted along with the signed and stamped Acceptance Form).
2. EDCL’s decision to award the work would be final and binding on the suppliers/ bidders.
3. The bidder agrees to non-disclosure of trade information regarding the purchase, identity of EDCL, bid process, bid technology, bid documentation and bid details to any other party.
4. The bidder is advised to fully make aware themselves of auto bid process and ensure their participation in the event of reverse auction, failing which EDCL will not be liable in any way.
5. In case of bidding through Internet medium, bidders are further advised to ensure availability of the infrastructure as required at their end to participate in the auction event. Inability to bid due to telephone line glitch, internet response issues, software or hardware hangs, power failure or any other reason shall not be the responsibility of EDCL.
6. In case of intranet medium, EDCL shall provide the infrastructure to bidders. Further, EDCL has sole discretion to extend or restart the auction event in case of any glitches in infrastructure observed which has restricted the bidders to submit the bids to ensure fair & transparent

competitive bidding. In case an auction event is restarted, the best bid as already available in the system shall become the basis for determining start price of the new auction.

7. In case the bidder fails to participate in the auction event due any reason whatsoever, it shall be presumed that the bidder has no further discounts to offer and the initial bid as submitted by the bidder as a part of the tender shall be considered as the bidder’s final no regret offer. Any offline price bids received from a bidder in lieu of non-participation in the auction event shall be out rightly rejected by EDCL.
8. The bidder shall be prepared with competitive price quotes on the day of the bidding event.
9. The prices as quoted by the bidder during the auction event shall be inclusive of all the applicable taxes, duties and levies and shall be FOR at site.
10. The prices submitted by a bidder during the auction event shall be binding on the bidder.
11. No requests for time extension of the auction event shall be considered by EDCL.
12. The original price bids of the bidders shall be reduced on pro-rata basis against each line item based on the final all inclusive prices offered during conclusion of the auction event for arriving at Contract amount.

Signature & Seal of the Bidder

Section-15. Implementation Plan – Grid Extension

The Detailed Project Report (DPR) for Grid Extension implementation plan is attached as Annexure-A in the below link, covering the following sections;

Section A: It covers executive summary along with graphs
Section B: It covers Scope of Work (quantity required) & Estimated Cost
Section C1: It covers province/district wise summary of infrastructure
Section C2: It covers province/district wise summary of customers
Section C3: It covers yearly province/district wise summary of customer
Section C4: It covers yearly province/district wise summary of infrastructure
Section D1: It covers extension/village wise coverage of infrastructure
Section D2: It covers extension/village wise coverage of customer
Section D3: It covers extension/village wise coverage of customer demand
Section E: Time Schedule
Section F-1: Bill of Material- MV line
Section F-2: Bill of Material- DT line
Section F-3: Bill of Material- LV line
Section F-4: Bill of Material- Customer connection

Link to download Complete Implementation plan under Grid Extension:
https://drive.google.com/file/d/1XB2fiqEtO0gHbXVKVmkZi2BRh-iDMCZS/view?usp=sharing

Section-16. Implementation Plan – Micro Grid

The Detailed Project Report (DPR) for Micro Grid implementation plan is attached as Annexure-B in the below link, covering the following sections;

Section A: It covers executive summary along with graphs
Section B: It covers Scope of Work (quantity required) & Estimated Cost
Section C1: It covers province/district wise summary of infrastructure
Section C2: It covers province/district wise summary of customers
Section C3: It covers yearly province/district wise summary of customer
Section C4: It covers yearly province/district wise summary of infrastructure
Section D1: It covers extension/village wise coverage of infrastructure
Section D2: It covers extension/village wise coverage of customer
Section D3: It covers extension/village wise coverage of customer demand
Section E: Time Schedule
Section F-1: Bill of Material- SPV system
Section F-2: Bill of Material- LV line
Section F-3: Bill of Material- Customer connection

Link to download Complete Implementation plan under Micro Grid:
https://drive.google.com/file/d/1gdy7UYl95KGRQzyRPiaFejy21HV3B-hA/view?usp=sharing