RWANDA: TRANSMISSION MASTER PLAN *(2021 – 2028)*

DECEMBER 2021

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LIST OF ABBREVIATIONS

BIA	Bugesera International Airport
BIP	Bugesera Industrial Park
HV	High Voltage
IP	Industrial Park
OHTL	Overhead Transmission Line
SS	Substation

EXECUTIVE SUMMARY

Reliable and resilient electricity supply is essential for any economy to grow and prosper. A strong, dependable and robust transmission network that has sufficient capacity to satisfy demand requirements is a necessary condition for provision of this electricity to all corners of a nation. The transmission network must therefore be developed and extended to meet increasing demands on the network by connecting new loads, power stations, substations and other network strengthening elements. This development must be least-cost while satisfying key network objectives and criteria set by the utility to ensure high quality electricity delivery and supply throughout the country.

The Transmission Development Plan 2021 – 2028 is the plan for the development of the Rwandan transmission network and interconnection over the next 7 years. This plan presents projects that are required for the operation of the transmission network. In addition, future needs that may drive future potential projects are represented in the demand forecast methodology.

Drivers of Transmission Network Development

The key objectives guiding investment in the Rwandan transmission network are summarized as follows:

I. Ensuring the security of electricity supply.
II. Ensuring interconnectivity with neighboring countries to foster regional electricity trade.
III. Ensuring the reliability, quality and resilience of the Rwandan grid.

Methodology

An existing and updated model of the entire national transmission system was done using DigSilent PowerFactory[1]. Existing and forecasted loads on the system were included in the model and simulation with the existing network was done (power flow study) to identify current and potential problematic areas in terms of voltage load, transformer loading and other key indicators of grid weaknesses. The future network (expected lines, interconnectors, transformers, loads and other elements) were then included in the model and further simulated to ensure grid stability. A contingency analysis[2] was then performed on the entire network and results presented in the report.

[1] Key transmission related parameters in annex.
[2] Results in Annex.

Transmission Network Reinforcements

This development plan considers all transmission-related projects – those underway and expected/required for transmission system reliability and stability (both funded and unfunded) – with their expected years of operation.

Capital Expenditure

All transmission development projects require funding for the planning period addressed within this plan. Annual cost breakdowns per projects over the planning horizon are presented within this plan – both funded and unfunded[3].

In addition, this particular update (December 2021) includes updated cost estimates (expropriation, customs and feasibility study related costs). Projects that still require funding have further been prioritized in order of their relevance to grid reliability requirements, based on power flow and contingency analyses done.

[3] See transmission project annual breakdown, Annex.

I. INTRODUCTION

The national transmission network is responsible for transporting the power produced by generation power plants throughout the country. To ensure that this network is reliable and efficient, a plan has been developed by REG to guide its expansion as the national load increases. This plan has been developed subject to specific criteria to ensure network strength and reliability in the country. This plan is reviewed every 6 months to ensure that the set objectives set out in this plan are still being fulfilled.

The Rwanda national high voltage (HV) transmission system operates at 220kV and 110kV. The 220kV network is used for larger generation power plants and for power trade, while the 110kV is the main transmission network used at national power transmission level to the end user. As of June 2021, the total length of the HV transmission system is 971.75 km with 35[4] substations on the network.

The following sections will highlight the general objectives, key methodologies, challenges of the existing network, planning methodology & criteria and planned network development projects.

II. OBJECTIVES

The function of the Transmission Network (110kV & 220kV) is to evacuate power from the generation stations to the main substations in the country. The objective is to do this efficiently to minimize losses, enable system reliability and allow flexibility in operation. This transmission plan aims to do the following:

1. To plan and design for regional transmission interconnectors.
2. To plan and design the network to function under contingency conditions.
3. To plan and design how every power plant with an installed capacity of over 5 MW must have more than one evacuation line. This is to ensure the availability of the power plants under all conditions.
4. To plan and design how existing lines can be upgraded or maintained without network interference or interruption of supply.
5. To install static or dynamic reactive control devices to control high voltages during off-peak conditions and low voltages on single and multiple contingencies.

[4] Excluding Mururu I and II, including the nearly completed Nyabihu S/S.

III. PROBLEM STATEMENT

Some of the key identified challenges that affect the national transmission system in Rwanda are outlined below:

1. The Rwandan national grid is isolated from the transmission networks of the neighbouring countries or interconnected with a weak link.
2. Many substations have only one source of supply and some of them don`t have n-1 connections.
3. All significant power plants have only one evacuation line each, which reduces the availability of the power plants during the failure of the evacuation line and this have for several occasions, resulted into catastrophic circumstance of blackout.
4. Frequent voltage drops on the high voltage network due to small size of network conductors, system overloading & long distance.
5. High voltages in the transmission lines due to light loading of transmission lines and limited reactive power control capability.

IV. TRANSMISSION NETWORK PLANNING METHODOLOGY

The following steps are taken to ensure efficient and relevant planning of the transmission network:

1. Modeling the existing network using Power Factory.
2. Modeling network with existing loads.
3. Simulation of existing network with future loads considering electrification and bulk loads to determine network supply limits.
4. Modeling future network.
5. Simulate future loads on future network.
6. Perform Contingency Analysis.

V. PLANNING CRITERIA

The following key criteria are used and incorporated within the existing Rwanda transmission model to ensure reliability and stability of the grid:

1. All transmission lines in Rwanda must have N-1 supply option (supplied from at least two sources).
2. All Power Substations in Rwanda must have N-1 supply (at least two evacuation options).
3. Evacuation of 5MW Generation and above from a single plant must be able to meet at least n-1 condition (at least two evacuation options).
4. High Voltage supply and substations must be installed at all major cities and industrial parks.
5. All regional interconnectors and transmission lines supplying major cities or bigger permanent loads are constructed to allow for two circuits (allow for future growth – use same corridor and structures).
6. Transmission lines shall be designed to provide for a minimum of N-1 physical contingency and this provision may provide a waiver to double circuit requirement if such is not justified by Generation or expected demand
7. The transmission lines constructed on voltages above 110kV will be operated at 110kV where required until the load justifies the 220kV (reduce reactive losses) or other reactive compensation is installed for local network conditions except Countries interconnection transmission 220kV lines.
8. The lines constructed for major international/regional load transfer/electricity trade will be operated on voltages at which they were designed for to ensure coordination and harmonization.
9. Distribution (15kV and 30kV) must not be on the same transformer as the regional interconnection network (220kV or above). Distribution must be done from the 110kV intermediate voltage network (to maintain the interconnection reliability).
10. Transmission Substations must be designed and positioned in accordance with the requirements of the Distribution Master Plan.
11. All substations shall have a double HV bus bar with split or double MV bus bar and coupler breaker to allow operational flexibility (and availability) of the network.
12. All new substations must be designed and prepared for two transformers (N-1) even if only one is installed initially.

13. A minimum transformer size of 20MVA must be used for all new Distribution substations.

14. All substations shall have disturbance fault recorders and synchro-check relays.

VI. LOAD FORECAST METHODOLOGY

To plan for transmission network growth and reliability, the load must also be considered and appropriate and country-relevant load forecasting methodology must be applied. This chapter outlines the key assumptions and methodology applied in this expansion master plan.

It is important to note than in transmission planning, it is not realistic to model a static/single load growth forecast percentage. This is due to different factors such as population (potential load) growth & distribution (which determines different substation feeder load growth percentages), urbanization (urban load growth is different from that of rural), load type and current/expected location on the network (e.g. residential, industrial, commercial) which is highly dependent on development plans (in the case of Rwanda secondary cities and their corresponding infrastructure such as industrial parks).

Bearing this in mind, the different feeder loads and expected load growth per substation throughout the country were considered to vary (e.g. lower growth in rural areas, versus medium or high growth in urban areas or areas expecting bulk loads like industrial parks and/or commercial centers).

In addition, loads were modelled according to 3 different categories:

1. Existing loads (already connected to the grid).
2. New loads (expected to be connected to the grid by 2024 as per the NEP expected grid connections).
3. Bulk loads (non-residential loads that normally require more available and stable power supply than residential loads, e.g. industrial parks, airports, commercial centers, etc.).

These different load types also correspond to dynamic load growth forecasts, given the factors stated earlier on.

ASSUMPTIONS:

The following assumptions were made to calculate load forecasting:

1. **Existing Loads**: The growth of the existing load is divided into 3 levels – low, medium, and high growth for urban and rural loads. Annual load growths are presented in percentages per growth forecast category (refer to table 1 below).

Table 1: Load growth per category

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Growth on Existing load LOW	0.0%	4.0%	4.0%	4.0%	4.0%	3.5%	3.5%	3.5%	3.0%	3.0%	3.0%	2.5%	2.5%	2.5%
Growth on Existing load MED	0.0%	5.0%	5.0%	5.0%	5.0%	4.5%	4.5%	4.5%	4.0%	4.0%	4.0%	3.5%	3.5%	3.5%
Growth on Existing load HI	0.0%	6.0%	6.0%	6.0%	6.0%	5.5%	5.5%	5.5%	5.0%	5.0%	5.0%	4.5%	4.5%	4.5%

Different substation feeders were simulated using different growth categories. For example, load growth observed on feeders supplying Nyamagabe is not expected to grow as fast as those supplying Kigali or Rubavu. Therefore, the feeders connecting Nyamagabe district load were modelled under low/medium growth conditions while those connected to Kigali or Rubavu were modelled as high growth conditions based on historical growth and expected connections as per the table above. *This assumption only applies for existing loads however*. The methodology differs when considering the new and bulk loads expected on the network.

This was done to capture a more realistic picture of the varying demand per feeder on the network for more prudent planning and investment channeling for network strengthening.

2. **New & Bulk Loads**: The population growth is taken as 3%[5]. That implies that target (new loads) connections are expected to grow annually by 3%. After 100% national electrification, the population growth must still be catered for.

DigSilent PowerFactory has a provision for expected load growths based on new connections in the form of expected curves (i.e. S-curve, step functions and other user-defined curves where applicable). For the new connections the "S" Curve for electrification and therefore new loads - was considered. This represents a gradual load increase, as the number of appliances increase per household.

For bulk loads, however the load increase was represented by step increase (step functions) on the expected feeder they are to be connected to. This is due to the higher nature of their demand on the network, which is typically different from residential loads in Rwanda.

METHODOLOGY:

Load forecasting methodology has been performed according to the following process:

[5] Obtained from population growth statistics as per the NISR.

I. Collection of data for population growth (date collected from NISR) (3% per year).

II. Following the development roadmap of Industrial Parks (data collected from MINICOM) for more accurate bulk load representation.

III. Use of arc-GIS software in determination of households located 37 meters from Low Voltage network (service connection length).

IV. Considering the After Diversity Maximum Demand (ADMD) in Rwanda (80Watts per household).

V. Modelling per substation per feeder, paying close attention to the area being modelled (urban/rural, existing, new, bulk or all load categories and their expected load growths and connection growths per area). The total expected annual peak load (MW) is then simulated in the model to reflect the following results:

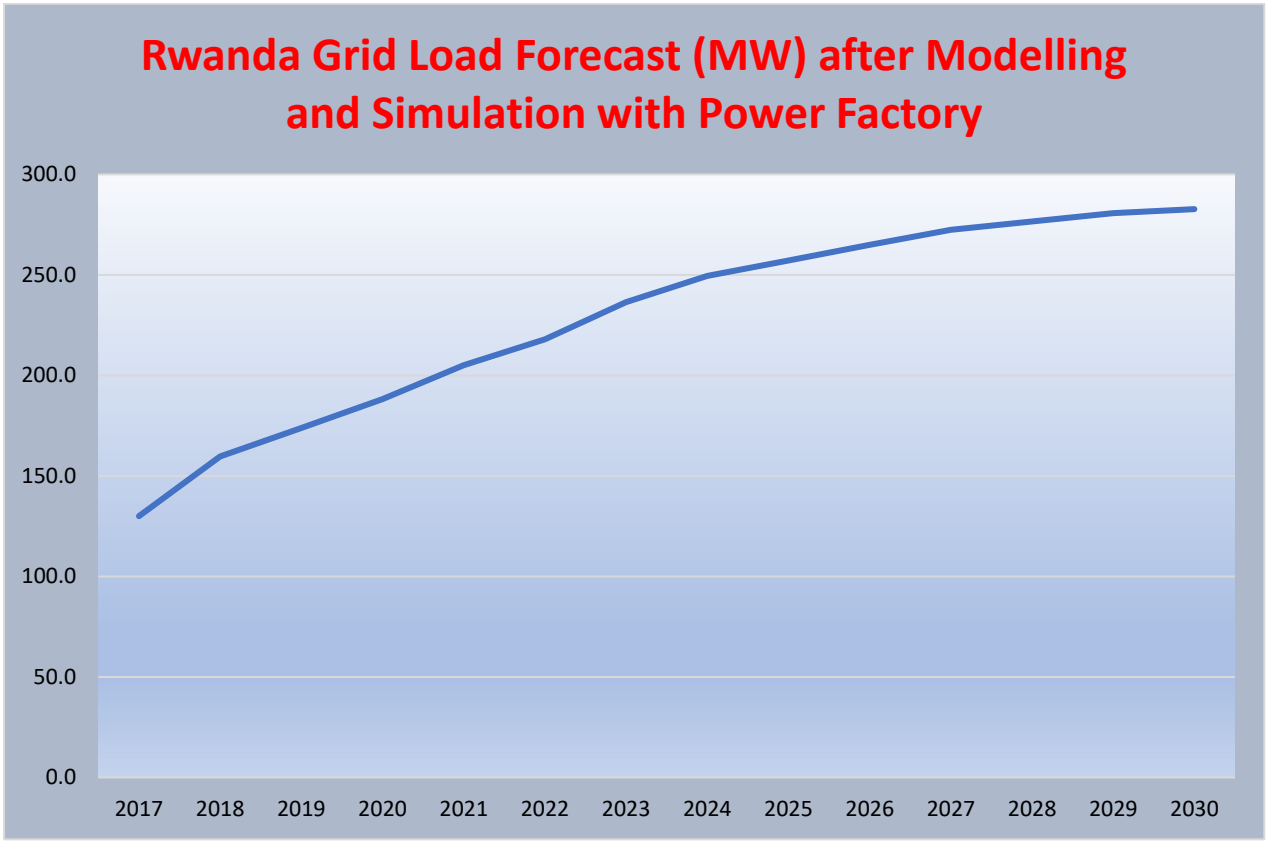

Figure 1: Grid load forecast (in MW)

Table 2: Peak demand

Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Peak demand (MW)	133.9	151	165.1	178.0	196.5	209.5	217.2	224.9	232.5	240.6	250.7	262.7

This aggreggated grid load forecast obtained from the modelling and simulation results in an average growth of 6.4% throughout the planning horizon. It is important to note that demand growth was done per feeder, taking into account load types, categories, expected connections as per the grid-off-grid target by 2024 as well as the area being modelled (urban/rural).

This is to ensure prudent planning and investment advisory as opposed to an overestimated aggreggated growth, and yet different areas of the country will grow at different paces. Demand growth considerations in transmission planning are heavily location-based, urbanization-dependent and bulk-load and electrification-target oriented. Therefore, these disparities in load growth have been captured in the model for a more realistic picture of the nature of loads and expected loads in Rwanda.

VI. Calculation of feeder load:

The total load per feeder is calculated using the equation below:

$$FL = ER \times HH \times ADMD + IPL$$

where:

FL	Feeder Load
ER	Electrification Rate
HH	Number of households located a maximum distance of 37 m from the LV network
ADMD	After Diversity Maximum Demand
IPL	Industrial Parks Load

The following is an illustration of the exercise done to identify households which are located 37m max from the LV network in arc-GIS software

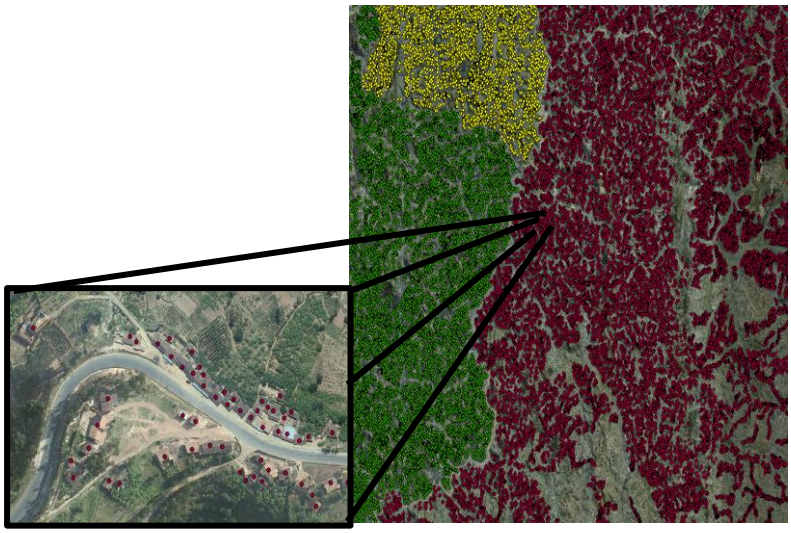

Figure 2: Illustration of households within 37m proximity to an LV network line

Using ArcGIS, the total number of these households are calculated and used in the feeder load calculation in step VI above.

VII. KEY UPDATES – DECEMBER 2021:

In addition to the June 2021 updates already incorporated into the transmission model, the following December 2021 updates were made:

- **Inclusion of REG Training Centre under unfunded projects.**
- **Project Cost Update:** Total project costs for transmission related projects were updated to include the following extra costs:
    I. **Expropriation Cost**: 5% of total cost.
    II. **Customs-related Cost**: 45% of total cost.
    III. **Feasibility Study (FS) Cost** 10% of total cost.

These changes were incorporated into the section that displays the unfunded transmission projects only. The update was not done on projects with funding. In addition, prioritization of the projects was done for unfunded projects based on the level of need of a given project projected to fulfill the transmission plan objectives in the given year

VIII. TRANSMISSION NETWORK DEVELOPMENT

This chapter shows the expected annual transmission network development from 2021 – 2028[6]. Maps and tables corresponding to the map, i.e. every line and/or substation that is scheduled for construction.

[6] For an updated list of ongoing, funded and unfunded transmission-related projects, please go to the annex.

2021 TRANSMISSION NETWORK

This section displays the High Voltage (HV) transmission network in 2021 (map below[7]), and the projects that were implemented in that year (table following).

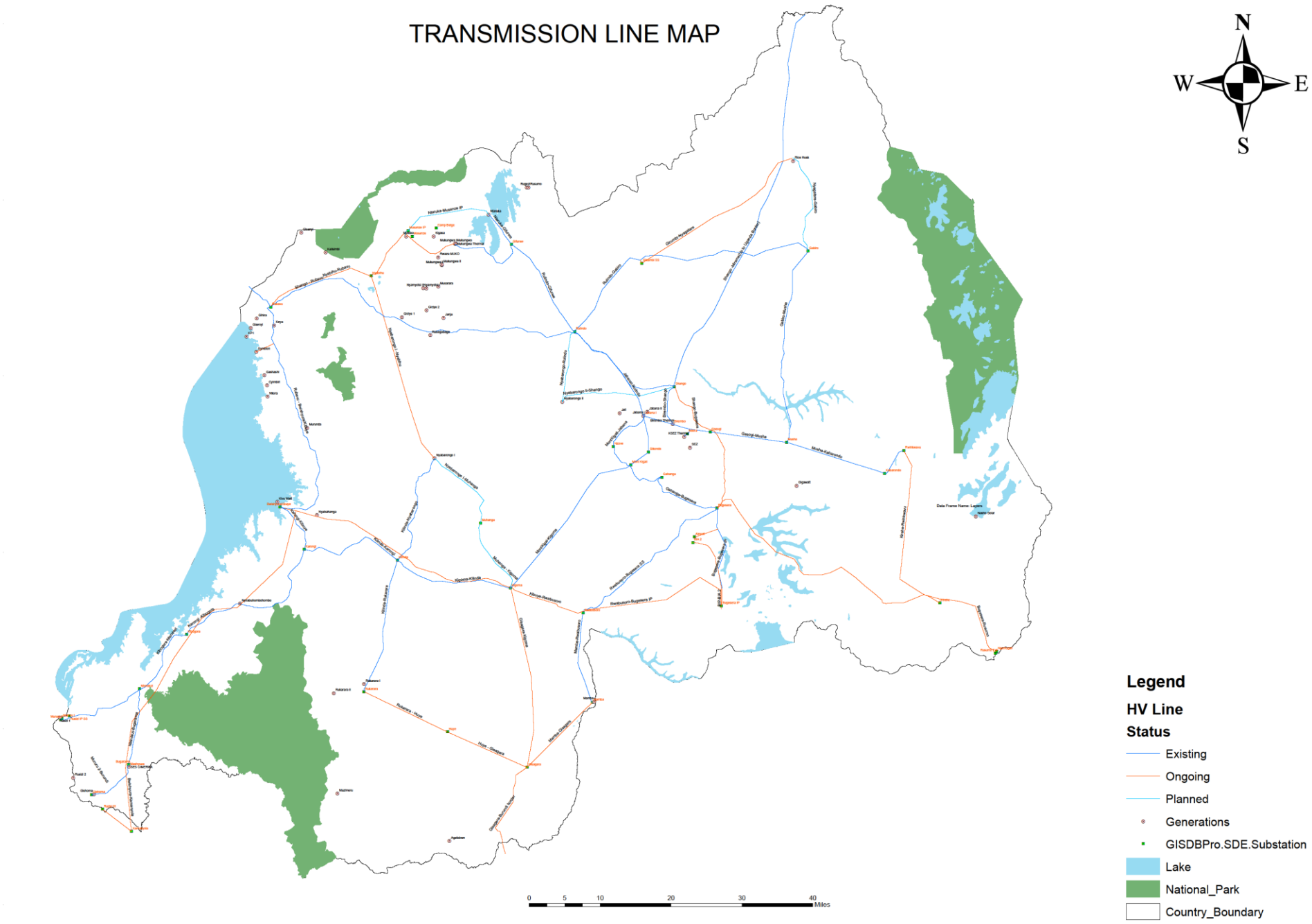

Figure 3: Transmission network (HV line) in 2021

[7] Double click on the map in this document to open PDF for review.

2021 PROJECTS

Table 3: Transmission network projects in 2021

N0.	Project Name	Components	Length/ Capacity	Estimated Cost(USD)
1.	110kV Nyabihu-Rubavu	Construction of Transmission Line Construction of Line Bays	40	7,200,000
2.	110kV Musanze Substation cutt-in cutt-out	Construction of Transmission Line, Construction of Musanze SS	0.596 2x20MVA	9,113,240
3.	220/110kV Gasogi SS Cut-in, Cut-out	Construction of Transmission Line Supply and Installation of 220/110kV Transformer(including 220kV Line Bay and Transformer Bay)	0.473 93.8MVA	10,000,000
4.	110kV Nyabarongo 1-Nyabihu	Construction of Transmission Line Construction of Line Bay at Nyabarongo	46	14,073,091

N0.	Project Name	Components	Length/ Capacity	Estimated Cost(USD)
5.	110/30kV Bugesera International Airport SS 1 Cut-in Cut-out	Construction of Transmission Line	12	2,280,000
6.	110kV BIP-BIA 2	Construction of Transmission Line	23.4	4,446,000
7.	220kV Mamba-Gisagara	Construction of Transmission Line Construction of Line Bays	21	4,620,000
8.	110kV Rwabusoro-Bugesera IP	Construction of Transmission Line Construction of Line Bays	21	4,620,000
9.	110 Nyabarongo 2-Rulindo	Construction of Transmission Line, Construction of Nyabarongo II Switchyard	16.65	14,995,200
		TOTAL		**71,347,531**

2022 TRANSMISSION NETWORK

This section displays the High Voltage (HV) transmission network in 2022 (map below[8]), and the projects that were implemented in that year (table following).

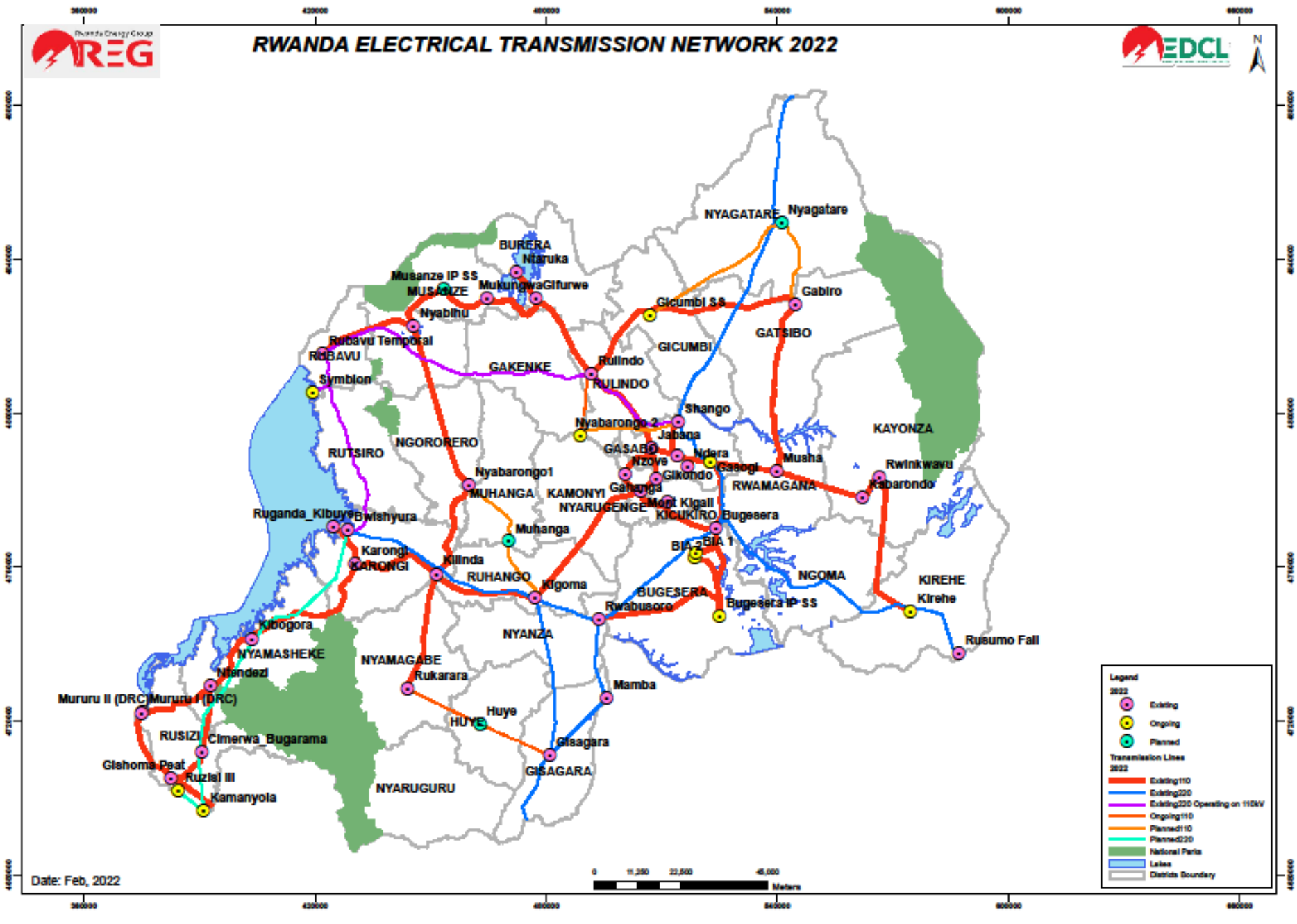

Figure 4: Transmission network (HV line) in 2022

[8] Double click on the map in this document to open PDF for review.

2022 PROJECTS

Table 4: Transmission network projects planned in 2022

N0.	Project Name	Components	Length/ Capacity	Estimated Cost(USD)
1.	110kV Rukarara - Huye - Gisagara	Construction of Transmission Line, Extension of Rukarara SS, Construct Huye substation	40.71	19,327,800
2.	Installation of 220/110kV Transformer at Gisagara SS	Upgrade of Gisagara SS	75/93.8MVA	2,057,819
3.	110kV Rusizi Substation cutt-in cutt-out	Construction of Transmission Line, Construction of Rusizi SS	0.661 2X20MVA	9,200,000
TOTAL				**30,385,619**

2023 TRANSMISSION PLAN

This section displays the High Voltage (HV) transmission network in 2023 (map below[9]), and the projects that were implemented in that year (table following).

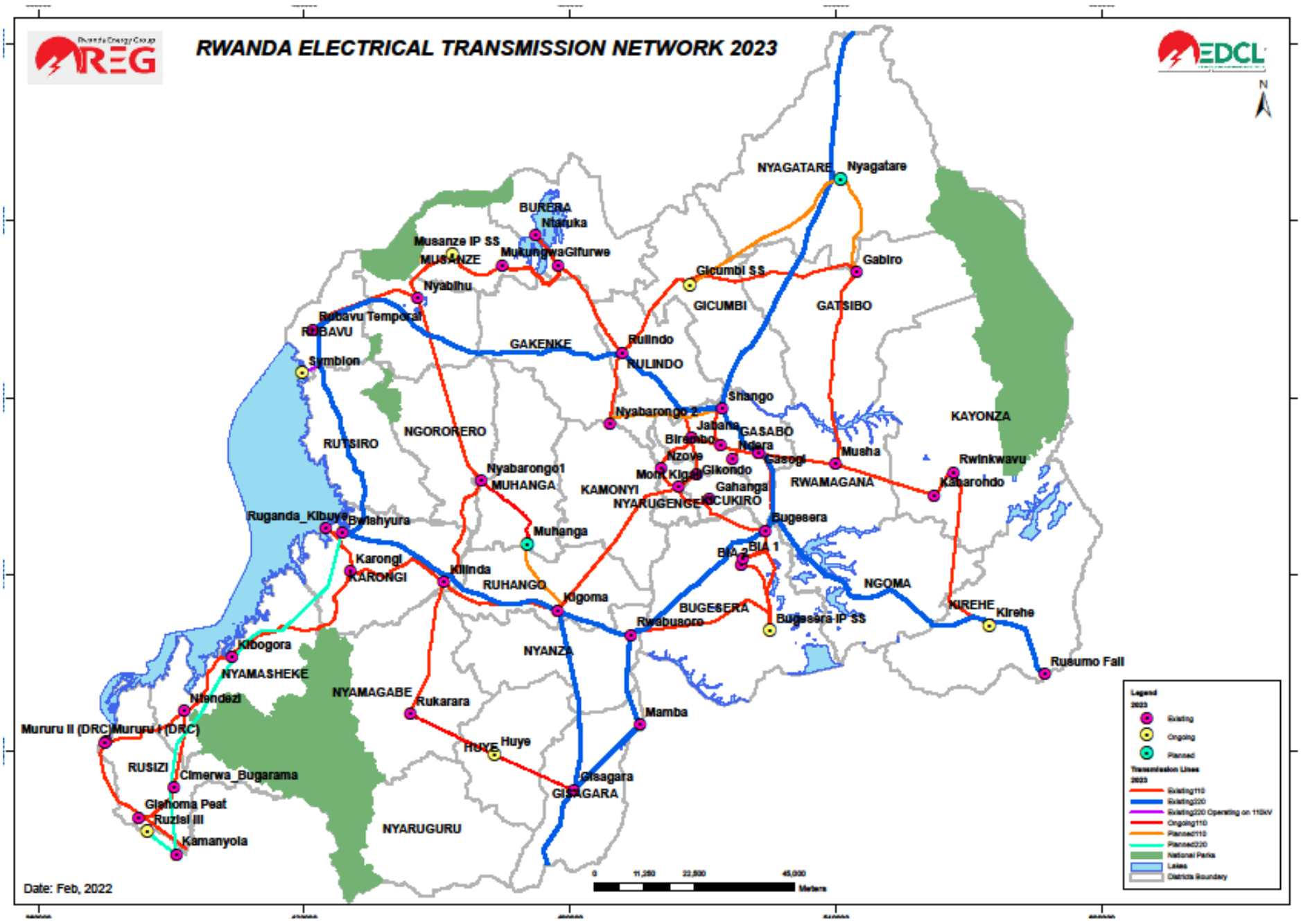

Figure : Transmission network (HV line) in 2023

[9] Double click on the map in this document to open PDF for review.

2023 PROJECTS

Table 5: Transmission network projects planned in 2023

N0.	Project Name	Components	Length/ Capacity	Estimated Cost(USD)
1.	220/110kV Kirehe SS cut-in cut-out	Construction of Transmission Line, Construction of Kirehe SS	2 75/93.8MVA	10,000,000
2.	110kV Kirehe-Rwinkwavu	Construction of Transmission Line	57.2	10,868,000
3.	110 Nyabarongo I-Muhanga and Muhanga Substation	Construction of Transmission Line Muhanga 110/30kV SS	20.35	8,866,500
4.	110kV Ntaruka-Musanze IP	Construction of Transmission Line	20.3	8,500,000
TOTAL				**38,734,500**

2024 TRANSMISSION NETWORK

This section displays the High Voltage (HV) transmission network in 2024 (map below[10]), and the projects that were implemented in that year (table following).

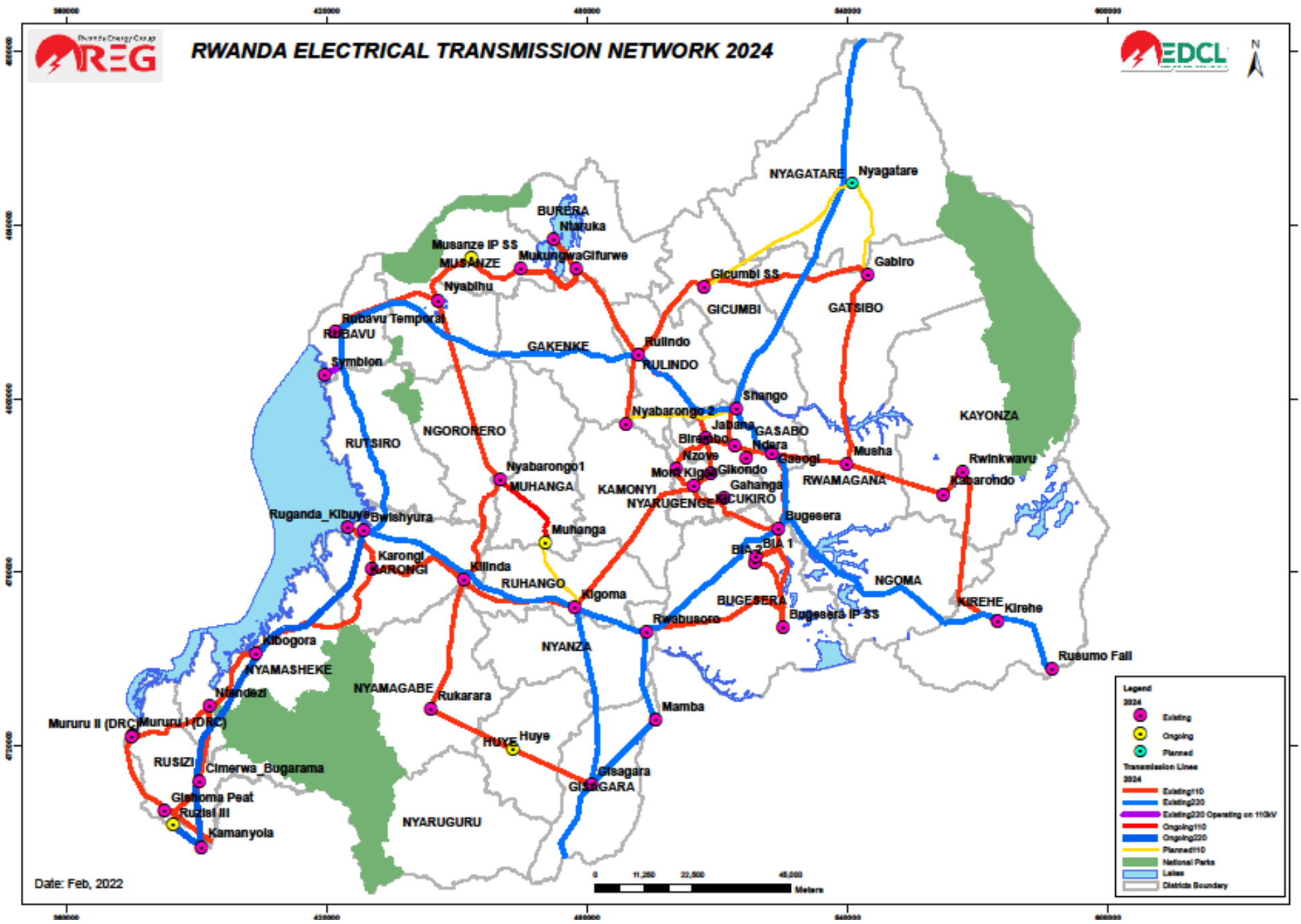

Figure 5: Transmission network (HV line) in 2024

[10] Double click on the map in this document to open PDF for review.

2024 PROJECTS

Table 6: Transmission network projects planned in 2024

N0.	Project Name	Components	Length/ Capacity	Estimated Cost (USD)
2	Replacement of 2*16.5MVA 6.6/110 Transformers at Nyabarongo I Switchyard	Upgrade of Nyabarongo I Switchyard	From 16.5MVA to 31.5MVA	3,500,000
3	220kV Bwishyura-Kamanyola-Rusizi III	Construction of Transmission Line, Construction of Kamanyola SS,Consctruction of Rusizi III Switchyard	93	30,353,201
TOTAL				**33,853,201**

2025 TRANSMISSION NETWORK

This section displays the High Voltage (HV) transmission network in 2025 (map below[11]), and the projects that were implemented in that year (table following).

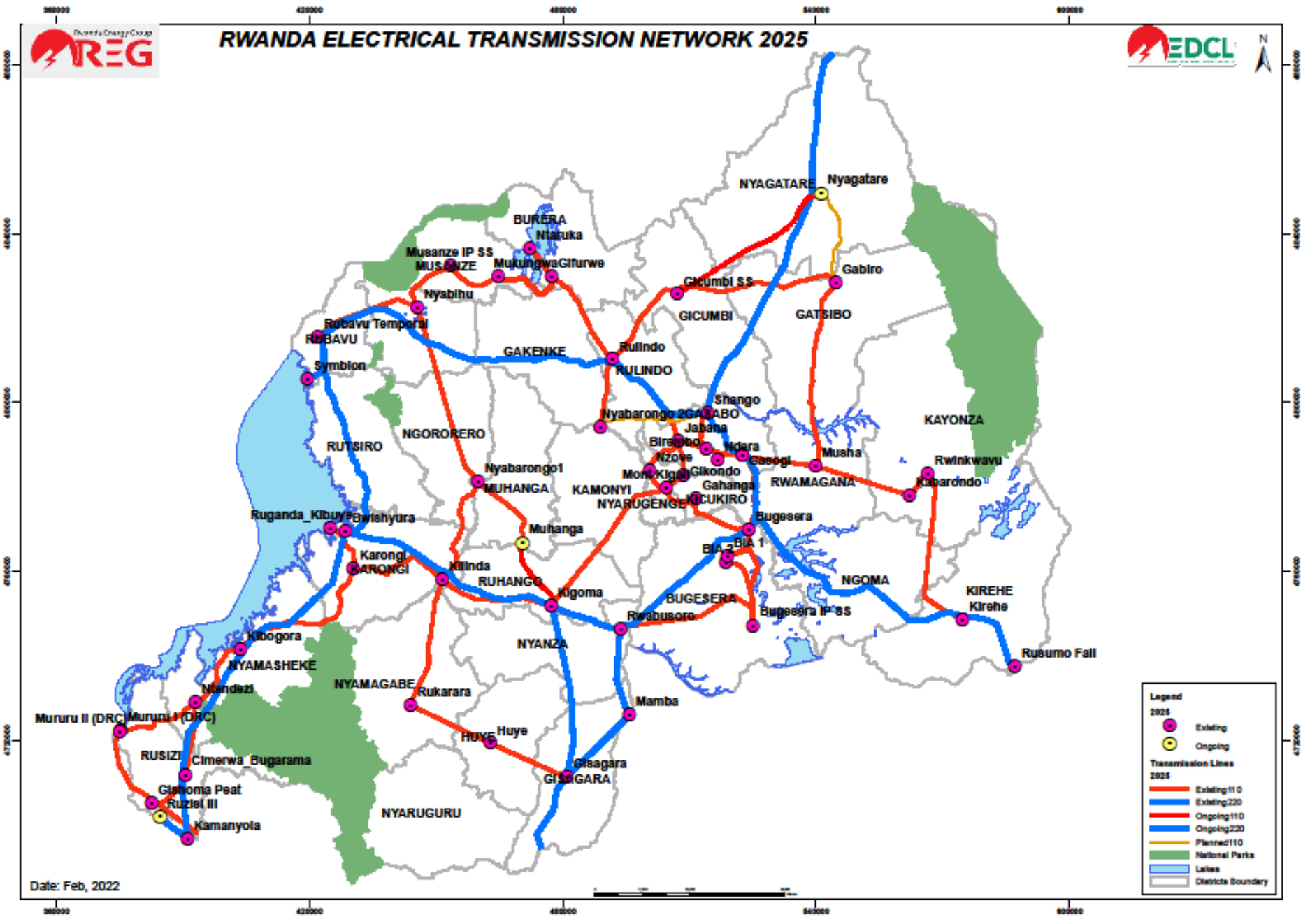

Figure 6: Transmission network (HV line) in 2025

[11] Double click on the map in this document to open PDF for review.

2025 PROJECTS

Table 7: Transmission network projects planned in 2025

N0.	Project Name	Components	Length/ Capacity	Estimated Cost(USD)
1.	110kV Gicumbi-Nyagatare	Construction of Transmission Line	43	8,113,000
2.	110kV Gicumbi cut-in cut-out	Construction of Transmission Line, Construction of Gicumbi SS	1.54	9,292,600
3.	110kV Kigoma-Muhanga	Construction of Transmission Line, Construction of Muhanga SS	17.59	12,342,100
		TOTAL		**29,747,700**

2026 TRANSMISSION NETWORK

This section displays the High Voltage (HV) transmission network in 2026 (map below[12]), and the projects that were implemented in that year (table following).

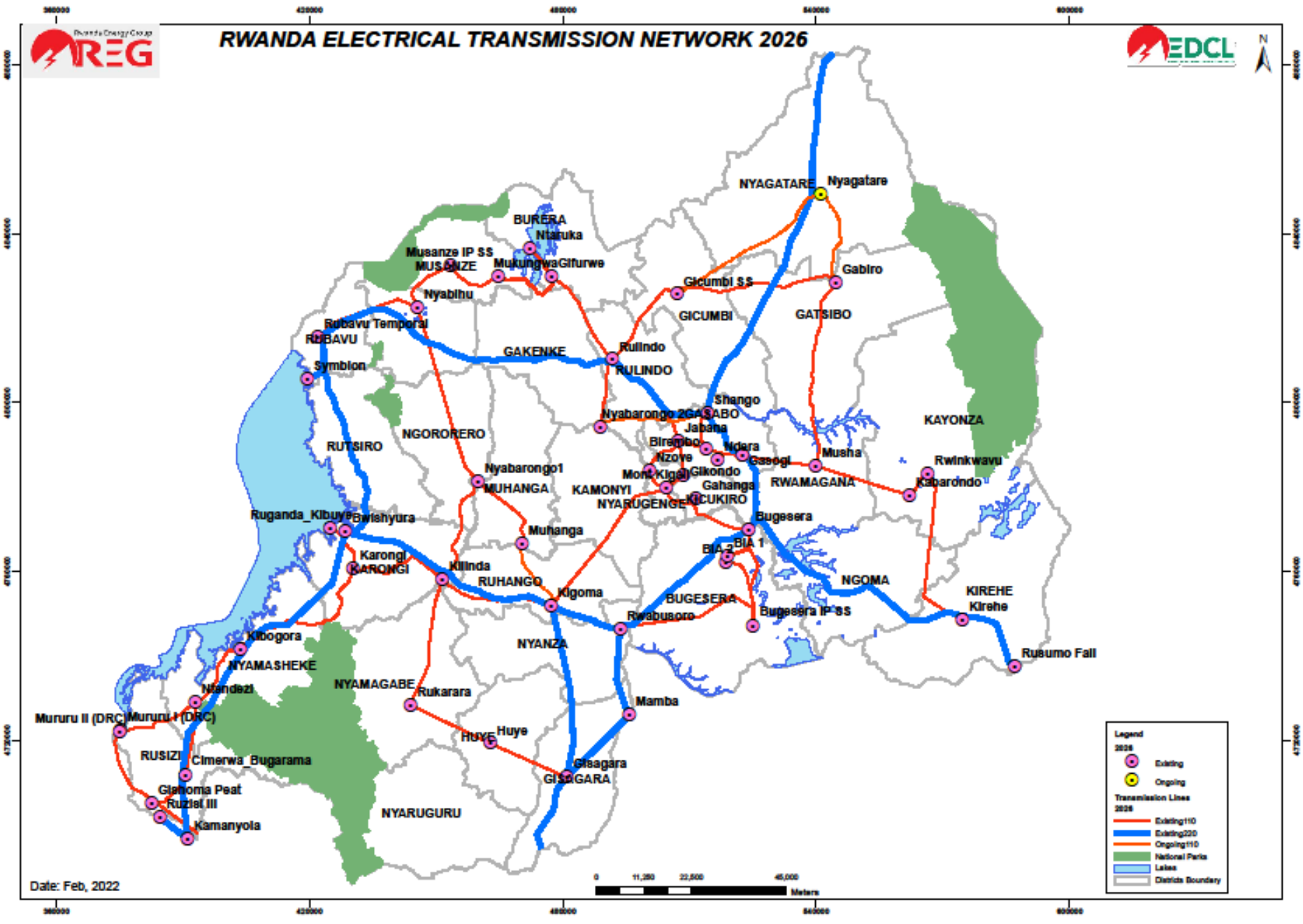

Figure : Transmission network (HV line) in 2026

[12] Double click on the map in this document to open PDF for review.

2026 PROJECTS

Table 8: Transmission network projects planned in 2026

N0.	Project Name	Components	Length/ Capacity	Estimated Cost (USD)
1	110kV Nyabarongo II-Shango	Construction of Transmission Line	26.55	23,732,637
2	110kV Nyagatare-Gabiro	Construction of Transmission Line, Construction of Nyagatare SS	23.87	4,535,300
TOTAL				**28,267,937**

2027 TRANSMISSION NETWORK

This section displays the High Voltage (HV) transmission network in 2027 (map below[13]), and the projects that were implemented in that year (table following).

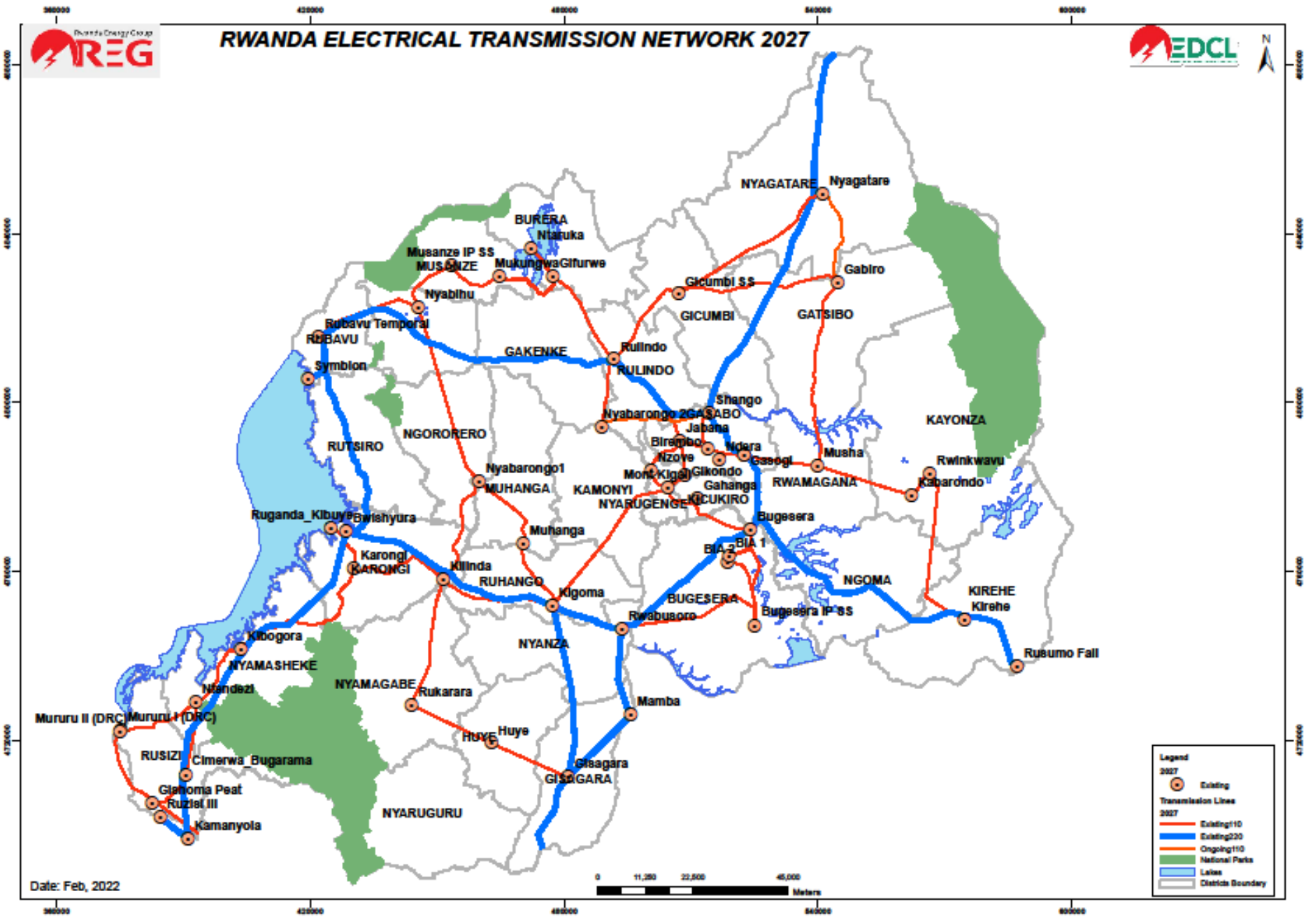

Figure 7: Transmission network (HV line) in 2027

[13] Double click on the map in this document to open PDF for review.

2027 PROJECTS

Table 9: Transmission network projects planned in 2027

N0.	Project Name	Components	Length/ Capacity	Estimated Cost(USD)
1	110kV Nyabarongo II-Shango	Construction of Transmission Line	26.55	23,732,637
2	110kV Nyagatare-Gabiro	Construction of Transmission Line, Construction of Nyagatare SS	23.87	4,535,300
TOTAL				**28,267,937**

2028 TRANSMISSION NETWORK

This section displays the High Voltage (HV) transmission network in 2028 (map below[14]), and the projects to be implemented in that year (table following).

It is important to note that in this year, there are no new planned projects unlike the preceding years. However, with subsequent updates and further load studies of the ever-evolving national transmission network, some required projects may be introduced to expect to operate in this year.

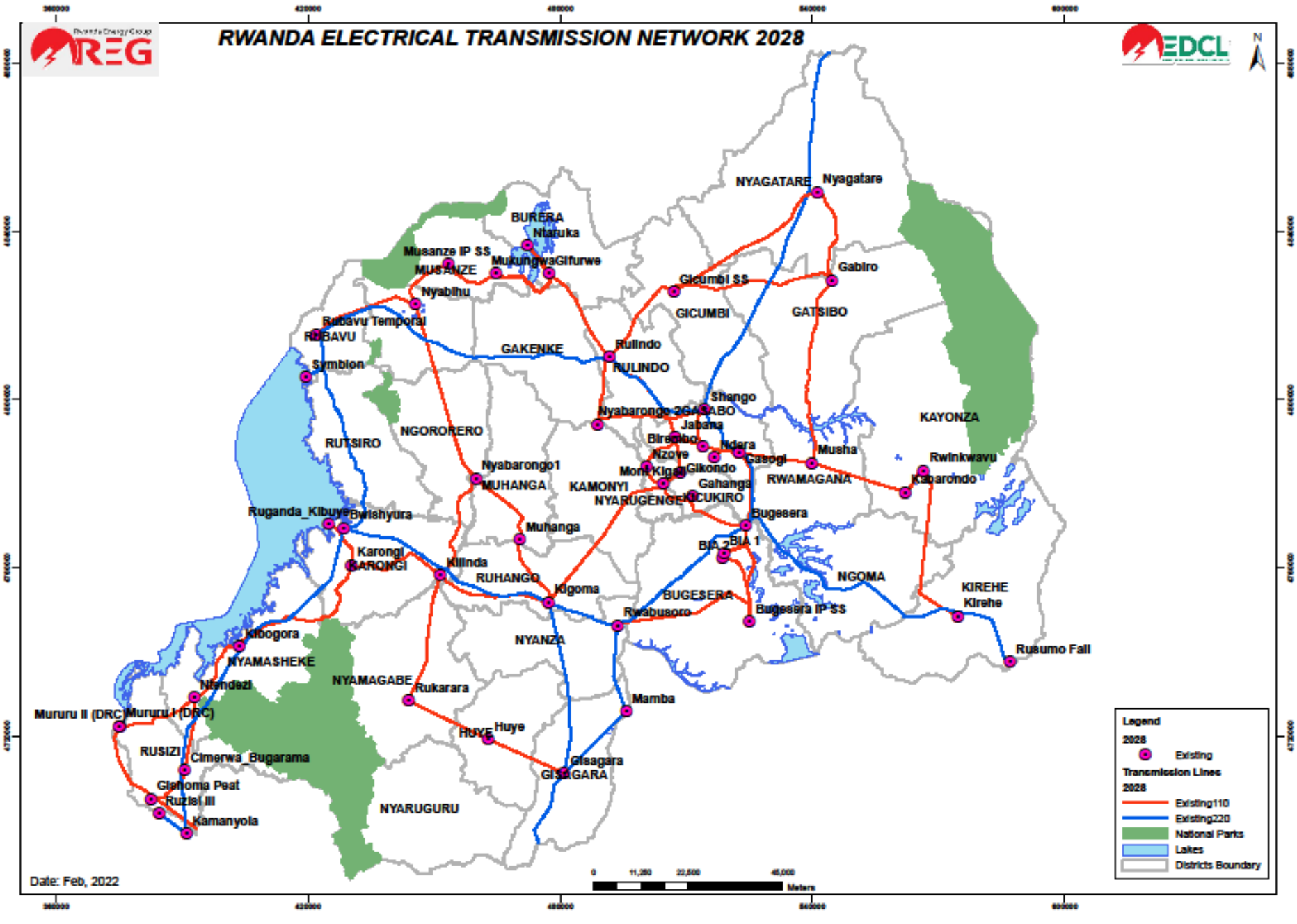

Figure 8: Transmission network (HV line) in 2028

[14] Double click on the map in this document to open PDF for review.

a. ROADMAP DEVELOPMENT OF INDUSTRIAL PARKS SUPPLY

Plans to accelerate national economic development include construction of industrial parks in the capital, secondary and other cities in Rwanda. The following table shows planned industrial parks across the country, the tentative construction timelines as per RDB and Ministry of Commerce and the dedicated substation that will serve each industrial park as well as the expected operational year for that substation.

Table 10: Electricity demand for industrial parks

S/N	Industrial Park					Dedicated Substation	
	Name		**Starting Year**	**Expected Completion**	**Source of funds**	**Name**	**Starting Year**
1.	Bugesera	Phase I	2019	2022	GoR	Bugesera Industrial Parks SS(BIP)	2023
		Phase II & III	2021	2024	GoR and Private Developers		
2.	Rwamagana		2019	2022	GoR	Musha	Existing
3.	Musanze		2021	2024	Private Developers	Musanze	2024
4.	Muhanga		2022	2025	Private Developers	Muhanga	2025
5.	Huye		2021	2024	Private Developers	Huye	2025
6.	Rusizi		2021	2024	Private Developers	Rusizi IP SS	2025
7.	Rubavu		2024	2025	Private Developers	Rubavu	2023
8.	Nyagatare		2024	2025	Private Developers	Nyagatare	2027

b. TRANSFORMER MOVEMENTS

Table 11: Transformer movements

Origin of transformer	Voltage ratio	Rating	Destination	Applied Voltage	Rationale	Current Status
Bwishyura	220/110kV	75/93.8MVA	Rubavu	220/110kV	To link/interconnect the local (110kV) network with that of neighboring countries, fostering regional trade in line with key master plan objectives.	The transformer is located at Shango store and it is yet to be used within the project scope.
Shango	220/30kV	25/31.5MVA	Shango	110/15kV	Transformer ratings of 220/30KV are no longer accepted on the network to prevent MV network disturbances from interfering with interconnectors and reducing quality of exported power from Rwanda. Therefore, the rating was changed to connect the local network through the existing 15KV network at Shango.	The transformer is located at Shango store and it is yet to be used within the project scope.
Rubavu	220/30kV	25/31.5MVA	Shango	110/15kV	Transformer ratings of 220/30KV are no longer accepted on the network to prevent MV network disturbances from interfering with interconnectors and reducing quality of exported power from Rwanda. Therefore, the rating was changed to connect the local network. This transformer was moved from Rubavu to Shango, as Shango has a connection to the 15KV network while Rubavu does not.	The transformer is located at Shango store and it is yet to be used within the project scope.
Mt Kigali/Old SS	110/30kV	20MVA	Rubavu	110/30kV	To satisfy the increased demand in Rubavu, including export requirement.	Completed

Origin of transformer	Voltage ratio	Rating	Destination	Applied Voltage	Rationale	Current Status
Birembo (redundancy transformer under the Nyabihu project)	110/15kV	20MVA	Musha	110/15kV	To increase the supply capacity of Rwamagana Industrial park load.	Completed
Nyabihu project 20MVA for Musha trf no 2	110/15	10MVA	Musha	110/15kV	Grid strengthening	Designs and project quotation have been approved
Bugesera substation	220/30kV	75/93.8MVA	Bugesera substation	220/110kV	Transformer ratings of 220/30KV are no longer accepted on the network to prevent MV network disturbances from interfering with interconnectors and reducing quality of exported power from Rwanda; this was negotiated with contractor to adapt the project scope and materials to reflect this new policy.	The notification for addendum contract negotiation has been sent to the contractor
Mt Kigali Old S/S	30/15kV	5MVA	METTITO water treatment plant (location: Kanzenze)	15kV	To prevent disturbances observed in Kanazi feeder from Mt Kigali, therefore supplying this water treatment plant with stable power from Gahanga S/S (15kV).	Completed
Hakan	110/11	20MVA	Return to Gishoma	110kV/11	This transformer was originally at Gishoma PP and was shifted when the PP was not operational. It was shifted to Hakan to test their boilers. This testing activity was completed, and the transformer is being returned to Gishoma PP (taken to Shema power for temporary use).	The transformer has already been shifted to SPLK Temporary S/S; however, it is not installed yet.
Musha Existing	110/15	10MVA	To be determined	110kV	The transformer is available for use; currently not on network but included in this table for record keeping on transformers owned and operated by the utility.	The transformer is stored in Ndera SS (still available for use)

c. OTHER TRANSFORMER UPGRADES REQUESTED

Table 12: Transformers requiring upgrades

Location	Ratio	Rating	Replaced with	Timeline	Defect	Current Status
Kilinda	110/30	6MVA	110/30 6MVA AfDB	2020/21	The existing transformer has been burnt	For the fast aid this transformer has been replaced by the previous transformer of 1.6MVA
Mukungwa (Replace old trf)	6.6/110kV	15MVA	6.6/110kV 15MVA AfDB	2020/21	The existing transformer has big oil leakage.	Problem not yet solved(no transformer bought to for replacement)
Gikondo	110/15kV	2 x 15MVA	2 x 30MVA AfDB	2019/20	The existing transformers have oil leakage, overloaded and are so old	Problem not yet solved(no transformer bought to for replacement
Karongi	110/30kV	4MVA	10MVA (located at Kabarondo SS)	2020	The transformer has been burnt	Replacement has been completed successfully
Kibogora (replace Old transformer)	110/30kV	6MVA	20MVA AfDB/ADF15	2021	The transformer is too old(1970), and is not working properly especially on voltage regulation (tape changers are not mechanically working conveniently)	Problem not yet solved(no transformer bought for replacement

d. NEW TRANSFORMERS REQUIRED

Table 13: New transformers to be installed

Location	Ratio	Rating	Funding/Project	Timeline	Recent Comments	Current Status
Gisagara	220/110kV	75/93.8MVA		2021/2022	This transformer will help to interconnect 220kV and 110kV networks	Pending
Rubavu	110/30kV	20MVA		2023/24	This transformer will be necessary to increase the capacity of the substation according to the load increment	Pending
Rubavu	220/110kV	75/93.8MVA		2023/24	This transformer will be necessary to increase the capacity of Rubavu SS and for redundancy(n-1) of the substation	This project will be performed during the resuming of the project left by ISOLUX contractor
Birembo - replace transformer moved to Musha	110/15kV	20MVA		2020/21	Highly required since the 20MVA remained at Musha is loaded at 17.5MW during the Peak Hours	This problem will be solved by the transformer that will be supplied by CCCE Ltd(Designs and project quotation have been approved)
Kirehe	110/30kV	20MVA		2023	This is required because: A. 110kV Kirehe-Rwinkwavu Bay. B. 110/30kV Transformer Bay	This scope will captured in 220/110kV Kirehe SS cut-in, cut-out project
Nyabarongo	110/30kV	20MVA	RBF/AFDB	2020	The tendering process is ongoing	The contract already signed
Spare transformer	110/30kV	20MVA			this will be mandatory for the future projects during the tender and contract preparation	This will depend on finance availability of the project.
New Gasogi substation	220/110kV	75/93.8MVA		2028	This transformer will serve to connect Gasogi SS to the ongoing 220kV Rusumo-Bugesera-Shango OHTL and this will help to extend Kigali Ring	This scope will be captured in 220/110kV Gasogi SS cut-in, cut-out project

IX. CONCLUSION & RECOMMENDATIONS

I. SVCs and Shunt Rector must be installed in 2021 to help stabilize the network from reactive power (The tender is completed for Bugesera and Shango SS).

II. All transmission lines must be installed as per guidelines of this document to ensure efficient power distribution and reliability for the Rwanda network. This specifically include in the medium term, installation of transmission lines recommended in tables 4, 5, 6 for the years 2022-2024. Recommendations regarding transformers upgrades and new transformers installations are presented in tables 12 and 13 respectively.

III. Since the study for ADMD (80W) per household is of 2013 and the development progress of the country is quick. It is recommended that this figure be updated through data collections from EUCL commercial unit.

X. ANNEX:

A. CONTINGENCY ANALYSIS:

Using Dig Silent Power Factory, a contingency analysis (N-1) was carried out on the national electricity transmission system to ensure that this condition is met.

Results from this analysis in the form of reports from Power Factory indicate that as time goes and more lines are constructed, the network will be further strengthened and less prone to tripping.

Table 14: Contingency analysis using Dig Silent Power Factory

Year	Tripped transmission line (Main cause of disturbances)			
		Minimum percentage considered for overloading: 60%		
		Affected feeder	**% loading at normal conditions (before disturbance conditions)**	**% loading after Tripping of a transmission line (at disturbance conditions)**
2021	220kV D/C Rwabusoro-Bugesera(both circuits tripped)	110kV Nyabarongo-Kilinda	28.7	79.1
		110kV Kilinda-Kigoma	28.8	74.9
		110kV Kigoma-Mount Kigali	19.9	62.3
		Minimum percentage considered for under voltage:90%		
		Affected Substations	**% voltage at normal conditions (before disturbance conditions)**	**% voltage after Tripping of a transmission line (at disturbance conditions)**
		Rulindo	97.7	89.5
		Birembo	97.8	87.9
		Jabana	97.4	87.9
		Nzove	97	87.5
		Gasogi	95.8	86.7
		Gikondo	96.9	87.5
		Mount Kigali	96.8	87.4
		Gahanga	96.3	87.1
		Gabiro	95.4	86.8
		Kigoma	98.2	88.7
		Gisagara	98.1	88.7
		Rwinkwavu	94.4	85.6
		Kabarondo	94.5	85.6
		Musha	95	85.6
		Ndera	95.8	86.6
		Affected feeder	**% loading at normal conditions (before disturbance conditions)**	**% loading after Tripping of a transmission line (at disturbance conditions)**
2022	220kV D/C Rwabusoro-Bugesera(both circuits tripped)	110kV Bugesera-Bugesera IP	20.6	73
		110kV Rwabusoro-Bugesera IP	27.2	79.5
		Minimum percentage considered for under voltage:90%		

Year	Tripped transmission line (Main cause of disturbances)		Minimum percentage considered for overloading: 60%	
		Affected Substations	**% voltage at normal conditions (before disturbance conditions)**	**% voltage after Tripping of a transmission line (at disturbance conditions)**
		No substation with voltage percentage under 90%	N/A	N/A
2023	220kV D/C Rwabusoro-Bugesera(both circuits tripped)	**Affected feeder**	**% loading at normal conditions (before disturbance conditions)**	**% loading after Tripping of a transmission line (at disturbance conditions)**
		110kV Bugesera-Bugesera IP	17.3	67.2
		110kV Rwabusoro-Bugesera IP	24.9	74.6
			Minimum percentage considered for under voltage:90%	
		Affected Substations	**% voltage at normal conditions (before disturbance conditions)**	**% voltage after Tripping of a transmission line (at disturbance conditions)**
		No substation with voltage percentage under 90%	N/A	N/A
2024	No feeder can trouble the network	N/A	N/A	N/A
2025	No feeder can trouble the network	N/A	N/A	N/A
2026	No feeder can trouble the network	N/A	N/A	N/A
2027	No feeder can trouble the network	N/A	N/A	N/A
2028	No feeder can trouble the network	N/A	N/A	N/A

B. TRANSMISSION SYSTEM & KEY PARAMETERS:

JUNE 2021 HV TRANSMISSION SYSTEM:

Table 15: Existing transmission links

No	Line kV	Description	Length_KM
1	110	Birembo-Gasogi	8.67
2	110	Birembo-Shango	9.59
3	110	Bugarama-Gishoma	12.27
4	110	Bugesera-Bugesera IP	23.10
5	110	Gabiro-Musha	45.96
6	110	Gahanga-Bugesera	17.31
7	110	Gasogi-Musha	17.48
8	110	Gifurwe-Mukungwa (Double Circuit)	18.46
9	110	Gikondo-MountKigali	5.22
10	110	Gikondo - Jabana I	8.36
11	110	Jabana I-Birembo	6.97
12	110	Jabana I-Jabana II	1.29
13	110	JabanaI-Rulindo	25.73
14	110	Kabarondo-Rwinkwavu	7.25
15	110	Karongi-Kibuye	12.41
16	110	Karongi -Kibogora	39.20
17	110	Kibogora-Ntendezi	18.46
18	110	Kibuye-KivuWatt	1.21
19	110	Kigoma-Kilinda	27.45
20	110	Kilinda-Karongi	25.11
21	110	Kilinda-Nyabarongo	27.85
22	110	Kilinda-Rukarara	31.29
23	220	Mamba-Rwabusoro	21.54
24	110	MontKigai-Kigoma	40.33
25	110	MontKigali-Gahanga	9.64
26	110	MontKigali-Jabana	17.25
27	110	Mururu II-Mururu I	0.37
28	110	Musha-Kabarondo	23.35
29	110	Ndera cut-In cut-out	2.14
30	110	Ntaruka-Gifurwe	8.51
31	110	Ntendezi-Bugarama	17.62
32	110	Ntendezi-Mururu II	20.89
33	220	Rubavu-Goma Border	7.01
34	220	Rubavu - Bwishyura/Kibuye	57.54
35	110	Rulindo-Gabiro	63.86
36	110	Rulindo-Gifurwe	24.93
37	220	Rwabusoro-Bugesera SS	40.64
38	220	Shango - Rubavu	106.11
39	220	Shango -Mirama(Up to Uganda Border)	92.01
	TOTAL		**944.39**

SUBSTATIONS:

Table 16: Current transmission/distribution substations

Item	Substation	Substation type	Voltage [KV]	Shunt Reactor type	Shunt size [MVA]	Shunt Reactor number	Static Var compensator size [Mvar]	Transformer Type	Transformer number	Rating [MVA]	Commissioning	Comment
1	Shango	transmission/Distribution	220	Shunt Reactor	7.5	3		220/110/11	1	93.8		two 110/15 transformer are being installed
2	Jabana	transmission/Distribution	110	Capacitor Bank	1.5	3		110/15	2	10		
3	Gikondo	transmission/Distribution	110	Capacitor Bank	1.5	3		110/15	3	15		Replace 15MVA TRF to 31.5MVA
4	Nzove	transmission/Distribution	110					110/15	1	10		
5	Mont Kigali	transmission/Distribution	110					110/30;110/15	2	10;20		10MVA for 110/30, and 20MVA for 110/15
6	Gahanga	transmission/Distribution	110					110/15	1	20		
7	Ndera	transmission/Distribution	110					110/15	2	20		
8	Musha	transmission/Distribution	110					110/15	1	20		New 20MVA TRF on site waiting to be installed
9	Kabarondo	transmission/Distribution	110					110/15	1	10		
10	Rwinkwavu	transmission/Distribution	110					110/15	1	6		
11	Gabiro	transmission/Distribution	110					110/30	1	20		
12	Rulindo	transmission/Distribution	110					110/30	1	20		
13	Gifurwe	transmission/Distribution	110					110/30	1	6		
14	Mukungwa	Switchyard	110					6.6/110;110/30	3	15 MVA		2 for 6.6/110KV and 1 for 110/30KV
15	Nyabihu	transmission/Distribution	110					110/30	2	20MVA		not commissioned
16	Bwishyura	transmission/Distribution	110					110/11	2	15		to be upgraded to 220KV
17	Karongi	transmission/Distribution	110					110/30	1	10		
18	Kibogora	transmission/Distribution	110					110/30	1	6		
19	Ntendezi	transmission/Distribution	110					110/30	1	10		
20	Mururu II	Switching	110					110/70	1	15		this transformer is dedicated for Burundi Part
21	Mururu I	transmission/Distribution	110					110/6.6;30/6.6	2	10;10		10MVA for 110/6.6; and 10MVA for 30/6.6
22	Rusizi II	Switchyard	110					110/6.6	3	15		
23	Gishoma	Switchyard	110					110/11	1	15		
24	Kilinda	transmission/Distribution	110					110/30	1	6		
25	Kigoma	transmission/Distribution	110					110/30	1	10		Being upgraded to accommodate 220KV line
26	Rukarara	Switchyard	110					110/30	2	10		
27	Gisagara	transmission/Distribution	220					220/110/30	1	75/93.8MVA	2022	Upgrade
28	Mamba	Switchyard	220					220/11	2	50		
29	Rwabusoro	transmission/Distribution	220					220/110/11	1	93.8		
30	Nyabarongo I	Switchyard	110					110/6.6;30/6.6	4	13.2MVA;4MVA		3 for 13.2MVA 110/6.6 TRF and 1 for 4MVA 30/6.6
31	Birembo	transmission/Distribution	110	Capacitor Bank	1.5	3		110/15	1	20		
32	Gasogi	transmission/Distribution	110					110/15	1	15		
33	Rubavu	transmission/Distribution	110					110/30		10 MVA		temporary substation
1	Nyagatare	Substation									2026	

Item	Substation	Substation type	Voltage [KV]	Shunt Reactor type	Shunt size [MVA]	Shunt Reactor number	Static Var compensator size [Mvar]	Transformer Type	Transformer number	Rating [MVA]	Commissioning	Comment
2	Gicumbi											
3	Kirehe											
4	Gasogi	Substation							2	15 MVA	2020	
5	Bugesera										2019	new SS 110KV
6	Bugesera	Substation	220					220/110 KV	1	75/93.8 MVA	2025	New Transformer
7	Bugesera IP	Substation	110					110/30KV	3	30	2020	
8	Rwabusoro										2019	
9	Mamaba											
10	Gisagara											
11	Huye	Substation									2022	
12	Rukarara											
13	Muhanga	Substation	110					110/30 KV			2023	
14	Ruganda											
15	Kamayola											
16	Rusizi III	Switchyard									2024	
17	Symbion											
18	Rubavu	SS	220					220/110		75/93.8 MVA	2021	Upgrade
19	Nyabihu										2019	
20	Musanze	SS							2	20MVA	2021	
21	Nyabarongo II	Switchyard									2024	
22	Symbion	Switchyard									2019	
23	Bugesera Airport	Switchyard							2	40MVA	2020	

2-WINDING TRANSFORMERS:

Table 17: 2-Winding transformers

Item	Substation	HV-Side(KV)	LV-Side (KV)	Rated (MVA)
1	Birembo	110	15	20
2	Birembo SoE	15	0.4	3.3
3	Birembo SoE	15	0.4	3.3
4	Birembo SoE	15	0.4	3.3
5	Birembo SoE	15	0.4	3.3
6	Birembo SoE	15	0.4	3.3
7	Birembo SoE	15	0.4	3.3
8	Bugarama	110	30	12.5
9	Cyimbiri	30	0.4	0.4
10	Gabiro	30	0.4	0.16
11	Gabiro	30	0.4	0.16
12	Gabiro	110	30	20
13	Gabiro	110	30	20
14	Gahanga	110	15	20
15	Gasogi	110	15	10
16	Giciye1	30	0.63	2.6
17	Giciye1	30	0.63	2.6
18	Giciye2	30	0.63	2.6
19	Giciye2	30	0.63	2.6
20	Giciye3	30	6.3	5.6
21	Giciye3	30	6.3	5.6
22	Gifurwe	30	0.4	0.16
23	Gifurwe	110	30	6
24	Gihira	30	6.6	3
25	Gikondo	110	15	15
26	Gikondo	110	15	15
27	Gikondo	110	15	15
28	Gisagara	110	30	20
29	Gisenyi	30	6.6	5
30	Gisenyi	15	0.4	6
31	Gisenyi	6.6	0.4	0.8
32	Gisenyi	6.6	0.4	0.8
33	Gisenyi	6.6	0.4	0.8
34	Gisenyi	6.6	0.4	0.8
35	Gisenyi	6.6	0.4	0.8
36	Gisenyi	6.6	0.4	0.8
37	Gishoma	110	11	15

Item	Substation	HV-Side(KV)	LV-Side (KV)	Rated (MVA)
38	Gishoma	110	11	15
39	Jabana I	110	15	10
40	Jabana I	110	15	10
41	Jabana I TPP	15	0.4	1.6
42	Jabana I TPP	15	0.4	1.6
43	Jabana I TPP	15	0.4	1.6
44	Jabana I TPP	15	0.4	1.6
45	Jabana I TPP	15	0.4	1.6
46	Jabana I TPP	15	0.4	1.6
47	Jabana II	110	6.6	15
48	Jabana II	110	6.6	15
49	Kabarondo	30	0.4	0.16
50	Kabarondo	110	30	10
51	Karongi	110	30	10
52	Keya	30	3.3	2.5
53	Kibogora	110	30	6
54	Kibuye	110	11	20
55	Kibuye	110	11	20
56	Kibuye	30	11	5
57	Kigoma	110	30	10
58	Kilinda	110	30	6
59	Mamba	220	11	50
60	Mamba	220	11	50
61	Mirama	220	132	60
62	Mirama	220	132	60
63	Mont Kigali	30	0.4	0.16
64	Mont Kigali	110	30	10
65	Mont Kigali	110	15	20
66	Mukungwa	110	30	15
67	Mukungwa	110	6.6	15
68	Mukungwa	110	6.6	15
69	Mukungwa II	30	0.63	3.15
70	Mukungwa II	30	0.63	3.15
71	Mukungwa SoE	6.6	0.4	3.3
72	Mukungwa SoE	6.6	0.4	3.3
73	Mukungwa SoE	6.6	0.4	3.3
74	Mukungwa SoE	6.6	0.4	3.3
75	Mukungwa SoE	6.6	0.4	3.3
76	Mukungwa SoE	6.6	0.4	3.3
77	Mururu I	110	6.6	10
78	Mururu I	30	6.6	10
79	Mururu II	110	70	15
80	Musha	15	0.4	0.1
81	Musha	110	15	20
82	Ndera	110	15	20

Item	Substation	HV-Side(KV)	LV-Side (KV)	Rated (MVA)
83	Ndera	110	15	20
84	Ndera SoE	15	0.4	3.3
85	Ndera SoE	15	0.4	3.3
86	Ndera SoE	15	0.4	3.3
87	Ndera SoE	15	0.4	3.3
88	Ndera SoE	15	0.4	3.3
89	Ndera SoE	15	0.4	3.3
90	Nkora	30	0.4	0.8
91	Ntaruka	110	30	15
92	Ntaruka	110	6.6	10
93	Ntaruka	110	6.6	10
94	Ntendezi	30	0.4	0.16
95	Ntendezi	110	30	10
96	Nyabarongo I	110	6.6	13.2
97	Nyabarongo I	110	6.6	13.2
98	Nyabarongo I	110	6.6	13.2
99	Nzove	110	15	10
100	Rubavu	110	30	10
101	Rugezi	30	0.68	1.6
102	Rugezi	30	0.68	1.6
103	Rukarara	30	0.4	0.16
104	Rukarara	30	0.4	0.16
105	Rukarara	110	30	10
106	Rukarara	110	30	10
107	Rukarara	30	0.69	15
108	Rukarara	30	0.69	15
109	Rukarara II	30	0.69	3.1
110	Rukarara V	30	0.4	1.7
111	Rukarara V	30	0.4	1.7
112	Rukarara V	30	0.4	1.7
113	Rulindo	30	0.4	0.16
114	Rulindo	30	0.4	0.16
115	Rulindo	110	30	20
116	Rulindo	110	30	20
117	Ruzizi II HPP	110	6.6	15
118	Ruzizi II HPP	110	6.6	15
119	Ruzizi II HPP	110	6.6	15
120	Rwinkwavu	15	0.4	0.1
121	Rwinkwavu	110	15	6

3-WINDING TRANSFORMERS:

Table 18: 3-Winding transformers

Item	Substation	Rated MVA	HV side (KV)	MV side (KV)	LV side (KV)
1	Shango	93.8	220	110	11
2	Rwabusoro	75	220	110	11
3	Bugesera	93.8	220	110	11

C. OVERVIEW OF HV TRANSMISSION PROJECTS – ONGOING, FUNDED AND UNFUNDED:

C.2. ONGOING PROJECTS

Table 19: On-going transmission network projects

No.	Project Name	Components	Length/Capacity	Estimated Cost (USD)	Starting Period	Source of Funds
1.	Replacement of a 15MVA 6.6/110 Transformer No1 in Mukungwa Switchyard	Upgrade of Mukungwa Switchyard	From 15MVA to 31.5MVA	1,750,000	2019	AFDB/RBF
2.	Installation of 110/30kV 20MVA Transformer at Nyabarongo I Switchyard	Extension of Nyabarongo I Switchyard	20MVA	1,750,000	2019	AFDB/RBF
3.	Replacement of 2*15MVA 110/15kV Transformers No 1 and No2) in Gikondo Substation by 2*31.5MVA	Upgrade of Gikondo SS	From 2*15MVA to 2*31.5MVA	3,500,000	2019	AFDB/RBF
4.	New Gasogi Substation	Construction of new Gasogi Substation	2 x 15MVA	23,542,130	2020	JICA
5.	110kV Nyabarongo II-Rulindo	Construction of Transmission Line, Construction of Nyabarongo II Switchyard	16.65	14,995,200	2024	GoR
6.	220kV Bwishyura-Kamanyola-Rusizi III	Construction of Transmission Line, Construction of Kamanyola SS, Construction of Rusizi III Switchyard	93	30,353,201	2024	EU
7.	Construction of Bugesera Industrial Park Substation	110/30kV substation	3 x 30MVA	14,400,000	2020	AfDB
8.	110kV Kirehe-Rwinkwavu	Construction of Transmission Line	57.2	10,868,000	2021	AfDB
9.	110kV Nyabihu-Rubavu	Construction of Transmission Line Construction of Line Bays	40	7,200,000	2022	Korea Exim Bank

No.	Project Name	Components	Length/Capacity	Estimated Cost (USD)	Starting Period	Source of Funds
10.	110kV Nyabarongo 1-Nyabihu	Construction of Transmission Line	46	14,073,091	2022	Korea Exim Bank
		Construction of Line Bays				
11.	110kV Rwabusoro-Bugesera IP	Construction of Transmission Line	21	4,620,000	2022	Korea Exim Bank
		Construction of Line Bays				
12.	110kV Bugesera-Gasogi OHTL(different scenarios to be discussed)	Construction of Transmission Line	17.8	5,050,000	2022	Korea Exim Bank
		Construction of Line Bays				
13.	220kV Mamba-Gisagara	Construction of Transmission Line	21	4,620,000	2022	Korea Exim Bank
		Construction of 220/110kV Transformer bay				
		Supply and installation of 220/110kV Transformer at Gisagara SS				
14.	110kV BIP-BIA 2	Construction of Transmission Line	23.4	4446000	2022	AfDB
15.	220/110kV Rubavu SS(Resuming)	Resuming of project for supply and construction of Rubavu SS	75/93.8MVA	6301021.29	2022	kfW
16.	220/110kV Bwishyura SS(Resuming)	Resuming of project for supply and construction of Bwishyura SS	75/93.8MVA	6582916.88	2022	kfW
17.	220/110kV Shango SS(Resuming)	Resuming the construction of line bay and shunt reactor at Shango SS		900015.22	2022	kfW
18.	220/110kV Birembo SS(Resuming)	Resuming the construction line bay at Birembo SS		808401.12	2022	kfW
19.	110/11kV Ruganda SS (Resuming)	Resuming the extension of Kibuye SS		498949.75	2022	kfW

No.	Project Name	Components	Length/Capacity	Estimated Cost (USD)	Starting Period	Source of Funds
20.	Rukarara-Huye-Gisagara	Construction of Transmission Line,	110	19,327,800	2022	AfDB
21.	Rwabusoro-Bugesera IP	Construction of Transmission Line,	110	4,620,000	2022	Korea Exim Bank
22.	Rulindo-Gicumbi cut-in, cut-out (from Rulindo-Gabiro-Musha)	Construction of Transmission Line,	110	9,292,600	2025	AfDB
			TOTAL	**189,499,326**		

C.3. FUNDED PROJECTS

Table 20: Funded transmission network projects

No.	Project Name	Components	Length/Capacity	Estimated Cost (USD)	Starting Period	Source of Funds
23.	Replacement of a 15MVA 6.6/110 Transformer No1 in Mukungwa Switchyard	Upgrade of Mukungwa Switchyard	From 15MVA to 31.5MVA	1,750,000	2019	AFDB/RBF
24.	Installation of 110/30kV 20MVA Transformer at Nyabarongo I Switchyard	Extension of Nyabarongo I Switchyard	20MVA	1,750,000	2019	AFDB/RBF
25.	Replacement of 2*15MVA 110/15kV Transformers No 1 and No2) in Gikondo Substation by 2*31.5MVA	Upgrade of Gikondo SS	From 2*15MVA to 2*31.5MVA	3,500,000	2019	AFDB/RBF

No.	Project Name	Components	Length/Capacity	Estimated Cost (USD)	Starting Period	Source of Funds
26.	New Gasogi Substation	Construction of new Gasogi Substation	2 x 15MVA	23,542,130	2020	JICA
27.	110kV Nyabarongo II-Rulindo	Construction of Transmission Line, Construction of Nyabarongo II Switchyard	16.65	14,995,200	2024	GoR
28.	220kV Bwishyura-Kamanyola-Rusizi III	Construction of Transmission Line, Construction of Kamanyola SS, Construction of Rusizi III Switchyard	93	30,353,201	2024	EU
29.	Construction of Bugesera Industrial Park Substation	110/30kV substation	3 x 30MVA	14,400,000	2020	AfDB
30.	110kV Kirehe-Rwinkwavu	Construction of Transmission Line	57.2	10,868,000	2021	AfDB
31.	110kV Nyabihu-Rubavu	Construction of Transmission Line	40	7,200,000	2022	Korea Exim Bank
		Construction of Line Bays				
32.	110kV Nyabarongo 1-Nyabihu	Construction of Transmission Line	46	14,073,091	2022	Korea Exim Bank
		Construction of Line Bays				
33.	110kV Rwabusoro-Bugesera IP	Construction of Transmission Line	21	4,620,000	2022	Korea Exim Bank
		Construction of Line Bays				
34.	110kV Bugesera-Gasogi OHTL(different scenarios to be discussed)	Construction of Transmission Line	17.8	5,050,000	2022	Korea Exim Bank
		Construction of Line Bays				
35.	220kV Mamba-Gisagara	Construction of Transmission Line	21	4,620,000	2022	

No.	Project Name	Components	Length/Capacity	Estimated Cost (USD)	Starting Period	Source of Funds
		Construction of 220/110kV Transformer bay Supply and installation of 220/110kV Transformer at Gisagara SS				Korea Exim Bank
36.	110kV BIP-BIA 2	Construction of Transmission Line	23.4	4446000	2022	AfDB
37.	220/110kV Rubavu SS(Resuming)	Resuming of project for supply and construction of Rubavu SS	75/93.8MVA	6301021.29	2022	kfW
38.	220/110kV Bwishyura SS(Resuming)	Resuming of project for supply and construction of Bwishyura SS	75/93.8MVA	6582916.88	2022	kfW
39.	220/110kV Shango SS(Resuming)	Resuming the construction of line bay and shunt reactor at Shango SS		900015.22	2022	kfW
40.	220/110kV Birembo SS(Resuming)	Resuming the construction line bay at Birembo SS		808401.12	2022	kfW
41.	110/11kV Ruganda SS (Resuming)	Resuming the extension of Kibuye SS		498949.75	2022	kfW
42.	110kV Gicumbi-Nyagatare	Construction of Transmission Line	43	12,980,800	2027	AfDB
			TOTAL	**169,239,726**		

C.4. UNFUNDED PROJECTS[15]

Table 21: Unfunded transmission network projects

PROJECT NAME	COMPONENTS	LENGTH/ CAPACITY	FS DONE? (Y/N)	ESTIMATED COST (USD)[16]	RATIONALE	OPERATIONAL STARTING PERIOD	PRIORITY
Replacement of 110/30kV 10MVA by 110/30kV 20MVA at Mururu I SS	*Demolishing of 110/30kV 10MVA *Installation of 110/30kV 20MVA	20MVA	Needs assessment was done based on potential for export (to Bukavu) and submitted to EDCL. There is a spare transformer at Mt Kigali ready to be moved to this location. Two export points: Rubavu (Goma) and Bukavu (Mururu I). So where the need for export arises, this transformer will be transferred there. Other modifications are required that are lacking e.g. the MV switchgears; submitted to EDCL (in needs assessment report) at planning department. 2 scenarios were presented; purchase of a new tx or using existing (this is because you only have 1 spare/redundant at the moment).	1,715,136	Power trade with neighboring countries.	2022	1
110kV Nyabarongo I-Muhanga and Muhanga Substation	Construction of Transmission Line, Muhanga 110/30kV SS	20.35	NO FS, ToRs to hire the consultant firm are prepared!!	29,416,919	Muhanga SS is needed to supply Muhanga IP that is	2025	1

[15] As mentioned, the total cost of these unfunded projects has been updated to include expropriation (3% of total cost), customs (45% of total cost) and feasibility study costs (10% of total cost) within the calculation.
[16] Adjusted to include NPV formula (20% discount rate), 20% contingency and expropriation (48% project cost).

PROJECT NAME	COMPONENTS	LENGTH/ CAPACITY	FS DONE? (Y/N)	ESTIMATED COST (USD)[16]	RATIONALE	OPERATIONAL STARTING PERIOD	PRIORITY
			Funding proposal are sent to AfDB		expected to come by 2025.		
110kV Gicumbi-Nyagatare	Construction of Transmission Line	43	FS done	47,775,744	Contingency supply between Gicumbi SS and Nyagatare SS	2027	1
110kV Kigoma-Muhanga	Construction of Transmission Line, Construction of Muhanga SS	17.59	NO FS, ToRs to hire the consultant firm are prepared!! Funding proposal are sent to AfDB	40,948,126	Contingency supply between Kigoma SS and Muhanga SS	2025	1
110kV Nyabarongo II-Shango	Construction of Transmission Line. Construct Shango line bay at Nyabarongo II. Construct Nyabarongo II line bay at Shango.	26.55	NO FS, ToRs to hire the consultant firm are prepared!! Funding proposal are sent to AfDB	39,414,988.80	For N-1 condition fulfilment at that time period.	2028	1
110kV Musanze Substation cut-in cut-out	Construction of Transmission Line, Construction of Musanze SS	0.596 2X20MVA	NO FS, ToRs to hire the consultant firm are prepared!! Funding proposal are sent to AfDB	25,196,286	Supply reliable power to Musanze IP	2024	2
110kV Rusizi Substation cut-in cut-out	Construction of Transmission Line, Construction of Rusizi SS	0.661 2X20MVA	No FS	25,436,160	Rusizi is a secondary city. This SS will supply Rusizi IP with high quality power.	2024	2
110kV Ntaruka-Musanze IP	Construction of transmission line. Extension of Ntaruka switchyard (20% contingency included in total project cost due to the landscape at Ntaruka HPP potentially driving the cost higher than the standard 110 line bay construction of USD300K). Construction of Musanze IP line bay at Musanze S/S.	20.3	NO FS, ToRs to hire the consultant firm are prepared!! Funding proposal are sent to AfDB	16,588,800.00	To supply power to Musanze IP and the surrounding areas as Musanze is as secondary city with a fast growing load.	2025	2

PROJECT NAME	COMPONENTS	LENGTH/ CAPACITY	FS DONE? (Y/N)	ESTIMATED COST (USD)[16]	RATIONALE	OPERATIONAL STARTING PERIOD	PRIORITY
REG Control Centre	- REG/EUCL has a SCADA system which was developed and installed by PSI Ag; a German Company in 2010. - Current system has its own weaknesses and REG/EUCL is mobilizing resources to upgrade. - Some of those weakness include key energy management aspects which current system cannot provide: ○ Short circuit calculation and overall faults analysis, ○ Outage management/reporting, ○ State estimation and load flow calculations, ○ Contingency analysis, ○ AGC (Automatic Generation Control). Even though REG/EUCL is mobilizing funds to upgrade the existing system, the critical component of replicating existing system to the secure location as backup for security reasons will not be addressed. It is therefore essential that an alternative site be secured to host SCADA as back up. Key components of the backup would include the following: i. Building/the backup site. ii. Software.	N/A		34,500,000	For security and emergency reasons, replicating existing SCADA to a safe and accessible site is very urgent and critical for a number of reasons: • Gikondo, the current National control Centre is an old area and even though its properly protected, it is known and shall continue to be accessed by people with various interests including study tours for learning purposes, • No back up at all for the current SCADA including data backup, which is very risk for the entire system • Data security gaps which exposes the system vulnerability for external attack/hackers, • Old system without any provision for inter-control protocol (ICCP) which make it difficult to interface current SCADA with other systems	ASAP	1

PROJECT NAME	COMPONENTS	LENGTH/ CAPACITY	FS DONE? (Y/N)	ESTIMATED COST (USD)[16]	RATIONALE	OPERATIONAL STARTING PERIOD	PRIORITY
	iii. Computer servers (data, workstations, etc.) iv. Displays/bigger screens or BARCO Rear Projector. v. Firewalls. vi. Switches/Routers. vii. Indoor and out cameras. viii. Standby power supply (generators and UPS). ix. GPS for synchronization. x. Air conditioners xi.SDH communication system, site equipment and required interfaces. xi. Etc. The above and other details shall be detailed to give the right quantities of each.						
REG Training Centre (REG TC)	Resource Mobilization & Purchase of land. Architectural designs & construction Procurement of equipment & materials. Staffing & Curriculum development. Launch/Start of operations.	The REG TC will contain the following key infrastructure: • 2 classrooms • 1 Mock network/external training field	The Feasibility/Project proposal of REG TC was finalized in May 2019	3,194,060,000 (EUR 2817 MILLION)	Capacity building is very critical for energy utilities to adapt to their mandates & evolving sector.	2025	1

PROJECT NAME	COMPONENTS	LENGTH/ CAPACITY	FS DONE? (Y/N)	ESTIMATED COST (USD)[16]	RATIONALE	OPERATIONAL STARTING PERIOD	PRIORITY
		• 9 State-of-the-art Laboratories. • MV lab • HV lab, • Meters lab, • Cables, isolators & lines lab • Protection lab, • Distribution Transformers lab • Solar lab, • hydro lab • Clean cooking/Biogas/ LPG lab/Geothermal lab • 6 administrative offices • 1 Technical warehouse • 1 restaurant			REG Training center (REG TC) is the capacity building arm of Rwanda Energy Group. The center will provide hands-on short-term technical trainings on energy/electricity & project management. The center targets clients in Rwanda, the region & beyond.		
		TOTAL		**3,455,052,159**			