MINISTRY OF INFRASTRUCTURE
RWANDA ENERGY GROUP
REPUBLIC OF RWANDA

THE PROJECT FOR PREPARATION OF ELECTRICITY DEVELOPMENT PLAN FOR SUSTAINABLE GEOTHERMAL ENERGY DEVELOPMENT IN RWANDA (ELECTRICITY DEVELOPMENT PLAN AND GEOTHERMAL STUDY)

FINAL REPORT

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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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SUMMARY

Project Background

Electrical power consumption per capita in Rwanda is extremely low comparing with other East African countries, electricity energy consumption accounts for only 4 % of the national energy consumption and 84 % of whole energy consumption is provided by traditional biomass sources such as charcoal and wood.

Electrical power generated has been increased since 2004, when the serious power shortage occurred, however, the indexes of power supply, such as an electrification rate of 16 % and installed capacity of 110 MW as of the year of the project started and of 22 % and of 140MW respectively in 2014, are still at the lower end and indicate insufficient power supply to meet increasing power demand that results from a consistently growing economy and improved living standards.

The power generation plants in Rwanda consists mainly of hydro (54 %) and diesel (46 %), and thus the country faces a big challenge to raise foreign currency to import fossil fuel whose prices on the world market are incessantly surging.

Under these circumstances, Rwanda is planning to increase the installed capacity and diversify energy resources by utilizing indigenous resources in accordance with the “Vision 2020” and “Economic Development and Poverty Reduction Strategy” as the national development plan and “Electric Development Strategy” as the sector development plan. In order to achieve the targeted increased and diversified electrical energy sector, a well prepared concrete electricity master plan is mandatory. However, the existing electricity development master plan is insufficient due to the electricity demand forecast included in the plan has not been authorized.

Since geothermal power is a clean, reliable and indigenous energy resource which is not influenced by short-term fluctuations on the international market and by climate, Government of Rwanda (GOR) considers geothermal development as a key component of its sustainable energy future and power security. According to the previous studies, Rwanda’s geothermal power generation potential has been estimated at more than 700 MWe and 300 MWe or more was expected as the least cost for base load operation.

In response to these situations, GOR is promoting geothermal power development by mainly Ministry of Infrastructure (MININFRA) and Energy and Water Sanitation Authority (EWSA) (EWSA has been restructured and Rwanda Energy Group (REG) has been taking the place of the working on the energy since 2014), but the development is in the early stages yet. In addition, there are few experts with adequate knowledge of geothermal power generation in Rwanda government agencies.

In the above context, the GOR requested the GOJ on the Project for the Preparation of an Electricity Development Plan for Sustainable Geothermal Energy Development and its integration into the Electricity Master Plan. The project also includes capacity development of counterpart personnel by JICA experts through on-the-job-training during the project period.

1. Electricity Development Plan

(1) Current status of power supply

Generally in the case where an economical power supply is being provided, as the right hand slide in Fig. 1-1 below which shows a daily load curve simulation, hydro generation which is low cost and

makes possible stable operation together with imported power which is also a hydro power source is used as a high load-factor base, while diesel is used to meet peak demand, thereby keeping down fuel costs to the extent possible. However, this kind of efficient operation is not happening in practice. 3 possible causes are following,

i) Limitations on availability of hydro

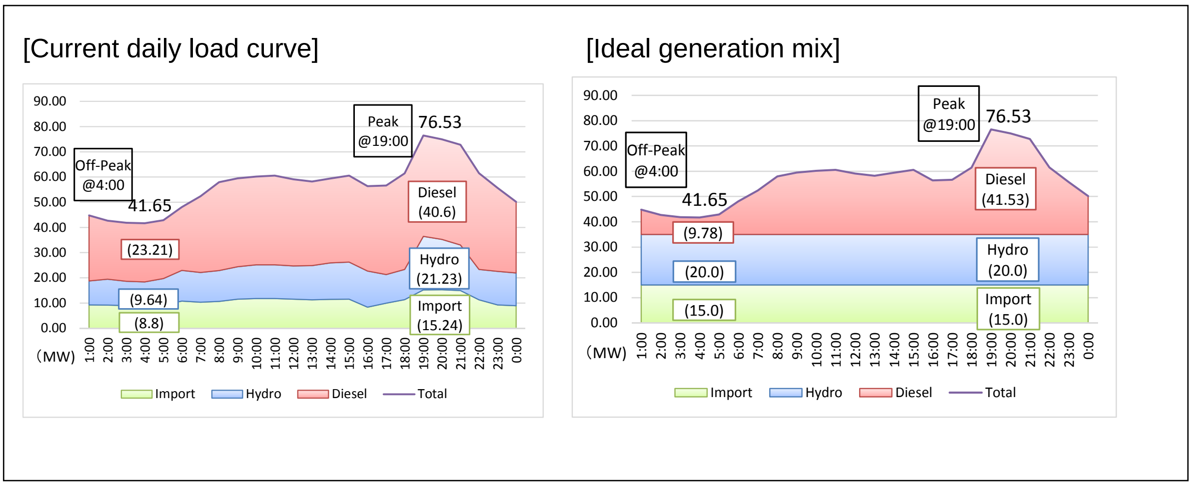
Domestic hydro availability cannot currently meet the high demand for power. Especially, the newly installed hydro power stations since 2011 are not performing well.

ii) Dependence on rental diesel

With the introduction of rental diesel, because it is necessary to pay fixed rental fees, despite high fuel costs there is no choice but to maintain high operation rates.

iii) Insufficiency of load dispatching infrastructure and operation technology

It is impossible to understand the status of supply and demand in real time, or make quick and reliable load-dispatching instructions.



Source: JICA study team, based on documentation obtained from EWSA central load dispatching office

Fig.1-1 Current status and ideal load curve (February 28, 2013)

Table 1-1 Annual load factors and capacity factors for power source facilities (2013)

	Name	Status	Year	Type	Installed Capacity (MW)	Available Capacity (MW)	Max Load in 2013 (MW)	Annual Generation (MWh)	Annual Load Factor	Capacity Factor	Load Factor (Average)	Capacity Factor (Average)
1	Gisenyi	REG	1957	Hydro	1.2	1.00	1.10	4,850	50%	46%		
2	Ntaruka	REG	1959	Hydro	11.25	9.00	11.70	23,323	23%	24%		
3	Mukungwa 1	REG	1982	Hydro	12	11.00	11.80	71,468	69%	68%	Stable Hydro	
4	Gihira	REG	1984	Hydro	1.8	1.80	1.63	9,330	65%	59%		
5	Murunda	IPP	2010	Hydro	0.1	0.10	0.1	571	65%	65%		
6	Rukarara	IPP	2010	Hydro	9	9.50	7.30	28,137	44%	36%	66%	44%
7	Rugezi	REG	2011	Hydro	2.2	2.20	3.50	438	1%	2%		
8	Keya	REG	2011	Hydro	2.2	2.20	2.2	683	4%	4%		
9	Nkora	REG	2011	Hydro	0.68	0.70	0.36	1,442	46%	24%		
10	Cyimbili	REG	2011	Hydro	0.3	0.30	0.16	271	19%	10%	New Hydro	
11	Mazimeru	IPP	2012	Hydro	0.5	0.50	0.5	227	5%	5%		
12	Nshili 1	REG	2013	Hydro	0.4	0.40	N/A	N/A	N/A	N/A		
13	Musarara	IPP	2013	Hydro	0.5	0.38	N/A	N/A	N/A	N/A		
14	Mukungwa 2	REG	2013	Hydro	2.5	0.80	0.8	2,563	37%	12%	31%	15%
15	Jabana 1	REG	2004	Diesel	7.8	7.20	2.84	5,042	20%	7%		
16	Aggreko Gikondo	Rental	2005	Diesel	10	10.00	10.30	84,694	94%	97%	Diesel	
17	Aggreko Mukungwa	Rental	2012	Diesel	10	10.40	10.78	67,759	72%	77%		
18	Jabana 2	REG	2009	Diesel(HFO)	20	20.00	19.83	97,452	56%	56%	62%	61%
19	KP 1	IPP	2008	Methane	3.6	1.20	1.20	9,938	95%	32%	95%	32%
20	Ruzizi 1 (SNELL)	Public	1957	Import	3.5	3.5	4.02	22,750	65%	74%		
21	Ruzizi 2 (CINELAC)	Public	1989	Import	12	12	15.51	70,610	52%	67%	55%	69%

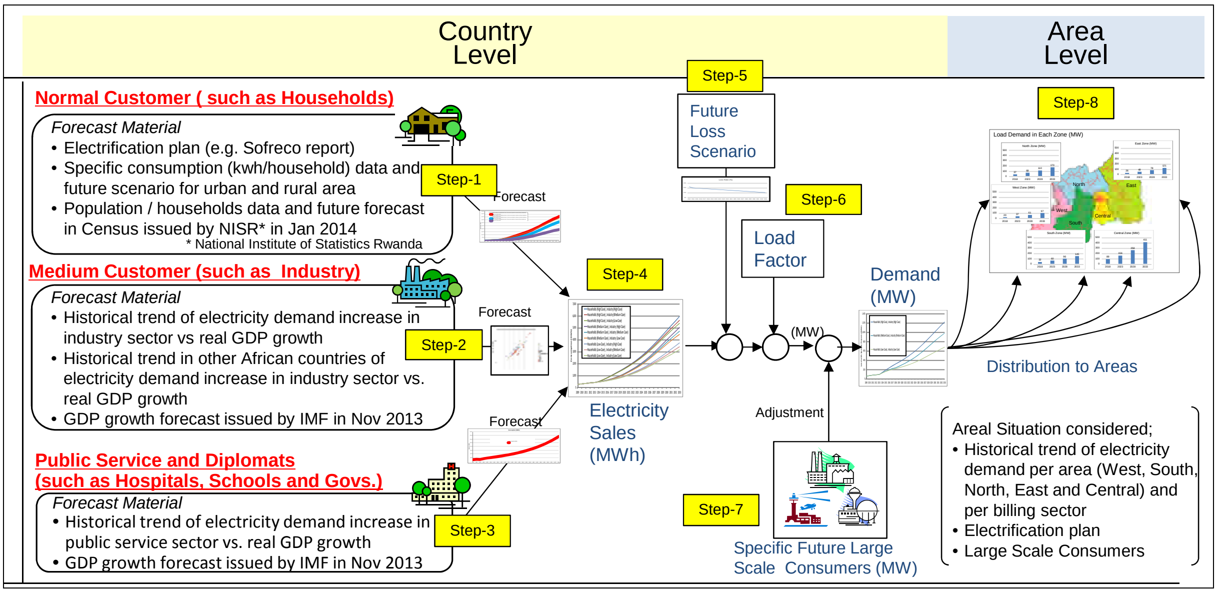
(2) Power Demand Forecast

Two approaches were taken to forecast power demand for different billing sectors which are categorized in three. The first approach was for the Normal Customer such as households, and used a bottom-up method (a product of the future number of customers and specific consumption). Upon forecasting, the rural electrification plan of EWSA was given thorough consideration.

The second approach was for the Medium Customer that includes industrial and commercial facilities and the Public Service Customer, and used a macroscopic method. This method creates a power demand model (approximate formula) based on the correlation between the historical economic and social indicators and power demand.

The JICA study team explained the methods used for the power demand forecast and the preliminary result of the forecast done by the team with those methods during the 2nd and 3rd Works in Rwanda. The counterpart has given an approval for the methods and requested an addition and changes to be made to the conditions for the power demand forecast as listed below:

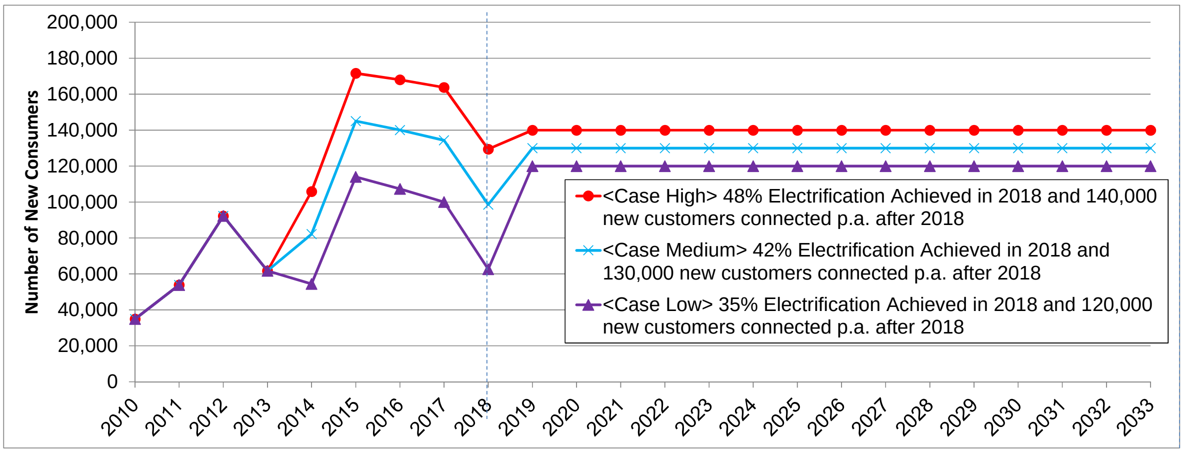
- To include a new case using a GDP growth rate of 11.5% which is the target set by the government
- To change the electrification rate achieved for 2017/18 to 48% / 42% / 35% (target of ESSP 2014)
- To use the number of households stipulated in the Combined Design Report of Electricity Access Roll Out Program by Sofreco to calculate the electrification rate achieved for 2017/18
- To correct the forecasted load based on the provided information about the Large-scale Customer prepared by EWSA with interviewing related ministries and agencies, and the feasibility of each project is high.



Source: JICA study team

Fig. 1-2 Power demand forecast flow

Fig. 1-3 below shows the change in the number of new customers to achieve the electrification rate 35%, 42% and 48% in 2017/2018 and the increase rate of 3.9% per year, which is reported in Census issued by the National Institute Statistics of Rwanda in Jan. 2014, is applied after the year of 2018.



Source: JICA study team

Fig.1-3 Change in the number of new customers

The integration of the electricity sales scenarios for each billing sector calculated for Normal Customer, Medium Customer and Public Service Customer was made and the following 4 cases were selected as High, Medium, Low and Extreme High shown in Table 1-2.

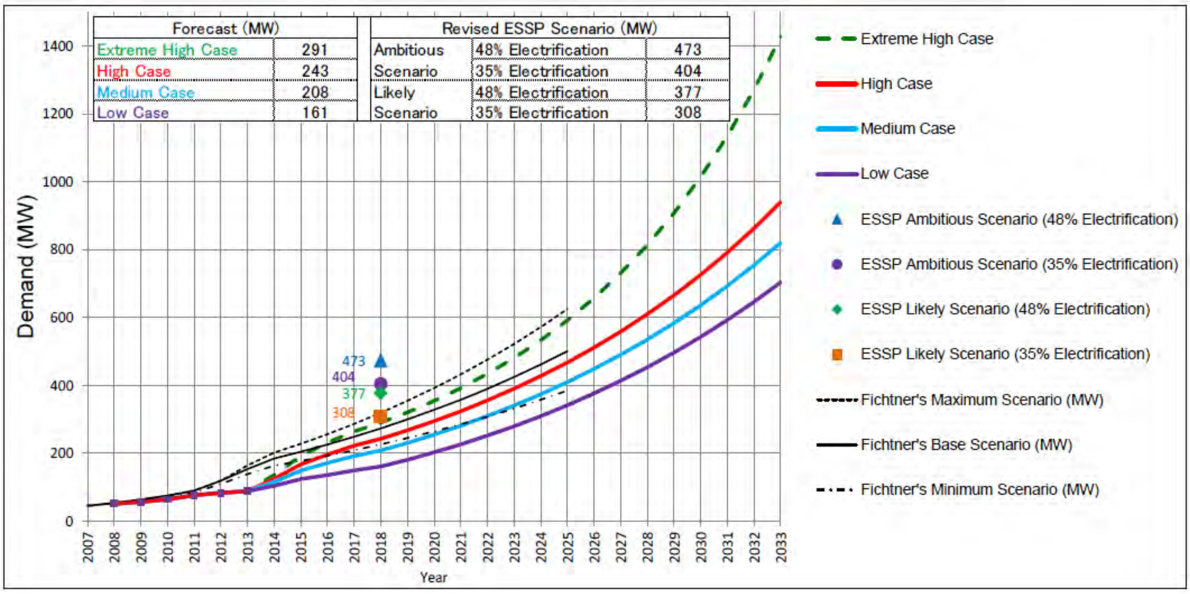
Power Demand Forecast until 2033 is shown in Fig. 1-4 that was considered of the loss in the grid which was predicted decreasing gradually from 22% in 2013 to 10.2% in 2033, of the load factor

Table 1-2 Selected scenarios

	High Case	Medium Case	Low Case	(Reference) Extreme High Case
Normal Customer	High (Electrification 48%)	Medium (Electrification 42%)	Low (Electrification 35%)	High (Electrification 48%)
Medium Customer	High (GDP Growth 8.5 %p.a.) & （Specific large scale customer load 70%）	Medium (GDP Growth 7.5% p.a.) & （Specific large scale customer load 50%）	Low (GDP Growth 6.5% p.a.) & （Specific large scale customer load 20%）	Extreme High (GDP Growth 11.5% p.a.) & （Specific large scale customer load 100%）
Public Service Customer	Base (GDP Growth 7.5 %p.a.)	Base (GDP Growth 7.5 %p.a.)	Base (GDP Growth 7.5 %p.a.)	Extreme High (GDP Growth 11.5 %p.a.)

Source: JICA study team

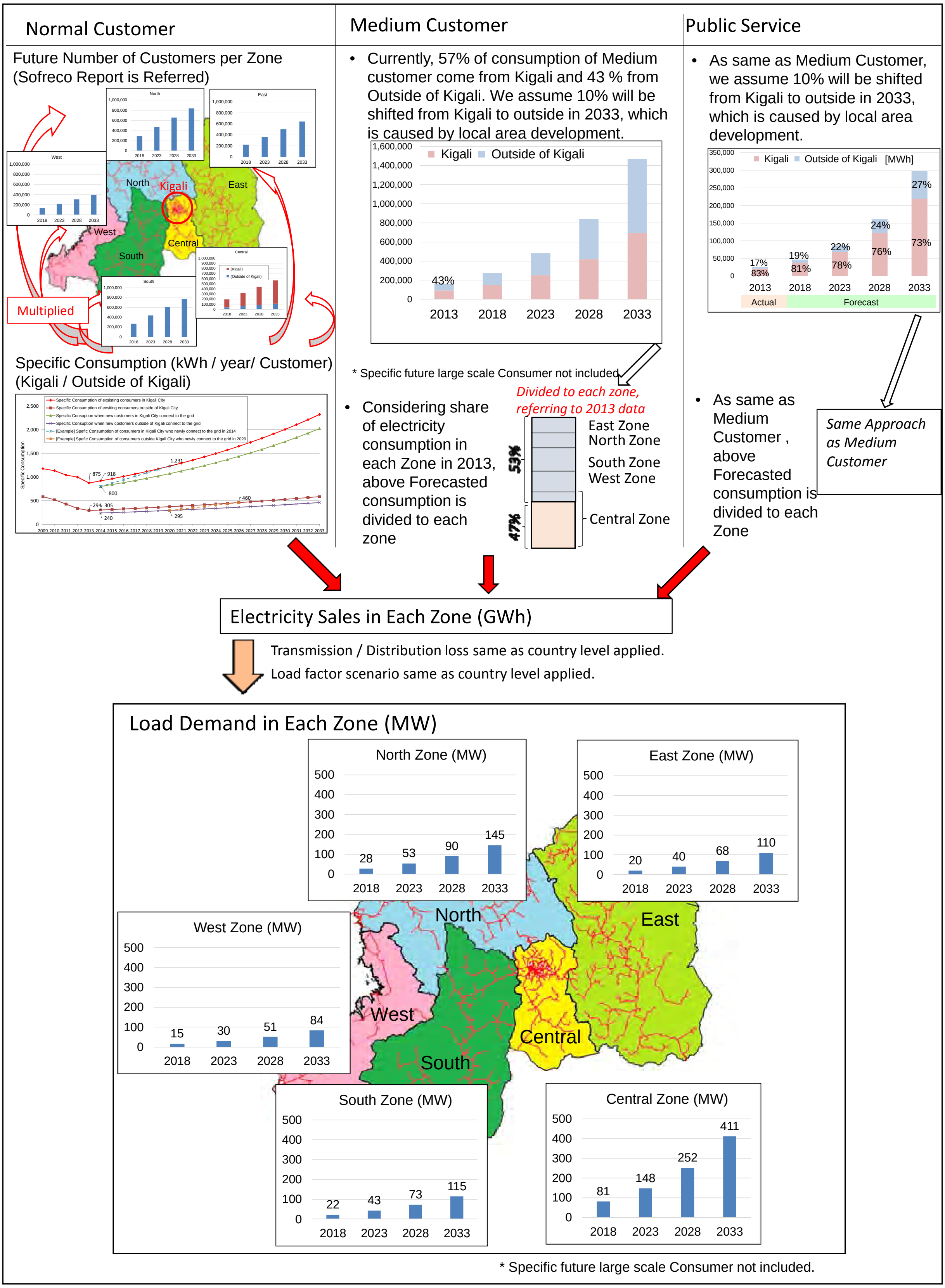
which was predicted 65% to calculate the annual peak load demand power (W) from the annual energy (Wh), and of adding correction of the large-scale load customers which are to be constructed in near future and were not captured in the macro forecast for the medium customer. The agreed forecast values in Fig. 1-4 are less than the ones in ESSP reviewed in 2014 which are also listed in Fig. 1-4.



Source: EWSA National Electricity Control Center Economic Data Collection and Demand Forecast, Dec. 2009, ESSP

Fig.1-4 Power Demand Forecast

Among four cases studied above, the High Case, described in red in Fig. 1-4 was used to divide the country-level load in 2018, 2023, 2028 and 2033 by five zones of East, West, South, North and Central. The load divided by the zones is shown in Fig. 1-5 and further, the load divided by the substations is shown in Fig. 1-6 for whole country except Kigali and Fig. 1-7 for Kigali field in order to study electricity development plan and power system analysis.

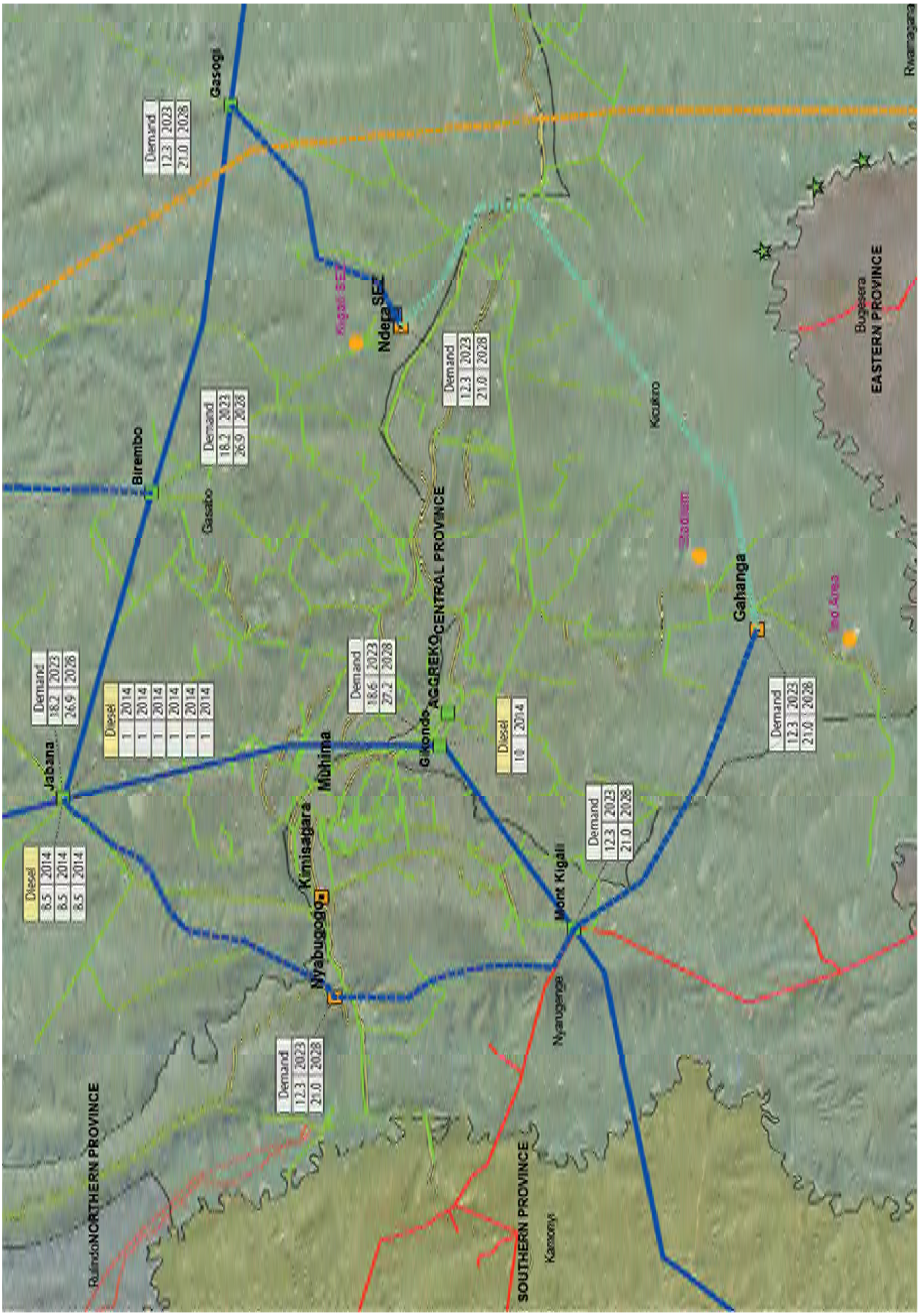


Source: JICA study team

Fig. 1-5 Division of the country-level power demand by zones

Source: EWSA-GIS and JICA study team

Fig. 1-6 Division of the power demand by substations excluding Kigali field



Source: EWSA-GIS and JICA study team

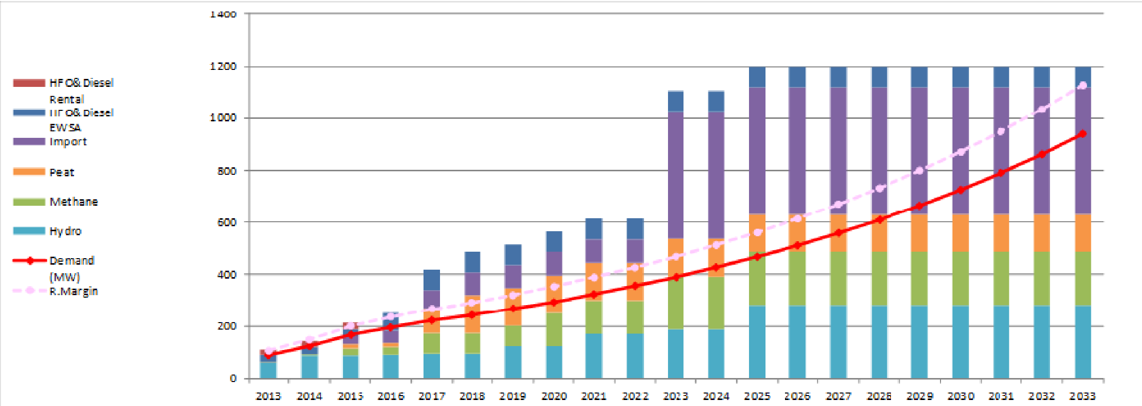
Fig. 1-7 Division of the power demand by substations in Kigali field

(3) Electricity Development Plan

The high case of power demand forecast mentioned earlier and the power plant development plans which were obtained until 3nd work in Rwanda were organized in Fig. 1-8 Power supply scenario planned by Rwanda side and Demand.

Geothermal power capacity is not included in the scenario. Because JICA study team has prepared the geothermal development action plan which includes the plants of 20 MW in Kinigi field and 5 MW in Bugarama field from the evaluation results of geothermal energy potential, however the plan requires the further exploitations of the areas before the decision of construction of those plants.

Furthermore, renewable energy such as photovoltaic and wind power is also not included in the scenario because of no contribution to the time of peak demand in the evening in Rwanda and uncontrollable power source corresponding to the change in load demand.



Year			2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Demand (MW)			87.9	124.5	167.1	196.3	222.4	243.0	267.7	294.7	324.1	355.8	390.2	427.4	467.7	511.4	558.7	610.0	665.7	726.1	791.7	863.0	940.4
R.Rargin(%)		20	106	149	201	236	267	292	321	354	389	427	468	513	561	614	670	732	799	871	950	1036	1128
Year			2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Type	Hydro	Existing (44.63) +Ruzizi Ⅰ, Ⅱ (15.5)	60.13	28		3	5		27		48		17		95								
			60.13	88.13	88.13	91.13	96.13	96.13	123.1	123.1	171.1	171.1	188.1	188.1	283.1	283.1	283.1	283.1	283.1	283.1	283.1	283.1	283.1
	HFO&Diesel EWSA		27.8			40	10																
			27.8	27.8	27.8	67.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8	77.8
	HFO&Diesel Rental		20	4		−24																	
			20	24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Methane		3.6		25		50			50			75										
			3.6	3.6	28.6	28.6	78.6	78.6	78.6	128.6	128.6	128.6	203.6	203.6	203.6	203.6	203.6	203.6	203.6	203.6	203.6	203.6	203.6
	Peat	Black Number: Planned Install Capacity			15		80	50															
		Red Number : Total Installed Capacity	0	0	15	15	95	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145
	Import				30	20	20	20					400										
			0	0	30	50	70	90	90	90	90	90	490	490	490	490	490	490	490	490	490	490	490

年	種類	Owner	名前	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
2014	Hydro	REG	Nyabarongo 1	28																			
	Diesel	Rental	Rental Aggreko	4																			
2015	Methane	IPP	Kivu Watt		25																		
	Peat	REG	Gishoma		15																		
	Import	Import	Import(from Kenya)		30																		
2016	Hydro	IPP	Rukarara 5			3																	
	Diesel	REG	KSEZ HFO			40																	
	Diesel	Rental	Rental Aggreko			−24																	
	Import	Import	Import(from Kenya)			20																	
2017	Hydro	IPP	Ntaruka B				5																
	Diesel	REG	KSEZ HFO				10																
	Methane	IPP	Simbion				50																
	Peat	IPP	Mamba				80																
	Import	Import	Import(from Kenya)				20																
2018	Peat	IPP	Rwabusoro					50															
	Import	Import	Import(from Kenya)					20															
2019～	Hydro	IPP	Rusumo						27														
	Methane	IPP	Simbion							50													
	Hydro	IPP	Ruzizi 3								48												
	Hydro	IPP	Nyabarongo 2										17										
	Methane	IPP	Kivu Watt Phase2										75										
	Import	Import	Import(from Kenya)										400										
	Hydro	IPP	Ruzizi 4												95								

Source: "Energy investment in Rwanda" edited by JICA study team

Fig. 1-8 Power supply scenario planned by Rwanda side and Demand

Bar chart above shows the generation capacity that is colored by kind of power source. The line in pink color in the graph indicates the necessary generation capacity that is calculated by the load demand with 20% reserve margin.

For the power import from foreign countries such as Kenya from the year of 2015, transmission lines for interconnection with neighboring countries are planned and constructing at present. Since the all planned import power will come from north side through Uganda, it is necessary to equip reactive power compensators (capacitors) to maintain the voltage allowable range at substations in the grid. The required capacities of capacitors, timings and the substations to install them are from the results of the power flow analysis and presented in the main report.

<2028-WET>

No.	接続	220KV S/S			110KV S/S		
		From	To	Flow	From	To	Flow
1	I-C	(Uganda)	Shango	→13.5MW→			
2	C-E	Rilima	Rusumo	→21.5MW→	Gasogi	Musha	→19.6MW→
					Rubona	Musha	→5.4MW→
3	C-N				Jabana 1	Rulindo	→20.4MW→
4	C-W	Shango	Rubabu	←129.9MW←			
5	C-S	Rilima	Rwabusoro	←171.9MW←	Mt.Kigali	Kigoma	←54.2MW←
6	N-E				Rulindo	Ngarama	→9.1MW→
7	N-W				Mukungwa	Nyabihu	←32.8MW←
8	W-S	Kilinda	Kigoma	→134.0MW→	Kilinda	Kigoma	→18.1MW→
					Kilinda	Rukarara	→10.4MW→

Source: JICA study team

Fig. 1-9 Results Summary of Load Flow Analysis in 2028 wet season (Example)

Furthermore, the necessity of power system development such as substations and transmission lines to accommodate the electric power which is increasing from power sources to customers has presented in the main report as well.

The results of the studies above are summarized in Table 1-3 as the approximate cost estimation of power stations and power system facilities development by year.

(4) Least Cost Power Development Plan

The least cost power developing plan was studied by preparing the annual load duration curve and seeking the portfolio of power generation sources that is expected to provide lowest generation cost.

For the study of least cost development in real world, it is necessary to consider constraints with existing and planned power stations, and operational restrictions of each power source.

The generation costs provided by counterparts for the study were by each power station and the actual simulation study was made by utilizing them, however, much of the data is not intended for disclosure so that the averaged costs by energy sources are used for the instruction of procedure as Fig. 1-10.

JICA study team calculated the installed capacity of the power plants that would minimize the total cost, based on the demand forecast carried out in this study (= peak load) and hourly load data in 2013. It was done by using the load duration curve for 2028 (horizon year) that was

Table 1-3 Approximate Cost Estimation of Power Stations and Power System Facilities Development

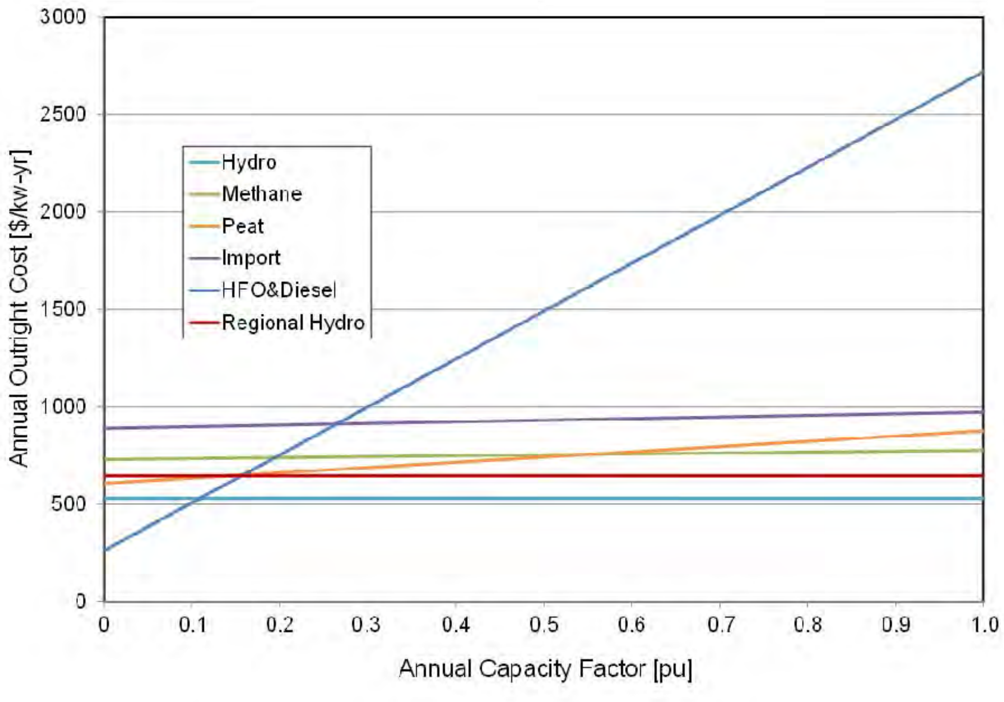
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Total Estimate Cost	**186,968,000**	**579,917,171**	**244,529,162**	**591,023,824**	**73,232,500**	**149,200,053**	**20,090,100**	**200,982,119**	**20,090,100**	**286,980,100**	**1,532,000**	**177,118,854**	**1,532,000**	**1,532,000**	**20,042,000**
Power Station	**162,800,000**	**351,456,971**	**88,943,662**	**519,787,324**	**52,350,000**	**112,769,953**	**0**	**180,892,019**	**0**	**251,000,000**	**0**	**175,586,854**	**0**	**0**	**0**
Nyabarongo 1	110,000,000														
Rental Aggreko	40,800,000														
S/M-Hydro	12,000,000														
Kivu Watt		191,549,296													
Gishoma		42,367,675													
Import		117,540,000													
Rukarara 5			15,000,000												
KESZ HFO			73,943,662												
Ntaruka B				N/A											
KESZ HFO				N/A											
Simbion				239,436,620											
Mamba				216,450,704											
S/M-Hydro				63,900,000											
Rwabusoro					N/A										
S/M-Hydro					52,350,000										
Rusumo						112,769,953									
Simbion							N/A								
Ruzizi 3								180,892,019							
Nyabarongo 2										60,000,000					
Kivu Watt Phase 2										191,000,000					
Ruzizi 4												175,586,854			
Sub Station	**16,380,000**	**161,370,000**	**86,810,000**	**42,210,000**	**18,750,000**	**27,980,000**	**11,640,000**	**11,640,000**	**11,640,000**	**27,530,000**	**504,000**	**504,000**	**504,000**	**504,000**	**19,014,000**
Bugarama	6,840,000														
Kibuye	450,000														
Ntendezi	5,540,000														
Rukarara	3,550,000														
Butare		22,280,000													
Gasogi		3,700,000	280,000												
Gifurwe		4,730,000			340,000					1,400,000					1,060,000
Gishoma		7,500,000								590,000					
Jabana 1		2,520,000								2,520,000					630,000
Mt.Kigali		5,940,000	630,000												
Musha		3,670,000	630,000							2,680,000					680,000
Ndera		8,690,000		590,000											1,180,000
Nyabihu		5,360,000													
Nyabugogo		9,740,000													1,180,000
Rilima		28,760,000													
Rulindo		2,210,000	630,000	630,000						590,000					1,030,000
Shango		49,520,000								750,000					6,000,000
Mukungwa		5,100,000								2,880,000					3,330,000
Kigoma		970,000	13,980,000	90,000						1,620,000					
Rwinkwabu		680,000								2,520,000					
Bwinshura			8,170,000												
Gahanga			8,960,000												
Huye			6,710,000												
Kirehe			6,080,000	340,000											
Ngarama			5,990,000							340,000					340,000
Rubabu			8,170,000												
Ruwabusoro			12,670,000												
Kabarondo			630,000												1,620,000
Kilinda			13,280,000												1,460,000
Mamba				8,980,000											
Nyabarongo 1				5,540,000											
Nyabarongo 2				6,260,000											
Simbion				19,780,000											
Nyabugari					18,410,000										
Rusumo						16,340,000									
(Estimate Cost)						11,640,000	11,640,000	11,640,000	11,640,000	11,640,000					
Air Port										13,460,000					
Birembo							58,200,000 / 5 = 11,640,000			4,410,000					
Kamanyora										27,950,000					
Ntaruka										1,890,000					
Rubona										10,490,000					
											504,000	504,000	504,000	504,000	504,000
Karongi															1,260,000
Kibogora												2,520,000 / 5 = 11,628,000			1,260,000
Transmission Line	**7,788,000**	**67,090,200**	**68,775,500**	**29,026,500**	**2,132,500**	**8,450,100**	**8,450,100**	**8,450,100**	**8,450,100**	**8,450,100**	**1,028,000**	**1,028,000**	**1,028,000**	**1,028,000**	**1,028,000**
220KV		54,447,000	46,179,500	22,354,500	92,500	6,311,700	6,311,700	6,311,700	6,311,700	6,311,700	740,000	740,000	740,000	740,000	740,000
							31,558,500 / 5 = 6,311,700			31,558,500		3,700,000 / 5 = 740,000			3,700,000
110KV	7,788,000	12,643,200	22,596,000	6,672,000	2,040,000	2,138,400	2,138,400	2,138,400	2,138,400	2,138,400	288,000	288,000	288,000	288,000	288,000
							10,692,000 / 5 = 2,625,600			10,692,000		1,440,000 / 5 = 288,000			1,440,000

Source: REG and JICA study team

created with the Monte Carlo simulation, and assuming that each plant is operated according to the concept of Economic Load Dispatching (as the load increases, plants with the smallest marginal cost will be put into operation first).

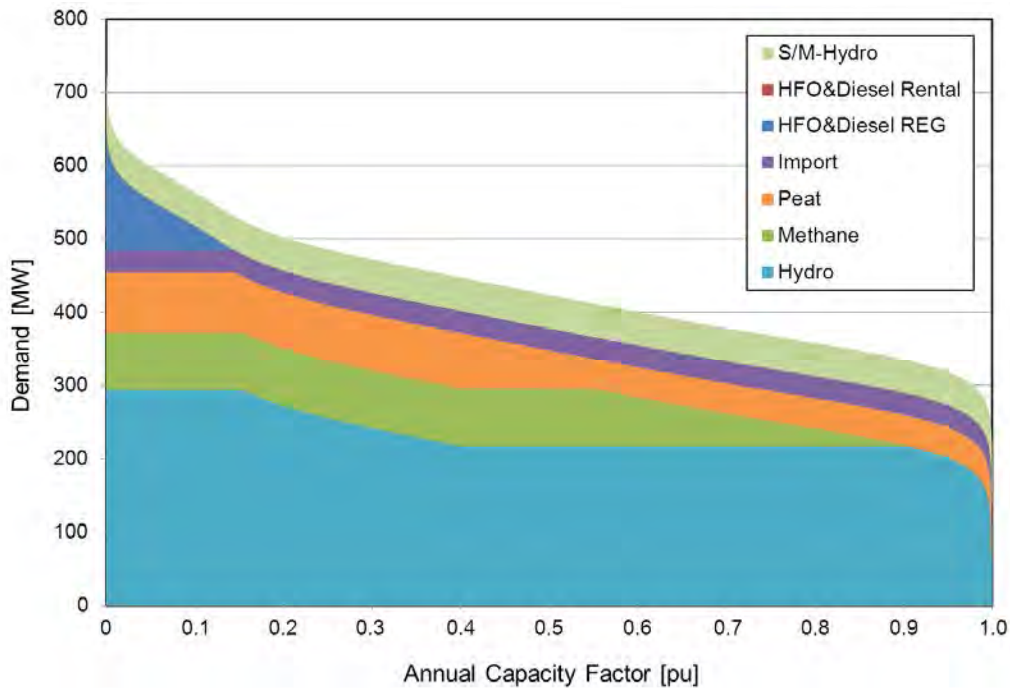
And here, the restriction on the operational output of the power plants were considered in the calculation.

Fig. 1-11 shows the result of studies as the ratio of power sources against the load duration curve.



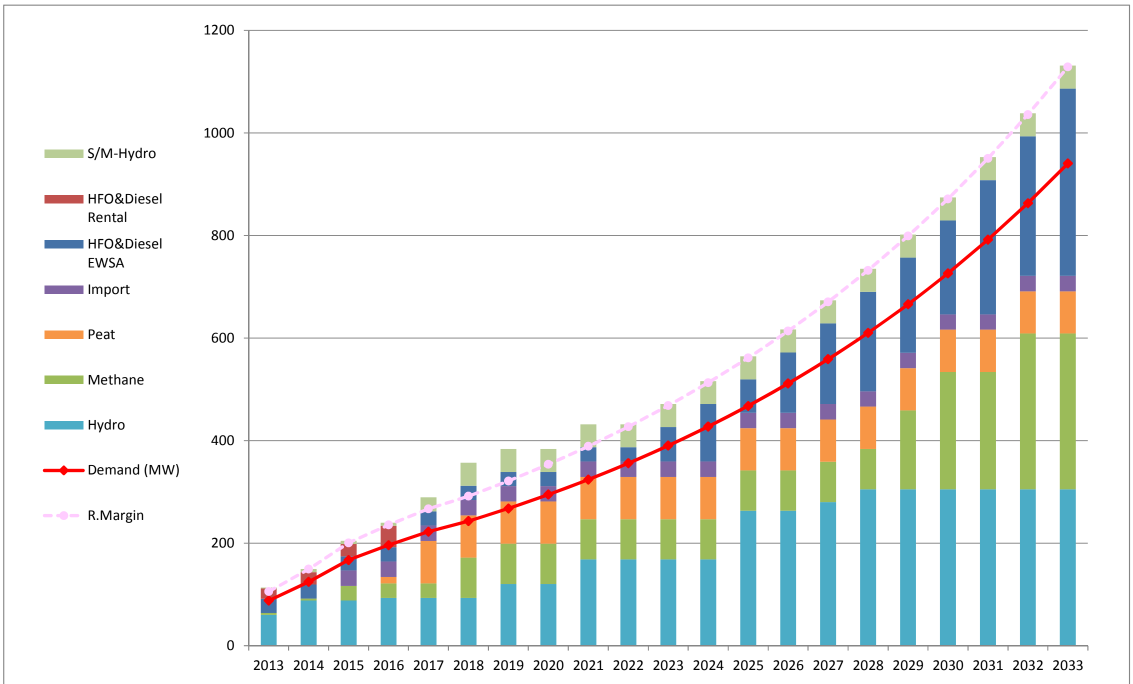
Source： JICA study team

Fig. 1-10 Generation Costs by Energy Sources for Generation Planning



Source： JICA study team

Fig. 1-11 Ratio of power sources based on the least cost development concept (2028)



Note: Hydro includes Ntarka (3.75MW x 3) operating only in peak hours.

Existing as of 2013

Year	Type	Owner	Name	Status	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
2013	Hydro[a]	-	-	Existing	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88	48.88
	HFO&Diesel EWSA	-	-	Existing	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8
	Methane	-	-	Existing	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	S/M-Hydro	-	-	Existing	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Planned as of 2013

Year	Type	Owner	Name	Status	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
2014	Hydro	REG	Nyabarongo 1	Committed	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
	S/M-Hydro	-	-	Committed	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
2015	Methane	IPP	Kivu Watt	Committed	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	Import	Import	Import(from Kenya)	Committed	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
2016	Hydro	IPP	Rukarara 5	Committed	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Diesel	REG	KSEZ HFO[c]	Not Committed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peat	REG	Gishoma	Committed	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
	Import	Import	Import(from Kenya)	Not Committed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	Diesel	REG	KSEZ HFO[c]	Not Committed		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peat	IPP	Mamba	Committed		70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
	Import	Import	Import(from Kenya)	Not Committed		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S/M-Hydro	-	-	Committed		21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3
2018	Methane	IPP	Simbion	Committed			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	Import	Import	Import(from Kenya)	Not Committed			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S/M-Hydro	-	-	Committed			17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
2019	Hydro	IPP	Rusumo	Committed				27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Methane	IPP	Kivu Watt Phase2	Not Committed				0	0	0	0	0	0	0	0	0	0	0	0	0	75	75
	Import	Import	Import(from Kenya)	Not Committed				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	Hydro	IPP	Ruzizi 3	Committed						48	48	48	48	48	48	48	48	48	48	48	48	48
2023	Hydro	IPP	Nyabarongo 2	Not Committed								0	0	0	0	17	17	17	17	17	17	17
	Import	Import	Import(from Kenya)	Not Committed								0	0	0	0	0	0	0	0	0	0	0
2025	Hydro	IPP	Ruzizi 4	Not Committed										95	95	95	95	95	95	95	95	95

Non-Identified Projects

Year	Type	Owner	Name	Status	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
2018	Diesel or HFO[c]	IPP	-	Not Committed			0	0	0	0	0	39.609	84.161	37.443	89.814	129.51	166.06	157.81	155.24	233.92	244.45	337.29
2021	Methane	IPP	-	Not Committed						0	0	0	0	0	0	0	0	75	150	150	150	150
	Peat	IPP	-	Not Committed						0	0	0	0	0	0	0	0	0	0	0	0	0
2023	Hydro	IPP	-	Not Committed								0	0	0	0	0	25	25	25	25	25	25

Category	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Existing (1)	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28	82.28
Committed (2)	104.5	195.8	263.3	290.3	290.3	338.3	338.3	338.3	338.3	338.3	338.3	338.3	338.3	338.3	338.3	338.3	338.3	338.3
Sub Total (3)=(1)+(2)	186.78	278.08	345.58	372.58	372.58	420.58	420.58	420.58	420.58	420.58	420.58	420.58	420.58	420.58	420.58	420.58	420.58	420.58
Not Committed (4)	0	0	0	0	0	0	0	39.609	84.161	132.44	184.81	241.51	303.06	369.81	442.24	520.92	606.45	699.29
Total (5)=(3)+(4)	186.78	278.08	345.58	372.58	372.58	420.58	420.58	460.19	504.74	553.02	605.39	662.09	723.64	790.39	862.82	941.5	1027	1119.9
Peak Demand (6)	196.3	222.4	243	267.7	294.7	324.1	355.8	390.2	427.4	467.7	511.4	558.7	610	665.7	726.1	791.7	863	940.4
w/margin (7)=(6)x1.2	235.56	266.88	291.6	321.24	353.64	388.92	426.96	468.24	512.88	561.24	613.68	670.44	732	798.84	871.32	950.04	1035.6	1128.5
Top Load (8)[b]	228.66	259.65	284.2	313.67	345.93	381.08	419.01	460.19	504.74	553.02	605.39	662.09	723.6	790.39	862.82	941.5	1027	1119.9
Top Load to be Covered by "Not Committed" (9)=(8)-(3)	41.88	-18.43	-61.38	-58.91	-26.65	-39.5	-1.572	39.609	84.161	132.44	184.81	241.51	303.02	369.81	442.24	520.92	606.45	699.29

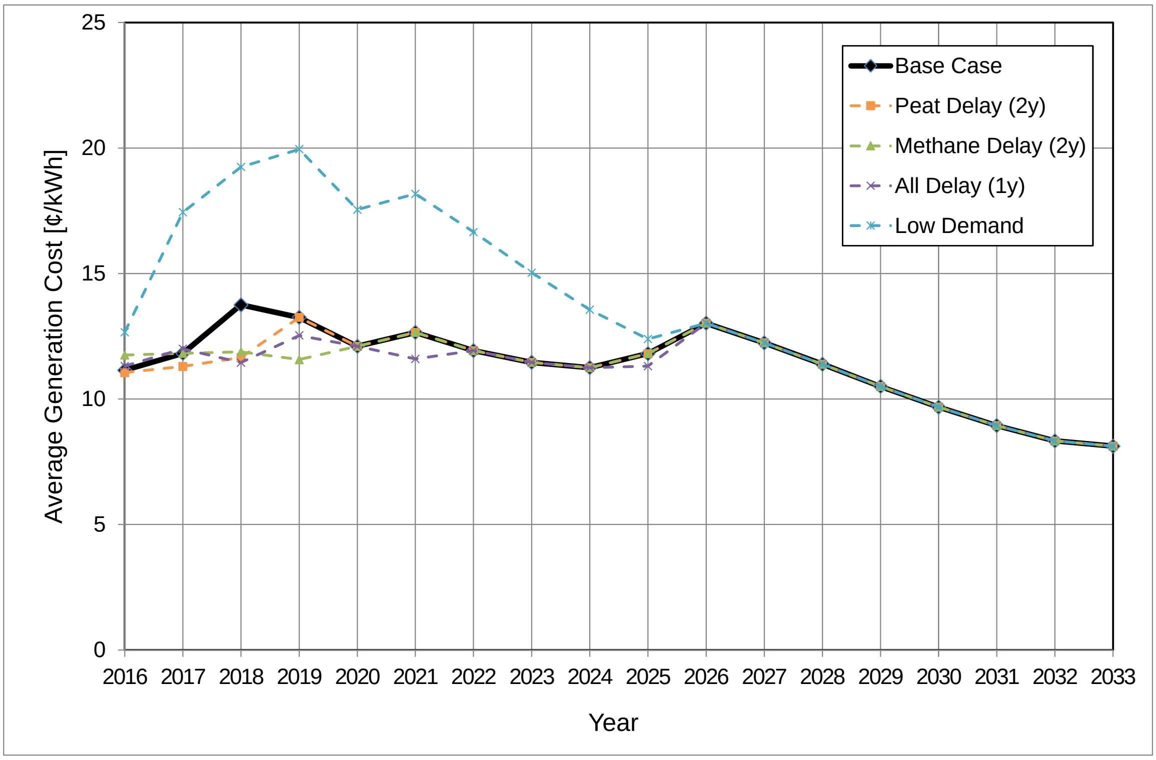
Notes:
(a) Excluding Ntarka (3.75MW x 3)
(b) Top of Duration Curve: Peak demand in consideration of peak shaving by Ntarka (3.75MW x 3)
(c) Capacities of Diesel generation are listed in "Non-Identified Projects" altogether; the optimal allocation to IPP, REG's own, and rental should be considered separately (see main text of the report).

Source：JICA study team

Fig. 1-12 Power source plan examined based on the least cost development method

The optimal power source composition for the years prior to the horizon year 2028 was made by following the process stated above, the examination was done for each year by going back from the base year and the results were shown in Fig. 1-12. The revised development plans from listed in Fig. 1-8 were marked yellow in Fig. 1-12.

The estimated average generation costs from 2016 through 2033, on the condition that the installation of generation facilities is carried out along the least cost development plan suggested above, are as in Fig. 1-13. The chart shows that the generation cost, after leveling off with some fluctuations until 2027, is thought to decline to dip from 10 US cent/kWh after 2030. This chart also includes the trends of the generation costs along risk scenarios of the two-year delay in Peat power plant projects, the two-year delay in Methane power plant projects, the one- year delay in overall power development projects and the demand falls as the Low Case of Fig. 1-4. If the construction schedule of power statins delays, the generation costs will stay lower. It is because the supply capability will exceed the demand and the delays of construction is favorable to the generation cost in the situation of oversupply. However, this figure shows that the generation costs rise significantly if oversupply and sluggish demand come together.



Source：JICA study team

Fig. 1-13 Estimated Generation Costs (2016 - 2033)

Based on the examination, the import of electricity planned after 2015 are not necessary. The reason was that there are other power source options and the imported electricity will be more expensive than those options. To put it the other way around, the import of electricity might come up as an option if the power purchase price goes down through negotiation with the partner countries or if the cost for other options goes up, or if other options became unavailable, making the power supply shortage likely. Therefore, it is necessary to collect the latest information on the alternative energy sources not limited to imported electricity and to periodically update the master plan and the supporting data in order to keep up with the ever-changing situation. Attention must be given to capabilities of the transmission and substation facilities by reviewing the network assuming the import of electricity and anticipating necessary reinforcement and improvement of facilities.

(5) Distinguishing Indigenous Energy Source in Rwanda

1) Peat

According to Peat Master Plan Updated conducted in 2012, the peat production potential dry matter is reported as 12.5 million tons only against the one reported as 155 million tons in Peat Master Plan conducted in 1992 and the value of 12.5 million tons would be only equivalent to 60TWh estimated power production if full potential reserve can be used. In simply conversion to a generating capacity, this potential quantity will supply fuel a 230MW plant for 25years.

Gishoma pilot power plant project with 15MW capacity is under construction and other private company projects such as Hakan in South Akanyaru (two 40MW units) and Punj Lloyd in North Akanyaru (two 50MW units) are planned, however, it is necessary to evaluate carefully in terms of sustainable procurement of fuel, dry-up treatment before combustion, and environmental & social consideration due to the almost area of peat distribution overlaps with irrigation agricultural terrain.

2) Methane in Lake Kive

Lake Kivu has enough methane reserves to fuel a max. 700MW of power generation according to studies by EWSA, and it is believed that 100 years of power generation would not exhaust the methane in the lake.

KP1 with 3.6MW capacity which was constructed as a pilot plant is now under commercial operation and the large scale 25MW Kivu Watt plant is under construction, however, like this large scale gas extraction plant has never operated over the world so that the it may face some difficulties to maintain the project schedule for commissioning and to plan the future lager plants to be constructed. Further the project cost is so expensive (approx. 5 million US$/MW) that the cost down of the EPC price will be key issue for low cost power purchase even though the fuel cost is free of charge.

(6) Trial Economic Calculation for Geothermal Power Plant

Based on the amount of geothermal resources estimated during the study of the geothermal development plans (see Chapter 2), the trial calculation of construction and operation cost was carried out by assuming that one 20MW-class geothermal power station will be built in Kinigi in northwest Rwanda and one 5MW-class power station in Bugarama in southwest Rwanda, which were selected as the relatively high priority regions for development.

This trial calculation of the power station construction and operation cost is merely to understand the approximate cost since the facility and equipment specifications or operation methods, etc. required for the power station could not be determined unless the preliminary study works listed in the geothermal development action plan have been conducted.

Therefore, the premises for the trial calculation were kept simple, and the level of the economic impact from cost increases or other fluctuations caused by the change in the precondition is explained with the responsiveness analysis as necessary.

Table 1-4 Calculation of Kinigi 20 MW Geothermal Power Plant's Levelized Cost of Electricity

Items	Unit	Value	
Plant Availability	%	97%	
Debt	MMUS$	130.232	
Loan principal payment period	year	27	
Loan interest rate	%	0.01%	
Tax	%	30%	
Generation cost total	MMUS$	184.47	100%
Construction cost	MMUS$	124.03	67.24%
EPC Consultant fee	MMUS$	6.2	3.36%
Interest during construction period	MMUS$	0.0527	0.03%
O&M, Major Inspection	MMUS$	48	26.02%
(per year)	MMUS$	1.6	-
Labor cost for O&M	MMUS$	6	3.25%
(per year)	MMUS$	0.2	-
Loan interest	MMUS$	0.1824	0.1%
Generation of plant life time	GWh	5,112	
Levelized cost of electricity	US cent /kWh	3.609	
Project IRR	%	16.2%	

Source：JICA study team

The calculated results for Kinigi 20 MW binary geothermal power plant are shown in Table 1-4. The income for the calculation was based on the average electricity tariff of 20.6 US cent/kWh in Rwanda at present.

As for the geothermal well deterioration, the calculation in Table 1-4 did not consider the decline of steam production for 30 years of power plant operation so that the sensitivity calculation was made assuming well drying up and aging deterioration as shown in Table 1-5. In terms of the loan interest rate, Japanese yen loan 0.01 % was applied in original calculation in Table 1-4, sensitivity calculation was also made up to the 17 % of the market rate in Rwanda and it is shown in Table 1-5. Table 1-6 shows the calculation results of Bugarama 5 MW binary geothermal power plant and the conditions of calculation were same as those of Kinigi's case.

Table 1-5 Sensitivity Calculation on Well Drying Up and Aging Deterioration

Years of production	30	15	12	8	6	3
Levelized cost of electricity (US cent/kWh)	3. 61	4. 60	5. 09	6. 33	7. 56	12. 50
IRR (%)	16. 2	12. 2	10. 8	8. 30	6. 5	2. 7

Source：JICA study team

Table 1-6 Sensitivity Calculation on Increase of Loan Interest Rate

Interest rate (%)	0. 01%	2. 6%	5. 1%	8. 5%	13. 6%	17. 0%
Levelized cost of electricity (US cent/kWh)	3. 61	4. 885	6. 402	8. 839	13. 531	17. 471

Source：JICA study team

Table 1-7 Calculation of Bugarama 5 MW Geothermal Power Plant's Levelized Cost of Electricity

Items	Unit	Value	
Plant Availability	%	97%	
Debt	MMUS$	41.591	
Loan principal payment period	year	27	
Loan interest rate	%	0.01%	
Tax	%	30%	
Generation cost total	MMUS$	65.67	100%
Construction cost	MMUS$	39.61	60.32%
EPC Consultant fee	MMUS$	1.98	3.02%
Interest during construction period	MMUS$	0.0168	0.03%
O&M, Major Inspection	MMUS$	18	27.41%
(per year)	MMUS$	0.6	-
Labour cost for O&M	MMUS$	6	9.14%
(per year)	MMUS$	0.2	-
Loan interest	MMUS$	0.0583	0.09%
Generation of plant life time	GWh	1,278	
Levelized cost of electriciy	US cent /kWh	5.138	
Projejct IRR	%	12.6%	

Source：JICA study team

(7) Power Information Database

The JICA study team prepared two kinds of the databases for the electricity development, one is Power Information Database by MS-Access file format and the other is Power System Information Database (PSI DB) by MS-Excel file format.

In Power Information Database, Almost all information and reports which the JICA study team obtained during the works in Rwanda were registered. And it has a strong search function that enables flexible search using multiple/refined (AND/OR) conditions for items for example title, national/regional, field, creator, issue and key words etc.

PSI DB has a concept similar to that of Power Information Database, but uses MS- Excel with an aim to integrally manage the equipment and specifications of the transmission and substation facilities subject to system analysis. It is important to manage and control data in a unified manner and define a locus of responsibility when a company engaged in infrastructure work plans, a new power source development or equipment renewal while controlling and operating facilities on a permanent basis. The data acquired in the Project were entered in the database. The datasheet has a maintenance mode, and can accommodate changes in the facility configuration due to facility renewals or additions from new constructions, making the datasheet permanently usable.

(8) Recommendations

1) Need for annual appropriate update of Power Demand Forecast

- Review demand forecasts once every year, and when carrying out a review verify the causes of any differences between demand forecasted the previous year and actual demand.
- Basic actual supply and demand data necessary for demand forecasts is to be collected by section responsible for demand forecasting once a year from related sections, and together with past data managed statistically
- Concerning future large-scale customers, collect detailed information including that on peak time periods, peak demand and load factor
- In the current demand forecast, multiple scenarios were not formulated for some prior conditions (e.g. rate of increase in specific consumption for Normal Customer, GDP Elasticity for Medium Customer, etc.). For future forecasts, where conditions are expected to change significantly, and it is thought that forecasting results will be sensitive to such prior conditions, formulate multiple scenarios

2) Generating plants development

a. Notes regarding the connection of peat power plants to the network

Thermal power plants that are developed by the private sector and utilize peat are included in the power development plan for the future. It must be remembered how peat power generation facilities differ from the conventional hydro, diesel or methane power generation facilities.

Currently, the frequency in Rwanda is below the reference value at all times since the capacity of the power supply facilities is less than the power demand.

The steam turbine used in peat power generation has its own resonant frequency based on its characteristics, and when the rotation speed drops, vibration might occur depending on the resonant frequency band. Generally, a protective device is installed in order to prevent vibration-caused damage and once the device is triggered, the turbine is shut down automatically.

Also, if the electric feed-water pump is used to supply water to the boiler, the drop in the rotation speed might cause the ability to supply water to the boiler to go down, which might lead to the boiler tube burnout or drop in water supply flow rate, and in turn trigger the protective device. When this happens, it might cause the automatic shutdown of the plant.

The automatic shutdown of large thermal power plants due to frequency drop on the network side could cause further drop in frequency and even a large-scale power outage. Depending on the contents of the PPAs, the businesses might impose a penalty for reasons of unstable network and frequency; therefore, it is important for those responsible to understand that adequate care must be taken to maintain proper frequency.

b. Note regarding the introduction of renewal energy such as small-scale hydro and photovoltaic power

Currently in Rwanda, planning and construction of small-scale hydroelectric and photovoltaic power plants are underway led mainly by IPPs, thanks to the developmental support by foreign donors and encouragement by FIT. The introduction of renewable energy plants such as these is significant since these energy sources are CO_2 free and the domestic energy resources are put to utilization effectively. However, it is necessary for REG, the entity responsible for the network operation, to always recognize the amount of electricity from renewable energy plants that can be introduced in the immediate future and measures to ensure network stability as well as associated costs. Generally, if the reverse power flow (bank reverse power flow) occurs in the bank of the distribution substation to which small-scale hydro or photovoltaic power plants are connected, trouble could occur in the voltage control or protective coordination of the distribution system. Therefore, the network operator has to take measures to prevent the reverse power flow in the back. In Rwanda where the land area is small and there are many intermountain regions, the areas where renewable power plants can be located might be limited due to its riverine systems and topographical features. That combined with the issue of power demand balance in surrounding areas, there could be a concentration of power sources in certain areas. Given these situations, REG must carry out detailed technological investigation on connections and necessary measures from the standpoint of stable network operation.

c. Need for updating the hydropower master plan

The study of Rwanda's hydropower development potential has not been carried out since "Hydro Power Atlas" which was a hydropower development feasibility study reported in 2008. According to the report, there are 333 sites that have been confirmed suitable for small-scale or micro hydropower plants in Rwanda. Currently, more and more small-scale or micro hydropower plants are being developed based on this FS. Now, different from the periods when old hydros were installed, elaborate hydrological analysis is available thanks to the detailed information such as local climate, satellite images, and GIS. In addition, technologies for numerical analysis and simulation as well as the advancement of the performance of personal computer hardware and software. It is worthy to seek the possibilities to improve overall output of a water system, not the hydros individually. JICA study team recommends that Rwanda considers the necessity of updating the hydropower master plan in order to effectively utilize hydropower continuously into the future as Rwanda's core power source that uses an indigenous energy resource.

d. Need for comprehensive review of hydropower rehabilitation and modernization

It is likely that measures are required to ensure soundness of the hydropower facilities through rehabilitation and to enhance power generation efficiency for the majority of REG's hydropower plants since they are old. The hydroelectric power plants have a high ability to control power supply and demand, and for this reason, not only the rehabilitation of the hydro plants but also the modernization of communication and control devices will be required to promote timely cooperation with the load dispatching center.

It is imperative that REG consider the rehabilitation and modernization as its important tasks, prioritize the measures through close collaboration with the network operation sector, plan appropriate renewal work to minimize the drop in the supply capability, and work to avoid unexpected supply deficiency as well as enhance supply capability flexibly and comprehensively.

3) Power grid development

a. Voltage fluctuation and impact on the network including the distribution line

The network analysis was conducted during this study assuming that the transmission bus voltage was within the reference value (rated bus voltage ±5%). Therefore, if the operation continues with the bus voltage deviating from the reference value, there could be a problem with the analysis result as well as with the stable operation of actual facilities. It must be recognized that the deviation of bus voltage from the reference value could greatly affect not only the transmission network but also the distribution line operation and facility design.

b. Need for meter on each feeder and understanding supply and demand situation

In Rwanda, not all feeders are equipped with an electricity meter at the substation; therefore, the network analysis for this study was done to analyze the balance between power supply and demand based on the data and information that are currently obtainable. However, it is desirable to install the meter on the feeders of all substations and to manage the trend of power demand and facility tolerance on the daily basis in order to improve the analytical precision for power supply and demand balance.

The precise management of the facility and power supply and demand situation offers benefits not only in the technological aspect but also with respect to productivity and economy such as the facility investment, and maintenance and management efficiency. Therefore, JICA study team recommends that REG, the operator of the network, to take initiative and plan and implement such an undertaking. It must also be noted that it will offer basic information for estimating power demand.

c. Need for following and analyzing the trend of power demand

In the effort to estimate power demand, the network analysis was carried out by assuming that the general customer loads connected to a new substation are distributed evenly throughout the area. This was because of the issue related to the meter on the feeders described above, as well as the limitation on the obtainable data and information. Depending on the future urban development and plans to attract factories, the load distribution could be different from assumed distribution and the reality could be that a large amount of load moves unevenly between the feeders and substations. Thus, if the estimated power demand per substation could change significantly, the network analysis must be carried out as appropriate, and the facility plan and the operation method must be reviewed.

d. Need of installation of capacitors

In this study, bus voltage drop is confirmed in some terminal substations as a result of conducting system analysis based on modeling of the projected demand and power stations planned for construction. Since active power can be increased through restoring voltage drop caused by transmission line losses and improving the power factor of generators by installing capacitors on distribution bus lines and supplying reactive power, it is recommended that capacitors be installed at appropriate locations. In Japan, when large scale customers are connected, installations of capacitors are sometimes discussed with operators. In Rwanda, too, it is recommended that guidelines be formulated concerning the new connection of receiving facilities such as tea plants and so on in future.

e. Management of new facility construction or renewal

Based on the power flow analysis in this study, revealed areas that require new facility construction or renewal of the existing facility with the timing and cost for such work. Upon planning a renewal work, it is necessary to determine the proper time by understanding in advance the demand increase for the area as well as the schedule for the equipment procurement and work itself. Care must also be taken so that no substation or other facility will suffer overload during the transmission system operation due to the suspension of the operation of the facility where the work is being conducted. Furthermore, it is necessary to collect the latest information on the alternative energy sources not limited to imported electricity and to periodically update the master plan and the supporting data in order to keep up with the ever-changing situation. Attention must be given to capabilities of the transmission and substation facilities by reviewing the network assuming the import of electricity and anticipating necessary reinforcement and improvement of facilities.

4) Least cost power development plan

a. Updating power development plan

Power development plan should be updated once a year in accordance with the demand forecast as a precondition. In addition, when material change such as the delay of construction schedule, long unscheduled outage of existing power station, significant impact on costs (e.g. ballooning oil price) occurred, power development plan should be updated to carry out necessary action immediately.

b. Integrating construction and O&M

The electric utility division of EWSA/REG is being separated into EUCL, in charge of O&M, and EDCL, in charge of expansion. Although the separation has merits such as clarity of powers and functions and expedition of decision, some concerns exist. For example, since trade-off exists between construction cost and O&M costs, comprehensive viewpoint, not from construction or O&M individually, is essential to optimize generation costs as whole. Therefore, construction staffs in EDCL should be familiar with O&M while managing staffs in EUCL should be familiar with construction.

Therefore, JICA study team suggests that even after the separation of EDCL and EUCL, information sharing and personal exchanges should take place perennially between the two organizations.

c. Systematic refurbishment in consideration of demand/supply balance

When the development of generation plants are proceeding well as per schedule in this report, demand-supply situation will be relaxed between 2017 through 2022. Under favor of the period, it is recommended to perform extensive works with long shutdown of power plant such as the inspection and repair of structures hydro power plant, intensive rehabilitation and renovation. In order to perform such activity smoothly, EDCL and EUCL should continue close communication.

d. Minimizing Reserve Margin

In the situation that power shortage is the pressing issue, higher forecasted demand and higher reserve margin tend to be set as target in order to avoid the risk of demand tightness. However, the lower the reserve margin it is better because reserve margin implies overinvestment and idle facilities. For power utility as an asset-based industry, the existence of redundant assets brings about higher generation costs. The measures to reduce unnecessary reserve margin are, (a) more accurate demand forecast and (b) operation of electric power facilities meeting the specifications and expectation. (a) is as previously noted, and (b) actualizes only if the perfect coordination from planning, construction, operation, and maintenance of each component of power system is achieved. Such purpose will become a reality only if every staff concerned understands the association with relevant tasks as well as the intimacy with own duties. In this context, systematic collaboration between EDCL and EUCL is inevitable.

5) Policy, organization and business management

a. Issues related to organizational change

REG was newly and legally established on August 12, 2014 after the repeal of the former EWSA law. As of November 2014, the CEO of REG appointed by the government and the Managing Directors (MD) of EUCL and EDCL were the only workers that have entered into a formal employment agreement with REG. However, the organization is at the base of all work and duties, and the sense of responsibility and loyalty to the organization could affect the quality and efficiency of work greatly.

The former EWSA was split up over three years, and JICA study team had an impression that the sufficient evaluation of the organizational and financial issues and performance was not carried out during the split up which led to this hasty organizational change. They are planning to establish an evaluation system only one year after the organizational change, without clearly explaining the tasks or segregation of duties, and to made decisions on employment and salary based on the evaluation result. JICA study team believes that it is critical for REG and the government to take caution to ensure that there is no arbitrariness in the establishment of the evaluation rules.

b. Issues related to a rapid shift to power source development led by the private sector

The study team believes that Rwanda should not rush into the discussion of the promotion scheme for the power source development that use geothermal energy and is led by the private sector until sufficient developmental potential has been confirmed. There are many uncertainties related to the subterranean resource development that it is hard for the private sector to take risks that exist at the beginning of the development. Therefore, the government and REG should lead the way for the time being and take steps to confirm the amount of resources by collaborating with donors from Japan and other countries. It would not be too late to discuss specific schemes such as the legal system for bringing in the private sector and setting up the funds once the development is in sight.

It appears also that REG started thinking about turning over many of its hydropower plants to the private sector. In the operation and maintenance of hydropower plants, there are many things that can be expected of the private sector such as technological capability, fund procurement or knowhow of market competition. On the other hand, it must be noted that a hasty judgment of the use of the private sector can produce many problems. Examples of such problems are:

- Stalled facility investment and repair in pursuit of profit
  → Issues related to power generation capability and quality maintenance

- Hindrance to comprehensive power source operation due to too many IPPs
  → Risks of reduced ability to coordinate power supply and demand

- Increase in O&M cost due to dispersed owners
  → Risks of power supply cost increase

The methane and peat power plants that are planned to be newly introduced will adopt the "Take or Pay" principle in the PPAs as a rule. If REG transfer hydropower plants which should be operated as base load plants to the private sector, the power sources that belong to REG will be middle-load or peak-load power sources among those in service. It means that REG's power sources will be mainly those that are used to balance or back up the power supply and REG would be forced to take on power generation with a low load factor and high cost. This is not a scenario that is likely to help REG improve its profitability. JICA study team believes that there is very little merit from inviting the private sector into Rwanda's electric power sector at this point in time, and therefore, the electricity development should be led by the government and REG for the time being.

c. Project management and cost-consciousness

Based on the fact that the hydropower plants constructed by EWSA in and after 2011 are experiencing many troubles and have not achieved the forecasted capacity, the JICA study team believes that the development of new power sources must go through fundamental review, including the entire process of the project management and system, starting with design, procurement of equipment and facility, to contracting and management of work.

JICA study team would like to emphasize that the ability to manage projects is an important factor for REG to ensure profitability and to work to become a sustainable project company. For example, a delay in the start of a power plant operation brings on disadvantages below, including cost increase.

- Increase in loan interest during the construction period and related cost due to deferred loan payment
- Increase in the construction and management expenses (labor cost, lease expense for offices and equipment and expenses for management by contract)
- Increase in unplanned expenses due to procurement of alternative power sources
- Adverse impact on revenue and expenditure due to the prolonged revenue recognition period
- Decrease in evaluation by the capital market due to disrepute
  → Future increase in the fund procurement cost

The study team hopes that the newly-emerged REG tackles managerial reform so that the project management and cost-awareness will sink in the minds of all staff of REG, from the top management to those working on site.

JICA study team recommends REG to study and take advantage of the balanced scorecard (BSC), which is one of the world-famous business management methods proposed by Drs. Kaplan and Norton in the United States in the 1990s and has been adopted by Japanese power companies. The concept of BSC is the examination of the issues and solutions of the corporate activities from the four perspectives (Financial, Business Process, Learning & Growth and Customer Perspectives) and that the consequences of all activities lead to a financial result and repeated sustainable growth.

d. Need for the financial management

IRR and capital cost were not adopted in EWSA's financial management. However, they are among the most common and important indexes that are used to estimate profit gained from facility investment for new power source development, large-scale renewal and other work. These indexes are essential when making decisions regarding the launch of a project, as well as the continuation of and withdrawal from a project once it was launched, and the restructuring of power generation assets (portfolio). JICA study team recommends that REG adopt and use these indexes as soon as possible as the basic tools for financing and project management.

EWSA plans to have EDCL, a subsidiary responsible for facility development, to manage each project after the restructuring to create a new REG. However, before IRR and capital cost can be calculated, it is necessary to understand the details of the financial activities of REG as a whole including the utility subsidiary EUCL, by using separate accounting and reallocating common expenses by subsidiary and section. EDCL and EUCL are practically one unit in REG's power supply chain. If the reasonable internal transaction prices cannot be set between the two companies, it will be impossible to recognize the income (sales from EUCL) when EDCL is to calculate IRR, for example. On the other hand, when EUCL calculates the electric bill and collects it from the consumers, it will be impossible to know the cause of the deficit in the electricity business and take necessary countermeasures. The study team recommends the creation of a financial management task force to grasp REG's financial situation quickly. It should be one group within REG and have access to both subsidiaries.

According to RURA, the government plans to have the new electricity tariff system to be introduced July 2015. JICA study team believes that REG should calculate the power supply cost for the power generation, transmission and distribution sections respectively, and allocate the broken down cost to different contract types, depending on the customers' receiving voltage and power consumption. The team sincerely hopes that the early introduction of the tariff system does not become the goal itself.

It appears that RURA plans to review the reasonableness of REG's costs quarterly once the new tariff system is introduced, which seems too frequent. The review might become an excess and unnecessary burden to REG and RURA, and there might be a risk of the review becoming a mere facade if it takes place too often. If the review is a limited investigation and approval as is the case of Japan where the variable factors associated with fossil fuel are reflected quarterly, then the quarterly review might be effective.

6) Organization of information and database

While collecting information for the study, an issue was highlighted that information was not organized and shared adequately. Generally, the planning unit of an electric power company is responsible for forecasting power demand and developing power plants and should have all necessary information, already organized and shared as necessary. In the case of EWSA, however, the situation was different. The electronic data were buried in the PCs of the respective employees and there was no library that housed books and various reports such as FSs in their office.

To address the situation, JICA study team created a database that is actually being used in Japanese offices, by using Microsoft software ACCESS which is simple and versatile. The study team then organized electronic files and paper files in the PDF form that were gathered for this study and provided the database to REG with a view to enhance information literacy of REG for the future.

JICA study team believes that REG must recognize the information organization and sharing as its basic task, implement what it can promptly without overextending itself, and promote speedy and efficient work execution. The team also believes that the other database system, so called Power System Information database provided together with Power database will help REG's technical activities effectively for O & M and newly development of power system facilities.

2. Study of Geothermal Development Plan

(1) Current Status of Geothermal Exploration and Development

There are no operating geothermal power plants in Rwanda, and each geothermal field is in the survey stage of geothermal resource development. Two geothermal exploratory wells have been completed in Karisimbi in March 2014, but no geothermal reservoir suitable for power generation has been discovered. The Rwanda government and international agencies have surveyed geothermal resources for development in Rwanda. From those results, Karisimbi, Kinigi, Gisenyi in the northwestern area and Bugarama in the southwestern area have been selected as promising geothermal areas (Fig. 2-1). Many kinds of surveys have been conducted in these four areas.

The status of geothermal exploration and development is summarized in Table 2-1 based on verbal information provided by geothermal organizations operating in Rwanda and existing reports and papers.

Source: JICA study team

Fig. 2-1 Location map of geothermal areas in Rwanda

Table 2-1 Status of Geothermal Exploration and Development Plans as of Feb. 2016

Progress of Geothermal Resource Study and Future Plan of the Study in Rwanda (as of February, 2016)

Prospect	Area	Surface Study (conducted)									Surface Study (planned)					Slim hole drilling	Integrated Analysis (Construction of geothermal concepual model)	Exploratory Well		Remarks
		Preliminary Study		Detailed Study (~ 10km^2)		Geophysical Study				Integrated Analysis (Construction of preliminary geothermal concepual model)	Geological Study	Geochemical Study	Geophysical Study					Deep well drilling	Well test	
		Geological Study	Geochemical Study	Geological Study	Geochemical Study	Gravity	Magnetic	MT/CSMT	Data Re-analysis				Gravity	Magnetic	MT/CSMT/TEM					
Karisimbi	Karisimbi	Done	Done	Done	Done	None	None	Done	Done by ISOR (MT etc.) (2014) Done (MT) by JICA (2015)	Done before exoloratory well drilling	-	-	-	-	-	None	-	KW-01 KW-02	KW-01 and KW-02: not productive	
	Karago	Done	Done	Done, supplemental study is desireble	Done, supplemental study is desireble	None	None	Partly covered	Partly covered	Done by JICA (2015)	-	-	-	-	-	-	-	-	-	
Kinigi	Kinigi	Done	Done	Done, supplemental study is desireble	Done, supplemental study is desireble	Done by JICA (2016)	None	Done	Done by ISOR (MT etc.) (2014) Done (MT) by JICA (2015)	Done by JICA (2015)	-	-	-	-	-	-	JICA (2015)	GRMF: Application for drilling of 3 slim holes (max. 2, 500m depth) was approved in December 2015 (Grant of 40%).	-	
Gisenyi	Gisenyi	Done	Done	Done, supplemental study is desireble	Done, supplemental study is desireble	None	None	Done	Done by ISOR (MT etc.) (2014) Done (MT) by JICA (2015)	Done by JICA (2015)	Study started in December, 2015 (survey period: 6 months).	Study started in December, 2015 (survey period: 6 months).	-	Study started in December, 2015 (survey period: 6 months).	Study started in December, 2015 (survey period: 6 months).	-	Study started in December, 2015 (survey period: 6 months).	-	-	
	Iriba	Done	Done	Done, supplemental study is desireble	Done, supplemental study is desireble	None	None	None	None	Done by JICA (2015)	-	-	-	-	-	-				
	Muhumba Cone	Done	Done	None	None	None	None	None	Done by ISOR (MT etc.) (2014) Done (MT) by JICA (2015)	None	Study started in December, 2015 (survey period: 6 months).	Study started in December, 2015 (survey period: 6 months).	-	Study started in December, 2015 (survey period: 6 months).	Study started in December, 2015 (survey period: 6 months).	-	Study started in December, 2015 (survey period: 6 months).	-	-	A part of this area is included by study area of Gisenyi by EU
Bugarama	Mashyuza	Done	Done	Done by EU (2014), by JICA (2015), supplemental study is desireble	Done by EU (2014), by JICA (2015), supplemental study is desireble	Done by JICA (2015)	Done by EU (2014)	TEM: Done by EU (2014)	None	Done by JICA (2015)	-	-	-	-	-	EU: Additional three-five thermal gradient holes will be drilled at depths between 100-300m.	Planned by EU (2016) after drillings	One well in one selected country: Planned by EU (2016)	-	-
	Bize	Partly done	Partly done	None	None	None	None	None	None	None	-	-	-	-	-	-	-	-	-	-

Source: Modified from EDCL data

(2) Geothermal Resource Assessment

1) Geological Study

Geological survey have conducted to obtain geological data to improve the precision of geothermal resource evaluation in selected fields. The purpose of field geological survey was to obtain additional geological data (stratigraphy, hydrothermal alteration, fractures etc.) and cross-checking against the existing data. Geological models in each field were constructed based on collected geological data and information considering geophysical and geochemical data. Geological models in each field are described in the section "Geothermal Resource Assessment".

2) Geochemical Survey

Seventeen (17) hot spring water and four (4) surface water sampled during the last field reconnaissance were analyzed in Japan. As a results of geochemical study of that, all of the water is dominated HCO_3 in anion and is classified as being of the conductively heated type (HCO_3 type). If those were dominated in Cl, classified as deep high-temperature reservoir water (Cl type). There are some possibility of mixing deep reservoir water in Gisenyi hot spring (Gisenyi field) and Mashyuza hot spring (Bugarama field) because Cl concentration of those was a little bit high (maximum 320 mg/L). However a water-rock interaction under high temperature is not shown even in those fields because no oxygen shift occurred in water isotope.

In determining the underground temperature, geothermometer was calculated based on the solubility of the rock and equilibrium between water-rock. From the silica geothermometer using solubility of silica minerals shows the shallow aquifer temperature. Calculated silica geothermometer are 81°C in Karago, 80°C in Gisenyi and 63°C in Mashyuza, respectively. Other hands, alkari-geothermometer, which shows deeper reservoir temperature, were considered to be not applicable for those hot spring water. Because HCO_3 concentration was very high and so chemical equilibrium was not attained.

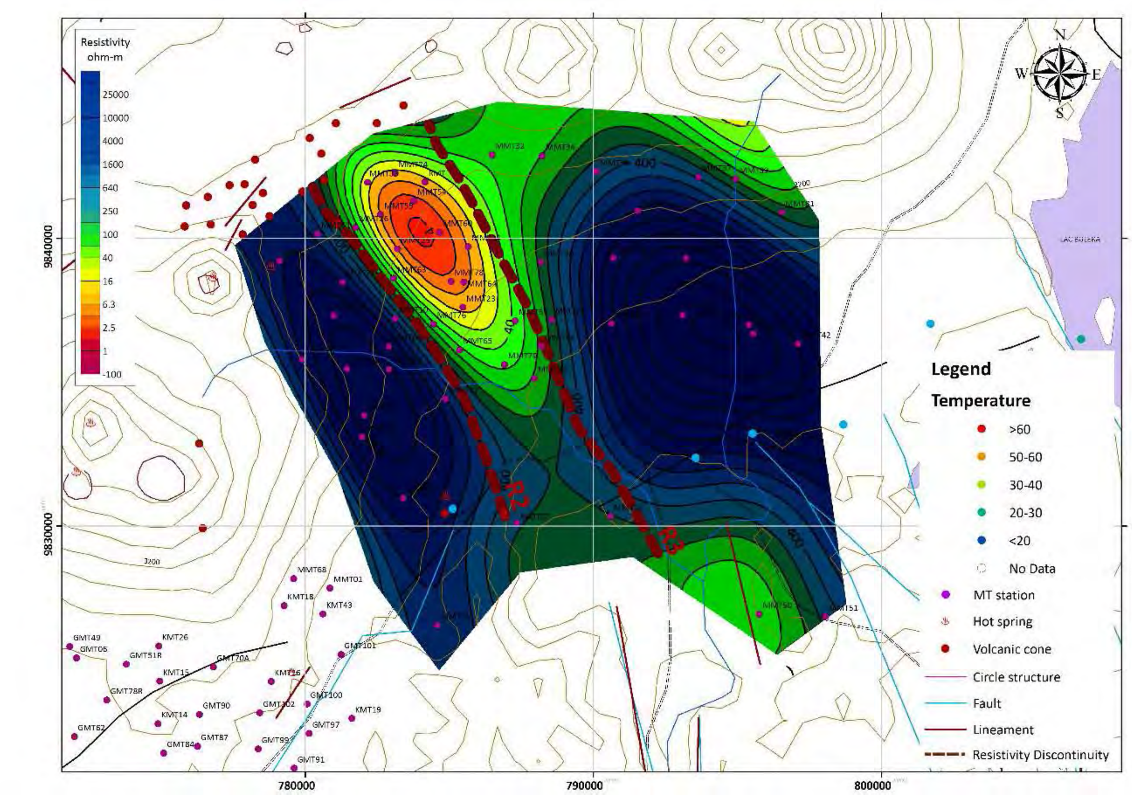
3) Geophysical Study

i) Summary of Resistivity Structure in the Karisimbi, Gisenyi and Kinigi fields

- In the whole field of the Gisenyi and Karisimbi fields, no low resistivity zone of less than 30 ohm-m has been detected from the ground surface level down to a depth of 5,000 m. This fact suggests that hydrothermal alteration minerals (smectite and/or interstratified clay minerals), functioning as a cap rock of geothermal reservoir have not been well developed, therefore geothermal activities in the Gisenyi and Karisimbi fields are likely to be relatively weak compared with other geothermal fields where geothermal power stations were installed and are being operated.

- Meanwhile, a widely distributed low resistivity zone is clearly detected at a depth of 2,000 m and deeper in the northern portion of the Kinigi field (Fig. 2-2). In addition, two remarkable resistivity discontinuities, R2 and R3, may indicate fracture zones, can be identified in and around the fields of the eastern edge and the western edge of the low resistivity zone, respectively. Because of this fact, relatively high temperature geothermal fluids may ascending in the fracture zones around the resistivity discontinuities R2 and R3, and these geothermal fluids may migrate in and around the low resistivity zone

- However, in the northern portion of the Kinigi field, an up-lifted high resistivity zone, usually indicating high temperature hydrothermal alteration minerals (illite, chlorite, etc) cannot be detected below the remarkable low resistivity zone. This may suggest that if geothermal fluids are reserved in and around the low resistivity zone in the northern portion of the Kinigi field, the temperature of the geothermal fluids are considered not to be sufficiently high for conventional type geothermal power generation.

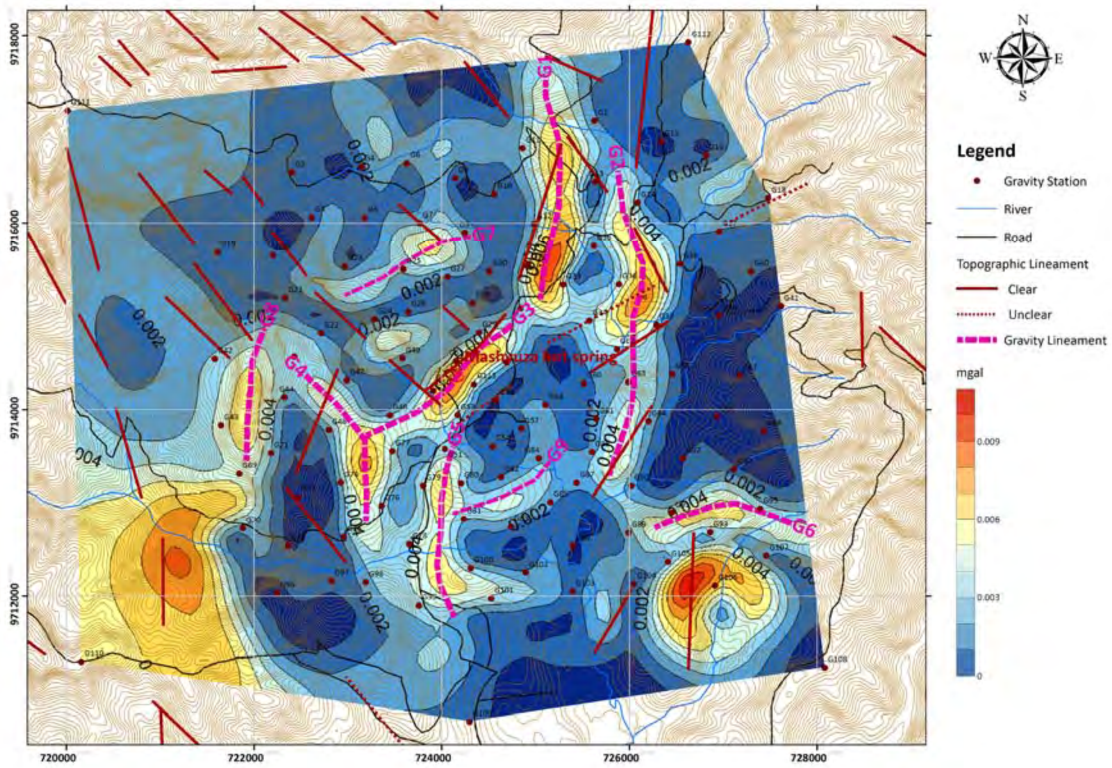


Source: JICA study team

Fig. 2-2 Resistivity Map at a Depth of 3,000m (Kinigi field)

ii) Summary of Gravity Survey Results in the Bugarama field

- The distributions of Bouguer anomaly and residual Bouguer anomaly indicate a presence of graben structure in the Bugarama field. The presence of the graben was deduced based on the geological studies.
- Eight gravity lineaments, G1 through G8 may indicate faults were detected by using filtering processes (Trend surface analysis and Horizontal derivative calculation) (see Fig. 2-3). Among the detected gravity lineaments, the gravity lineaments, G1, G2 and G3 are probably indications of faults located at the west and east edges of the deduced graben.
- Mashyza hot spring is located close to the center portion of the gravity lineament, G3, and thus the gravity lineament G3 is likely to indicate a fault and geothermal fluids may migrate in fracture zones existing along the fault.
- The other gravity lineaments (G4 through G8) have the possibility of reflecting faults controlling geothermal fluids, but further geoscientific information is required to identify whether or not geothermal fluids migrate along and around the gravity lineaments.



Source: JICA study team

Fig. 2-3 Map for Horizontal Derivative Values of Residual Bouguer Anomaly

4) Geothermal Resource Assessment

i) Geothermal Conceptual Model

a) Karisimbi Field

The north part of Karisimbi field is located in Virunga Volcano Range (VVR), whereas the southern part is in the Butare Horst composed of Proterozoic mylonitised granitic and phyllitic complexes. The geothermal conceptual model for Karisimbi field models the two fields separately as “the Karisimbi field”, the northern part of Karisimbi field, and “the Karago field”, the southern part of Karisimbi field.

In the Karisimbi field, no data or information indicating high temperature conditions in the subsurface in and around exploratory wells KW-01 and KW-02 have been obtained in the course of the well drilling. Result of 3D MT inversion analysis suggest that geothermal activity in the Karisimbi field is relatively weak and that the hydrothermal alteration zone functioning as a cap rock of the geothermal reservoir is not well developed.

In the Karisimbi field, it seems that permeability is strongly controlled by faults, considering that this field is comprised of hard rock of Proterozoic age. However, no highly permeable structures have been identified by well drilling, or by geological and geophysical investigation in the Karisimbi field.

Exploratory well KW-01 has a linear relationship between temperature and depth; temperature increases at a steady rate with increasing depth. It is considered that conductive heat flow is dominant in this layer, giving a linear temperature increase.

In conclusion, geothermal activity in the Karisimbi field is likely to be relatively weak compared with other geothermal fields where geothermal power stations have been installed and are being operated. It is considered that a geothermal system exploitable for power generation is not well developed in the Karisimbi field.

There are two hot springs in the Karago field, Karago and Mbonyebyombi hot springs. In this study, geothermal resources were assessed in Karago field. Geothermal conceptual model in Karago field is summarized as follows. The conceptual model of geothermal system in Karisimbi Field and estimated geothermal resource extent field in Karisimbi and Gisenyi Fields are shown in Figs.2-4 and 2-5, respectively.

- **Geological structures controlling geothermal activity**

NW-SE trending topographic lineaments are well detected, which implies the presence of faults. These inferred faults are considered to be permeable zones related to the path of fluid flows in the Karago field.

- **Heat source of geothermal system**

There is no recent volcanism in or around the field. It is supposed that thermal springs in the field are associated with the deep circulation of natural waters across faults, and the high temperature results from the relatively high geothermal gradient, or the conductive heat of the magmatic materials situated in a deeper part of the crust, or the conductive heat of intrusive rocks.

- **Host rock**

Proterozoic basement (granite)

- **Possibility of existence of geothermal reservoir**

Geochemical data of hot spring shows a mixing correlation between Karago and Mbonyebyombi water that implies that those waters are diluted from the same parental fluid. There is uncertainly whether geothermal reservoir at deeper depth exist or not, Cl concentration in hot spring water suggests that a possibility of presence of parental fluid at deeper depth.

- **Estimated reservoir temperature**

Shallow aquifer : 81 ^{o}C, Parental fluid : > 81 ^{o}C

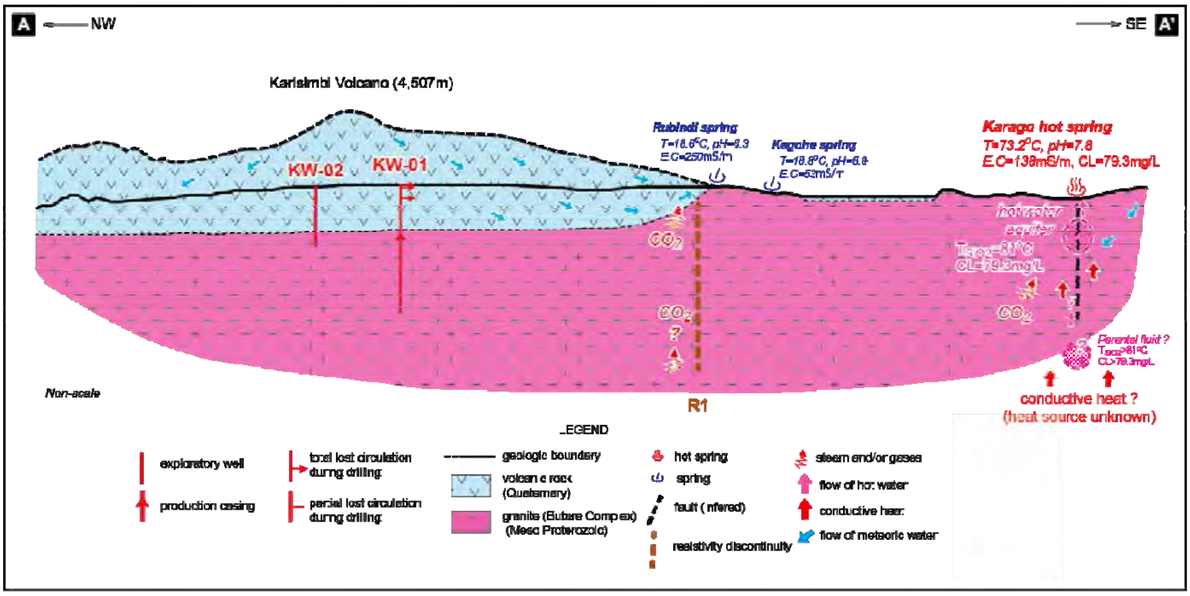
- **Fluid flow model**

Meteoric water is penetrating into the deep levels of the mountainous field at a higher elevation than the Karago field, where it is heated by conductive heat. Hot fluids are stored in a permeable zone developed in granite that trends NW-SE. The geothermometry temperatures for spring water suggest that the temperature of the hot water aquifer is around 81^{o}C. The hot fluid ascending along fractures yields the hot springs of Karago and

Mbonyebyombi. Considering the Cl concentration in the hot spring water, the parental fluid is likely to be present at greater depth in the Karago field

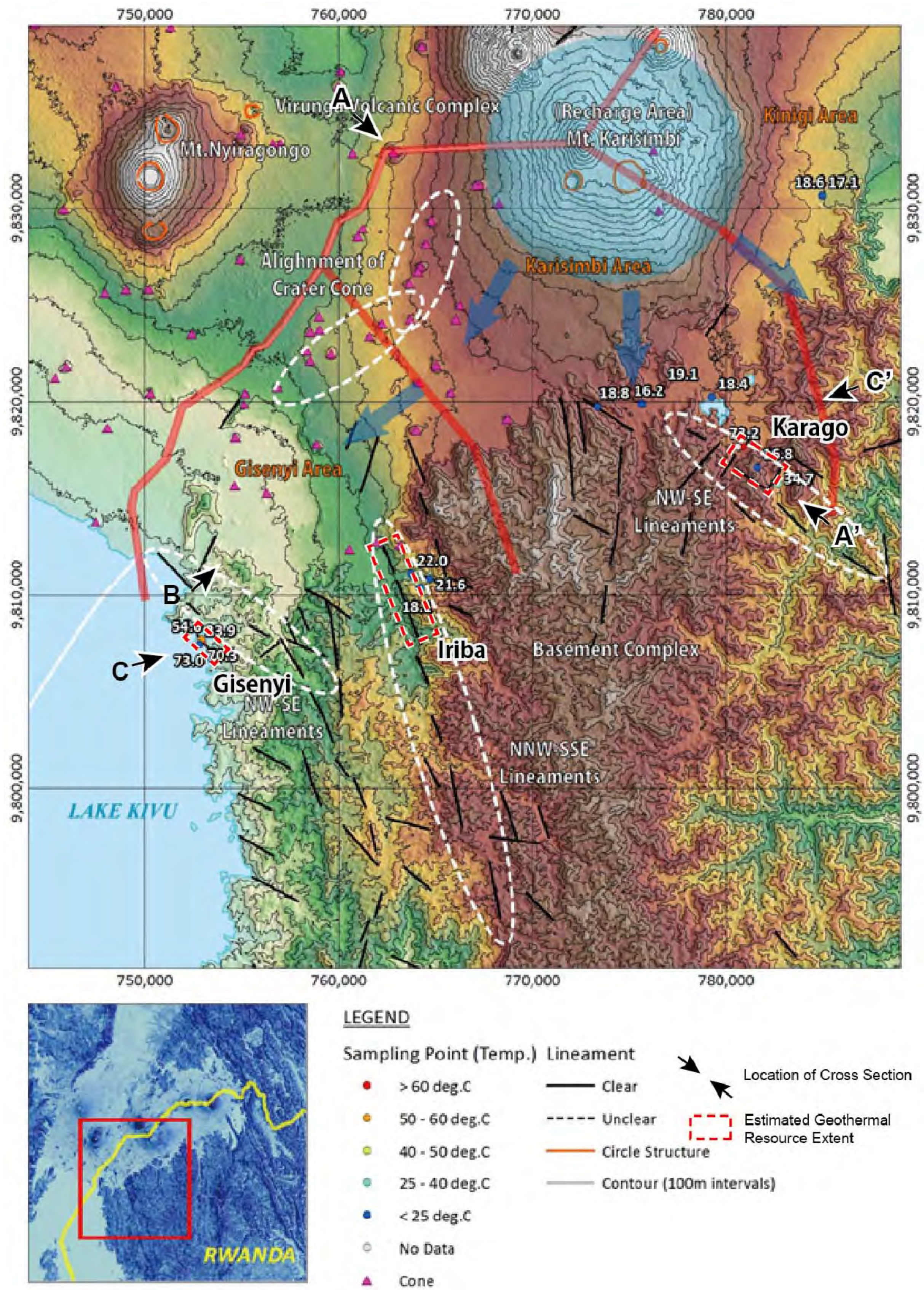
- **Extent of geothermal resource**

High permeable zone along NW-SE trending faults



Source: JICA study team

Fig. 2-4 Conceptual model for Karisimbi field



Source: JICA study team

Fig. 2-5 Estimated geothermal resource extent field in Karisimbi and Gisenyi fields

b) Kinigi Field

Geothermal conceptual model in Kinigi field is summarized as follows. The conceptual model of the geothermal system in Karisimbi – Kinigi fields and estimated geothermal resource extent field in Kinigi field is shown together with resistivity map at a depth of 3,000m are shown in Fig. 2-6 and 2-7, respectively.

- **Geological structures controlling geothermal activity**

NNW-SSE trending faults inferred from 3D MT inversion analysis

- **Heat source of geothermal system**

The northern part of Kinigi is located close to the Karisimbi, Visoke, Sabinyo, Gahinga and Muhavura volcanoes that erupted in the Quaternary. Southern flank of Mt. Sabinyo is composed of andesite. In general, andesitic volcanic activity is accompanied by magma chamber at relatively shallower depth, which will be candidate heat source of geothermal system. K-Ar rock dating of the andesite is obtained as 0.5 ± 0.1 Ma. These analytical results inferred a possibility of that magma chamber in late Quaternary to be a heat source of geothermal system exist at relatively shallower depths in and around Mt. Sabinyo. The heat source of the Kinigi geothermal system is assumed to be related to the Quaternary activity of Sabinyo volcanoes.

- **Host rock**

Proterozoic basement

- **Possibility of existence of geothermal reservoir**

A widely distributed low resistivity zone is clearly detected at a depth of 2,000 m and deeper in the northern portion of the Kinigi field. In addition, two remarkable resistivity discontinuities, R2 and R3 were identified at a depth of 1,500 m and deeper. Geological structures in the northern part of Kinigi (in the Butare Horst) are characterized by the presence of NNW-SSE trending faults. Considering these geological structures, R2 and R3 delineated by 3D MT inversion show the presence of NNW-SSE trending faults developed in the Proterozoic basement seated below the volcanic rock. It is still uncertain whether a geothermal reservoir at greater depth can be expected or not, but relatively high-temperature geothermal fluids may possibly ascend in the fracture zones around resistivity discontinuities R2 and R3, and these geothermal fluids may migrate in and around the low resistivity zone.

- **Estimated reservoir temperature**

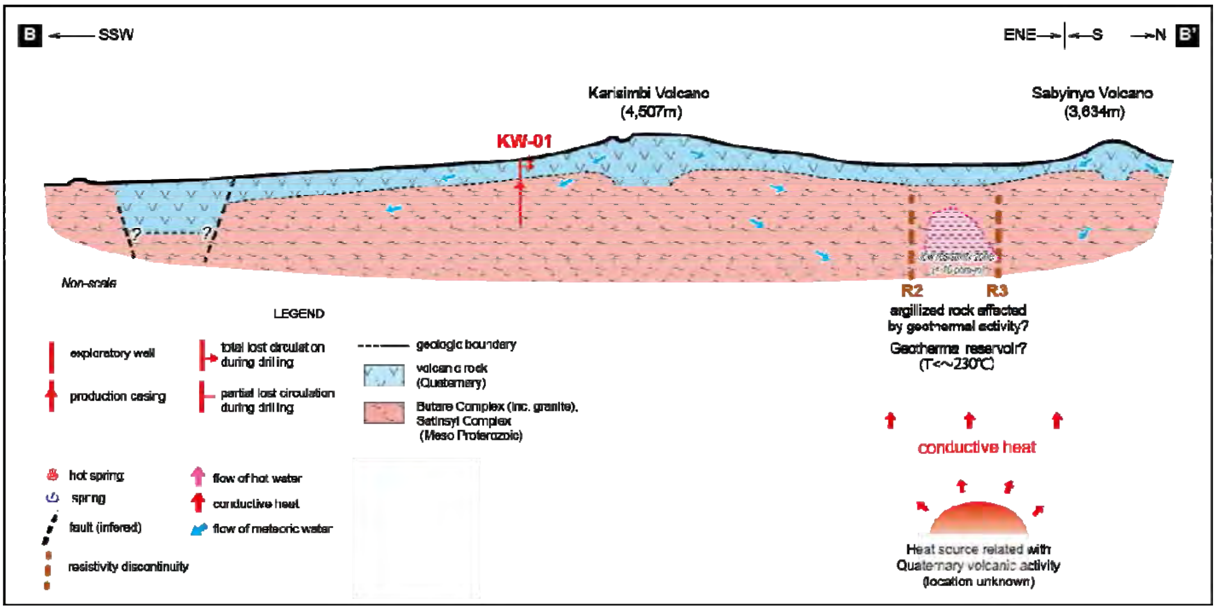
Geochemical thermometer is not applicable. An up-lifted high resistivity zone, usually indicating high temperature hydrothermal alteration minerals (illite, chlorite, etc) cannot be detected below the remarkable low resistivity zone. This may suggest that if geothermal fluids are reserved in and around the low resistivity zone in the northern portion of the Kinigi field, the temperature of the geothermal fluids are considered not to be sufficiently high for conventional type geothermal power generation.

- **Fluid flow model**

Meteoric water penetrating into the deep level at mountainous field is heated up by conductive heat from magmatic body related with late Quaternary volcanism. The thermal fluids is ascend through the permeable zones related with faults trending NNW-SSE, and may store in these permeable zones in Proterozoic basement.

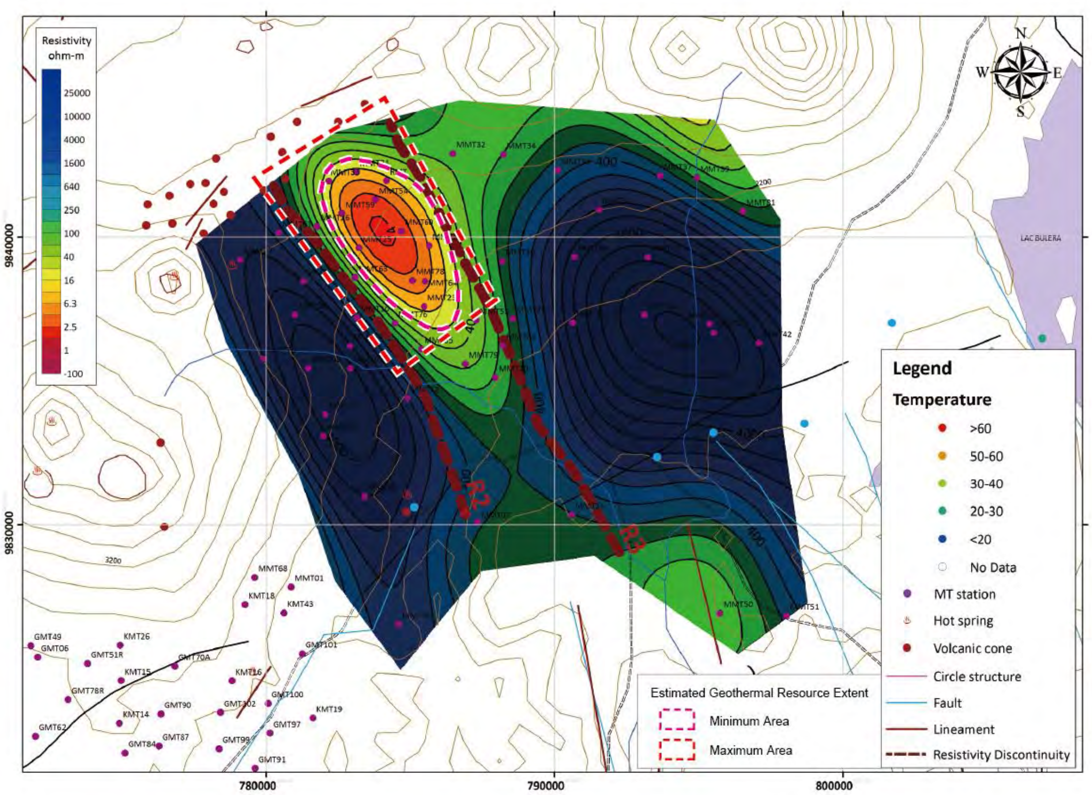
- **Extent of geothermal resource**

Although uncertainty concerning the presence of a geothermal reservoir remains, there is a possibility of that geothermal reservoir extent in and around low resistivity zone detected at a depth of 2,000 m and deeper and along resistivity discontinuity R2 and R3.



Source: JICA study team (created in March 2015)

Fig. 2-6 Conceptual model for Karisimbi - Kinigi fields



Source: JICA study team (created in March 2015)

Fig. 2-7 Estimated geothermal resource area extent in Kinigi field

c) Gisenyi Field

Geothermal resource assessment is conducted in Gisenyi hot spring area and Iriba spring area. Although the temperature of discharged water in Iriba is low (22^{o}C), the Cl concentration of the discharged water reaches a maximum of 320 mg/L, implying some mixing of deep high-temperature reservoir water. Geothermal conceptual models in Gisenyi hot spring area and Iriba spring area are summarized as follows. The conceptual model of geothermal system in Gisenyi - Karisimbi fields is shown in Fig.2-8. In Fig. 2-5, estimated geothermal resource extent area in Karisimbi and Gisenyi Fields are shown together with the result of image interpretation using satellite data.

Gisenyi hot spring area:

- **Geological structures controlling geothermal activity**

In and around Gisenyi hot springs, NW-SE trending topographic lineaments are well-recognized as implied faults which are considered to play a role as an upflow zone for hot fluid.

- **Heat source of geothermal system**

The heat source of the Gisenyi geothermal system is assumed to be related with late Quaternary volcanic activity in and around Virunga volcanic region

- **Host rock**

Proterozoic basement

- **Possibility of existence of geothermal reservoir**

The relatively high Cl concentration implies some mixing of deep high-temperature reservoir water in Gisenyi hot spring. There is uncertainly whether geothermal reservoir at deeper depth exist or not, Cl concentration in hot spring water suggests that a possibility of presence of parental fluid at deeper depth.

- **Estimated reservoir temperature**

Shallow aquifer : 80°C, Parental fluid : > 80°C

- **Fluid flow model**

Meteoric water penetrating into the deeper level in the mountainous area above Gisenyi hot spring area, where it is heated by conductive heat. Hot fluids are stored in a permeable zone trending NW-SE developed in the Proterozoic basement. The geothermometry for the spring water suggests that the temperature of the hot water aquifer is around 80°C. The hot fluid ascending along the fractures gushes out as the hot springs of Gisenyi. The Cl concentration in the hot spring water suggests the presence of a parental fluid at deeper depth in Gisenyi. It is difficult to estimate reservoir temperature at depth because the reliability of geothermometry in this area is very limited (only the silica geothermometer is reliable in this area).

- **Extent of geothermal resource**

High permeable zone along NW-SE trending faults

Iriba spring area:

- **Geological structures controlling geothermal activity**

A NNW-SSE trending inferred fault is mapped in Iriba. This fault is considered to control fluid flow in Iriba.

- **Heat source of geothermal system**

K-Ar rock dating of basalt in Gikombe crater situated near Iriba spring is obtained as 1.0 ± 0.4 Ma. The heat source of the Iriba geothermal system is assumed to be related to the late Quaternary volcanic activity in this field.

- **Host rock**

Proterozoic basement

- **Possibility of existence of geothermal reservoir**

Although the temperature of discharged water in Iriba is low (22°C), the Cl concentration of the discharged water reaches a maximum of 320 mg/L, implying some mixing of deep high-temperature reservoir water. The estimated geothermometry temperature is 79°C in Iriba, which is considered to indicate the temperature of a shallow hot water aquifer. There is uncertainly whether geothermal reservoir at deeper depth exist or not, Cl concentration in hot spring water suggests that a possibility of presence of parental fluid at deeper depth.

- **Estimated reservoir temperature**

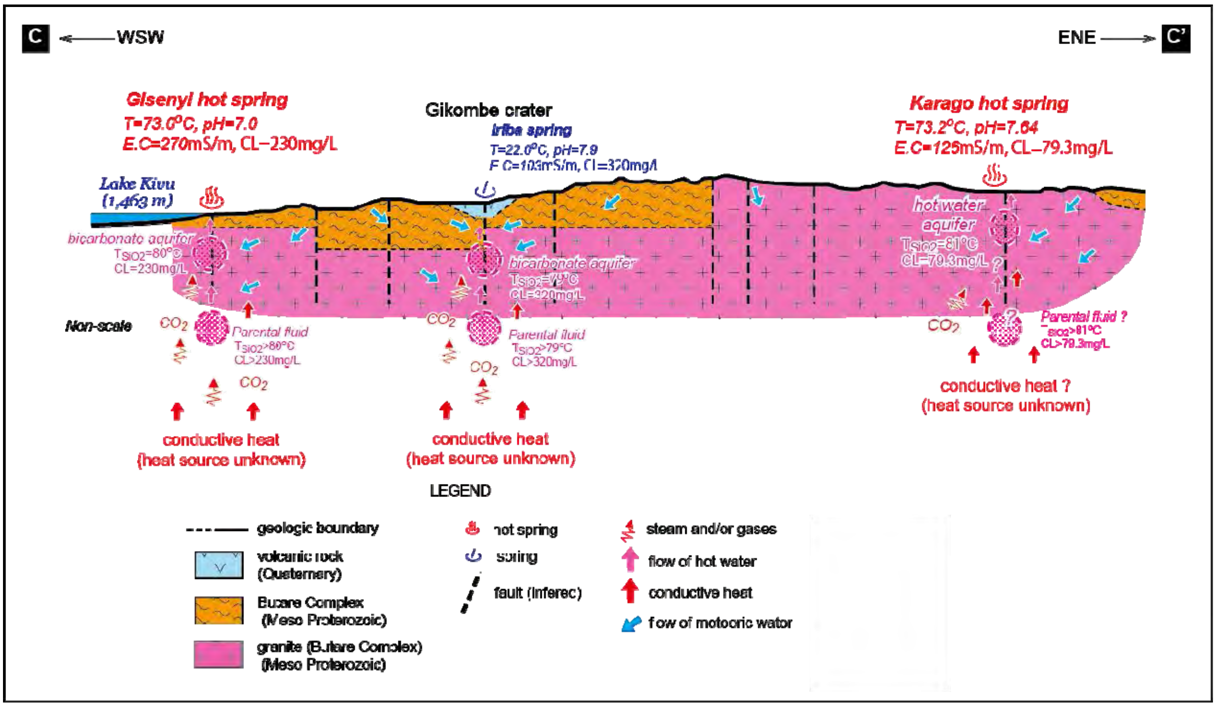
Shallow aquifer：79°C, Parental fluid：> 79°C

- **Fluid flow model**

Meteoric water penetrating into the deep level at mountainous area is heated up by conductive heat from magmatic body related with late Quaternary volcanism. The thermal fluids is ascend through the permeable zones related with faults trending NNW-SSE to the shallow level and is likely diluted and cooled by cold shallow groundwater and/or river water, and stored in these permeable zones at relatively shallower depth. The geothermometries for spring water suggest that the temperature of shallow aquifer is estimated to be 79°C. Cold water resulting from the dilution and cooling discharges to the surface at Iriba.

- **Extent of geothermal resource**

High permeable zone along NNW-SSE trending faults



Source: JICA study team

Fig. 2-8 Conceptual model for Gisenyi - Karisimbi fields

d) Bugarama Field

Two hot springs area are recognized in Bugarama Field: One is in Mashyuza and the other is in Bize. The Bize hot spring area is located in the national border of Rwanda and Burundi. Part of geothermal resource in and around Bize hot spring area is considered to be stored in the Burundi side. Therefore, Bize field is excluded from resource assessment in this study.

Geothermal conceptual model in Mashyuza field is summarized as follows. The conceptual model of geothermal system in Mashyuza field is shown in Figs.2-9. In Fig. 2-10, estimated geothermal resource extent area in Mashyuza field is shown together with the result of image interpretation using satellite data.

- **Geological structures controlling geothermal activity**

N-S to NE-SW trending faults bounds eastern margin of Bugarma graben (gravity lineaments G1, G2 and G3) and NW-SE trending fault (gravity lineament G4)

- **Heat source of geothermal system**

There do not appear to be any young volcanoes related to the magmatic heat source in and around Bugarama field. The heat source of the Bugarama geothermal system is considered to be the conductive heat of the magmatic materials situated in a deeper part of the crust, or the conductive heat of intrusive rocks.

- **Host rock**

Tertiary basaltic rocks and Proterozoic basement

- **Possibility of existence of geothermal reservoir**

Relatively high Cl concentration implies some mixing of deep high-temperature reservoir water in Mashyuza hot spring. There is uncertainly whether geothermal reservoir at deeper depth exist or not, Cl concentration in hot spring water suggests that a possibility of presence of parental fluid at deeper depth.

- **Estimated reservoir temperature**

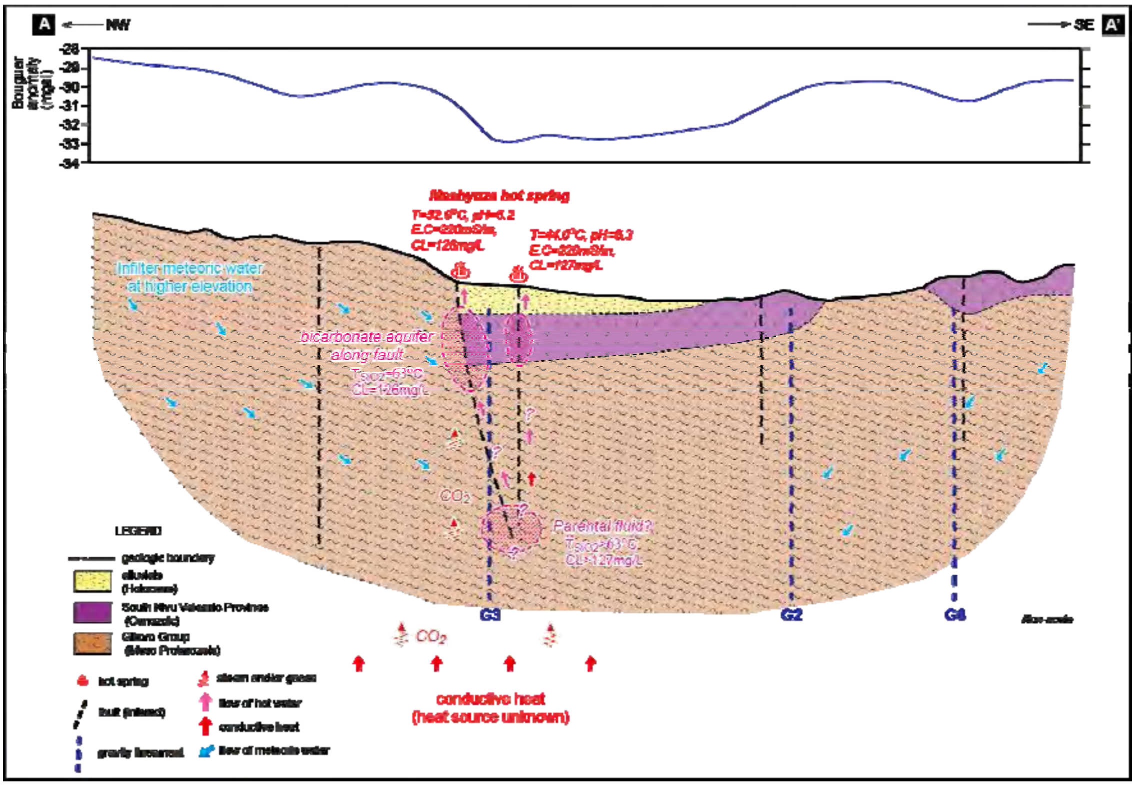
Shallow aquifer : 63^{o}C, Parental fluid : > 63^{o}C

- **Fluid flow model**

Meteoric water penetrating into the deep level in the mountainous area at a higher elevation to the west and northwest of the Mashyuza hot spring area, where it is heated up to over 63^{o}C by conductive heat. The thermal fluid at depth in the area is considered to be up-flowing through the permeable zones found mainly along gravity lineament G4 trending NW-SE and gravity lineament G3 trending NE-SW. Up-flowing thermal fluid is stored in the fractures developed in metamorphic and volcanic rocks. The hot water, having ascended to the shallow level mainly along G3, is likely diluted and cooled by cold shallow groundwater and/or river water, and stored in these permeable zones at relatively shallower depth. The geothermometry for spring water estimates the temperature of the shallow aquifer to be 63°C. Warm water resulting from the dilution and cooling discharges to the surface at Mashyuza.

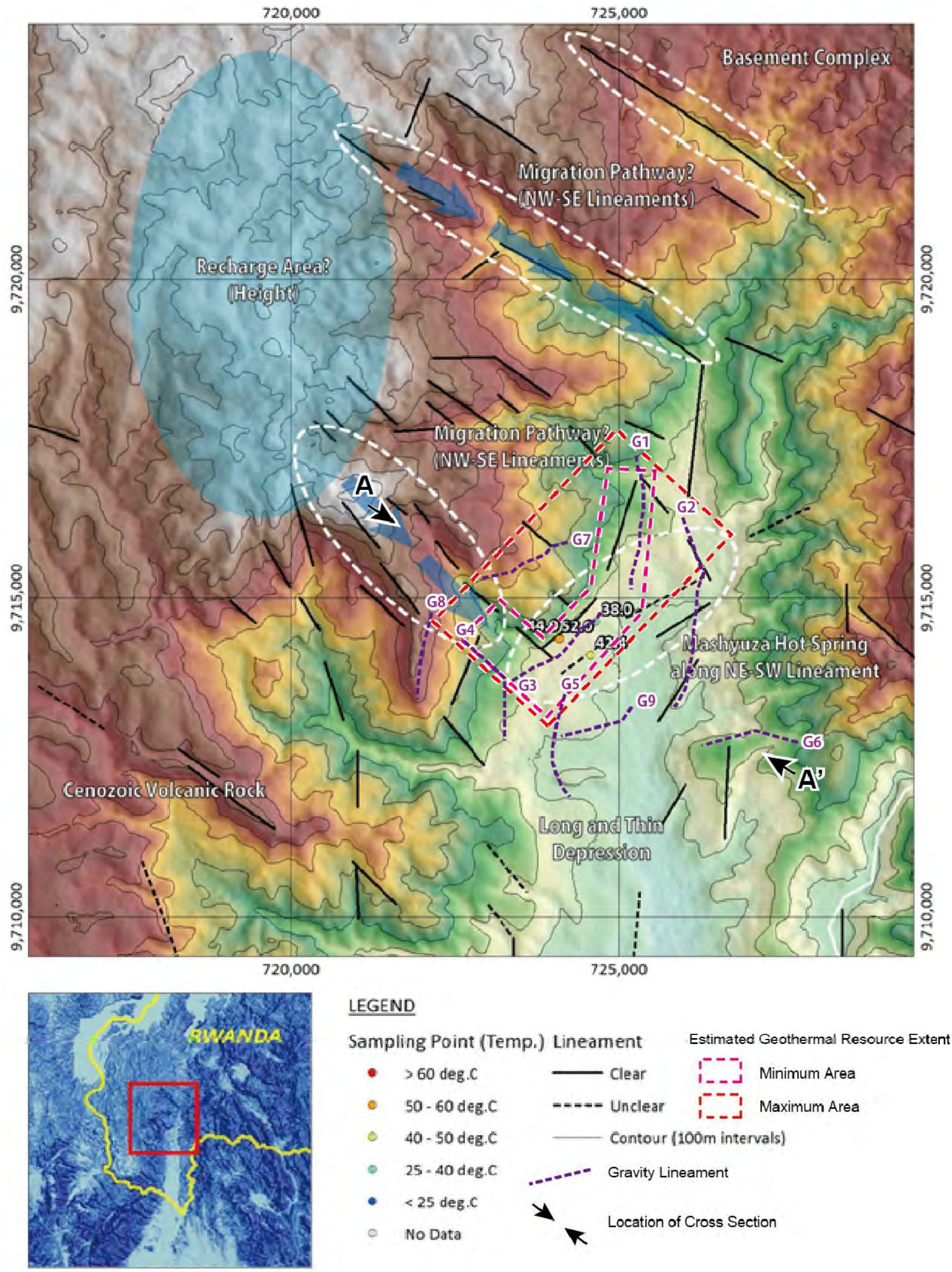
- **Extent of geothermal resource**

The area is determined considering the distribution of permeable zones which control geothermal fluid flow and thermal manifestations. The minimum assumed area is located along gravity lineaments G4, G3 and G1, which are considered to represent the main permeable zone. The maximum area includes gravity lineaments G4, G3, G1 and G7. The eastern boundary of the maximum area is determined by the eastern margin of the graben.



Source: JICA study team

Fig. 2-9 Conceptual model for Bugarama field



Source: JICA study team

Fig. 2-10 Estimated geothermal resource extent area in Bugarama field

ii) Estimated Geothermal Resource Potential in Rwanda

Using the volumetric method of applying a Monte Carlo method based on the survey results as of the 2nd year work, the amount of geothermal resource potential stored in 5 survey fields were estimated. The geothermal resource potential calculated by the Monte Carlo method is represented with a probability distribution. Since the computed resource potential of the field has wide range in its distribution, the potential at the 80% and 50% confidence levels are determined to be the representative potential value of the field. The results are summarized in Table 2-2. The total geothermal power generation potential of the 5 fields are estimated to be about 47.3 MWe at the 80% confidence level, 89.5 MWe at the 50% confidence level, respectively.

Kinigi was evaluated to be a field with highest priority for detailed investigation and development among five fields because the obvious low resistivity structure was detected. The geothermal resource potential of Bugarama area with the low resistivity structure was estimated to be higher than that of Gisenyi, Karago and Iriba.

Since exploratory wells drilled in Karisimbi field showed the low temperature till deep zone, and the well in other fields has not been drilled, it was difficult to evaluate the geothermal temperature structure in deeper zone. Therefore, the geothermal reservoir temperature for calculation was set based on the assumption that the geothermal fluid stored in deep has the temperature about 200^{o}C. The presence and temperature of reservoir have to be clarified by exploratory well drilling targeted at the most promising zone, if it is required to improve accuracy of potential estimation and to conduct reliable judgment on the feasibility of a resource development project.

Table 2-2 Summary of resource evaluation for 5 fields

Field name	**Resource Potential at 80% Confidence Level (MWe)**	**Resource Potential at 50% Confidence Level (MWe)**
Kinigi	32.6	58.6
Bugarama	6.6	15.1
Gisenyi	1.9	3.7
Karago	2.5	4.9
Iriba	3.7	7.2
Total	**47.3**	**89.5**

Source: JICA study team (created in March 2015)

5) Formulation of Geothermal Development Plan

i) Prioritization of the Development of Geothermal Field

For prioritization, we evaluate the criteria for each of the respective evaluation items. At the current stage of exploration, the highest emphasis in prioritizing geothermal fields for future exploration activity was placed on the geothermal resource potential based on the survey results as of the 2nd year work in each geothermal field. The second highest emphasis was given to the progress of geothermal exploration and topographic conditions, considering not only the future development itself but also the field work in the exploration stage.

In light of the results of the ranking and given the present status of each field among the 5 fields described in the sections above, the Kinigi and Bugarama fields can be regarded as the most prospective ones (highest priority). The remaining 3 fields are of secondary priority.

ii) Formulation of Geothermal Development Plan

a) Possible geothermal power development in Rwanda

Even in the Kinigi and Bugarama fields, the presence of a geothermal reservoir adequate for power generation has not yet been confirmed, so the resource development risk is thought to be relatively high. However, a tentative geothermal development plan is formulated as a reference for Kinigi and Bugarama fields, which are ranked as having the highest priority for exploration activity. It should be noted that the details of geothermal power plant projects will be formulated in a feasibility study, which will be carried out later on the basis of the geothermal resource study (Phase 3).

The development scale, namely the output capacity of the geothermal power plant for Kinigi and Bugarama fields, is proposed based on the estimated resource potential. A binary cycle type plant is considered optimal in both fields, considering the resource potential and its characteristics. The required number of geothermal wells is estimated according to the results of evaluation of well productivity. The main specifications for possible power development in the fields are shown in Table 2-3.

Table 2-3 Main specifications for possible power development in the promising fields

Field Name	Resource Potential P80 (MWe)	Plant Capacity (MWe)	Power Unit	Number of Production Wells	Number of Reinjection Wells
Kinigi	32.6	20	5MW x 4	5	3
Bugarama	6.6	5	5MW x 1	2	1
Total	39.2	25	-	-	-

Source: JICA study team (created in March 2015)

The power output capacity is assumed based on the resource potential at an 80% confidence level with allowance of some margin. The number of required production wells in each project (excluding make-up wells drilled during the plant operation period) is estimated based on the following assumed conditions:

- Mass output from one well in each field: 4,000kW

In estimating the required number of wells, it is thought that 2 exploratory wells will be utilized for the operation (one a production well, the other a reinjection well) in each field. The number of reinjection wells required for each project is estimated based on the number of production wells required, the amount of produced brine, which depends on the brine productivity of the production wells, and the estimated reinjection capacity per well (300 t/h).

According to the conceptual model of the geothermal system in each promising field, the Kinigi field will require wells to be drilled to a depth of 3,000 m for production wells and 1,500m for reinjection wells. In Bugarama field, both production and reinjection wells will need to be 2,000-2,500 m deep.

b) Development plan and schedule in Kinigi and Bugarama fields

As mentioned above, the resource development risk is thought to be relatively high in both Kinigi and Bugarama fields. In order to reduce this fatal risk to the economical development of geothermal power, it is indispensable to further confirm the structure and extent of the geothermal reservoir, the physical and chemical characteristics of the geothermal fluids and so on.

Geothermal power development plans for Kinigi and Bugarama fields in case of using an ODA Yen Loan are shown in Tables 2-4 and 2-5, respectively. Required period of the project using other financing is estimated as almost same period as using an ODA Yen Loan.

Table 2-4 Kinigi Geothermal Power Plant Construction Project Overall Schedule: 5MW x 4 units (as Yen Loan Project)

Activity	Duration (month)
Exploration Stage	
Phase 2	12
Engineering Services by Consultant	12
Surface Study	11
Judgement to Progress Next Stage (Phase 3)	
Environmental Study, Acquisition of Permission etc.	2
Finance Procurement of Phase 3	3
Phase 3	33
Engineering Services by Consultant	33
Resource FS in Kinigi	32
Exploratory Well Test Study/Evaluation	32
Judgement to Progress Next Stage (Exploitation)	
Environmental Impact Asssessment, Feasibility Study	
Environmental Impact Asssessment, Feasibility Study	12
Appraisal Mission, E/N, L/A	
Appraisal Mission, E/N, L/A	12
Construction Stage	
Procurement Engineering Consultant	**9**
Procurement Engineering Consultant	9
Engineering Services by Consultant	**55**
Engineering Services by Consultant	55
Procurement of Contractor	**17**
Procurement of Contractor	17
Steam Field Development (for 20 MW)	**22**
Survey, Design	4
Field Development, Rig Mobilization	6
Drilling & Testing (5 production wells, 3 reinjection wells)	16
Fluid Collection and Reinjection System (5MW x 4)	**23**
Survey, Basic design	6
Design, Fabrication & Delivery, Construction/Installation	20
Power Plant (5MW x 4)	**26**
Survey, Basic design	6
Design, Manufacturing, Delivery, Construction/Installation	20
Commissioning	3
Transmission Line and Switchyard	**20**
Survey, Basic design	6
Design, Manufacturing, Delivery, Construction/Installation	17
Post Construction Stage	**12**
Warranty Period (inc. Operation and Training)	12

Source: JICA study team (created in March 2015)

Table 2-5 Bugarama Geothermal Power Plant Construction Project Overall Schedule: 5MW x 1 unit (as Yen Loan Project)

Activity	Duration (month)
Exploration Stage	
Phase 2	12
Engineering Services by Consultant	12
Surface Study	11
Judgement to Progress Next Stage (Phase 3)	
Environmental Study, Acquisition of Permission etc.	2
Finance Procurement of Phase 3	3
Phase 3	30
Engineering Services by Consultant	30
Resource FS in Bugarama	29
Exploratory Well Test Study/Evaluation	29
Judgement to Progress Next Stage (Project FS)	
Environmental Impact Asssessment, Feasibility Study	
Environmental Impact Asssessment, Feasibility Study	12
Appraisal Mission, E/N, L/A	
Appraisal Mission, E/N, L/A	12
Construction Stage	
Procurement Engineering Consultant	**9**
Procurement Engineering Consultant	9
Engineering Services by Consultant	**45**
Engineering Services by Consultant	45
Procurement of Contractor	**17**
Procurement of Contractor	17
Steam Field Development (for 5 MW)	**10**
Survey, Design	3
Field Development, Rig Mobilization	6
Drilling & Testing (1 production well, 1 reinjection well)	4
Fluid Collection and Reinjection System (5MW x 1)	**9**
Survey, Basic design	3
Design, Fabrication & Delivery, Construction/Installation	8
Power Plant (5MW x 1)	**16**
Survey, Basic design	3
Design, Manufacturing, Delivery, Construction/Installation	12
Commissioning	3
Transmission Line and Switchyard	**9**
Survey, Basic design	3
Design, Manufacturing, Delivery, Construction/Installation	8
Post Construction Stage	**12**
Warranty Period (inc. Operation and Training)	12

Source: JICA study team

iii) Action Plan of Each Field

In Rwanda, considering of the lack of experience in geothermal development, government-led surveys corresponding to Phase 2 and Phase 3 are very much desired to confirm the presence of geothermal reservoirs and to promote geothermal development in this country. It is recommended that support by the donors in this situation is best directed to enabling these early-stage surveys by the government or governmental agencies (REG). In addition, support for capacity-building among policy makers and/or survey staff involved in early stage development is important. Considering the present situation of Rwanda, the following projects of Phase 2 and Phase 3 are listed up here. Tables 2-6 to 2-8 show possible projects in Kinigi and Fig. 2-11 shows the area of proposed exploration study in Kinigi. Tables 2-9 to 2-11 show possible projects in Bugarama and Fig. 2-12 shows the area of proposed exploration study in Bugarama. It must be noted that personnel costs of REG are not included in cost estimates. Likely sources of funding for these projects are JICA grants, or financing from AfDB, UNEP, EU and Geothermal Risk Mitigation Fund.

Table 2-6 Possible projects in Kinigi (Phase 2)

Field	Kinigi
Project Outline	To carry out supplemental surface geoscientific surveying to update the geothermal conceptual model and select drilling targets in the Kinigi field.
Details	➢ Supplemental geological and geochemical study ➢ Gravity survey (200 stations) ➢ Supplemental MT/TEM survey ➢ Resource Assessment/Planning (Integrated analysis) ➢ Study of multi-purpose utilization
Remarks	Permission for work in the National Park is required. Supplemental MT/TEM survey is recommendable in case of that the survey can be done in the National Park and area in Uganda.

Source: JICA study team (created in March 2015)

Table 2-7 Possible projects in Kinigi (Phase 3)

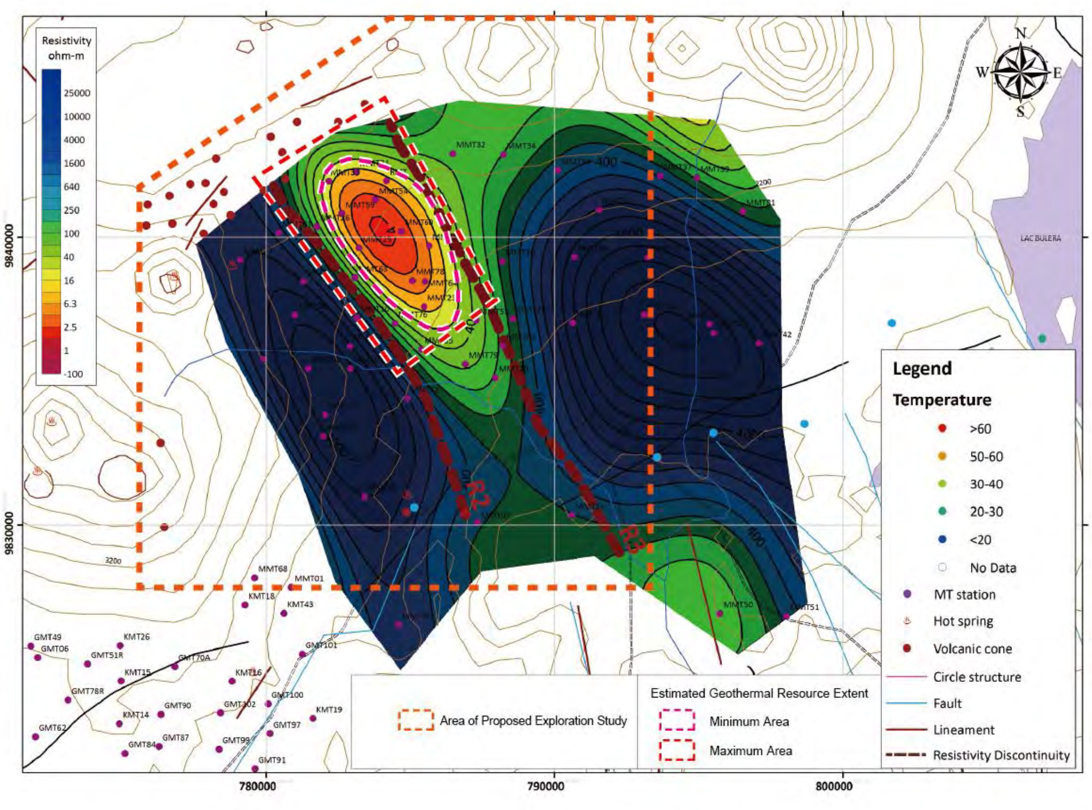
Field	Kinigi
Project Outline	To carry out an exploration survey including drilling three (3) exploration wells in the Kinigi field to confirm presence of a geothermal reservoir and to evaluate the geothermal resource.
Details	➢ Exploratory Well Drilling & Testing (3,000m x 2 wells, 1,500m x 1 well) ➢ Production testing ➢ Resource Assessment/Planning/basic Design etc. ➢ Study of multi-purpose utilization

Source: JICA study team (created in March 2015)

Table 2-8 Details and schedule of proposed exploration study in Kinigi

	Months	1st year (1–12) / 2nd year (13–24) / 3rd year (25–36) / 4th year (37–48)
Exploration Stage		
Phase 2	***12***	
Engineering Services by Consultant	**12**	
Procurement Engineering Consultant	1	
Engineering Services by Consultant	11	
Surface Study	**11**	
Preparation of Supplemental geological and geochemical study	2	
Supplemental geological and geochemical study	3	
Preparation of Geopysical Survey	3	
Gravity survey (200 stations)	4	
Supplemental MT/TEM survey	4	
Resource Assessment/Planning (Integrated analysis)	4	
Judgement to Progress next stage (Phase 3)		
Environmental study, Acquisition of Permission etc.	***3***	Certificate of RDB has obtained (but it should be revised)
Finance Procurement of Phase 3	***3***	
Phase 3	***33***	
Engineering Services by Consultant	**33**	
Procurement Engineering Consultant	1	
Engineering Services by Consultant	32	
Resource FS in Kinigi	**32**	
Exploratory Well Test Study/Evaluation	**32**	
Bidding &Contracting	9	
Field Development, Access Road, Mobilization	6	
Exploratory Wells Drilling & Testing (3,000m x 2 wells, 1,500m x 1 well)	9	
Production test	3	
Resource Assessment/Planning/basic Design etc.	6	
Judgement to Progress Next Stage (Exploitation)		

Source: JICA study team (created in March 2015)



Source: JICA study team (created in March 2015)

Fig. 2-11 Area of proposed exploration study in Kinigi

Table 2-9 Possible projects in Bugarama (Phase 2)

Field	Mashyuza
Project Outline	To carry out supplemental surface geoscientific surveying to update the geothermal conceptual model and select drilling targets in the Bugarama field.
Details	➢ Supplemental geological and geochemical study ➢ Review of existing geophysical survey data (TEM, Magnetic etc.) ➢ Supplemental MT/TEM survey ➢ Resource Assessment/Planning (Integrated analysis) ➢ Study of multi-purpose utilization

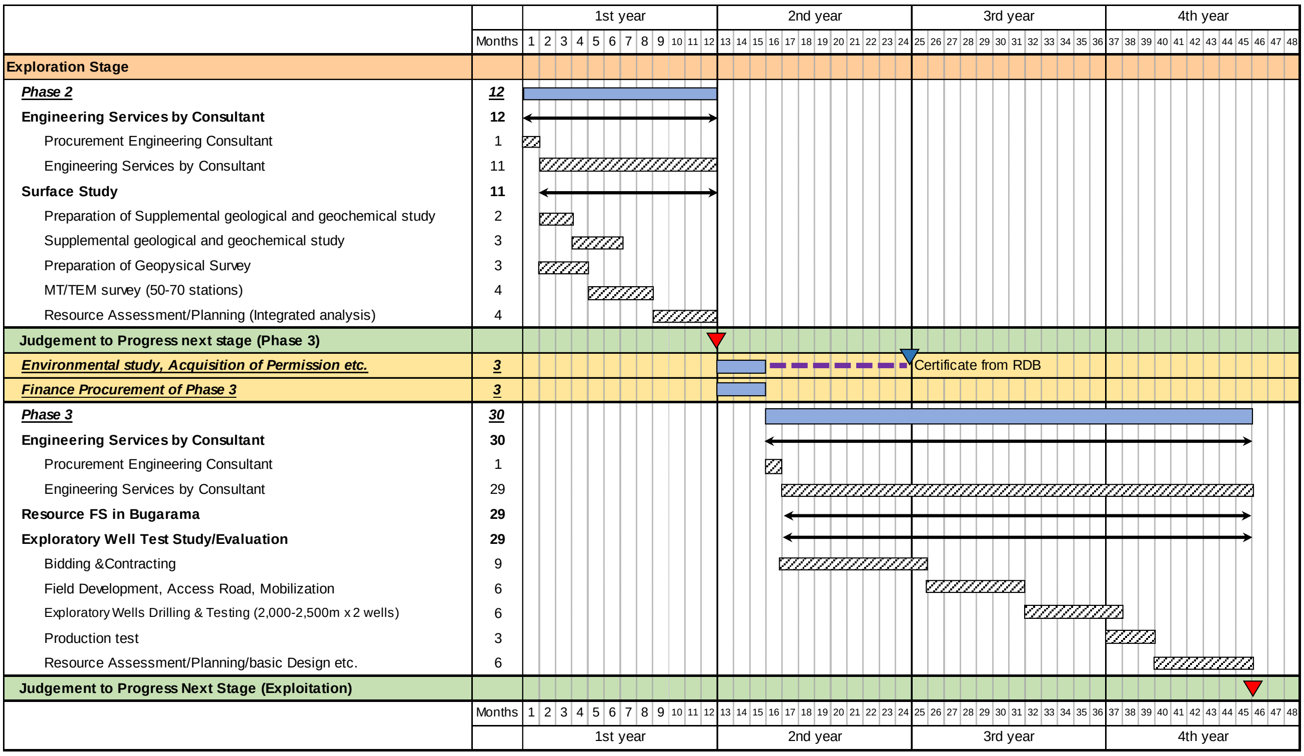
Source: JICA study team

Table 2-10 Possible projects in Bugarama (Phase 3)

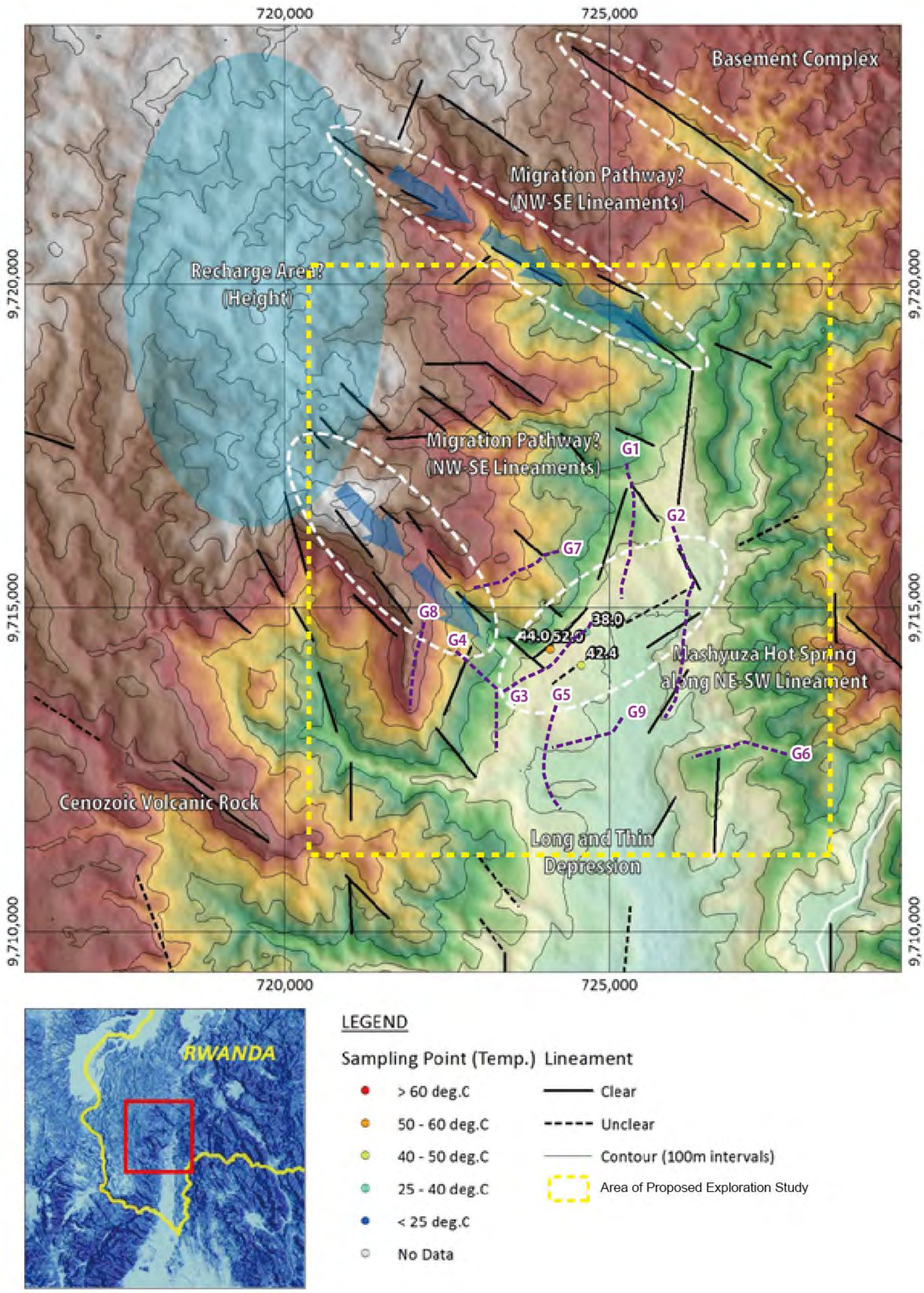
Field	Bugarama
Project Outline	To carry out an exploration survey including drilling two (2) exploration wells in the Bugarama field to confirm presence of a geothermal reservoir and to evaluate the geothermal resource.
Details	➢ Exploratory Well Drilling & Testing (2,000-2,500 m x 2 wells) ➢ Production testing ➢ Resource Assessment/Planning/basic Design etc. ➢ Study of multi-purpose utilization

Source: JICA study team

Table 2-11 Details and schedule of proposed exploration study in Bugarama



Source: JICA study team



Source: JICA study team

Fig. 2-12 Area of proposed exploration study in Bugarama

The fields of second highest priority for exploration are Gisenyi, Karago and Iriba. These fields can be regarded as being in the Detailed Exploration Phase (Phase 2). As mentioned above, the risk for resource development is thought to be relatively high. Considering the present status of these 3 fields, it is impossible to discuss detailed development planning at present. Therefore, only exploration activity (Phase 2) including detailed geophysical surveying is planned. This Phase 2 exploration activity is required before a judgement can be made to progress to the next stage (Phase 3) and to ascertain the possible presence of an exploitable reservoir prior to resource development. Taking into consideration the above-mentioned field exploration situations as well as identified and estimated temperature conditions, exploration activity is proposed for each field and summarized as follows. Fig. 2-13 shows areas of proposed exploration study in Karago field, Gisenyi hot spring area and Iriba-Mufumba cone area. Bize hot spring area in Bugarama field is considered to be Phase 1. Phase 1 study in Bize is also shown.

Possible projects in Karago (Phase 2)

- Supplemental geological and geochemical study
- Supplemental MT/TEM survey (40-50 stations)
- Resource Assessment/Planning (Integrated analysis)

Possible projects in Gisenyi hot spring area

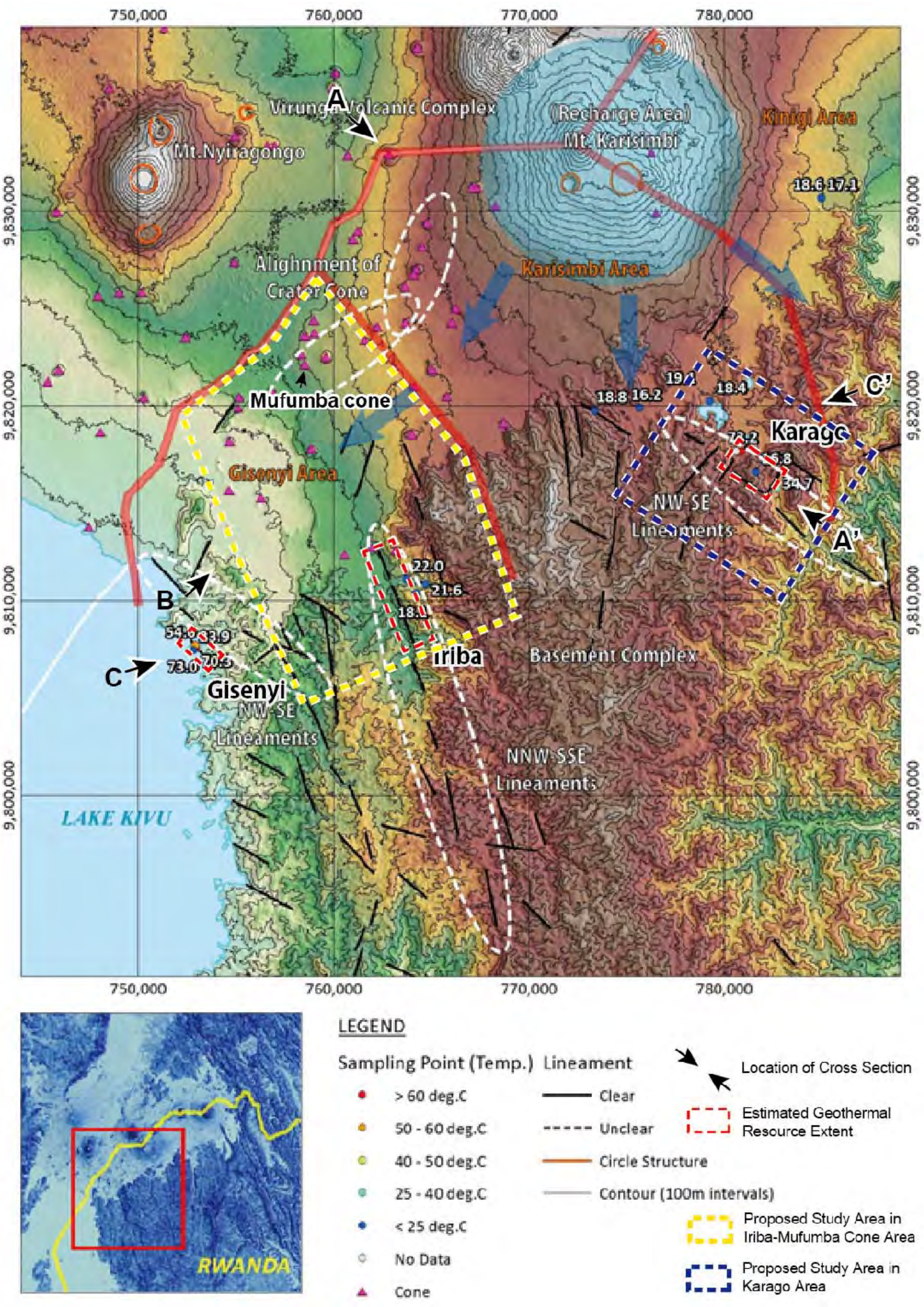
- Supplemental geological and geochemical study
- Resource Assessment/Planning (Integrated analysis)
- Study of multi-purpose utilization

Possible projects in Iriba-Mufumba cone area (Phase 2)

- Supplemental geological and geochemical study
- Regional gravity survey, covering Iriba and Mufumba cone area (200 stations with spatial interval of 1-2 km)
- Integrated analysis and selection of prospective area
- Formulation of detailed surface study in detected prospective area

Possible project in Bize hot spring area (Phase 1)

- Supplemental geological and geochemical study
- Construction of preliminary geothermal conceptual model
- Planning of detailed geoscientific survey including geophysical survey



Source: JICA study team

Fig. 2-13 Areas of proposed exploration study in Karago field, Gisenyi hot spring area and Iriba-Mufumba cone area.

The implementation body for geothermal development in the governmental organization of Rwanda is the Geothermal Unit of REG/EDCL. As mentioned above, the experience of experts in the governmental organization (REG) is insufficient in the area of resource development technologies including geothermal well-drilling and geothermal power plant technology, and capacity building in this area is barely existent. Therefore, technical advisory services by consultants and/or researchers who have knowledge of and experience in geothermal development are critical to the implementation of the exploration activities listed above. Capacity building in REG is expected to result from the collaborative work between the staff of REG and consultants and/or researchers on exploration activities. In strengthening the capacity of REG, the following issues should be considered.

- Capacity building in geothermal exploration technology (geology, geophysics, geochemistry, reservoir engineering and environmental study) through geothermal exploration activity and through participation in training courses such as those held in Japan, New Zealand, Iceland, Kenya. Practical training through collaborative study is necessary.
- Management of geothermal resource and development database
- Capacity building and supervision of project planning and management including procurement procedure, financial aspects etc.
- Enrichment of basic survey equipment and software for geothermal investigation and analysis

iv) Construction of Geothermal Development Database

The electricity development database is newly constructed in this study. The constructed electricity development database (POWER DB) was utilized to construct geothermal development database by adding other information about geothermal development. The geothermal development database not only focuses on specific geothermal fields to provide detailed information concerning the fields, but also provides general information on geothermal development in Rwanda and basic information for each geothermal field in the country. The geothermal development database can be utilized to search and update the necessary information regarding geothermal development in Rwanda. The database is expected to assist in accelerating geothermal development in Rwanda. The database was introduced and installed to the counterparts. It was confirmed that the database works well in the system in the counterparts.

6) Study of Multi-Purpose Utilization of Geothermal Resource

Table 2-12 shows both the current and future multipurpose uses of geothermal resources by geothermal resource in Rwanda.

a) Mashyuza

In Mashyuza in the southern area, there is a hot-spring already welling up hot water of around 47-53°C and can be used as SPA or hot-spring pool.

b) Kinigi

In Kinigi field, there is currently no available geothermal resource. However, in a case where hot water or steam is obtained in the future, there is a potential of geothermal direct use as SPA, hot-spring pool, or greenhouse for flower glowing.

c) Karago

In Karago, hot water at 73^{o}C is currently welling up, but the establishment of facility like SPA and hot-spring pool is difficult, because the acreage is limited. In a case where steam around 190^{o}C is obtained in the future, then there is a potential of geothermal use as the heat source for drying tea leaf at a tea processing factory.

d) Gisenyi

In Gisenyi field, there is also hot water welling up at around 70-73^{o}C. However, direct use of geothermal resources cannot be expected, since the establishment of facilities is difficult due to the limited acreage.

e) Iriba

There is a spring welling up at Iriba with the water temperature of 22^{o}C. However, the temperature is too low to be used easily. If a hot water of around 80 degrees Celsius can be obtained in the future, then it can be used as SPA and hot-spring pool.

Table 2-12 Potential of Multipurpose Geothermal Uses in Rwanda By field

Fields		Characteristics	Uses
South	Bugarama (Mashyuza)	(1)47-53°C hot water (2) In the event that steam is obtained in the future	(1)Spa, hot-spring pool (2)Rice drying
Northwest	Kinigi	Geothermal resources are not available at present. Uses described on the right may be possible if hot water or steam is obtained in the future.	(1) Spa, hot-spring pool (Collaboration with Gorilla Tours) (2) Cultivation of flowers such as roses in greenhouses (3) Potato conservation (4) Pyrethrum drying
	Karago	(1) 73°C hot water (2) If steam of about 190°C is obtained in the future	(1) Facility establishment is difficult due to the limitation of acreage (2) Heat source for drying tea leaves at a tea factory
	Gisenyi	(1) 70-73°C hot water (2) If steam is obtained in the future	(1)Facility establishment is difficult due to the limitation of acreage (2) Potato conservation
	Iriba	(1) 22°C water (2) If hot water of higher temperature is obtained in the future	(1) Facility establishment is difficult due to low temperature (2) Spa, hot-spring pool

Source: JICA Study Team

7) Supplemental surface geoscientific survey in Kinigi

i) Geological Survey in Kinigi

Kinigi is situated in the Virunga Volcano Range (VVR) where there are some late Quaternary volcanoes. The southern part of Kinigi is in the Butare Horst composed of Proterozoic mylonitised granitic and phyllitic complexes. Kinigi is geologically composed of the Proterozoic mylonitised granitic and phyllitic complexes as a basement rock of young volcanoes, Cone volcanics, Sabyinyo volcanics, Gahinga volcanics, Visoke volcanics, Karisimbi volcanics and overlying debris flow deposits. According to the results of remote sensing study, lineaments trending NW-SE and NE-SW dominate in the volcanic terrains of the northern part of Kinigi. In the southern part of Kinigi, the NNW-SSE trending lineaments dominate, and this trend is in harmony with the orientation of the geological structure.

It is estimated that volcanic activity in Kinigi started with eruptions of Cone volcanics (the 1st stage, before 1.6Ma), which are situated in the northern part extending in a NE-SW direction, and that the volcanic activity continued up to 0.7Ma. In the northeastern part of Kinigi, Mt. Sabyinyo, Mt. Gahinga and Mt. Muhabura are arranged along an E-W orientation. Sabyinyo volcanics are divided into two stages of volcanism, one of them basaltic volcanism (1.6Ma) and the other andesitic volcanism (1.0Ma ～ 0.5Ma). At the same time, the volcanic activity of basaltic Gahinga was occurring (after 1.0Ma)., The volcanic activity of Mt. Visoke also occurred after 1.0 Ma, followed by the volcanic activity of Mt. Karisimbi occurring after 0.24 Ma.

Technology transfer of geological survey techniques was carried out to convey an understanding of geological survey methods, the remote sensing technology, and hydrogeology (geochemistry).

ii) Gravity survey in Kinigi

A gravity survey was conducted in Kinigi field. In the Bouguer anomaly map in Fig.2-14, high-gravity anomaly zones are identified in and around the northwestern and the northeastern parts of the survey area. On the other hand, a low-gravity anomaly zone is distributed in and around the southwestern and the southern parts of the survey area. This low gravity anomaly zone extends from the southern part to the northwestern part of the survey area. In order to extract underground structures such as faults in this area, horizontal first derivative analysis was performed. From the continuity of the high anomaly of the horizontal first derivative values, eight gravity lineaments (G1~G8) were detected (Fig.2-15). Moreover, on the basis of the results of the three-dimensional resistivity inversion with MT data which was conducted in 2014, a low resistivity zone of less than 10 ohm-m, which often indicates a hydrothermally altered zone, is recognized in the northern part of the Kinigi field at a depth of 2,000m and deeper. In order to understand the underground structures, trend surface analysis and horizontal first derivative analysis were performed for the selected gravity data in and around the low resistivity zone detected. As a result of the analysis, three gravity lineaments were detected (G9~G11) as shown in Fig.2-16. The extracted gravity lineaments G9 and G10, and the northern part of gravity lineament G1 mentioned above are located in and around the low resistivity zone, which may reflect a hydrothermally altered zone, and thus these gravity lineaments possibly indicate fracture zones which control the flow of geothermal fluid at depth.

Technical transfer of gravity survey techniques was performed in the supplemental surface geoscientific survey in Kinigi with the aim of communicating an understanding of the skills involved in gravity data acquisition, gravity data processing including data correction, filtering processes, three-dimensional gravity inversion technique using a 2 layer density model and extracting subsurface structures (faults, intrusive rock, etc.) in light of the results of gravity data analysis.

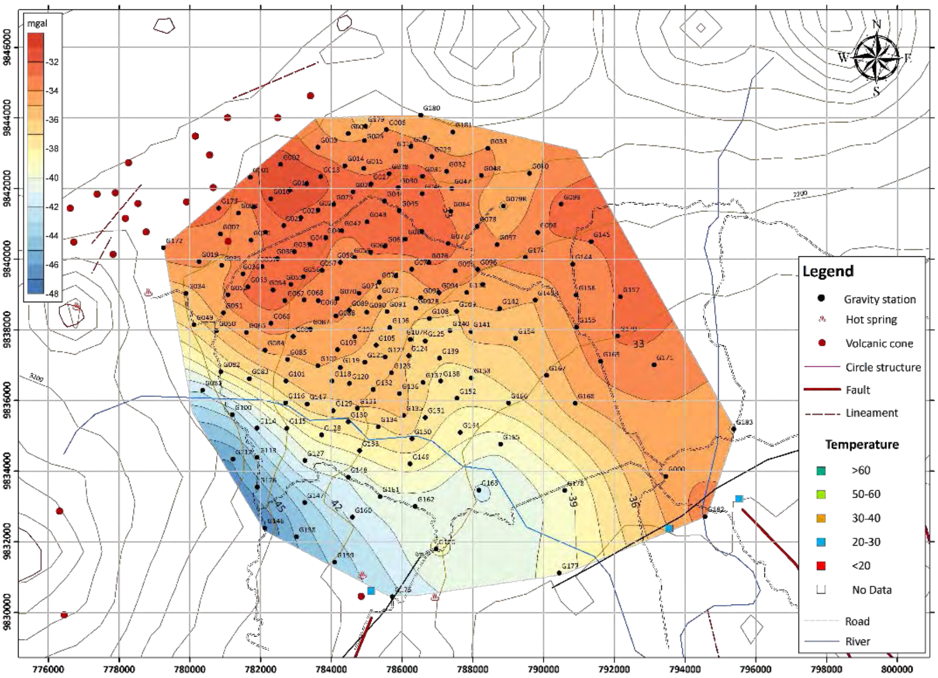


Fig.2-14 Bouguer anomalies map（Density；2.40g/cm³）

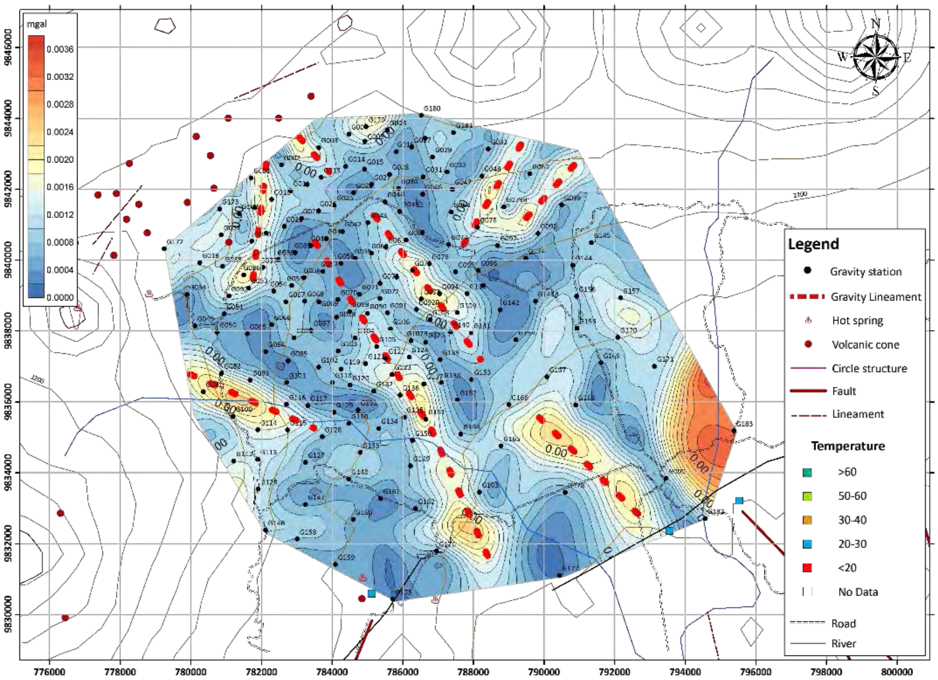


Fig.2-15 Horizontal first derivation of residual of 3rd trend surface map

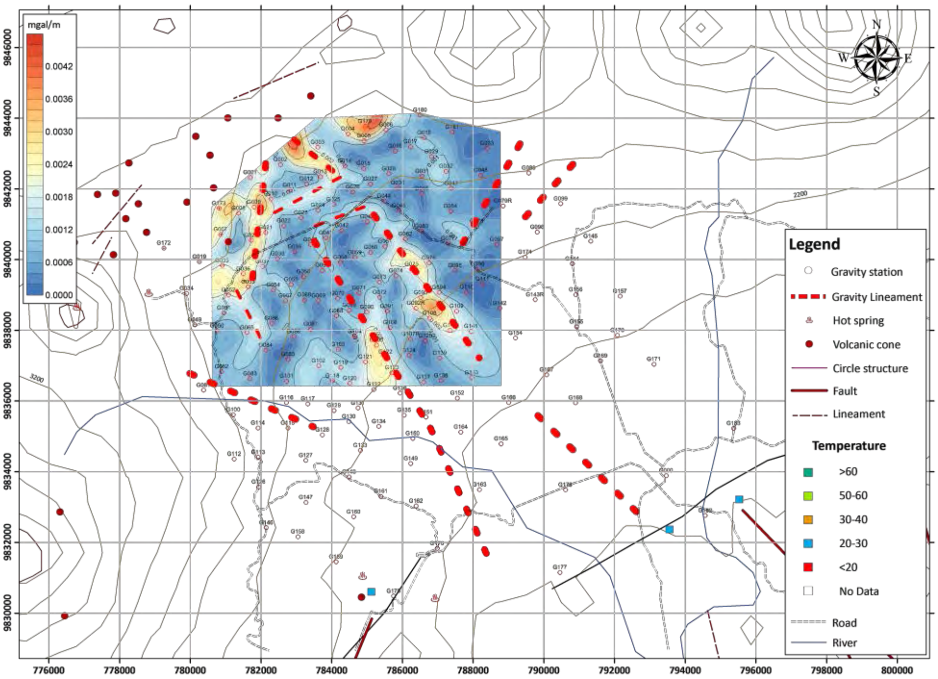


Fig.2-16 Horizontal first derivation of residual of 2nd trend surface map

iii) Technology transfer related to the geothermal conceptual model update

A comprehensive analysis map of Kinigi and geothermal conceptual model are shown in Fig. 2-17 and Fig. 2-18 respectively. This geothermal conceptual model was created as part of the update support offered as part of the capacity building exercises.

Kinigi field is geologically composed of Proterozoic basement rocks and Quaternary volcanic rocks. According to the reanalysis of MT data, a widely distributed low resistivity zone is clearly detected at a depth of 2,000 m and deeper in the northern portion of Kinigi. In addition, two remarkable resistivity discontinuities can be identified at a depth of 1,500 m and deeper in and around the fields at the eastern edge and the western edge of the remarkable low resistivity zone respectively. Also, gravity lineaments trending NNW-SSE are distributed in the study area. Geological structures in the southern part of Kinigi (in the Butare Horst) are characterized by the presence of NNW-SSE trending faults. Considering these geological structures, R2 and R3 delineated by 3D MT inversion and gravity lineaments G1 and G4 show the presence of NNW-SSE trending faults (F1, F2 and F3) developed in the Proterozoic basement seated below the volcanic rock. Cone volcanics are distributed in a NE-SW orientation between the Visoke volcano and Sabyinyo volcano. In addition, gravity lineaments G9 and G10 are distributed in the same direction as the structure in the northern part of the study area. This suggests the possibility of the presence of a deep seated fracture system.

Andesitic volcanic rocks erupted at Visoke and Sabyinyo volcanoes. K-Ar rock dating of the andesite shows 0.5 to 1.0 Ma. These analytical results suggest the possibility that a magma chamber existed in the late Quaternary and could be a heat source of a geothermal system which exists at relatively shallower depths in and around Mt. Sabyinyo. Although Visoke volcano likewise is andesitic, when considering the scale of the volcanic bodies, the most promising heat source for geothermal activity in Kinigi would be Sabyinyo volcano.

A widely distributed low resistivity zone is clearly detected at a depth of 2,000 m and deeper in the northern portion of Kinigi by the reanalysis of MT data. The low resistivity zone in the northern portion of Kinigi may be the result of argillized rock affected by geothermal activity and containing considerable amounts of smectite and/or interstratified clay minerals. In this case, fault F1 (resistivity discontinuity R2) and F3 (R3) probably reflect fracture zones at depth.

No geothermal manifestations such as fumaroles, hot springs, or altered ground have been recognized in the Kinigi field. Cold springs are distributed at the topographic boundary of the volcanic region in the north and the Butare Horst in the south. It is estimated that these spring water is not contaminated by deep hot water, but rather that the CO_2 has been added to the shallow ground water, and it is estimated that the spring water is flowing through the volcanic rock. Since these spring water does not reflect information concerning the deep subsurface fluid, it is unclear about the properties of the geothermal fluid.

NNW-SSE trending faults are developed in the Proterozoic basement seated below the volcanic rock in the Kinigi field. If there are permeable fracture zones around these faults, it is considered that geothermal fluid is stored in the fracture zones and that an alteration zone identified by a low resistivity zone is generated by the geothermal fluid. Precipitation at high elevation in this field penetrates deep into the ground through faults trending mainly NE-SW in the study area and is heated by magma. However, this suggests that even if geothermal fluid is stored along the permeable fracture zone around the faults in the northern portion of Kinigi, the temperature of the geothermal fluids may not be high enough for conventional type geothermal power generation.

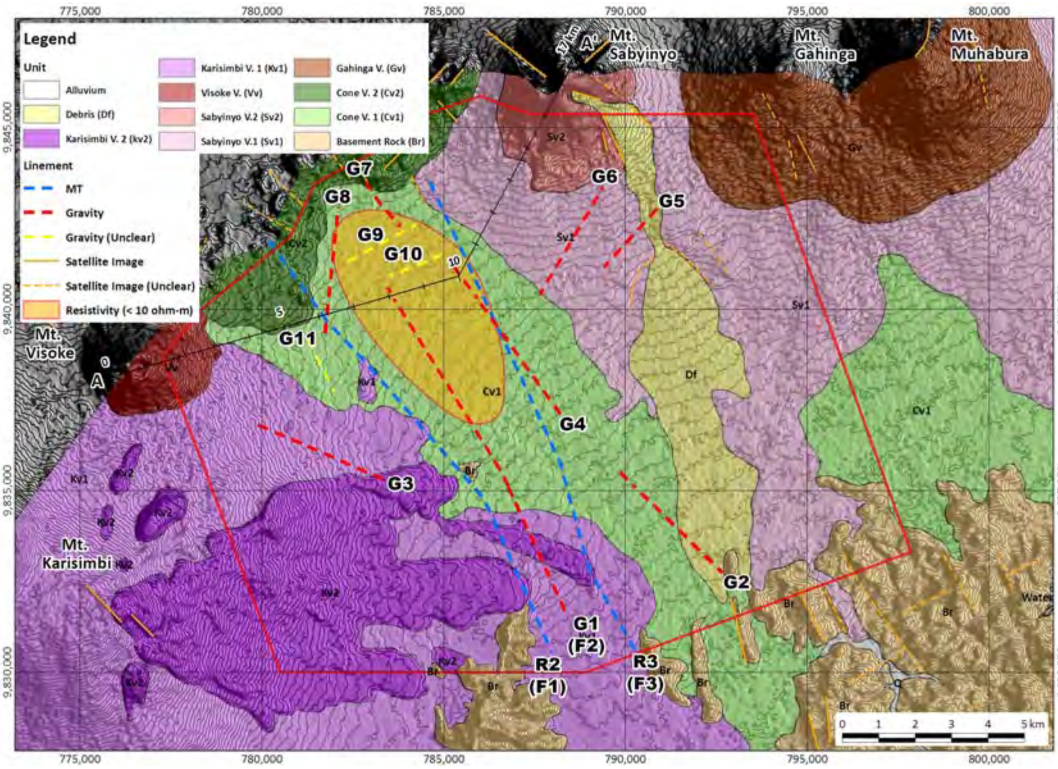


Fig.2-17 Geological map in Kinigi field

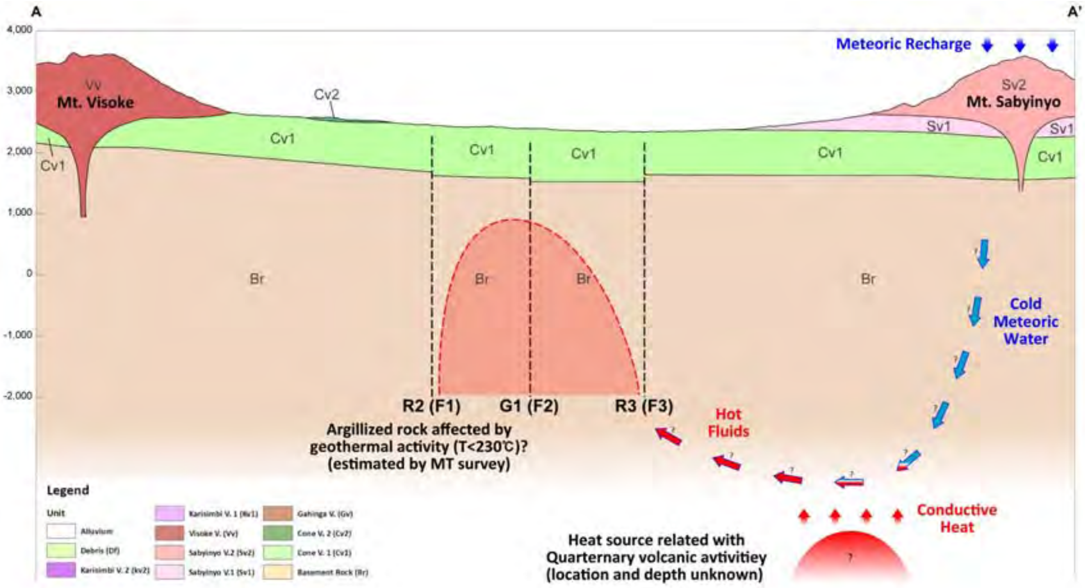


Fig.2-18 Geological cross section in Kinigi field

(3) Recommendation on Formulation of Geothermal Development Plan

Even in the Kinigi and Bugarama fields, the presence of a geothermal reservoir adequate for power generation has not yet been confirmed, so the resource development risk is thought to be relatively high. However, a tentative geothermal development plan was formulated as a reference for Kinigi and Bugarama fields, which were ranked as having the highest priority for exploration activity in Rwanda. The earliest commencement of power generation will be 2023 in Bugarama field.

In Kinigi field, it is assumed that about 10 years will be necessary to commencement from the selection of the consultant for “Phase 2”. However, these formulated development plans were based on results of resource potential evaluation as of 2nd year work. These provisional estimate does not always correctly indicate the sustainable optimum power output at that point.

Particularly, the geothermal conceptual model of Kinigi field constructed in the 3rd year of this project may not provide clear evidence for the interpretation of the resistivity construction and the geothermal system (fluid temperature in basement rock etc), so the low possibility of the presence of geothermal fluid cannot be denied. Furthermore, even when geothermal fluid is present along the permeable zone around faults, it is assumed that the presence of high temperature geothermal fluid around the permeable zone is low. Therefore, in case of drilling exploration wells, the possibility that the wells will not self-discharge may not be denied. Based on the above, large scale geothermal power generation may not be possible in this area. In this regard, the surveys in this project did not provide confirmatory information regarding the existence of a geothermal reservoir. Considering the results of these surveys, the geothermal development risk in Kinigi field is determined to be high. Furthermore, if the next step in exploration is decided to be undertaken, even though geothermal development risk need to be fully considered as described above, exploration well shall be drilled to confirm the underground structure and the existence of geothermal reservoir.

Considering this current situation of geothermal development in Rwanda, the JICA study team describe recommendation and issues of concerns for future geothermal development activity in Rwanda as follows.

- Some technical tasks in the assessment of the geothermal resource remain because an exploitable geothermal reservoir has not been confirmed by drilling in all geothermal fields in Rwanda. Data presently available for all prospects are not sufficient to evaluate the geothermal resource and the presence of a geothermal reservoir adequate for power generation has not yet been confirmed. Therefore, geothermal exploration study is required for the judgment of resource feasibility of geothermal power development in Rwanda.
- Geothermal resource evaluation based on exploratory well drilling and production testing in the next stage (Phase 3) is required to identify the optimum sustainable power output. It should be noted that the details of geothermal power plant projects should be formulated in a feasibility study, which will be carried out later on the basis of the geothermal resource study (Phase 3).
- In this study, exploration studies necessary for above-mentioned judgment in Phase-2 and Phase-3 are formulated as an action plan. It is desirable that resource assessment will be done at each Phase and judgments at each Phase would be required to progress next stage or not in all fields.
- Government-led surveys corresponding to Phase 2 and Phase 3 are desired to confirm the

presence of geothermal reservoirs and to promote geothermal development in this country, because the resource development risk is thought to be relatively high. It is recommended that support by the donors in this situation is best directed to enabling these early-stage surveys by the government or governmental agencies (REG).

- Support for capacity building among policy makers and/or survey staff involved in early stage development is important. In strengthening the capacity of REG, the following issues shall be considered.
  - ✓ Capacity building in geothermal exploration technology (geology, geophysics, geochemistry, reservoir engineering and environmental study) through geothermal exploration activity and through participation in training courses such as those held in Japan, New Zealand, Iceland, Kenya. Practical training through collaborative study is necessary. In this project, capacity buildings in geology, geochemistry and geophysics etc was carried out.
  - ✓ Management of geothermal resource and development database
  - ✓ Capacity building and supervision of project planning and management including procurement procedure, financial aspects etc.
  - ✓ Enrichment of basic survey equipment and software for geothermal investigation and analysis

3. Environmental and Social Consideration Study

Rwanda has plans to develop power generation using hydro and thermal (diesel, methane, peat, etc.) sources, as well as to develop power systems. At the beginning of this study, geothermal development was considered the most promising generation method, and the viability of development plans for other options was uncertain. For these reasons, this study surveyed existing conditions for the four potential geothermal development areas, and evaluated the environmental impact in a strategic environmental assessment (SEA). This report presents a summary of the fundamental SEA results for the geothermal power plant sites, and the results of qualitative assessment of transmission lines to be connected to the geothermal power plants.

(1) Summary of Geothermal Development Potential Sites

Figure 3-1 summarizes land use and other factors at potential geothermal development sites.

Bugarama: In Bugarama, the land is mainly used for various agricultural activities such as the production of bananas, potatoes and cassavas, with dispersed residential areas. There are some large rice paddies and a cement factory near the site. The main facilities identified nearby include a coffee washing station, health centers, schools, markets, and churches.

Karisimbi: Karisimbi is located in the southern part of Volcanoes National Park, and several geothermal development activities are already underway, including test drilling. The altitude is high, between 2,500 and 2,700 meters, and the site is occupied mainly by the production of Irish potatoes and pyrethrum. Farmers' houses are located along the local roads. The main facilities identified include schools and churches.

Gisenyi: The Gisenyi field is located alongside Lake Kivu, and includes a hot spring site on a small peninsula. The main facilities identified include coffee washing stations, health centers, churches and schools. There is also a brewery near the potential geothermal development site. There is a densely populated residential area along the lakeshore north of the site. The area is home to many hotels as well, as Lake Kivu is popular tourist destination.

Kinigi: Like Karisimbi, the Kinigi site is located at a high altitude in the southern part of Volcanoes National Park. The area is marked by crop fields and individual houses surrounded by forest. It is also famous for organizing its mountain gorilla trekking tours, which is an important tourist resource. The main facilities located in the area

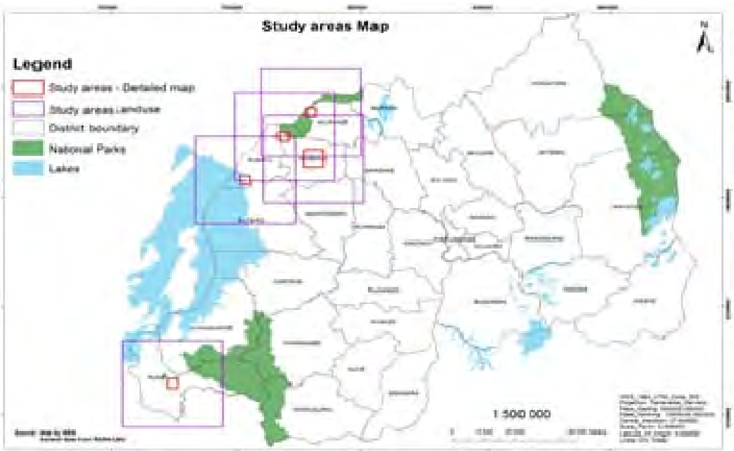


Fig. 3-1 Study Area Map include schools, health centers, and markets.

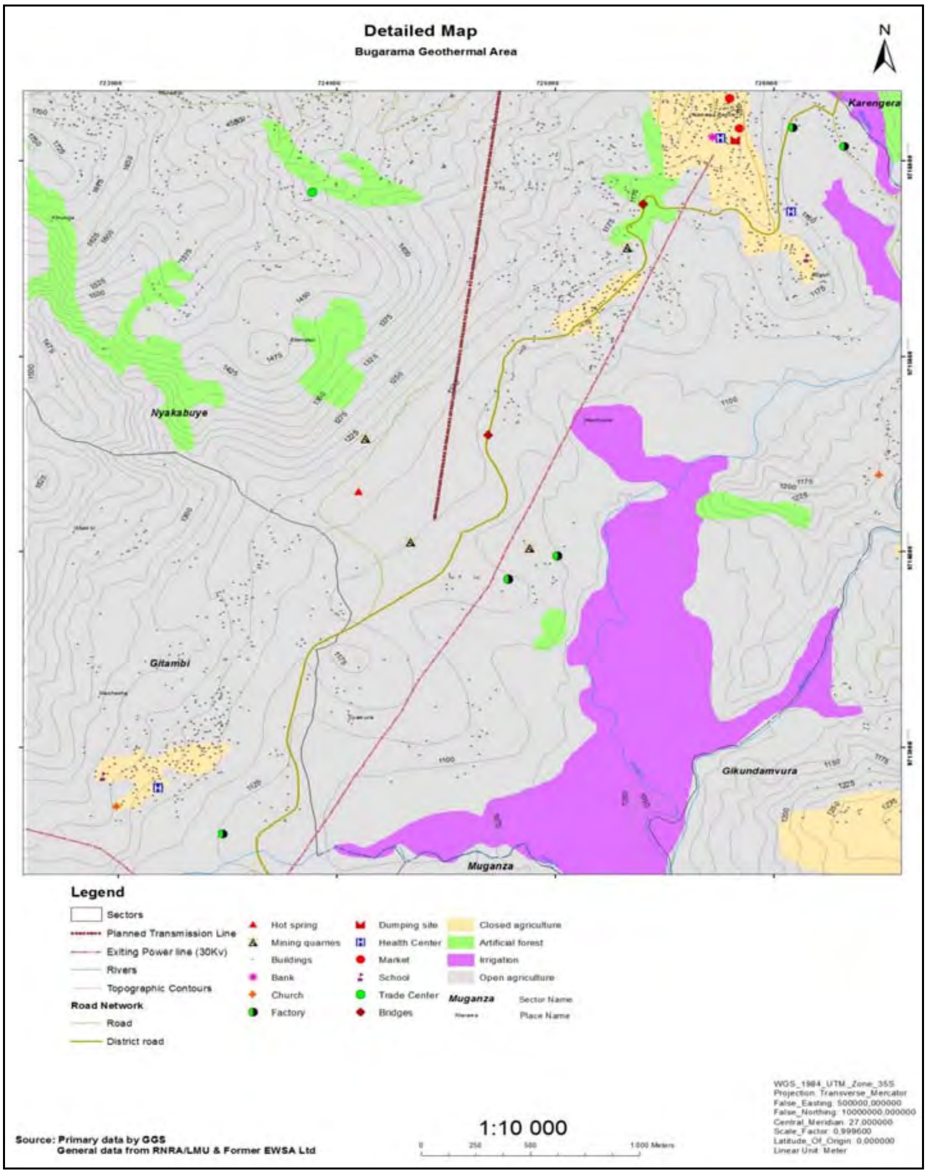


Fig. 3-2 Bugarama Detailed Map

Photo 3-1 Bugarama Rice Field view

Photo 3-2 Area around Bugarama project area

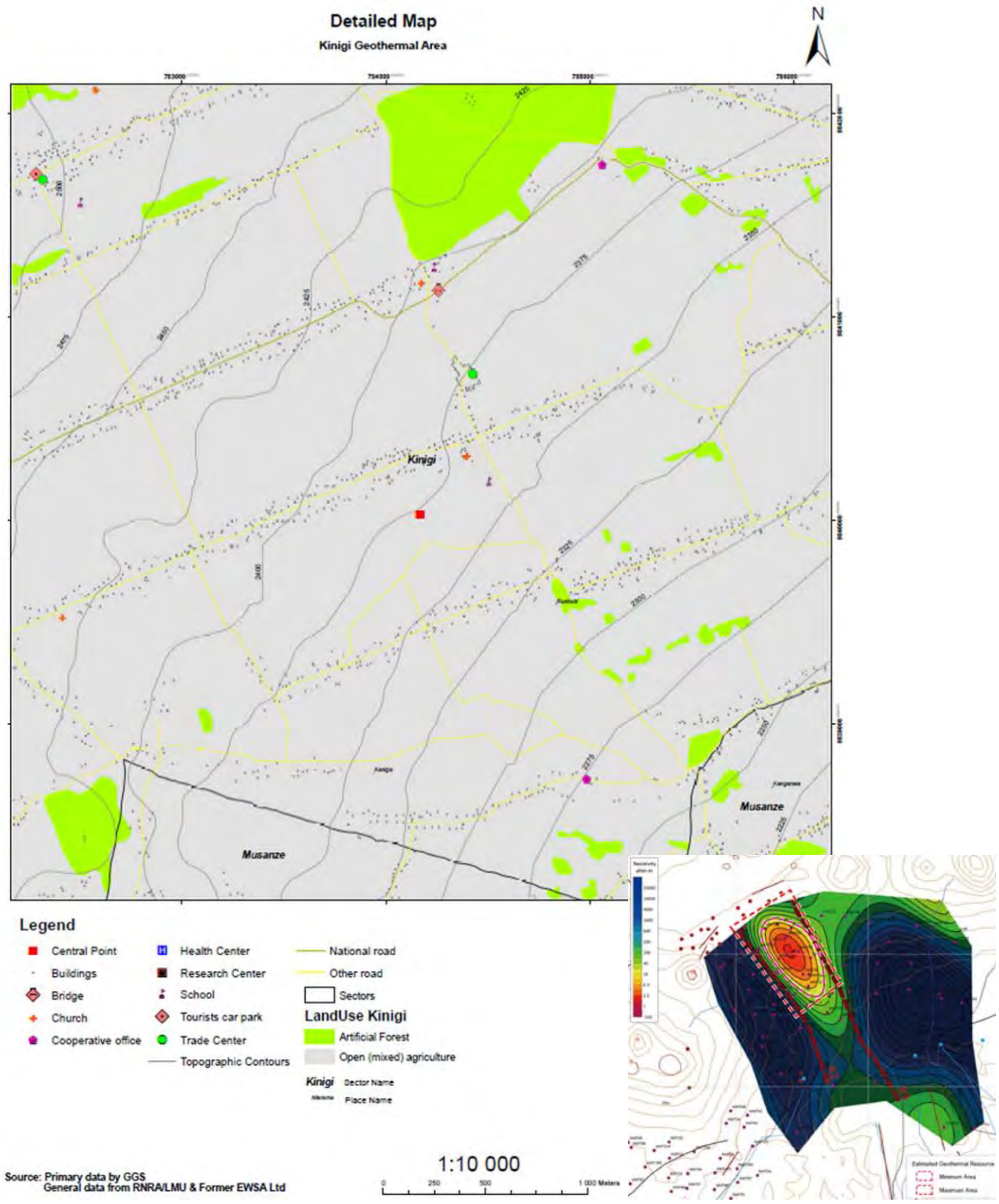


Fig. 3-3 Kinigi Detailed Map (Estimated Geothermal Resource Extent Area)

Photo 3-3 Field at Centre point (Estimated Geothermal Resource Extent Area)

(2) Water Quality

This study identified five different sites of different important water resources (rivers, lakes, springs...) in the area of potential geothermal sources. Water samples were collected from various areas in the country, including BUGARAMA, GISENYI, KALISIMBI, KINIGI and KARAGO.

Based on the water quality survey results for this time, features of water quality in Rwanda will be summarized as follows from the point of EIA for geothermal development.

The rainy seasons and the dry seasons influence the annual environment in Rwanda such as the river system significantly. Water drainage planning to the river system during geothermal development and its operation must consider the system's hydrological feature and its water quality fluctuation caused by the seasonal changes. The mountain side in Kinigi field in the Northern Province seldom has surface water flows during the dry seasons and only underflows are identified. Thus, there is a risk that geothermal project drainage would be directly connected to the underflows and join the river system. We should pay attention to this point and consider potential impacts to water quality and the ecosystem around the water system.

Groundwater through water springs is commonly used as domestic water in many places of Rwanda. At the same time, an agricultural practice to apply for fertilizers to farmlands such as tea plantation is quite active. One typical environmental issue of groundwater cased by agriculture is its pollution by nitric acid. Drinking water polluted by nitric acid would cause malfunction of blood circulation especially of babies and infants. Nitric acid pollution of groundwater has a feature to be revealed after tens of years of incubation period. In case of Japan, introduction of measures to deal with the pollution delayed and we still see many groundwater sources that are difficult to be recovered. It is important in Rwanda to introduce prevention measures to avoid such pollution with a long-term vision. During geothermal development, we should take sufficient preventative measures not to drain and/or permeate polluted elements such as organic liquid waste and heavy metals to the surface water or groundwater systems.

The water quality of the Lake Kivu is currently fine and this supports enhancement of value of the lake as a tourist resource. However, through economic development in Rwanda, the lake is more and more receiving drainage of high nutrients, organic matters, pesticides and other elements that increases environmental burden and pollutes the lake. In case of the Lake Karago, as the depth of the lake is shallow, there is a risk to see water blooms such as Microcystis of Cyanobacteria that generate toxic substances if inputs of pollutants such as nutrients continue to increase. Water blooms decrease biodiversity, make domestic and industrial usage of water difficult, and prevent economic development.

During geothermal development, it is ideal to prepare necessary measures such as impact assessments and pollution prevention activities by considering the whole water system including the river and the lakes/marshes where the water flows in through monitoring of water quality of the whole system. Additionally, all collected data through this exercise should be open to the public so that people can use it for proper management of the hydrological environment, the biological environment, and the living environment. This will help realization of sustainable national development. From the point of avoiding emission of toxic methane gas in the Lake Kivu, we also need to reduce inputs to the lake of organic pollutants, phosphorus that nurtures phytoplankton and organic matters, and nitrogen. A long-term measures must be implemented by considering potential future impacts to the countries down the water system.

The water sources of rivers in Bugarama are at the hot spring area. Thus, high contents of elements linked to the hot spring are identified. When we design measures to study, evaluate, and protect water quality and to use water during geothermal development, it is critical to keep in mind features of the water quality of the targeted river. Additionally, as downstream from the geothermal development area is used for irrigation, we need to assess impacts of the development to it.

(3) Noise

This time, we measured noise levels mainly along roads for 10 minutes during the daytime as a reference. The levels were: 43.0 to 71.0 dB (Leq) in Bugarama, 59.8 to 70.6 dB (Leq) in Gisenyi, 48.4 to 73.0 dB (Leq) in Karago, and 46.3 to 71.0 dB (Leq) in Kinigi. The maximum noise levels of all the sites were mainly caused by traffic and they reached around 70 dB (Leq). The minimum noise level in Kinigi was relatively high because it was influenced by wave sound from the Lake Kivu, voices of hot spring visitors, etc.

(4) Mountain Gorillas

Photo 3-4 Mountain Gorilla

Gorillas inhabit areas in Angola, Uganda, Gabon, Cameroon, The Republic of the Congo, The Democratic Republic of the Congo (DRC), Equatorial Guinea, The Central African Republic, Nigeria and Rwanda. They belong to the Mammalia Class, Primate Order, Hominid Family, and Gorilla Genus. There are two species: Gorilla gorilla and Gorilla beringei. Mountain gorillas are a subspecies of Gorilla beringei. Only about 800 mountain gorillas inhabit the planet and they are designated as an Endangered Species (EN) by IUCN (International Union for Conservation of Nature) Red List of Threatened Species.

Gorillas are polyphagic, though they prefer to eat plants. Their principal foods are plant leaves, fruits, and insects. During the dry seasons, when there is less available food, mountain gorillas also eat plant shoots, bark, roots, etc. The lifespan averages around 40 to 50 years, and they are diurnal. They prepare different nests to sleep in every night. Their home range is about 10 to 50 square km, and they move around 0.5 to 2km every day (Obara, et al., 2000). They give birth every 4 to 5 years and gestation during pregnancy lasts an average of 258 days. Females show reproductive behaviour o for nly about two days during their menstrual cycle of about one month. Around 1 to 2 fertile gorillas can be born to each female gorilla, so it takes long time to rebuild the population once it drops (Yamagiwa, 2005). This low breeding coefficient is one reason so much importance is placed on their protection.

The protection of mountain gorillas is led by NGOs such as the Dian Fossey Gorilla Fund International (established by late Dr. Dian Fossey), by eliciting worldwide support and by maintaining strong ties with the governments of Rwanda, Uganda and the DRC. Protection activities not only include monitoring of movements of mountain gorillas, but also medical examinations of the gorillas when needed.

The distribution of gorilla groups over several years is illustrated in Figure 4-5.7. We only see one group in the Karisimbi area, but about 10 groups have been identified in the Kinigi field. We have extracted data of the same groups. According to the result, the habitat location size is fluctuating but the location itself is rather stable.

Though a buffer zone of 800 meters should be installed at the border of the national park, farmlands actually encroach right up to the border. In the Kinigi field, where many gorilla groups have been identified near the border, geothermal development will be placed away from the border by at least 1 km, in consideration of the buffer zone. The buffer zone was originally established by the former national tourism board (which has since been integrated into the RDB) after a study in the national park investigated the movements of mountain gorillas.

Currently, some investigations are being conducted on relationships between gorilla habitats and human activities in the park, but there is no quantitative data on the impact of development activities.

With regard to the impact assessment during test drilling in Karisimbi, no significant changes in mountain gorilla activities were found during that period. Thus, the test drilling impact was recognised as minor (ex-EWSA).

However, this assessment was not conducted by visiting the project site intensively and frequently, or by considering the impact of field work such as land development and drilling. Further, the assessment does not include an investigation of data on gorilla movements during the drilling period gathered by NGOs (who best understand the situation) dealing with mountain gorilla conservation.

Sufficient monitoring and assessments based on these results, in addition to the introduction of impact mitigation measures when necessary, would be essential for future geothermal project implementation near any mountain gorilla habitat. Moreover, monitoring, impact assessments and the introduction of needed measures should be realised with frequent communication and the involvement of NGOs and other stakeholders. We should also consider the impact not only directly on mountain gorillas, but on other fauna and flora that are part of the mountain gorilla habitat.

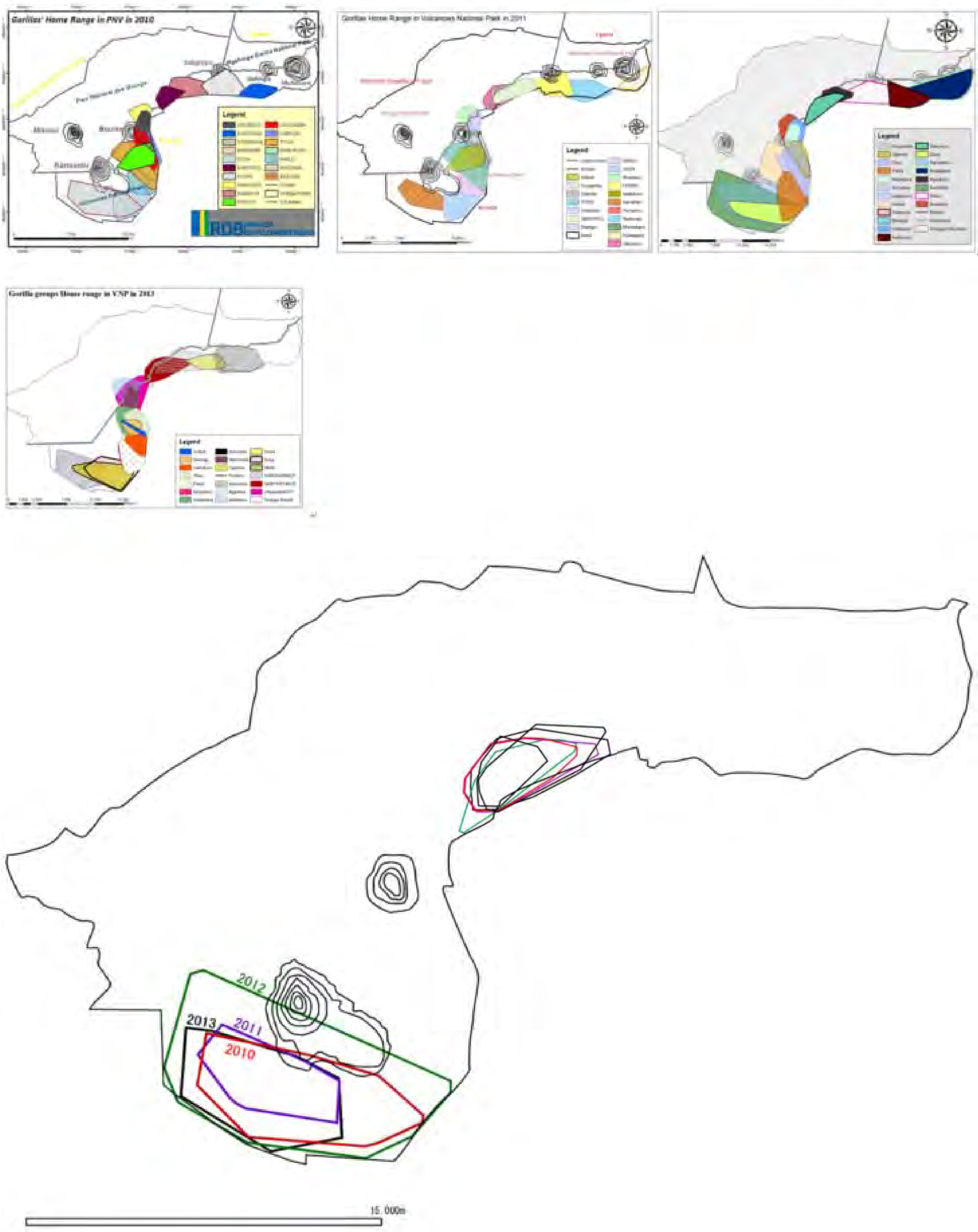


Fig. 3-4 Annual changes of mountain gorilla habitat (Karisimbi and Kinigi:Sabyinyo Group)

(5) Basic Scoping

In order to consider which items should be addressed in the initial environmental studies, basic scoping was carried out for the project areas where development plans have been made clear to some extent. This scoping was based on the assumption that the projects would involve the construction of geothermal power plants and the installation of transmission lines to accompany the plants, and rather extended ranges were defined as potentially affected areas. The results are shown in Table 3-2.

Table 3-1 Basic Scoping

Item	1. KARISIMBI			2. KINIGI			3.BUGARAMA			4. GISENYI			5. KARAGO		
	Evaluation		Sum mary	Evaluation		Sum mary	Evaluation		Sum mary	Evaluation		Sum mary	Evaluation		Sum mary
	Const-ruction	Operation		Const-ruction	Operation		Const-ruction	Operation		Const-ruction	Operation		Const-ruction	Operation	
H2S	B-	A-	A-	B-	A-	A-	B-	A-	A-	B-	A-	A-	B-	A-	A-
Dust	B-	D	B-	B-	D	B-	B-	D	B-	B-	D	B-	A-	D	A-
Water quality	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-
Waste	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-
Sediment	D	D	D	D	D	D	D	D	D	C	C	C	C	D	C
Soil contamination	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Noise and vibration	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	B-	B-	B-
Odor	B-	B-	B-	B-	B-	B-	B-	B-	B-	B-	B-	B-	B-	B-	B-
Pretected area, Ecosystem& Biodiversity	A-	A-	A-	A-	A-	A-	B-	B-	B-	C	C	C	B-	B-	B-
Lakes and Rivers	B-	D	B-	B-	D	B-	B-	B-	B-	A-	A-	A-	A-	D	A-
Topography, Soil erosion and geographical features	B-	D	B-	B-	D	B-	B-	D	B-	A-	D	A-	A-	D	A-
Land use and Involontary resettlement	B-	B-	B-	B-	B-	B-	B-	B-	B-	A-	B-	A-	A-	B-	A-
Minorities and indegenous peoples	D	D	D	D	D	D	C	C	C	B-	C	B-	C	C	C
Local economy and employment and livelhoods	B+	B+	B+	B+	B+	B+	A+	B+	B+	A+	B+	B+	A+	B+	B+
Existing infrastructures and services	C	B+	C	C	B+	C	C	B+	C	C	B+	C	B+	B+	B+

A+/-: Significant positive/negative impact is expected.
B+/-: Positive/negative impact is expected to some extent.
C: The degree of impact is unidentified, and future investigation for clarification is needed.
D: As the impact will be minimal, future investigation is unnecessary.

(6) Alternative Solutions

Geothermal development is more technically reliable, and less land is needed for development than with other power generation options. Negative environmental impact caused by emissions is also relatively limited. By considering other points as well, we can conclude that geothermal development has well-balanced positive features. As little land is needed for development, this power generation modality is more suitable and environmentally friendly than other options, especially in Rwanda.

(7) Policy, Legislative and National Environmental Management System

1) Rwandan National Policy on Environment

The National Policy on Environment (NPE) in Rwanda was established in November 2003 to develop a framework for sustainable environmental protection and management. The Policy establishes the basis for improving people's well-being, the prudent use of natural resources and the protection and rational management of ecosystems for sustainable development.

Following establishment of the environmental policy, Article 49 of the Constitution of the Republic of Rwanda of 4th June, 2003 (as amended), states that: "Every citizen is entitled to a healthy and satisfying environment. Every person has the duty to protect, safeguard and promote the environment. The State shall protect the environment. The law determines the modalities for protecting, safeguarding and promoting the environment."

2) Institutional Framework of Rwanda

The institutional framework for environmental management is set out in the Organic Law, which determines the modalities of protection, conservation and promotion of the environment in Rwanda. It is published in the Official Gazette RWA Nº 9 of the 1st May 2005, particularly in Chapter III which relates to the establishment of the institutions.

Article 65 of the Organic Law establishes the Rwanda Environment Management Authority (REMA) as being responsible for managing environmental issues in Rwanda with a duty to implement policies and laws related to the environment. REMA was established under the Organic Law (No. 04/2005 of 08/04/2005) and was given the responsibility of overseeing, coordinating and supervising the Environmental Impact Assessment (EIA) process, compliance and monitoring in Rwanda.

Recently, the responsibilities for EIA review and approval has been transferred from REMA to the Department of Environmental Compliance of the Rwanda Development Board (RDB).

According to the recent restructuring, governmental institutions involved directly or indirectly in environmental management include the following:

- Ministry of Natural Resources (MIINIRENA),
- Ministry of Local Governance (MINALOC) through provinces and decentralized entities (districts, sectors),
- Ministry of Agriculture and Animal Husbandry (MINAGRI),

- Rwanda Environment Management Authority (REMA),
- Rwanda Natural Resources Authority (RNRA),
- Rwanda Bureau of Standards (RBS),
- Rwanda Utilities Regulatory Agency (RURA)

3) Environmental Law in Rwanda

The Constitution of the Republic of Rwanda, adopted in June 2003, ensures the protection and sustainable management of the environment and encourages the rational use of natural resources. Organic Law (No. 04/2005 of 08/04/2005) and various socio-economic development policies and strategies such as “Vision 2020” call for a well regulated environmental management system that takes into account principles of sustainable development while at the same time contributes to poverty reduction.

Following the establishment of the Constitution of the Republic of Rwanda and the National Environmental Policy in 2003, the legislative framework for environmental management was set up by the Government of Rwanda through Organic Law No 4/2005 of April 8, 2005, which established modes of protecting, safeguarding, and promoting the environment in Rwanda.

There are also a number of decrees, statutory instruments and ministerial orders which govern environmental protection in Rwanda.

Relevant national laws, ministerial orders and policies relating to this Project include:

- The Law on Land Use and Management (Organic Law N° 08/2005 of 14/07/2005)
- The Law on Forestry (No 47/1988 of 5 December 1988)
- The Water Law (Law N°62/2008 of 10/09/2008)
- The Land Title and Registration Law (Ministerial order N°002/2008 of 01/4/2008)
- Ministerial Order establishing the list of protected animal and plant species (Ministerial Order No 007/2008 of 15/08/2008)
- Ministerial Order relating to the requirements and procedure for environmental impact assessment (Ministerial Order n° 003/2008 of 15/08/2008)
- Ministerial Order determining modalities of establishing and functioning of occupational health and safety committees (Ministerial Order N°01 of 17/05/2012)
- National Strategy on Climate Change and Low Carbon Development for Rwanda,(DOI 10.4210/SSEE.PBS.2011.0002)
- The National Land Policy, 2004
- The Water and Sanitation Policy, 2004
- The Mines and Geology Policy, 2004
- National Forestry Policy, May 2010.

4) Social Law in Rwanda

The following laws and policies governing social protection are in place in Rwanda:

- Rwanda Environmental Policy, 2003

- Rwanda Health Sector Policy, 2005
- Rwanda Agricultural Policy, 2008
- Rwanda Land Policy, 2004
- Rwanda Water and Sanitation Policy, 2010,
- National Water Resources Management Policy, 2011
- National Poverty Reduction Strategy, 2008
- Rwanda Vision 2020 which aims to reduce poverty through a pro-poor national growth agenda
- Organic Law N° 04/2005 of 08/04/2005 determining legislation around environmental management and protection
- Rwanda Constitution of 2003
- Law N° 18/2008 of 23/07/2008 Relating to the Punishment of the Crime of Genocide Ideology
- N° 13/2009 of 27/05/2009 Law regulating labour in Rwanda (also covers health and safety)

The following national laws relate to land use and are applicable to land acquisition and resettlement.

- Land Act of 2004
- Organic Land law No. 08/2005 of 14/07/2005 determining the use and management of land in Rwanda
- Land Valuation Law promulgated in 2007
- Land Expropriation Law promulgated No. 18/2007 of 19/04/2007
- Presidential Order No. 54/01 of 12/10/2006 determining the structure, the responsibilities the functioning and the composition of Land Commissions
- Ministerial Order No. 001/2006 of 26/09/2006 determining the structure of Land Registers, the responsibilities and the functioning of the District Land Bureau.

5) Requirements for stakeholder participation and Disclosure

Consultation with affected communities and individuals is regarded as an essential element of the ESIA process in Rwanda. Throughout the Rwandan ESIA process, stakeholder engagement in the form of consultation and involvement of the local communities and the affected persons is required. This occurs at three key stages:

1. During the screening stage to inform the terms of reference for the ESIA
2. On-going consultation during the ESIA study
3. During public hearings following submission of the ESIA

Following submission of the Project Brief (a summary of information about the Project and the ESIA), RDB, who are responsible for the ESIA process, will publish the Project Brief and determine if a public hearing is necessary at this stage. This can include meeting with local communities and stakeholders to explain the ESIA process.

During the ESIA process, ESIA experts are required to seek the views of persons who may be affected by the Project. This will be performed particularly during the scoping phase of the Project in order to identify any significant issues, and at any other crucial stages considered necessary by the Permitting Authority (RDB).

Following submission of the ESIA to the authorities, the report is made available for public review before a public hearing is held. The purpose of a public hearing is to provide interested and affected parties and the public with an opportunity to comment on, or raise issues relevant to an application for environmental authorization. The range of individuals, agencies and organizations to be involved in public hearings should include as a minimum: government ministries likely to have their areas of responsibilities affected by the Project; the local government body with jurisdiction over the area where the Project is proposed; environmental committees; trade associations; local communities; non-governmental organizations; and the Developer. After the public hearing and following approval and issuance of the ESIA Clearance Certificate by the RDB, the Project Developer is required to make the ESIA non-technical summary (NTS) available to the public by announcing the project in local newspapers as well as the location at which the ESIA NTS can be found. The ESIA NTS must remain available at RDB for at least 120 days.

(8) Brief Summary of Resettlement Policy Framework

1) Justification for and Scope of the Resettlement Policy Framework (RPF)

The Resettlement Policy Framework (RPF) provides guidelines for development of appropriate mitigation and compensation measures, for the impacts caused by future project activities whose exact locations are not known. This RPF is the instrument through which the project's environmental and social impacts are identified, assessed, evaluated and have appropriate mitigation, management and monitoring measures, designed and incorporated within the sub project itself.

2) Objectives and Principles of Resettlement Planning

This Resettlement Policy Framework (RPF) outlines the principles and procedures to ensure that if resettlement needs are identified, then the project follows the procedures for involuntary resettlement in compliance with the Government's own applicable laws and regulations along with the WB's policy OP 4.12 on Involuntary Resettlement. The RPF sets out the legal framework, eligibility criteria of displaced population, valuation methodology, compensation provision, entitlement matrix, implementation process, consultation procedures, grievance remedy mechanisms, entitlement payment procedures, and monitoring-evaluation procedures for land acquisition and resettlement under this project.

The basic objectives of the RPF are to:

1. Guide the in properly identifying, compensating, and restoring the livelihoods of Project Affected Persons (PAPs),

2. Serve as a binding document to ensure payment of compensation and assistance to PAPs, and
3. Provide direction in preparing, updating, implementing and monitoring project RAPs.

(9) Monitoring Plan

The Environmental Monitoring Plan to be implemented during different phases of the project must take into account the characteristics of each project and the environmental situation of the area where the project is located. This plan is a technical mechanism for environmental control in determining and assessing parameters when monitoring the quality of different environmental factors, as well as the control systems and measurement of these parameters (Table 3-1).

Table 3-2 Environmental monitoring plan

Item	Parameter	Exploration, drilling and construction	Operation
Air Quality	H_2S	Location: 2-4 points in the surroundings of the drilling fields and 1-4 point in nearby house and public infrastructure of each community. Frequency: Monthly.	Location: 2-4 points in the surroundings of the plant and drilling fields and 1 point in nearby house or each community. Frequency: Monthly.
	PM_{10}, $PM_{2.5}$, NO_X	Location: 2-4 points in the surroundings of the plant construction site and 3 points in accesses roads. Frequency: Quarterly.	-
Noise	Noise level	Location: 4 points in the surroundings of the plant construction site and 1 point in each sensitive area (nearby house or community). Frequency: Quarterly.	Location: 4 points in the boundary of the plant site and 1 point in each sensitive area (nearby house or community). Frequency: Quarterly.
Surface Water Quality	Parameter of Rwanda standard	Location: Surroundings the plant construction site upstream and downstream of river and lakes. Frequency: Quarterly.	Location: Surroundings the plant upstream and downstream of river and lakes. Frequency: Quarterly.
Groundwater Quality	Parameter of Rwanda standard groundwater and high altitude wetlands levels	Location: 1-3 points in the surroundings of the project area (if there are well and lakes or wetlands) Frequency: Quarterly (water quality), Level (monthly).	Location: 1-3 points in the surroundings of the Plant and wells pad (if there are well and lakes or wetlands) Frequency: Quarterly (water quality), Level (monthly).
Effluents quality	Water temperature, pH, SS, BOD_5 and Oil and Grease	Location: Temporary grit chamber outlet Frequency: Monthly.	Location: Plant and domestic effluents outlet Frequency: Quarterly.

Item	Parameter	Exploration, drilling and construction	Operation
Hot spring	Temperature, pH, EC, Na^+, Ca^{2+}, Cl^-, SO_4^{2-}, etc. and volume.	Location: Hot spring in the surroundings of the project area. Frequency: Monthly (before drilling started 3 months and exploration, drilling period). Evaluation method: Comparative analysis of survey results.	Location: Hot spring in the surroundings of the plant and well pad. Frequency: Quarterly period. Evaluation method: Analysis of survey results over time.
	H_2S (The case of in which H_2S was detected)	Location: Gushing point of hot spring in the surroundings of the project area. Frequency: Monthly (before drilling started 3 months and exploration, drilling period). Evaluation method: Comparative analysis of survey results.	Location: Gushing point of hot spring in the surroundings of the plant and well pad. Frequency: Quarterly period. Evaluation method: Analysis of survey results over time.
Subsidence	Ground elevation	Location: 4-6 points in the surroundings of the plant and well pad and 2-4 point in settlement site Frequency: Annually. Methods of measurement: Land elevation of the point from leveling. Evaluation method: Comparative analysis of survey results	
Flora, Fauna (If rare species are there)	Flora, Fauna (including birds) and diversity of flora and fauna.	Location: EIA baseline survey sites. Frequency: Twice a year (Rainy and dry seasons during the construction period) Survey of mountain gorilla movements before, during and after the development work	Location: EIA baseline survey sites. Frequency: Twice a year (Rainy and dry seasons) Survey of mountain gorilla movements
Hydrobiology	Algae and benthos and the relative abundance in the case of fauna.	Location: Surroundings the plant construction site upstream and downstream of rive and lakes. Frequency: 2 Twice a year ((Rainy and dry seasons during the construction period)	Location: Surroundings the plant site upstream and downstream of rive and lakes. Frequency: Twice a year (Rainy and dry seasons)
Archeological	Effect of archeological sites and cultural heritage	Location: Archeological and cultural heritage sites Frequency: 2 Twice a year ((Rainy and dry seasons during the	Location: Archeological and cultural heritage sites Frequency: 2 Twice a year ((Rainy and dry seasons during the

Item	Parameter	Exploration, drilling and construction	Operation
		construction period)	construction period)

(10) Recommendation on Environmental and Social Considerations through Geothermal Development

Potential local development advantages brought by geothermal development are significant, and include: job creation; the construction of infrastructure and public facilities; the production of dried agricultural products such as tea, pyrethrum and coffee achieved by utilizing waste heat and electricity; greenhouse cultivation; and groundwater being pumped up for use in agricultural irrigation. Considering the local context of Rwanda, we can propose the following activities for local development.

1) Linkage with Gorilla Conservation

Currently, farmlands in Kinigi extend up to the border of Volcanoes National Park, where protected mountain gorillas are located. Through our field survey, agricultural activities were observed near the park border. According to one NGO dealing with mountain gorilla conservation, there are some problematic cases where either local farmers enter the park, or gorillas come out of the park and enter the farms. For geothermal development in Kinigi, we recommend purchasing farmland near the national park border and using it as a buffer zone. This could have a positive impact on gorilla conservation, and help avoid the overlapping movements of humans and gorillas. Additionally, it might be a good idea to recruit local farmers for use as nature conservation field staff and nature guides. Then, we can ask them not only to protect the natural resources of the area but also to play a key role in building awareness of environmental protection with local farmers and citizens.

2) Prevention of Soil Erosion and Dust Emission

Potential geothermal development sites are located in rural areas, where there is a great deal of exposed ground, unpaved roads, and points of soil erosion at sloped surfaces alongside roads. As a result, the water in nearby rivers and creeks is filled with suspensions from the eroded soil. More specifically, in Bugarama, there is a major cement factory where many large trucks are used to transport cement products. The major roads there are unpaved, and dust raised by truck traffic is a serious concern. When we conduct geothermal development, we must implement various environmental protection measures starting from the time of geothermal facility construction. These measures could include tree planting, the improvement of exposed ground, the paving of roads, and the protection of sloped surfaces. This would contribute to an improved living environment in the community and the prevention of soil erosion, which is one of the key environmental challenges in Rwanda. When doing this, it is essential to work together with local citizens, local governments, and the nearby private sector, after first building consensus.

3) Networking of Potential Local Resources

The northern area (i.e. Kinigi and Gisenyi) and southern area (i.e. Bugarama) are home to many potential ecotourism and techno-tourism resources that are in need of development (or renovation) and better networks. A combination of various development activities, such as the preparation of scenic points, promotion of local cultural assets, identification of academically valuable sightseeing spots and improvement of access roads, would be needed to attract visitors to the area. These activities must also consider other development projects, including tourism development at Lake Kivu and the cable car installation at Mt. Karisimbi.

In the northern area, linkage with existing mountain gorilla tourism is important, as well. Although it is difficult to increase the numbers of gorilla visitors under current conditions (according to an NGO involved in mountain gorilla conservation), our geothermal project can provide technical and financial support to construct infrastructure that will minimize the negative impact on mountain gorillas. This may include helping to build tourist facilities, a spa, roads, and other projects which could enhance the gorilla conservation activities of NGOs and NPOs. The geothermal plant can also be a hub for networking. We can design the facility to promote tourism, along with gorilla conservation, by adding an environmental awareness education program, shops for local products and other such enhancements to the facility. By using these efforts to differentiate Rwanda mountain gorilla tourism from that of the neighboring countries, we could contribute not only to local development but to the development of the country as a whole.

4) Protection and utilization of the Ecosystem Service

Recently, natural ecosystems are being re-evaluated globally from the point of view of their economic value, and this viewpoint reaffirms the concept that the ecosystem is providing various benefits to the human society (Ecosystem Service) and that it supports human well-being. The value of the global ecosystem service is estimated as 33 trillion US dollars on average per year, and financial trading of the service is emerging (Ecosystem Service Trade-Off). Precious ecosystems are well preserved in many areas in Rwanda, and recognizing those systems as a national asset and protecting/utilizing them would contribute to Rwanda's national development.

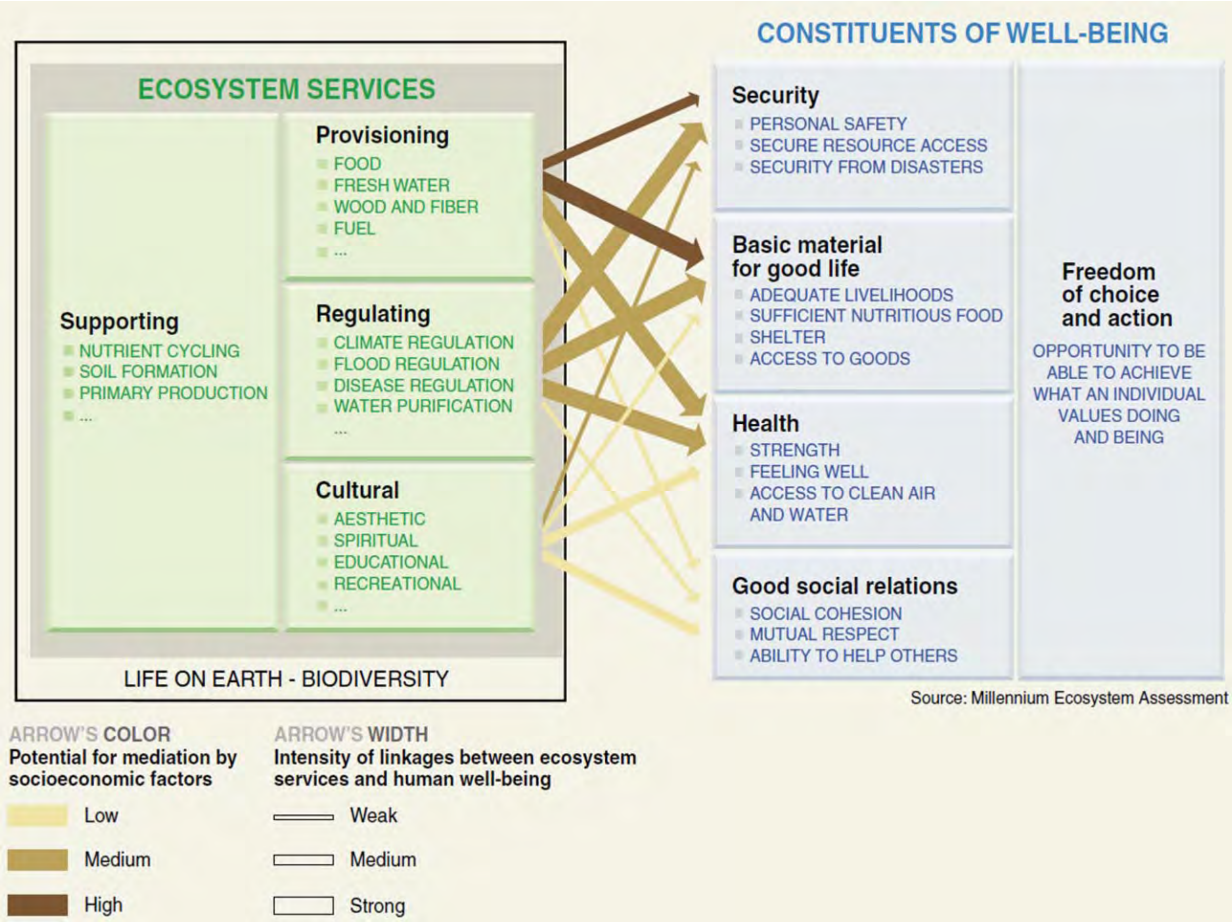


Fig. 3-5 Ecosystem Servic

Abbreviations and Acronyms

Abbreviations and Acronyms	Definition
AFD	Agence Française de Développement
AfDB	African Development Bank
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources of Germany)
BRGM	Bureau de Recherches Géologiques et Minières
BTC	Belgian Development Agency
CDM	Clean Development Mechanism
CEPGL	Communaute Economique des Pays des Grands Lacs (the Economic Community of the Great Lakes Countries)
CITES	Convention on International Trade in Endangered Species
CO	Carbon monoxide
CO2	Carbon dioxide
DFID	Department for International Development
DRC	Democratic Republic of the Congo
EAC	East African Community
EAPP	East African Power Pool
EARP	Electricity Access Roll-out Program
EDPRS	Economic Development and Poverty Reduction Strategy
EDCL	Energy Development Corporation Limited
EGL	Energie des Grands Lacs
EIA	Environmental Impact Assessment
EIACA	Environmental Impact Assessment certificate of authorisation
EIR	Environmental Impact Assesment Report
EMP	Environmental Management Plan
Ep-he	Electrostatic precipitator – high efficiency
EP-le	Electrostatic precipitator – lower efficiency
ESIA	Environmental and Social Impact Assessment
ESME	Energy Small and Medium-Sized Enterprises
ESSP	Energy Sector Strategic Plan
EU	European Union
EUCL	Energy Utility Corporation Limited
EUEIPDF	EU Energy Initiative Partnership Dialogue Facility
EWSA	Energy Water and Sanitation Authority
FF-jp	Fabric filter – sleeve type/jet pulse cleaning
FF-sm	Fabric filter – sheet type/mech. Rapping
FMO	Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden
GEAC	Geothermal Energy Advisory Committee
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GRMF	Geothermal Risk Mitigation Facility
ICEIDA	Icelandic International Development Agency
IESE	Institute of Earth Science and Engineering
IL	Impact Level
ITER	Institute of Technology and Renewable Energy
IMF	International Monetary Fund
IPP	Independent Power Producer
ISOR	Islenskar Orkurannsoknir (Iceland geosurvey)
IUCN	The International Union for Conservation of Nature
KenGen	Kenya Electricity Generating Company

KfW	Kreditanstalt fur Wiederaufbau
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Governance
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources
MINECOFIN	Ministry of Finance and Economic Planning
MLTC	Multiclone
MOU	Memorandum of Understanding
NAFA	National Forestry Authority
NAS	National Agriculture Survey
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NGO	Non Governmental Organizations
NOx	Oxides of Nitrogen
NPE	National Policy on Environment
NSGRP	National Strategy for Growth and Reduction of Poverty
NTS	non-technical summary
ORTPN	The Office of Tourism and National Parks
PM2.5	Particulate Matter 2.5
PPA	Power Purchase Agreement
REMA	Rwanda Environment Management Authority
RBS	Rwanda Bureau of Standards
RDB	Rwanda Development Board
REG	Rwanda Energy Group
RNRA	Rwanda Natural Resources Authority
RPM	Respirable particulate matter
RURA	Rwanda Utilities Regulatory Authority
SEA	Strategic Environmental Assessment
SOx	Sulphur oxides
SPM	Suspended particulate matter
SWG	Sector Working Group
TICAD	Tokyo International Conference on African Development
ToR	Terms of Reference
UniServices	Auckland UniServices Limited
WB	World Bank

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1. Introduction

1.1. Project Background

Electrical power consumption per capita in Rwanda is extremely low comparing with other East African countries, electricity energy consumption accounts for only 4 % of the national energy consumption and 84 % of whole energy consumption is provided by traditional biomass sources such as charcoal and wood.

Electrical power generated has been increased since 2004, when the serious power shortage occurred, however, the indexes of power supply, such as an electrification rate of 16 % and installed capacity of 110 MW as of the year of the project started and of 22 % and of 140MW respectively in 2014, are still at the lower end and indicate insufficient power supply to meet increasing power demand that results from a consistently growing economy and improved living standards.

The power generation plants in Rwanda consists mainly of hydro (54 %) and diesel (46 %), and thus the country faces a big challenge to raise foreign currency to import fossil fuel whose prices on the world market are incessantly surging.

Under these circumstances, Rwanda is planning to increase the installed capacity and diversify energy resources by utilizing indigenous resources in accordance with the “Vision 2020” and “Economic Development and Poverty Reduction Strategy” as the national development plan and “Electric Development Strategy” as the sector development plan. In order to achieve the targeted increased and diversified electrical energy sector, a well prepared concrete electricity master plan is mandatory. However, the existing electricity development master plan is insufficient due to the electricity demand forecast included in the plan has not been authorized.

Since geothermal power is a clean, reliable and indigenous energy resource which is not influenced by short-term fluctuations on the international market and by climate, Government of Rwanda (GOR) considers geothermal development as a key component of its sustainable energy future and power security. According to the previous studies, Rwanda’s geothermal power generation potential has been estimated at more than 700 MWe and 300 MWe or more is expected as the least cost for base load operation.

In response to these situations, GOR is promoting geothermal power development by mainly Ministry of Infrastructure (MININFRA) and Energy and Water Sanitation Authority (EWSA) (EWSA has been restructured and Rwanda Energy Group (REG) has been taking the place of the working on the energy since 2014), but the development is in the early stages yet, and initial exploration well drilling is underway. In addition, there are few experts with adequate knowledge of geothermal power generation in Rwanda government agencies.

In the above context, the GOR has requested the GOJ on the Project for the Preparation of an Electricity Development Plan for Sustainable Geothermal Energy Development and its integration into the

Electricity Master Plan. The project will also include capacity development of counterpart personnel by JICA experts through on-the-job-training during the project period.

1.2. Project Objectives

The objectives of the project is a formulation of electricity development plan integrating geothermal energy development by which the existing electricity development plan of Rwanda review and preparation of geothermal development plan, by means of making priorities in terms of unified standards, promising and necessity on the basis of the survey and study results, as well as construction of databases both for electricity and geothermal development, in taking into consideration the project background mentioned above. Furthermore, the capacity building of the counter parts is considered through joint study activities at the every phase of the project.

1.3. Project Implementation and Schedule

1.3.1. Content of Project Implementation

The project implementation method is indicated in the project implementation flowchart as shown in Fig. 1-3.1. The study activities are classified into: 1) study for electricity development plan; 2) study for geothermal power development plan; and 3) study for environmental and society consideration.

(1) **Study related to electricity development plan**

1) [The 1st year work (Fiscal year 2013)] Collection and organization of existing information relating to electricity development plan
   - Collection and review of existing data
   - Discussion on the Inception report and data/information collection
   - Study toward power demand forecast

2) [The 2nd year work (Fiscal year 2014)] Establishment of electricity development plan
   - Power demand forecast
   - Study on power plant development and transmission line development
   - Power system analysis
   - Establishment of electricity development plan (consolidated plan of power sources and transmission system development)
   - Construction of database for electricity development plan
   - Recommendation on electricity policy and organization

(2) **Study related to geothermal development plan**

1) [The 1st year work (Fiscal year 2013)] Collection and review of data and information on geothermal development
   - Collection and review of existing data
   - Discussion on the Inception report and data/information collection

- Preliminary study of geothermal resource assessment

2) [The 2nd year work (Fiscal year 2014)] Formulation of geothermal development plan
   - Discussion on Progress report and data/information collection
   - Geothermal resource assessment
   - Study for multi-purposes utilization of geothermal resource
   - Construction of geothermal development database
   - Formulation of geothermal development plan

3) [The 3rd year work (Fiscal year 2015)] Supplemental survey in Kinigi
   - Preparation of geological and geophysical surveys
   - Geological and geophysical surveys
   - Assistance in update of geothermal conceptual model

(3) **Study of environmental and social considerations**

1) [The 1st year work (Fiscal year 2013)] Collection and organization of existing information associated with environmental and social considerations
   - Collection and organization of existing information
   - Discussion on the Inception report and data/information collection
   - Scoping for environmental and social considerations
   - Organizing items that need to be surveyed

2) [The 2nd year work (Fiscal year 2014)] Surveys on Environmental and Social Considerations
   - Environmental and social considerations survey and evaluation results
   - Analysis of impact avoidance and mitigation measures
   - Analysis of alternative plans
   - Study of land acquisition and resettlement of residents
   - Study of monitoring plan

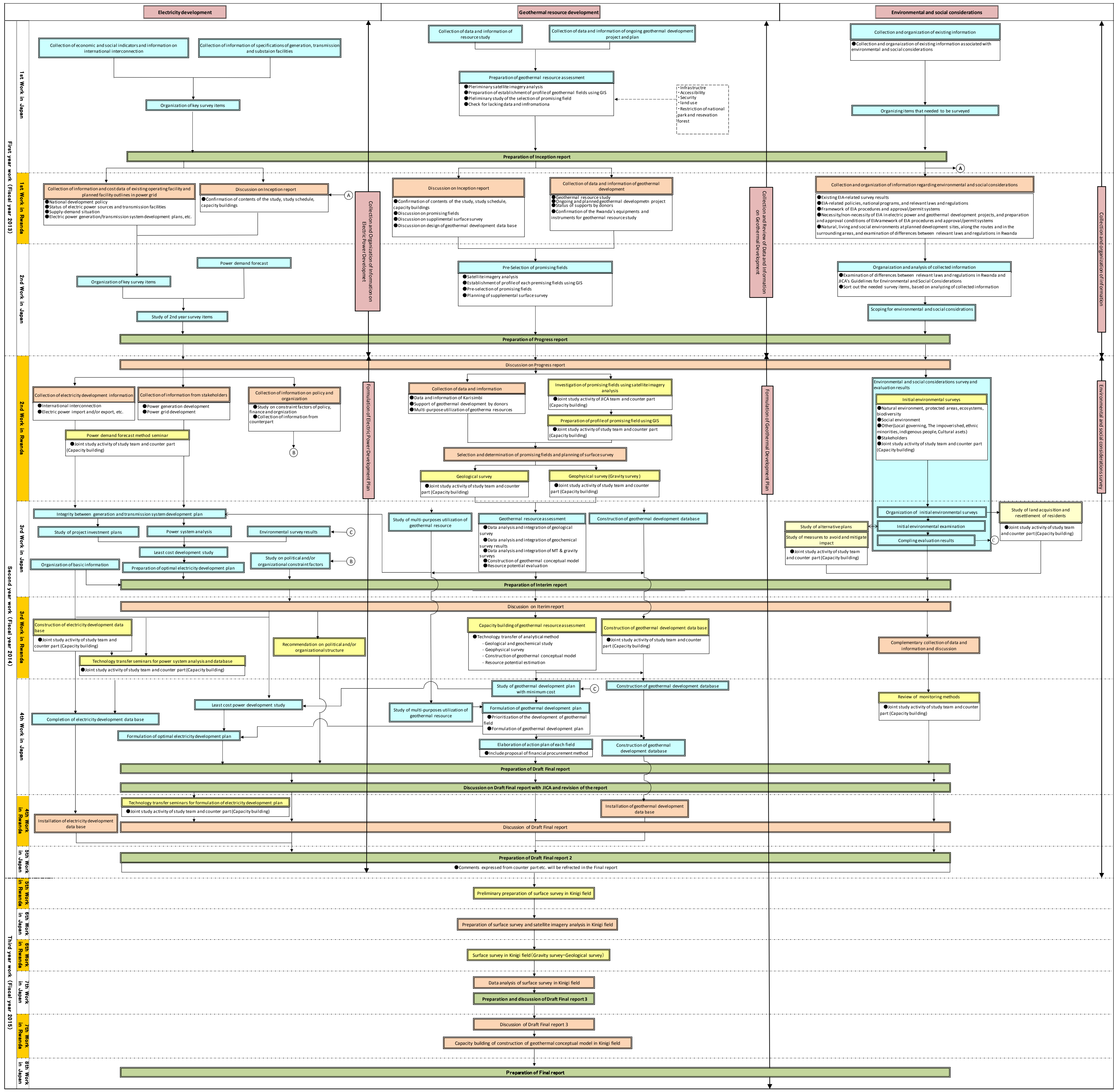


Fig. 1-3.1 Flowchart of project implementation

1.3.2. Project Schedule

The schedule of the project is shown in Fig. 1-3.2.

In the 1st work in Rwanda, explanation and discussion of the inception report for Rwanda side were conducted. In addition, collection of data and information for study, and preliminary examination on electricity development, geothermal resource assessment and environmental and social consideration were conducted.

In the 2nd work in Rwanda, discussions on the preliminary examination made in the 2nd work in Japan, supplemental site survey of candidate geothermal area and additional data collection were conducted.

In the 3rd work in Japan, preparation of the electricity development master plan formulation, assessment of the geothermal resource and examination of the environmental site survey report performed by the local consultant were conducted.

In the 3rd work in Rwanda, discussions on the electricity demand forecast and the assessment of geothermal resource were conducted.

In the 4th work in Japan, studies on the electricity development master plan and the geothermal development action plan and preliminary assessment of the environment for the geothermal promising area were conducted. Furthermore, the databases of electricity master plan and geothermal master plan were prepared.

In the 4th work in Rwanda, discussions on Final Draft Report, in which all studies made during the project period were integrated, were conducted.

In the 5th work in Japan, Draft Final Report 2 was prepared to reflect the comments on Draft Final Report.

In the 5th work in Rwanda, discussion on the plan of supplemental survey (gravity and geological surveys) in Kinigi and the preliminary preparation for field survey including the transportation of equipment were also conducted. In addition, the technology transfer related to geological and gravity surveys was performed.

In the 6th work in Japan, the supplementary survey preparation and the satellite image analysis were conducted.

In the 6th work in Rwanda, geological and gravity surveys in Kinigi were conducted. The technology transfer of techniques related to field surveys and data analysis was also executed.

In the 7th work in Japan, the geothermal conceptual model was constructed after the analysis of data obtained from geological and gravity surveys in Kinigi. Afterwards, Draft Final Report 3 was prepared based on these analytical results.

In the 7th work in Rwanda, discussion of Draft Final Report 3 was conducted. Also, assistance was provided for the construction of the geothermal conceptual model of Kinigi.

In the 8th work in Japan, the Final Report was prepared reflecting the comments on Draft Final Report 3.

1.3.3. Organization of JICA Survey team

The JICA survey team member is shown in Table 1-3.1.

1.4. General Outline of Progress on the Project

The Project was launched in December 2013, the 1st work in Rwanda was conducted in January 2014 after the 1st work in Japan including collection and review of existing data, preparation of the inception report.

In the 1st and 2nd year works in Rwanda, beginning from explanation of the inception report, collecting the information and materials through both discussions with counterparts and site surveys which include gravity survey in Bugarama area and supplemental surveys in promising geothermal area were performed. In addition, sharing information about the project through Sector Working Group (SWG) with other donors for upcoming electricity and geothermal development.

By considering the collected information and materials, two master plans have been formulated, one is the geothermal development action plan in which the evaluation result of the geothermal energy in Rwanda is reflected and the other is the electricity master plan in which the result of geothermal action plan is integrated.

Capacity building to the counterparts has been implemented by means of collaborative works during the supplemental survey and holding the workshop in each stage of the study.

In the 3rd year work in Rwanda, geological and gravity surveys in Kinigi were conducted by the JICA study team and staff members of GDU, and the technology transfer of techniques related to field surveys and data analysis was also executed. Furthermore, discussion on Draft Final Report 3 was conducted with staff members of GDU, and assistance was also provided in the construction of the geothermal conceptual model of Kinigi.

As for environmental and social consideration, preliminary environmental assessment for the geothermal promising areas was conducted after collecting data and information.

The following is general outline of progress on each expert teams.

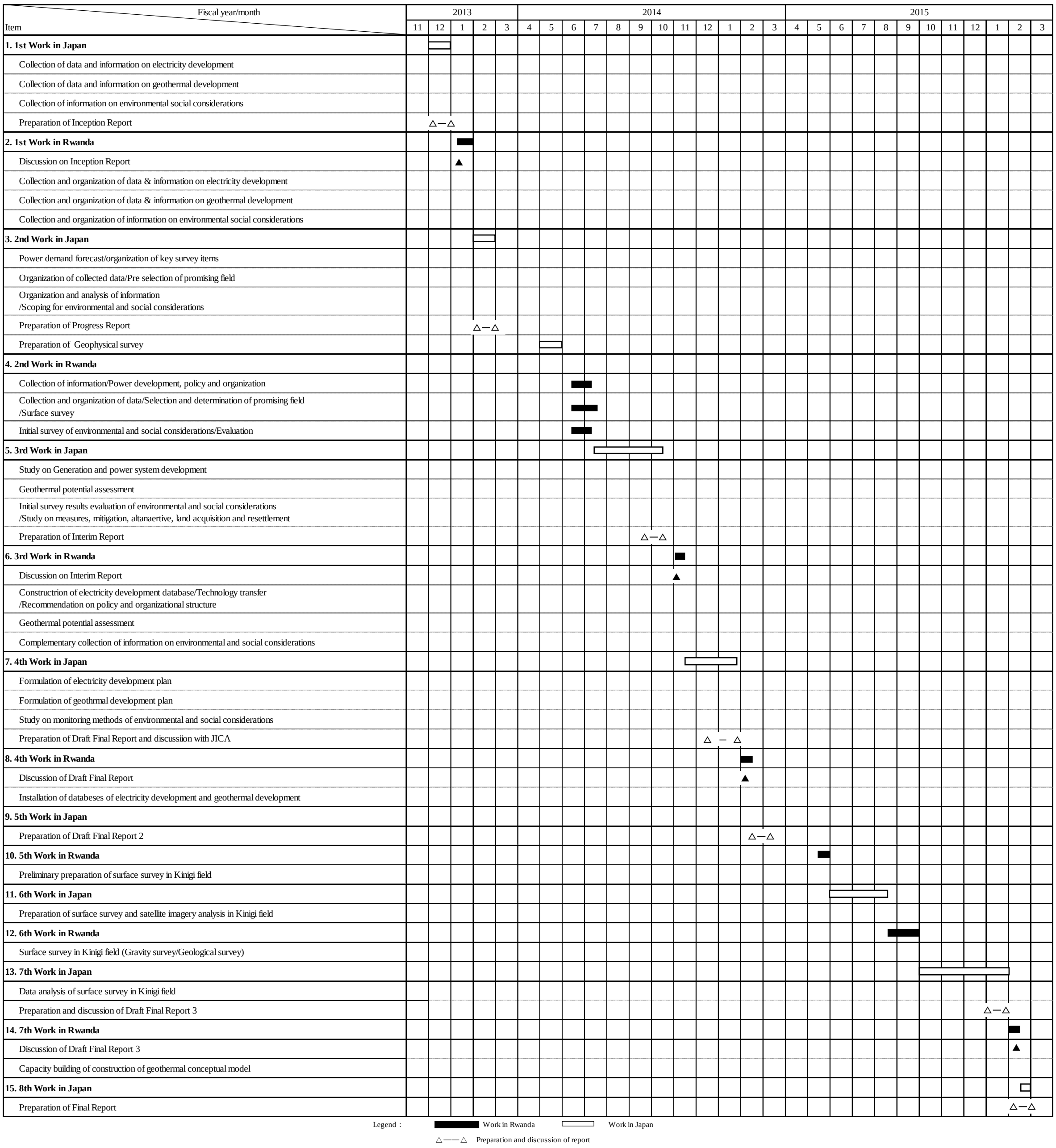


Fig. 1-3.2 Project implementation schedule

1.4.1. Study Related to Generation and Electricity System Development Plan

The requirements against inception report were subjected from Rwanda side as following, and accepted by JICA study team.

1. Flexible response for the Project implementation to suit actual condition of EWSA
2. Addition of study for international grid connection
3 Integration of power demand stated in EDPRS II and EARP into power demand forecast

In the 2nd work in Rwanda, the JICA study team discussed about the power demand forecast with Rwanda side and obtained the agreement on the method of forecasting, however additional scenario which corresponds to the government target that reaches electricity demand of 463 MW in 2017 was requested and the team agreed to add. In addition, site survey of several stations was conducted such as methane gas combustion power station construction project site beside Kivu Lake and existing substations for collecting information and data for further study.

In the 3rd work in Japan, the preparation works for least cost development plan of generators such as calculation sheet preparation and collected data analysis, and configuration of power system model in the power system simulation application software were conducted in order to accommodate the geothermal power development plan which would be made after geothermal potential assessment works.

In the 3rd work in Rwanda, discussions on the electricity load demand forecast were made and the values were agreed with the counterparts for further studies of electricity development plan. In addition, the method of demand forecast has been transferred through the workshop to the counterparts for future prediction.

With respect to collection of data and information, the necessary information was obtained by questionnaire but not everything could be obtained by reason of organization change in counterpart or obstacles of management method. Thus, it was agreed that alternative figures could be utilized in the studies if the data were unavailable.

The generation development plan was considered to utilize Rwanda's resources effectively including peat and methane gas based on the judgment from the viewpoints of technical, price, operational and environmental.

In the 4th work in Rwanda, discussions on Draft Final Report were conducted. In addition, two kinds of workshops as a technology transfer on the least cost power development methodology and on the power information databases constructed by JICA study team were performed. The comments on the scenario of the power development plan had been provided from MININFRA and REG at the meetings and the workshop, and those were reflected to Draft Final Report 2 after reviewing the existing development plan utilizing the least cost development methodology that was shared with the counterparts during workshop.

EWSA was already restructured and new companies EUCL and EDCL in REG were established as independent energy section, but the detailed organizational and operational system are underway of constructing step by step. For those reason, the recommendation for electricity policy/scheme/organization are tentative at present.

1.4.2. Study Related to Geothermal Development Plan

In the 1st work in Rwanda the requirements against inception report were subjected from Rwanda side as following, and accepted by JICA study team.

1. Flexible arrangement for the Project implementation schedule to suit preparation of geothermal development roadmap (MININFRA)

2. re-analysis for existing data in northwest geothermal candidate point and re-study for geothermal conceptual model (EWSA)

3 re-examination for items of surface exploration associated with conducting re-analysis above.

However, JICA survey team explained that it was difficult to change expected schedule by EWSA to the Project. On the other hand, re-analysis for existing data required by MININFRA was conducted in the 3rd work in Japan in terms of potential evaluation.

In the 2nd work in Rwanda, supplemental site surveys of geological and geochemical at the area of Karisimbi, Kinigi, Gisenyi, Bugarama, etc. were conducted in accordance with the discussion results in 1st work in Rwanda. As for surface geophysical exploration, gravity survey in Bugarama area was conducted considering support contents which have been made by other donors. Those site surveys were conducted together with EWSA staff in view point of technical transfer.

In the 3rd work in Japan, JICA study team conducted evaluation of geothermal potential at five (5) areas with construction of conceptual geothermal model. The results of previous surveys which the team conducted and re-analysis of MT exploration data in north-west area of Rwanda were utilized for construction of the conceptual geothermal model.

The exploration data of wells drilled in the Karisimbi (KW-01 and KW-02) were analyzed, but the data as evaluated a promising geothermal reservoir could not be obtained.

With respect to collection of data/information, the necessary information was obtained substantially by questionnaire prepared in advance, but some specially related to the results of KW-02 are still necessary to follow.

In the 3rd work in Rwanda, JICA study team explained the content of Interim report to MININFRA, REG and Energy Sector Working Group and especially discussed on the geothermal resource assessment results. Afterwards, the capacity building of the technical method on geological, geochemical, geophysical survey and resource evaluation was conducted to staffs of GDU in REG. Geothermal development plan including action plan of each geothermal field, especially necessary exploration activity in each field, were discussed together with JICA study team and staffs of GDU.

In the 4th work in Japan, JICA study team conducted the study for multi-purpose utilization of geothermal resources, the formulation of geothermal development plan and the construction of geothermal development database.

In the 4th work in Rwanda, JICA study team discussed about the content of Draft Final report with MININFRA, REG and Energy Sector Working Group. Afterwards, the capacity building on the multipurpose utilization of geothermal energy and on the utilization of geothermal data base was conducted to staffs of GDU in REG. Finally geothermal development plan including action plan of each geothermal field, especially necessary exploration activity in each field, were formulated by JICA study team and staffs of GDU. The results of those discussions and activities were reflected in Draft Final Report 2.

In the 5th work in Rwanda, discussion on the plan of supplemental survey (gravity and geological surveys) in Kinigi and the preliminary preparation for field survey including the transportation of equipment were also conducted with staffs of GDU. In addition, the technology transfer related to geological and gravity surveys was performed.

In the 6th work in Japan, the supplementary survey preparation and the satellite image analysis were conducted.

In the 6th work in Rwanda, geological and gravity surveys in Kinigi were conducted with JICA study team and staffs of GDU. The technology transfer related to field survey and data analysis was also executed.

In the 7th work in Japan, tthe geothermal conceptual model was constructed after the analysis of data obtained by geological and gravity surveys in Kinigi. Afterwards Draft Final Report 3 was prepared based on these analysis results.

In the 7th work in Rwanda, discussion on Draft Final Report 3 was conducted with staffs of GDU. Also the assistance for the construction of the geothermal conceptual model of Kinigi was conducted.

In the 8th work in Japan, Final Report was prepared to reflect the comments on Draft Final Report 3.

1.4.3. Study of Environmental and Social Consideration

The comment on the inception report was not remarked from Rwanda side with respect to environmental and social considerations.

In the 1st and 2nd works in Rwanda, the documents and information were obtained such as laws and regulations related to EIA activities, EIA reports of power development projects, the environmental information about the water quality and biological diversity in Rwanda, procedures to obtain environmental standards, etc. The information obtained was organaized and summarized in the report.

Scoping works were made for survey before 2nd work in Rwanda and supplemental research and evaluation of environmental and social considerations were started in the 2nd work in Rwanda by local environmental consultants who are under contract and instruction of JICA study team.

By consideration of the results of above information, preliminary environmental assessment for the geothermal promising areas was conducted.

In the 4th work in Rwanda, the reactions toward the comments on the preliminary environmental assessment from REG were discussed. The results of the discussions were reflected in Draft Final Report 2.

Table 1-3.1 JICA survey team member

Name	Specialty	Assignment
Keiichiro OHASHI	Team Leader / Power development planning	General control of the project, power development planning and overall control, transfer of technology
Yasuhiro FURUNO	Load demand forecast / Construction of database A	Study of load demand situation , load demand forecast (20 years), construction of database, transfer of technology
Hiroshi FUCHINO	Power generation planning / Power system planning A	Power generation planning, collecting data regarding power system planning, power system planning, transfer of technology
Kiyotaka TOKIMOTO	Power system planning B/ Construction of database B	Collecting and analyzing data regarding power system, power system analysis, construction of database, transfer of technology
Katsumi YOSHIDA	Policy analysis and institution arrangement / Investment planning and financial and economic analysis	Collecting and analyzing data regarding electricity policy, institution and organization, research and examination of the legal framework relating to geothermal power development, economical evaluation, investment planning, transfer of technology
Tetsuya YAHARA	Sub- Team Leader, geothermal resource evaluation	Geothermal reservoir analysis, resource potential evaluation, geothermal development plan, technical transfer
Yoshio SOEDA	Geological survey A/ Database B	Integration of geological survey results, analysis of geological structures, construction of geothermal conceptual models, geothermal development plan, geothermal development database, technical transfer
Soichiro KAGEYAMA	Geological survey B	Satellite imagery analysis, preparation of profile using GIS, geological survey, analysis of geological structures, technical transfer
Noriaki UCHIYAMA	Geochemical survey A	Geochemical survey and data analysis, resource potential evaluation, geothermal development plan, technical transfer
Takehiro KOSEKI	Geochemical survey B/ Geological survey A/ Database B	Geochemical data analysis, integration of geological survey results, construction of geothermal conceptual models, technical transfer
Mitsuru HONDA	Geophysical survey A	Geophysical survey (Gravity survey), gravity survey data analysis and evaluation, MT/TEM data process and reanalysis, technical transfer

Susumu ENDO	Geophysical survey B	Geophysical survey (Gravity survey), gravity survey data analysis, technical transfer
Hiroki SAITO	Geophysical survey C	Geophysical survey (Gravity survey), gravity survey data analysis, evaluation and reanalysis
Koichi TAGOMORI	Geophysical survey D	MT/TEM data process and reanalysis, gravity survey data analysis and evaluation, geophysical survey analysis evaluation
Haruhiro INAGAKI	Assistant of geophysical survey	Assistant of gravity survey data analysis
Tomonori IDE	Geophysical survey E	MT/TEM data process and reanalysis, gravity survey data analysis
Norio SHIGETOMI	Geothermal multi-purpose utilization plan	Study of multi-purpose utilization of geothermal resources
Yasushi ISERI	Environmental and social consideration	Study of environmental and social consideration, technical transfer

2. Study of Electricity Development Plan

2.1. Institutional and Organizational Framework in Electric Power Sector

2.1.1. Roles and Responsibilities

Ministry of Infrastructure (MININFRA) is mainly in charge of electric power sector, and the government policy for developing power generation and electricity supply are implemented by the Energy Water and Sanitation Authority (ESWA)as of July 2014.

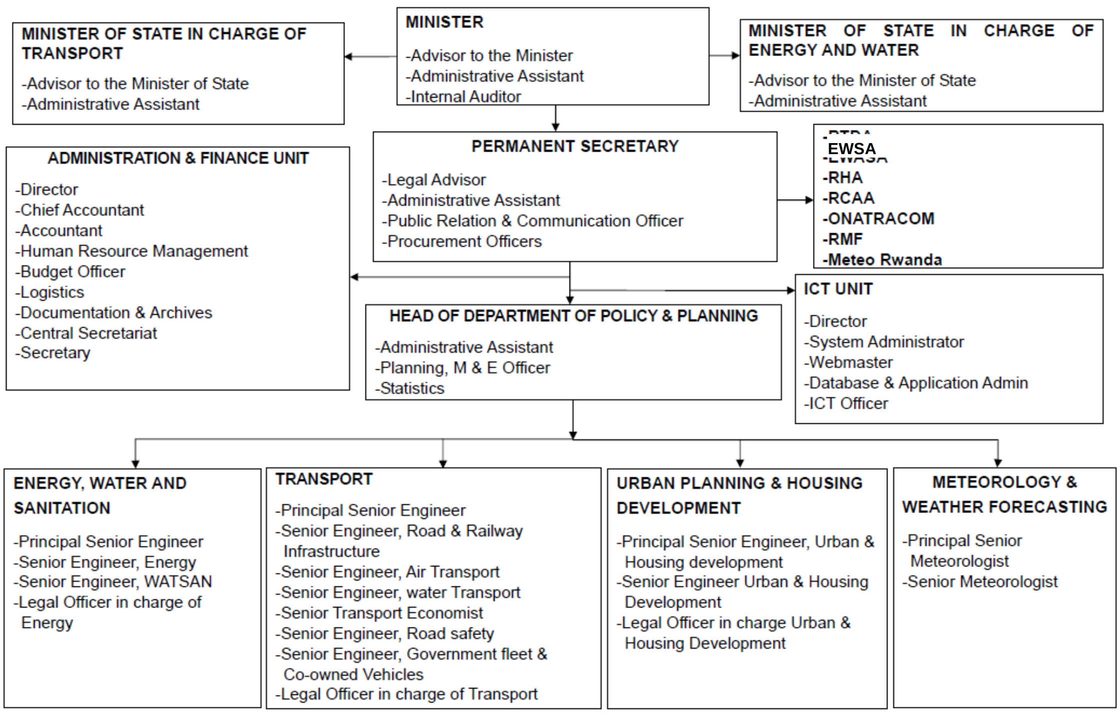
Although, in the process of the on-going reform of electric power sector, Rwanda Energy Group Limited (REG) which succeeds to EWSA, has been established due to the annihilation of EWSA law in August, 2014, the formulation of REG has not been completed yet with step by step approach. Therefore, the proposals regarding the institutional and organizational framework in this report, are considered due to the review of EWSA which had supplied electricity in the past 3 years, with the latest information of REG.

(1) MININFRA

MININFRA is as the lead ministry of energy and infrastructure, covers development, institutional and legal frameworks, national policies, strategies and master plans.

Specifically rolls on energy sector of MINIFRA are follows:

- To develop institutional and legal frameworks, policies, strategies and master plans relating to the energy sector
- To initiate the development of national energy infrastructure
- To initiate, and monitor the supply of sustainable power generation facilities and uninterrupted energy for the country and the region
- To design and implement programs to enhance human resource capacities in the entire energy sub-sectors
- To supervise, monitor and assess the implementation of national policies and programs on matters relating to energy
- To lead in resource mobilization and partnerships in the area of energy at a national and regional level



Source: MINIINFRA Web Site *Official Gazette nº Special of 21 June 2012* ANNEX I

Fig. 2-1.1 MININFRA Organization Chart

(2) EWSA

Following the law on 7/Dec/2010, two national parastatal in charge of energy and water distribution (RECO& RWASCO) respectively were merged into one multi-utility authority in the names of EWSA. The mission of EWSA is to implement government policy for developing energy, water and sanitation sectors.

EWSA's key roles specifically on energy were followings:

- Coordinating the implementation of all activities related to and programs aimed at development and exploitation of energy sources
- Conducting analytical studies on energy supplies and demand, evaluation and programming of actions for energy sector activities
- Protection of Lake Kivu and its shores, and the environment around the lake during and after Methane gas extraction activities
- Ensuring proper management of electricity infrastructure, gas and petroleum products
- Organizing sensitization campaigns for consumers of energy in all its forms to boost products demand

Newly established multi-utility authority EWSA by the 2010 Energy Reform, the integration process among energy and water services had been canceled soon, no later than 4 years since its initiation.

The main reason of the change of EWSA's integration policy was that after the preparation of the government's second Economic Development and Poverty Reduction Strategy (EDPRS 2) approved in March 2013 (as will hereinafter be described in chapter 2-1-1 (1) "Power Sector Policy and Strategies"), due to a detailed review of the institutional arrangements for the energy and water sectors carried out by leading international experts, as a conclusion, this drastic reform of EWSA was required in order to increase the new infrastructure and operating larger and more complex networks.

In October, 2013, following the EDPRS II, in order to promote increase of capital investment and expansion of the business scale of EWSA, operational efficiencies and financial sustainability of the utility would be essential, and the Rwandan Cabinet officially approved the policy of energy and water sectors being separated again. Therefore, about 3 years' EWSA's operation as one multi-utility was closed, new corporate framework for establishing the two individual energy and water company, 100 % owned by the government commenced ("Rwandan Cabinet Approves Institutional Reform in the Energy and Water Sectors" announced by MININFRA on 24/10/2013).

(3) Other Ministry and Authority related to Energy Sector

Along with the MININFRA and EWSA which are leading organizations as policy maker and implementation in energy sector, other related specific bodies will be described as follows.

a. MINECOFIN (Ministry of Finance and Economy Planning)

The Ministry of Finance and Economic Planning will ensure the provision of necessary funding to support responsibilities undertaken by the different Ministries that are party to the energy sector and operational/managerial agencies arising out of this policy.

b. MINIRENA (Ministry of Natural Resources)

The Ministry of Natural resources is in charge of natural resources and environment issues in Rwanda, and will engage and influence other ministries to follow and comply with environmental concerns during energy related development.

c. Rwanda Environment Management Authority (REMA)

Rwanda Environment Management Authority is the subordinate of MINIRENA, leads in ensuring that the relevant environment regulations for developing projects by monitoring and evaluation. While regarding the Environmental Impact Assessment (EIA), as a prior requirement to obtain authorization of business projects, are conducted by Rwanda Development Board (RDB).

d. RURA (Rwanda Utilities Regulatory Authority)

Rwanda Utilities Regulatory Authority is responsible for regulating and licensing certain public utilities, namely: energy, water, sanitation, telecommunications, information technology, broadcasting, postal services and transport. Review and approval of electricity tariff and/or FIT for renewable energy are conducted by RURA.

e. MINEAC (Ministry of East African Community）

The Ministry for East African Community Affairs is a coordinating body for EAC which is the regional intergovernmental organization of the Republics of Burundi, Kenya, Rwanda, the United Republic of Tanzania, the Republic of Uganda and Rwandan priorities under the EAC Protocols, Treaties, Strategies and so forth. MINEAC follows commitments signed by Rwanda on energy projects, in coming five years (towards the end of the EDPRS 2 period), a larger proportion of energy will be sourced from joint regional projects and transmitted through EAC-funded transmission lines.

(4) Financial management of EWSA

On the 1st work in Rwanda, JICA study team collected EWSA's financial statements for the past 3 years (FY2010, FY2011, and FY2012), as well as their action plan (individual budgets for power generation, transmission and distribution sectors) from the EWSA Finance Unit, and confirmed accounting data for electric power business (incl. IFRS compliance, depreciation scheme) and taxation data. However, at EWSA, the energy services sector was integrated with the water and sanitary services sector in December, 2010. Therefore, it is difficult to examine accounting continuity and clearly separate finances for energy services from those for water and sanitary services. Specifically, it was very hard to identify the O&M cost and investment costs for each of the existing power generation, transmission and distribution sectors.

JICA study team received the guidelines for distribution work costs (unit costs) from the EWSA Distribution Unit. It was, however, difficult to estimate O&M costs for the distribution sector, because EWSA has not carried out management of other costs separately for the power generation, transmission and distribution sectors.

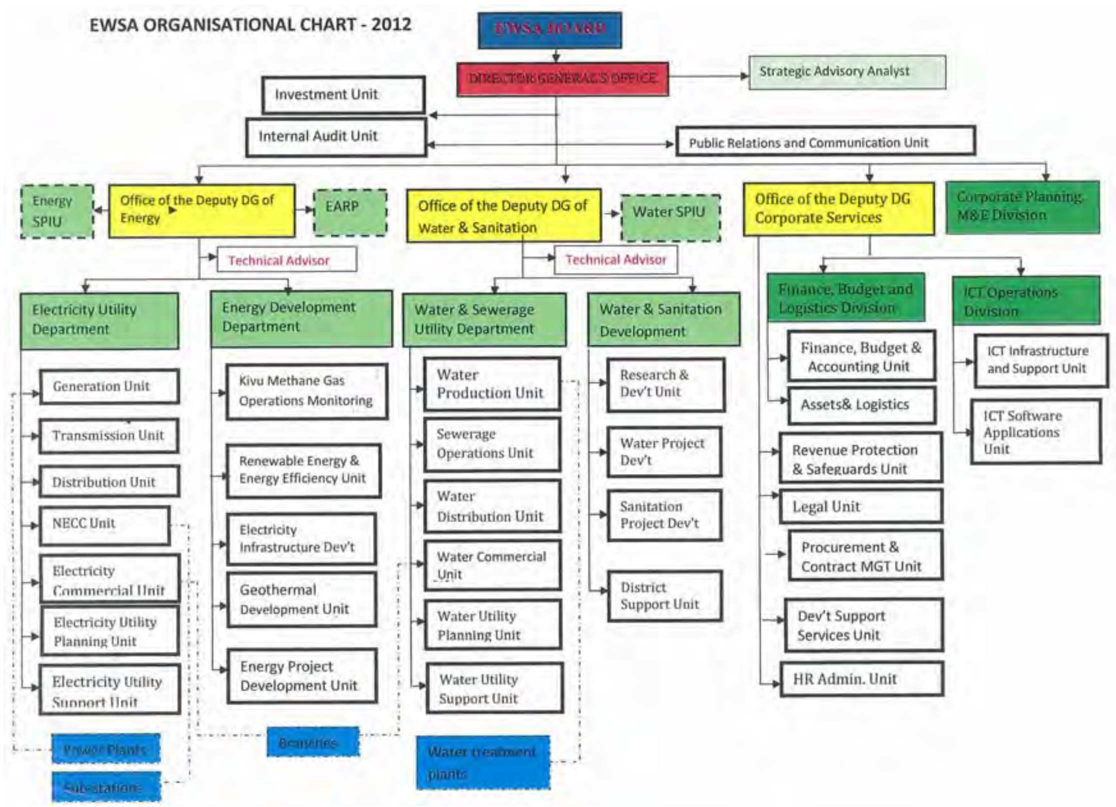
JICA study team also asked EWSA about their capital cost (taking into account debt/equity ratio and interest), which was to be compiled by EWSA, and necessary in order for them to evaluate the profitability of each investment project. In response, EWSA answered that they do not manage these projects from the standpoint of investment cost and IRR (internal rate of return), but they do handle/manage borrowing rate of interest. IRR and capital cost are among the most common and important indexes that are used to estimate the profit gained from facility investment for new power source development, large-scale renewal and other work. These indexes are essential when making decisions regarding the launch of a project, as well as the continuation of and withdrawal from a project once it was launched, and the restructuring of power generation assets (portfolio). The study team recommends that EWSA adopt and use these indexes as soon as possible as the basic tools for financing and project management.

(5) EWSA's reform to REG

The current EWSA organization is still under the fundamental restructuring about from October 2013. JICA study team carried out interviews with EWSA HQs about EWSA's current organizational structure and future approaches.

EWSA's current organization was established by Energy Reform at the end of 2010; however, scheduled organizational restructuring has been suspended by the Rwanda government. The government had decided on a plan to separate the water supply service sector from the electric power service sector in 2014; and new 100% government-owned holding companies structure is to be established. In the current situation, in which there has been no complete transition, it was difficult to carry out sound analysis and evaluation of the EWSA organization that existed in 2010.

The former organizational chart of EWSA is as following figure; however, actual allocation of the human resources is still restrained for near future reorganization, and on an incomplete organizational structure, EWSA had been conducting current operation.

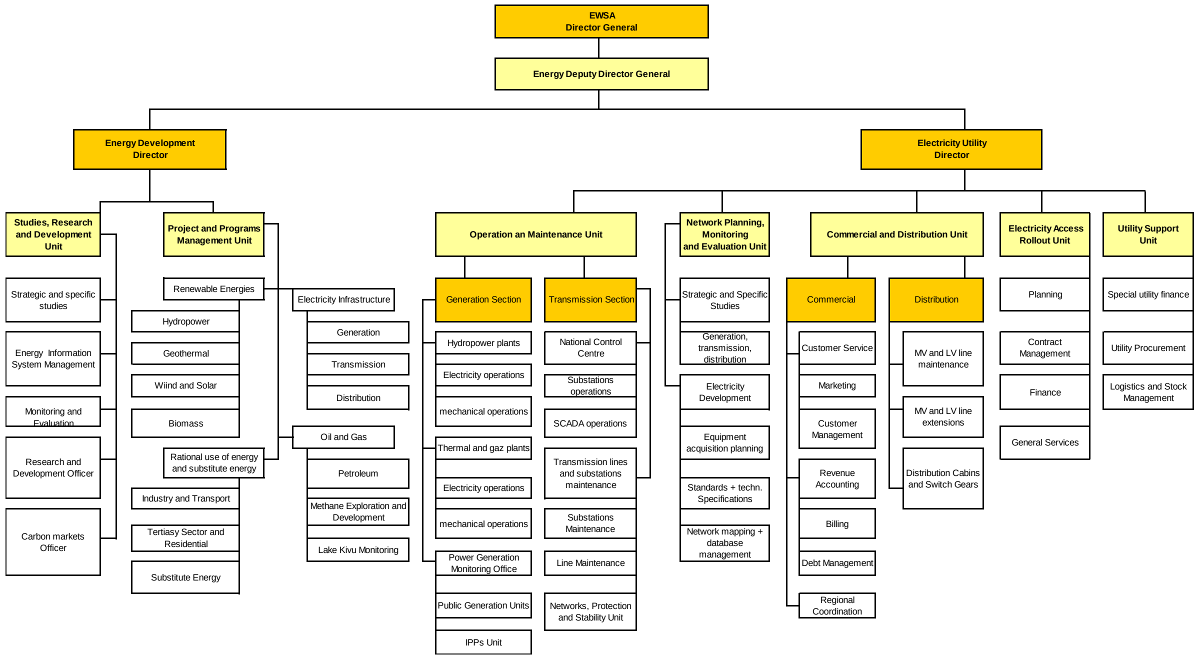


Source: EWSA

Fig. 2-1.2 EWSA Organization Chart

During the 1st work in Rwanda, as of January 2014, decisions had not been taken on organizational structure, regime and roles after EWSA's organizational restructuring. According to EWSA, the detailed design for their new organizational structure would be examined and be targeted to be set by the middle of April 2014. Since January, 2014, procedures to appoint an outside consultant have been underway. Thus, EWSA will rebuild their organizational structure, ensure human resources, separate assets, consolidate the related legal system, improve work processes, etc. with assistance from such specialists.

The organization chart below is that one of the initial daft idea of the future newly established energy company organization received from EWSA as a reference purpose that JICA study team collected in 1st work in Rwanda.



Source: EWSA edited by JICA study team

Fig. 2-1.3 An initial draft of the New Energy Company Organization Chart (reference)

The basic policy concerning EWSA's organizational restructuring was formally approved by the Rwanda government in October, 2013. Over the following five months, the framework of their organizational restructuring plan was decided on. For the scheduled new organization, the proactive introduction of IT systems and an appropriate work process scheme were being planned. With this, it was expected that they will be able to provide updated management/financial information to the newly-established company management and government; and thereby contribute to effective decision-making and company business management policy. Management responsibility for EWSA was to be transferred from governmental agencies to two newly-established companies, allowing for greater power and authority in company management and a more rapid decision-making process.

Notice of EWSA's organizational restructuring through official gazettes was implemented in April, 2014. Over the following six months, after a process of congressional approval and the signature of the President on relevant documentation, new 100% government-owned holding companies was planned to established.

〈Current status of EWSA restructuring〉

With the abolition of the law governing the former EWSA on August 12, 2014, EWSA was split to form new subsidiaries that took over its power section and are managed under REG (Rwanda Energy Group) which is an energy-related holding company owned by the government. One is a utility-related subsidiary EUCL that covers the conventional power supply section (power generation, transmission, distribution and retail), and the other is EDCL, a subsidiary in the field of new power facility development to specialize in power source development, power procurement from IPPs, and the development of transmission facilities. The JICA study team interviewed Mr. Dieudonné in the Planning section of EDCL, Mr. Emmanuel of MININFRA and Mr. Carlo Polacco, Energy Advisor for MININFRA among others during its 3rd work, and confirmed the progress of the EWSA restructuring and power-related policies and schemes.

As of November 2014, the CEO of REG appointed by the government and the Managing Directors (MD) of EUCL and EDCL were the only ones that have concluded a formal employment agreement with REG and all those in the director position and below had not entered into a formal employment agreement. As a tentative measure, former employees of EWSA are engaged in the actual work under a one-year contract (August 2014 to August 2015) with a guarantee that they get the same pay and benefit package as they did under the former EWSA. To tackle this issue, REG hired outside consultants and plans to create a system to evaluate those interim employees and to formally employ them after such evaluation under the new employment system by August 2015. REG has prepared a tentative organization chart; however, no specific organization or system, or task assignment has been decided.

If an (interim) employee in the management position at REG is assigned to EDCL based on the section he was part of during his time with the former EWSA, there is a possibility that his staff might belong to EUCL. At the work site of EDCL that is newly entrusted with power source development, some confusion is expected to ensue due to issues of coordination with EUCL, etc. The restructuring is moving forward while thinking and planning is going on at the same time. However, the organization is at the base of all tasks and the sense of responsibility and loyalty to the organization greatly influence work quality and efficiency.

The JICA study team had an impression that the sufficient evaluation of the organizational and financial issues and performance was not done after the former EWSA was split up over three years, and it led to this rough restructuring. The plan is to stop the subsidies in the next three years and to make the new companies highly profitable. However, they plan to create an evaluation system after one year into restructuring, without clarifying the specific task assignment or allotment of duties, and to make employment and salary decisions based on the evaluation result. The JICA study team believes that REG and the government must practice care in establishing the evaluation rules so that there will be no room for arbitrariness in the endeavor.

In the beginning of January 2015, REG offered the JICA study team the staffing scheme for EDCL and EUCL. However, the relations to the former organization, duty allotment or tasks were not included, making it hard to extract issues and review specific improvement proposals. The JICA study team inquired REG and MINIFRA about the concept and issues for the new organizations and the relationship between EDCL and EUCL during the 3rd work (November 2014), but did not receive clear answers.

Fig. 2-1.4 only shows a part of the chart related to the Planning section of EDCL. The organization chart of EDCL is to include the High Level management section, Generation & Transmission section, electrification section (EARP), Primary & Social Energy section responsible for domestic energy resource (geothermal, peat, methane, etc.) development, Finance and Administration section and Transaction Advisory, in addition to the Planning section, and have 268 staff members (Table2-1.1). EUCL, an entity responsible for utility aspect, is comprised on the Operation (power generation, transmission and distribution), Regional, Finance, Corporate Services, Human Resources and Commercial sections. Much of the functions of the former EWSA are concentrated in this company (the number of the staff members of EUCL is 1025, about half of that of former EWSA). It might seem that EDCL was created by separating the power source development function away from the former EWSA; however EDCL also develops transmission facilities.

Since REG has not supplied data and information on the operation of the new organizations, the issues and risks expected from the organization chart and the number of staff members is explained tentatively.

① Cost increase due to doubled staff

✧ Based on the number and ratio of employees of EUCL (1025) and EDCL (268), if each company assigns employees for the respective finance, administration, and power source & transmission (development and operation) sections, the increase in the personnel expenses and other fixed expenses cannot be avoided unless each company has a certain scale of operation.

✧ Each company lacks human and managerial resources to carry out respective functions and roles, and the companies cannot be expected to ensure work quality or to improve efficiency.

② Conflict of missions

✧ Based on the general understanding, EUCL works to reduce cost while placing priority on the public benefit and EDCL makes investment to improve profitability. It means that there are a cost center and profit center within a holding company. With their small company size and market size, there is a risk that the organizational operation might not be smooth for the companies, and with shared staff use (power generation & transmission development and operation, etc.), there might be an adverse effect on the mindset and motivation on the part of the employees and company. Also, if the companies are to compete against each other, it could create many other issues from the establishment of rules to objective evaluation since the indicators to measure the work performance such as KPI are different.

③ Technology transfer and human resource development

✧ The split up of the technology sections that had been important for REG, including power generation and transmission which once were within the same section, could cause trouble in terms of technology transfer and human resource development due to information blocking, as pointed out in “Conflict of missions” above.

The JICA study team heard that this organization restructuring was planned based on the advice of outside consultants. However, it is doubtful if the benchmarks, companies and the market size that were used as models were compatible with Rwanda’s power situation. The JICA study team believes that it is possible for the organizations to be improved or reintegrated as an electric business section in the course of the REG operation.

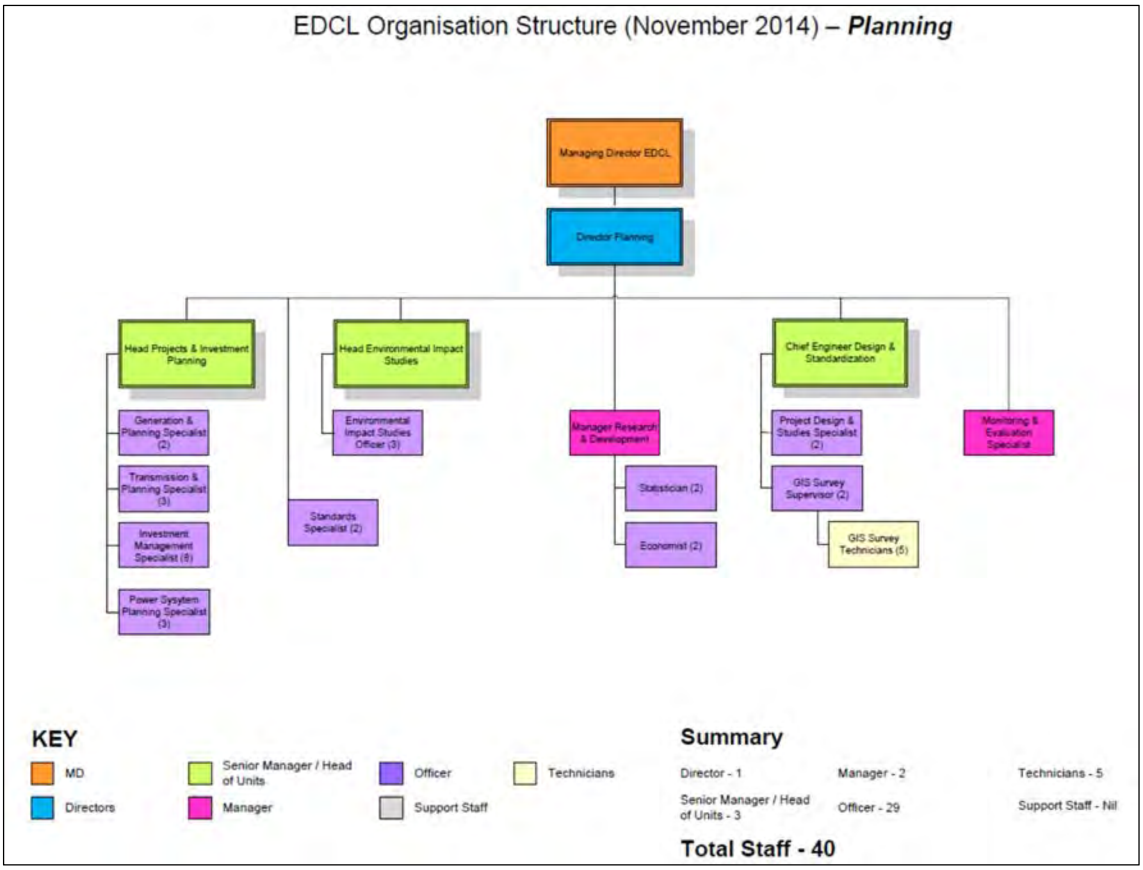


Fig. 2-1.4 Organization chart (tentative)

Table 2-1.1 Employee assignment plan (tentative)

Category		CEO	MD	Directors	Manager	Technicians	Senior Manager / Head of Units	Officer	Support Staff	Others	TOTAL
Holding Company		1		Nil	14		5	11	1		32
Subtotal		1	0	Nil	14	0	5	11	1	0	32
EUCL	MD		1	Nil	2		1	8	Nil		12
EUCL	Operations			1	21	408	5	175	Nil		610
EUCL	Regional				5	104		26	57		192
EUCL	Finance			1	3	Nil	1	26	Nil		31
EUCL	Corporate Services			1	5	Nil	4	44	30		84
EUCL	Human Resources			Nil	2	Nil	1	10	Nil		13
EUCL	Commercial			1	4	20	5	53	Nil		83
Subtotal			1	4	42	532	17	342	87	0	1025
EDCL	High Level		1		1	Nil	1	3	Nil		6
EDCL	Generation & Transmission			1	2	Nil	2	14	Nil		19
EDCL	Planning			1	2	5	3	29	Nil		40
EDCL	EARP			4	3	Nil	Nil	26	22	7	62
EDCL	Primary & Social Energy			1	3	3	5	45	Nil		57
EDCL	Finance and Administration			1	7	Nil	4	31	30		73
EDCL	Transaction Advisory			Nil	2	Nil	1	8	Nil		11
Subtotal			1	8	20	8	16	156	52	7	268
Total all		1	2	12	76	540	38	509	140	7	1325

2.1.2. Policy and Strategy for Power Sector

(1) Overview

Under the Rwanda Vision 2020, the country's long term development plan has been conducted on the Poverty Reduction Strategy Programme (2002-2005) and the Economic Development and Poverty Reduction Strategy (EDPRS) (2008-2012).

As the implementation plan of Energy Sector in EDPRS, MININFRA established「National Energy Policy and National Energy Strategy 2008-2012」,and promoted the following 9 specific approaches to meet goals.

- Integrated approach to energy planning
- Use of indigenous energy resources
- Energy efficiency and conservation
- Energy pricing and subsidy policies
- Regulatory framework
- Energy sector governance
- Institutional framework and capacity-building
- Private sector participation in energy
- Financing energy sector investments

In reflection of the achievement of EDPRS completed in 2012, Rwanda government established EDPRS 2. Main goal of Electricity Sector in EDPRS 2 are follows,

- Increased electricity generation capacity to 563 MW (current capacity is approx. 110 MW) , and for which improved engagement of the private sector investment
- Increased access to electricity: 70 % of the households with grid electricity by 2017/2018, the remaining 30% benefiting from off-grid solutions.

Under the EDPRS 2, MININFRA has made the specific action plan as Energy Sector Strategic Plan 2013-2018：ESSP in 2013. According to the first draft of ESSP in June, 2013, key policy priorities of electricity sector were based on the electrification ratio of 70% and as follows,

- **Increased Generation Capacity**
  The current projections of demand for electricity indicate between 250 MW and 470 MW in 2017. Considering a 20% policy reserve margin, the required installed capacity would be 563MW. In consideration of the risk of development, the generation options from the available diversified energy resources and the private participation are significant.
- **Electricity Supply (Electrification)**
  Though the 100 % electricity connection to the entire households in the country is the goal, 70 % of the households will be supplied with power grid by 2017/2018 and the remaining 30 % would be benefited from off-grid solutions through such as mini-grids of small hydro or solar PV solution.
- **Electricity Tariff and Subsidies**
  The Rwanda government provides subsidies to offset high-price power generation costs caused by using diesel power generators, therefore to some extent electricity tariff are held down. By proactively introducing low-cost electric power sources, the use of diesel power generators will be gradually decreased, and the target is to eliminate subsidies to reduce electricity tariff in 2015.

Final draft in ESSP as of October 2014, passing over one year from June 2013, target of electrification ratio has been decresed to the 2 scinarios as 48% and 35% from 70%, in reflection of the difficulties and progress on the electrification plan. However demand forecast in 2017/2018 was set as 473MW on the ambitions scenario and the power source development plan was set as 563MW with the consideration of 20% margin. Basically, the targets in the ESSP drafted as of June, 2013 and EDPRS 2 have been kept in the final draft of ESSP.

(2) Electricity tariff

a. Electricity tariff

The average electricity tariff remained unaltered between 2006 and 2012; accounting for inflation this represented a decrease in real terms of around 31% less than those in 2006.

Table 2-1.2 Electricity Tariff (excluding VAT)

	Previous tariff (RWF/kWh)	Tariff from August 2012 (RWF/kWh)
Average Tariff	110 (17.2 US cent)	132 (20.6 US cent)
Domestic	112 (17.5 US cent)	134 (20.9 US cent)
Industry (time-of-use)		
Low (23:00 – 7:00)	80 (12.5 US cent)	96 (15.0 US cent)
Mid. (7:00 – 17:00)	105 (16.4 US cent)	126 (19.7 US cent)
High (17:00 – 23:00)	140 (21.9 US cent)	168 (26.3 US cent)

Source: EWSA Web Site and Electricity Commercial Unit (US cents in parentheses calculated based on 1USD = 640RWF)

EWSA proposed a tariff increase of 30%, however, only 20% (RFW132-158 RFW) of the increase was effected by RURA in order to protect consumers from too significant a price increase.

Around 40% of the existing generation capacity runs on expensive diesel. EWSA's actual cost of power generation in 2011/2012 was around 210RWF/kWh (32.8 US cent); almost double the current tariff.

Given the situation, in order for it to match the level of electricity tariff in neighboring countries, the current tariff is subsidized with almost 43% of EWSA's revenue (20.9 billion RWF (3,266,000 USD)) coming through government subsidies in 2011/12.

EWSA has a projection of significant drop of using diesel power as the connection of additional power supplies to the grid from a hydro-power plant (Nyabarongo 28 MW) and methane power plant (KivuWatt 25 MW), which are now under construction. And it was expected that EWSA's power generation cost would fall to approx. 140RWF/kWh (21.9 US cent) in 2015.

b. Feed in Tariffs

A Renewable Energy Feed In tariff (FIT) scheme for hydropower up to 10 MW was conducted by RURA and approved in February 2012.

Table 2-1.3 FIT for small hydro power generation

Tariff($US/kWh)	Plant Installed Capacity
16.6cent	50 kW
16.1 cent	100 kW
15.2 cent	150 kW
14.3 cent	200 kW
13.5 cent	250 kW
12.9 cent	500 kW
12.3 cent	750 kW
11.8 cent	1 MW
9.5 cent	2 MW
8.7 cent	3 MW
7.9 cent	4 MW
7.2 cent	5 MW
7.1 cent	6 MW
7.0 cent	7 MW
6.9 cent	8 MW
6.8 cent	9 MW
6.7 cent	10 MW

Source: REFIT Regulations in RURA Web Site

C. Revision of the Electricity Tariff System

The JICA study team met with Mr. Alexis Mutware, Head of Electricity Section, who is in charge of power regulation in RURA, and Mr. William Gbonay, Advisor, and they conducted an interview concerning preparations for introduction of the new electricity tariff system currently being promoted by RURA and future plans for the FIT already introduced.

1) New Electricity Tariff System

- RURA employed external consultants to start review of a new electricity tariff system and calculation method in April 2014. As of November 2014, the rough draft of the new tariff system has been submitted to MININFRA, which is responsible for reviewing the system rationality and REG financial integrity, and MINECOFIN, which will review the budget for providing subsidies to REG, and final government approval is awaited.
- In the new tariff system, reflecting power supply costs, it is scheduled to revamp types of contract according to receiving voltage (LV, MV, HV) and type of customer, etc. (In the current tariff system, contracts are classified as general, medium voltage, and public services, and the general category which entails the same unit tariff applies to household supply, agricultural supply, small business supply, and factory supply).

・Specific contract categories for electricity tariffs are as follows.

① Residential (230-400V)
② Non-Residential(230-400V)
③ Medium Voltage Customer (business:15-30kV)
④ High Voltage Customer (industrial: 31kV~110kV) … There are currently no receivers, however, it is planned to start supply to a cement plant in the south of Rwanda from the start of 2015. In addition, it is scheduled to supply power for a new airport project and so on.

・As the method for reflecting power supply cost, first the REG power supply cost will be grasped separately according to generation, transmission, and distribution, and these itemized costs will be allocated by type of contract according to the receiving voltage and conditions of use (supply voltage and generation situation seen from the REG side). RURA will review the rationality of the cost allocation and approve the tariff rates. It is expected that this review process will be conducted quarterly four times a year.
・In order to establish a smooth tariff rate calculation and approval process, RURA and REG intend to start a joint taskforce team from January 2015 to examine practical operating measures. It was originally planned to launch the taskforce in July 2014, however, plans have been greatly delayed by the start of reorganization of EWSA. RURA considers the way in which REG calculates the detailed department-separate costs to be an important factor.
・The government expects the new electricity tariff system to be introduced in July 2015, and to abolish subsidies for REG during fiscal 2017, when rental diesel will be suspended and operation of an inexpensive peat plant (Hakkan: 80MW) and methane power plants (Kivu Watt: 25MW, Simbion: 50MW) around Lake Kivu will be started.
・By adopting electricity tariffs in reflection of costs, without the REG subsidies, tariffs will naturally increase and some customers will have to pay higher charges.
・Agreement has already been reached with MINECOFIN concerning subsidies in fiscal 2015 (the first year of the new tariff system), however, subsidies beyond then will be subject to negotiation.

2) **Introduction of FIT**

・The present FIT in Rwanda, review is underway with a view to lowering the target scope from 10MW to 5MW so that the FIT can be applied to more power producers. (Moreover, when RURA was asked about the prospects for FIT in July 2014, it was found that it was considering limiting targets no higher than 5MW to new power sources and producers located no further than 5km from the grid).
・Solar power, peat, methane, geothermal, etc. are not targeted, and it is planned to procure power on the PPA base from private operators that can make the lowest cost proposals possible.

- In any case, since Rwanda has no experience of this method, the initial introductory stage will be viewed as a demonstration stage. Until the cost structure becomes clear, there will be no rush to introduce FIT to the targets here.
- Concerning new REG development plans too, review and approval will be conducted with a view to ensuring that priority is given to introducing cheap power sources.

Photo 2-1.1 Interview at RURA offices

3) Move towards the promotion of power source development

During the 3rd work, opinions were exchanged with MINIFRA and REG regarding the scheme for the promotion of power source development, and the status of the Geothermal Law which has been slated to be enacted in the summer of 2014 was confirmed. At the time of the interviews during the 2nd work (June 2014), the plan was that the draft of the Geothermal Law was to be prepared by the outside consultants hired by MININFRA, the validation of the contents by RURA to be finished in July 2014, the final draft to be compiled by MININFRA and to go through the two month-long governmental procedure to hear stakeholders' comments, and the law to come into force in the fall of 2014 after the cabinet approval and proposal and parliament approval.

However, from what the JICA study team learned, the possibility of geothermal development turned out to be more difficult than originally assumed based on the result of the two test drillings done by EWSA and the interim report by the JICA study team. Reflecting such situation, the work on the Geothermal Law which had been promoted with the donors' support from Europe has been suspended in reality. The JICA study team explained about the advantages including the establishment of a government support fund based on the idea of a large-scale electricity-related investment project, tax holiday and accelerated depreciation. However, the discussion on the creation of laws to promote private sector-led investments has been suspended after the discussion of their outlines just like the Geothermal Law, ever since the possibility of geothermal development has become uncertain.

The JICA study team believes that the discussion of the promotional scheme for private selected power source development should not be rushed until the development possibility has been fully confirmed, especially considering the issues related to the EWSA restructuring. There are so many uncertainties in subterranean resource development that it is hard for the private sector to bear the risk in the early stage of development. Therefore, the government and REG should take a lead in the beginning to confirm the amount of resources with the cooperation of donors from Japan and other countries. It would not be too late to discuss specific schemes such as the legal system for the participation of the private sector and fund creation after an idea is formed about the development. To this end, it is effective as well as less risky financially and politically to promptly train geothermal specialists through technological transfer such as the one done in the study of the geothermal development plans in this work or training programs in Japan.

2.2. Power Supply-Demand

2.2.1. Status of Power Generating and Transmission Facilities

(1) Power Generating Facilities

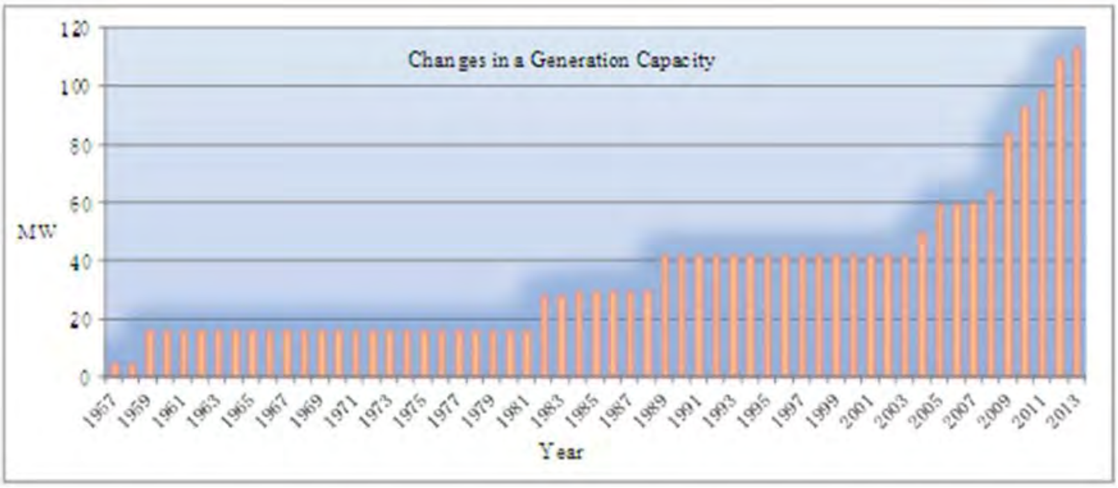
Rwanda's sources of power are covered mainly by hydro and diesel, which have generating facilities within the country, together with power imported from neighboring countries. Power supply capacity as of the end of 2013, on a rated-output basis, was approximately 110MW. This was made up of hydro 44.6MW (40%), diesel 47.8MW (43%) and methane gas 3.6MW (3%), together with imported power connected to the transmission network from power output by hydro power stations shared with neighboring countries 15.5MW (3%). Also, small-scale power sources such as small and micro hydro, together with photovoltaic (0.25MW) supplied by IPP Jali Power which began operation in 2007, is connected to the distribution network. In addition, while it is little-utilized, 1.5MW (contract capacity) of power supplied at 33kV can be accessed from Uganda. Existing power source facilities (as of the end of 2013) connected to the transmission network are shown in Table 2-2.1.

Table 2-2.1 Existing power generating facilities (2013)

Year	Name	Status	Installed Capacity	Type
1957	Gisenyi	REG	1.2	Hydro
1959	Ntaruka	REG	11.25	Hydro
1982	Mukungwa 1	REG	12	Hydro
1984	Gihira	REG	1.8	Hydro
2010	Murunda	IPP	0.1	Hydro
2010	Rukarara	IPP	9	Hydro
2011	Rugezi	REG	2.2	Hydro
2011	Keya	REG	2.2	Hydro
2011	Nkora	REG	0.68	Hydro
2011	Cyimbili	REG	0.3	Hydro
2012	Mazimeru	IPP	0.5	Hydro
2013	Nshili 1	REG	0.4	Hydro
2013	Musarara	IPP	0.5	Hydro
2013	Mukungwa 2	REG	2.5	Hydro
2004	Jabana 1	REG	7.8	Diesel
2005	Aggreko Gikondo	Rental	10	Diesel
2012	Aggreko Mukungwa	Rental	10	Diesel
2009	Jabana 2	REG	20	Diesel(HFO)
2008	KP 1	IPP	3.6	Methane
1957	Rusizi 1 (SNELL-Hydro)	Public	3.5	Import
1989	Rusizi 2 (CINELAC-Hydro)	Public	12	Import

Source: JICA study team, based on documentation obtained from EWSA (excluding power sources and interconnection lines connected to distribution network

As can be seen from Table 2-2.1, of Rwanda's power source facilities, hydro-power facilities accounting for the majority of hydro-power supply (26.5MW) have been in operation for 30 or more years and have become aged, and to meet the rapid growth in demand for power from around the mid 2000's, diesel generators were introduced. In the beginning of the 2010's, with developments such as the entry of IPP's, albeit on a small scale, hydro power stations were constructed, and as a pilot project to utilize methane gas discharged from Lake Kivu, the government-led KPI project began operation in 2008. Rwanda, whose purely domestic energy resources are limited, proactively imports power through international interconnection lines, procuring 3.5MW and 12MW (contract capacity) from Rusizi 1 (1957) and Rusizi 2 (1989) respectively, which are shared-use hydro power stations located on the border with Democratic Republic of the Congo and Republic of Burundi. The transition in installed capacity is shown in Figure 2-2.1. Up until 2004 there was little change in capacity, then the period until 2009 saw slow expansion, and subsequently there has been rapid growth in power source development.



Source: EWSA Web Site

Fig. 2-2.1 Transition in Rwanda's installed capacity

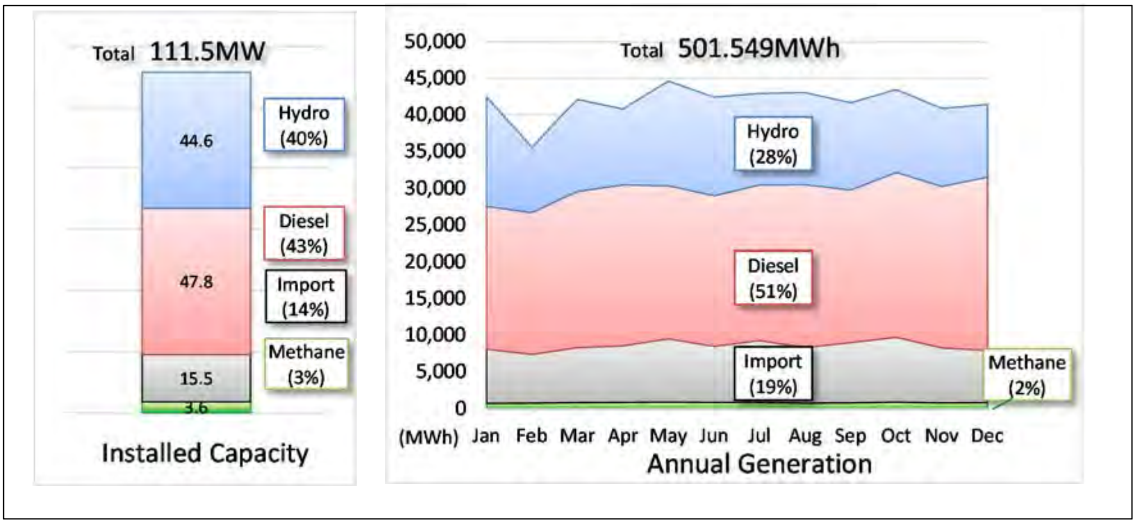
In the power source development rush during the period from 2004 to 2013, installed capacity doubled from approximately 50MW to around 110MW, with power supply and demand (refer below: 2-3 Power Supply and Demand) doubling similarly. However unfortunately, expensive-to-generate diesel has come to make up a large proportion of power availability. Transition in annual generation for 2013 (Table 2-2.2), together with installed capacity and share of annual generation (Figure 2-2.2) are shown below.

Installed capacity for hydro (44.6MW) and diesel (47.8MW) are approximately the same. And following proper load-dispatching instructions that stress economic efficiency, relatively cheap-to-generate hydro as base power source should be operated at a high utilization rate, while generating diesel at a low-as-possible utilization rate to cover peak period and seasonal needs. However, annual generated power for hydro is 143,305MW (28%), while that for diesel is 254,946MW (51%), which is a very different ratio compared to that for installed capacity. Even considering that at approximately 39.9MW, available capacity for hydro is about 10% below rated output, as a proportion of annual generated power 28% is low.

Table 2-2.2 Transition in annual generation (2013)

	Installed Capacity (MW)	Available Capacity (MW)	Annual Generation(MWh)													
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Hydro	44.63	39.88	14,922	8,903	12,548	10,361	14,288	13,456	12,500	12,548	11,926	11,301	10,630	9,923	143,305	28%
Diesel	47.8	47.6	19,413	19,277	21,217	21,866	20,796	20,451	21,135	22,160	20,732	22,408	21,923	23,570	254,946	51%
Import	15.5	15.5	7,399	6,656	7,521	7,736	8,629	7,644	8,444	7,597	8,212	8,860	7,520	7,140	93,360	19%
Methane	3.6	1.2	730	760	838	868	918	878	866	748	814	896	803	819	9,938	2%
Total	111.53	104.18	42,464	35,596	42,124	40,831	44,632	42,428	42,945	43,052	41,683	43,465	40,877	41,452	501,549	100%

Source: JICA study team, based on documentation obtained from EWSA (excluding power sources and interconnection lines connected to distribution network)



Source: JICA study team, based on documentation from EWSA

Fig. 2-2.2 Rwanda's installed capacity and share of annual generation

The main cause of the low utilization rate for hydro is the low operation rate of new power sources, especially those introduced since 2011. From data on generated power and maximum power by power source for 2013 provided by EWSA, the JICA study team calculated and analyzed annual load factors by power source. Even though Rwanda is said to have abundant hydro resources throughout the year, the extremely low load factors for new power sources stand out. Compared to the high annual load factor of 66% for the group of power sources that commenced operation between 1957 and 2010, the annual load factor for the group of new power sources is less than half of that figure at 31%. Furthermore, the capacity factor for the new power source group is, at 15%, half of the annual load factor. Even though these are new facilities, it can be understood that it is not just operation, but also output that is not being realized (group average annual load factors and capacity factors were calculated by taking a weighted average based on installed capacity and available capacity).

Table 2-2.3 Annual load factors and capacity factors for power source facilities

	Name	Status	Year	Type	Installed Capacity (MW)	Available Capacity (MW)	Max Load in 2013 (MW)	Annual Generation (MWh)	Annual Load Factor	Capacity Factor	Load Factor (Average)	Capacity Factor (Average)
1	Gisenyi	REG	1957	Hydro	1.2	1.00	1.10	4,850	50%	46%		
2	Ntaruka	REG	1959	Hydro	11.25	9.00	11.70	23,323	23%	24%		
3	Mukungwa 1	REG	1982	Hydro	12	11.00	11.80	71,468	69%	68%		
4	Gihira	REG	1984	Hydro	1.8	1.80	1.63	9,330	65%	59%		
5	Murunda	IPP	2010	Hydro	0.1	0.10	0.1	571	65%	65%		
6	Rukarara	IPP	2010	Hydro	9	9.50	7.30	28,137	44%	36%	66%	44%
7	Rugezi	REG	2011	Hydro	2.2	2.20	3.50	438	1%	2%		
8	Keya	REG	2011	Hydro	2.2	2.20	2.2	683	4%	4%		
9	Nkora	REG	2011	Hydro	0.68	0.70	0.36	1,442	46%	24%		
10	Cyimbili	REG	2011	Hydro	0.3	0.30	0.16	271	19%	10%		
11	Mazimeru	IPP	2012	Hydro	0.5	0.50	0.5	227	5%	5%		
12	Nshili 1	REG	2013	Hydro	0.4	0.40	N/A	N/A	N/A	N/A		
13	Musarara	IPP	2013	Hydro	0.5	0.38	N/A	N/A	N/A	N/A		
14	Mukungwa 2	REG	2013	Hydro	2.5	0.80	0.8	2,563	37%	12%	31%	15%
15	Jabana 1	REG	2004	Diesel	7.8	7.20	2.84	5,042	20%	7%		
16	Aggreko Gikondo	Rental	2005	Diesel	10	10.00	10.30	84,694	94%	97%		
17	Aggreko Mukungwa	Rental	2012	Diesel	10	10.40	10.78	67,759	72%	77%		
18	Jabana 2	REG	2009	Diesel(HFO)	20	20.00	19.83	97,452	56%	56%	62%	61%
19	KP 1	IPP	2008	Methane	3.6	1.20	1.20	9,938	95%	32%	95%	32%
20	Ruzizi 1 (SNELL)	Public	1957	Import	3.5	3.5	4.02	22,750	65%	74%		
21	Ruzizi 2 (CINELAC)	Public	1989	Import	12	12	15.51	70,610	52%	67%	55%	69%

Source: JICA study team, based on documentation from EWSA

$$\text{Annual load factor} = \frac{\text{Average load (=Annual generation/ (365 days X 24 hours per day))}}{\text{Maximum load in a year}}$$

$$\text{Capacity factor} = \frac{\text{Annual generation}}{\text{Maximum possible output(=Capacity* X (365 days X 24 hours per day)}}$$

*Name plated capacity of generator

Fig. 2-2.3 Equations for annual load factor and capacity factor

According to EWSA's power generation section, Rugezi (LF: 2%), Keya (LF: 4%), Mukungwa 2 (LF: 12%), Nkora (LF: 24%) and Cyimbili (LF: 10%), new facilities with low load factors (LF), have been experiencing a lot of trouble since they commenced operation, some of which have not even achieved designed output, and are currently undergoing repair work (as of November 2014).

In light of EWSA's financial condition and tight supply and demand predicament, its short-term and low-cost power source facility introduction policy itself cannot be denied. However, in light of the situation where trouble is being experienced to the current extent and envisaged output is not being obtained, it is necessary to carry out a fundamental review of the overall process of new power source development from design to equipment and facility procurement, order placement and management of works, and the system under which these are carried out.

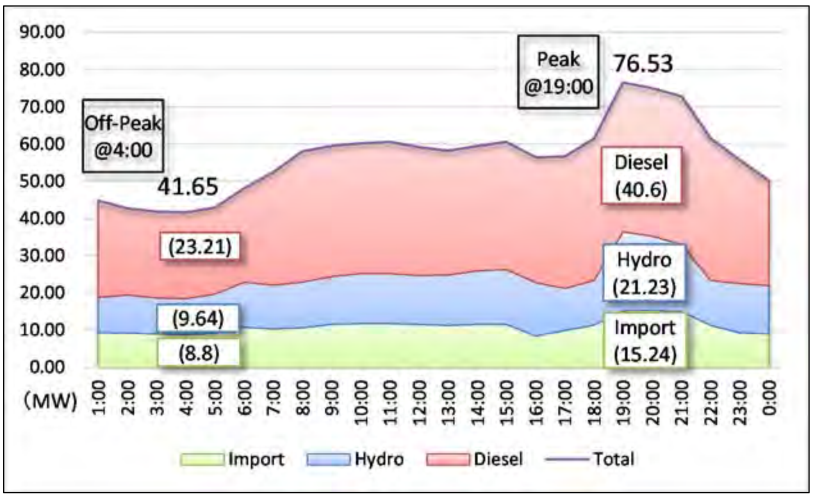
The JICA study team believes that the cause of plateauing of new development work during the 30-year period from 1984 until the 2010's was also lack of progress in dissemination of engineering technology at EWSA. In the development of new power sources, the development of human resources is also key.

The negative influence on economic operation due to low-load hydro can be seen in the daily load curve. Load fluctuation for February 28, the day when maximum power for February 2013 was recorded, is shown below in Table 2-2.4 and Figure 2-2.4.

Table 2-2.4 Transition in output by power source on February 28, 2013

Type	**Hydro**						**Diesel**				**Import**		
Name	Gisenyi	Ntaruka	Mukungwa 1	Gihira	Rukarara	Nkora	Jabana 1	Aggreko Gikondo	Aggreko Mukungwa	Jabana 2	Ruzizi 1 (SNELL)	Ruzizi 2 (CINELAC)	**Total**
Installed (MW)	1.20	11.25	12.00	1.80	9.00	0.68	7.80	10.00	10.00	20.00	3.50	12.00	**99.23**
Available (MW)	1.00	9.00	11.00	1.80	9.50	0.70	7.20	10.00	10.40	20.00	3.50	12.00	**96.10**
1:00	0.41		8.00	0.88		0.23		9.90	10.26	5.80	2.50	6.80	**44.78**
2:00	0.45		8.70	0.89		0.23		10.00	7.32	5.90	2.50	6.70	**42.69**
3:00	0.45		8.10	0.86		0.23		10.00	7.32	5.90	2.20	6.80	**41.86**
4:00	0.45		8.10	0.86		0.23		10.00	7.31	5.90	2.60	6.20	**41.65**
5:00	0.46		8.90	0.90		0.23		10.00	7.31	5.90	2.70	6.50	**42.90**
6:00	0.43		10.50	0.97		0.23		10.00	9.26	5.90	2.90	7.90	**48.09**
7:00	0.39		10.20	0.95		0.24	0.87	9.62	10.40	9.36	3.02	7.32	**52.37**
8:00	0.39	1.20	9.40	0.99		0.24	2.77	10.02	10.40	11.90	3.32	7.33	**57.96**
9:00	0.45	1.40	9.80	0.91		0.24	2.72	10.03	10.40	11.98	3.44	8.13	**59.50**
10:00	0.44	1.80	10.00	0.91		0.24	2.57	10.05	10.40	11.96	3.35	8.43	**60.15**
11:00	0.43	1.60	10.20	0.90		0.24	2.66	10.03	10.35	12.38	3.28	8.52	**60.59**
12:00	0.44	1.50	10.10	0.90		0.24	2.62	10.07	10.17	11.53	3.37	8.17	**59.11**
13:00	0.42	1.60	10.40	0.90		0.24	2.63	9.62	10.13	10.99	3.30	7.98	**58.21**
14:00	0.43	1.90	10.90	0.93		0.24	2.60	9.90	9.58	11.43	3.26	8.27	**59.44**
15:00	0.43	1.90	10.90	1.23		0.23	2.67	10.03	10.13	11.48	3.33	8.23	**60.56**
16:00	0.43	1.90	10.80	1.00		0.22	2.02	10.00	10.10	11.51	2.35	6.06	**56.39**
17:00	0.43	1.40	8.30	1.00		0.20		10.03	10.08	15.24	2.31	7.63	**56.62**
18:00	0.42	2.40	7.90	1.00		0.21		10.01	10.24	17.88	2.35	9.03	**61.44**
19:00	0.42	8.30	11.30	1.00		0.21	1.85	10.08	10.24	17.89	2.86	12.38	**76.53**
20:00	0.42	8.20	10.10	1.00		0.21	1.70	10.07	10.07	17.91	2.78	12.54	**75.00**
21:00	0.43	7.10	9.30	1.00		0.21	1.50	10.07	10.21	17.96	2.55	12.46	**72.79**
22:00	0.48		7.40	1.00	3.00	0.21		10.07	10.22	17.90	1.77	9.49	**61.54**
23:00	0.48		8.50	1.20	2.90	0.23		10.03	10.22	12.90	2.43	6.83	**55.72**
0:00	0.49		8.20	1.10	3.00	0.23		9.97	10.22	8.00	2.23	6.72	**50.16**

Source: JICA study team, based on documentation obtained from EWSA central load dispatching office



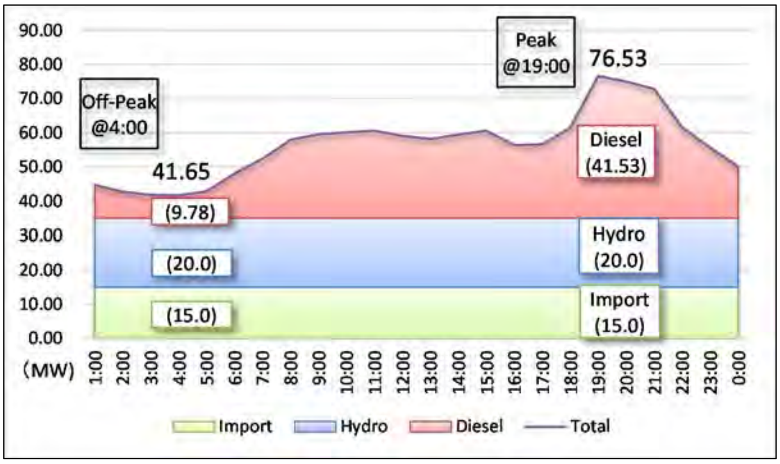
Source: JICA study team, based on documentation obtained from EWSA central load dispatching office

Fig. 2-2.4 Daily load curve (February 28, 2013)

The above data for transition in output by power source and daily load curve was provided by the EWSA central load dispatching office. The lineup of power sources in Table 2-2.4 does not include data from some hydro facilities and the methane facility. The reason for this is that currently the central load dispatching office does not have the facilities or environment to enable it to measure the output of all power sources or total operational status in real time. However, the total installed capacity for the lineup of power sources shown in the Table amounts to 99.23MW, which means that more than 90% of output fluctuation for total power output is understood on the hour.

Off-peak (morning 4:00) total load is 41.65MW, which was supplied by diesel, hydro and import power sources in the ratio of 2 (23.2MW): 1 (9.6MW): 1 (8.8MW) respectively. By contrast, peak (evening 19:00) total load was approximately double at 76.53MW, which was supplied in the ratio 2 (40.6MW): 1 (21.23MW): 1 (15.24MW).

Generally speaking, in the case where an economic power supply is being provided, as in Figure 2-2.5 below which shows a daily load curve simulation, hydro generation which is low cost and makes possible stable operation together with imported power which is also a hydro power source is used as a high load-factor base, while diesel is used to meet peak demand, thereby keeping down fuel costs to the extent possible. However, this kind of efficient operation is not happening in practice.



Source: JICA study team, based on documentation obtained from EWSA central load dispatching office

Fig. 2-2.5 Ideal daily load curve simulation

It is considered that there are 3 main reasons why EWSA's actual load-dispatching instructions cannot follow the ideal power source output structure in Figure 2-2.5 above.

[Limitations on availability of hydro]

- Domestic hydro availability cannot currently meet the high demand for power
- ・ In the February 28 hydro power station operation case, NTARUKA (regulating reservoir type,

11.25MW) is kept on standby to meet peak demand, while others are operated at fixed high output. NTARUKA was introduced in 1959, its capital cost has been fully recovered, and its variable costs are at a low level, so properly it would be desirable for this power station to operate covering base load. However, perhaps because sufficient reservoir storage capacity could not be ensured, it has an annual load factor of just 24%, which is less than half of the average for other aging hydro (average for power sources introduced 1957-2010: refer Table 2-2.3). However, because maximum output of 11.3MW and even 11.7MW at peak demand exceeds installed capacity (11.25MW), for an aged facility it has a high level of performance.

- As mentioned above, EWSA's new group of hydro power sources (facilities which were introduced and commenced operation in 2011 or later) has an annual load factor and capacity factor of 31% and 15% respectively, which at less than half the figures for the overall hydro average of 64% and 37%, are very low.

[Dependence on rental diesel]

- With the introduction of rental diesel, because it is necessary to pay fixed rental fees, despite high fuel costs there is no choice but to maintain high operation rates. That is to say, it is a negative spiral in which even with high non-rental costs, the rental equipment must be kept in use.
  - The total output of EWSA diesel power sources is 37.8MW, of which more than half (totaling 20MW) has been introduced through rental. In the February 28 case, rental equipment continued to be operated for 24 hours at close to rated output, while EWSA-owned diesel power sources were used for load adjustment to meet peak demand. Annual load factors for rental are 94% for Aggreko Gikondo (10MW) and 72% for Aggreko Mukungwa (10MW), far exceeding load factors for hydro, and in comparison, those for EWSA-owned facilities of 20% for Jabana 1 (7.8MW) and 56% for Jabana 2 (20MW) are rather low. It should be noted that from partway through 2013, rehabilitation work was carried out on Jabana 1, and it must be considered that its capacity factor dropped due to this.
  - Concerning the priority given to the use of rental diesel to recover the fixed cost (= rental fee), even though this has a degree of rationality, it should be considered that for EWSA-owned diesel as well, that construction and equipment costs, as well as fixed investment costs were incurred. With attention being paid to recovery of these fixed costs, a policy for ideal load-dispatching instructions should be studied, taking into overall consideration rental diesel and EWSA-owned diesel operating costs. Unfortunately, when the JICA study team was on-site, preparation of financial statements from this kind of perspective, that is bookkeeping for activity-based cost accounting was not being carried out, so the team stopped short of carrying out an analysis of cost comparisons.

[Insufficiency of load dispatching infrastructure and operation technology]

- It is impossible to understand the status of supply and demand in real time, or make quick and reliable load-dispatching instructions.

- From a load dispatching infrastructure point of view, because equipment is old, in poor condition and inadequate, there are power stations and substations where the majority of SCADA system functions cannot be introduced. In addition, there were cases of power stations for which it took the central load dispatching office several months to aggregate their operating status (these were regional power stations where manually input summary tables were aggregated by the central load dispatching office). And even though switching circuit breaker of substations is possible in emergencies, comprehensive regulation of supply and demand is impossible. For example, sometimes, when Kigali is subject to rolling blackouts, central load dispatching office staff make decisions based on rule of thumb to carry out manual switching.
- Due to factors such as the inadequacy of transmission-transformation infrastructure and the aging deterioration of substations, it is impossible to take advantage of SCADA functions. However, the JICA study team heard from central load dispatching office staff during interview that they have neither a full understanding of SCADA, nor have they received sufficient training on how to use it effectively, and therefore even though there is a superficial renovation with the new introduction of SCADA to the central load dispatching office facilities, there has not been a significant change in the way power is supplied.
- Insufficiency of the latest equipment and operating skills are not the only issues. The organization of information on power facilities overall necessary for load dispatching instructions is also inadequate. For example, there are no ledgers with organized basic information such as specifications for power source or transmission-transformation facilities connected to the transmission network. Facility ledgers are necessary basic documentation used in taking decisions, in particular when handling emergencies such as network accidents. The JICA study team, making use of an opportunity that arose when carrying out a network analysis as part of this study, has provided REG with network analysis software “ETAP” input conditions as a database that can be used to create a facility ledger, during the fourth on-site survey.

The hydropower plants that were commissioned in and after 2011 have relatively low performance (mainly REG plants). However, according to the German International Assistance Agency (GIZ) that supports small-scale hydropower generation by IPPs, IPPs Mazimeru (2012 with 0.5MW) and Musarara (2013 with 0.5MW) operate soundly with the annual load factor of 57% and 80%, respectively. It is too hasty to conclude that the power source development by the private sector should be recommended based on these examples, since energy security, etc. must also be considered. However, it might be necessary to conduct a comparative analysis of the developmental processes implemented by REG and the private sector in recent years.

1) Hydro-power

Hydro-power, as Rwanda’s valuable, purely domestically produced energy, accounts for approximately half of total installed capacity of 110MW (including 15.5MW of imported hydro-power). Rwanda is geographically in the eastern part of the upper Nile drainage basin, covering its 33% are accounted for by the country's plentiful water resources. Along the main rivers such as Kagera, Rusizi, Nyabarongo, Mukungwa and Akanyaru, hydro-power stations of various types including regulating reservoir, run-of-river and dam have been developed at differing scales.

The JICA study team carried out on-site inspections of 3 hydro power stations, Gisenyi, Gihira and Mukungwa 1.

[Gisenyi Power Station] [Gihira Power Station]

Gisenyi is Located in the western part of Rwanda on the bank of Lake Kivu, Gisenyi Power Station (rated output: 1.2MW) commenced commercial operation in 1957, and is the oldest power station in the country. Gisenyi's output under actual operation of 1MW is a little less than at commencement of commercial operation, however even now as a backbone power source in this part of the country it supplies power to large hotels and other customers.

Gisenyi Power Station together with 4 other power stations, Gihira (1.8MW), Keya (2.2MW), Cyimbiri (0.3MW) and Nkora (0.68MW), which are all in the same water system, are managed together as a single block. The generator was supplied by AVK of the UK (nameplate shows that it was made in Romania), while control panel equipment was made in China.

Gihira Power Station commenced operation in 1984, but despite its age still maintains its rated output of 1.8MW (0.6MW x 3), which together with Gisenyi are backbone power sources for Rwanda which maintain high operation rates (2013 annual load factors were 50% and 65% respectively).

Source: JICA study team

Photo 2-2.1 Gisenyi Power Station generator and transformer (insulating oil seemed to be leaking)

[Mukungwa 1 Power Station]

Mukungwa 1is a hydro power station (12MW: 6MW x 2) that was built with assistance from Germany, France and Belgium, and commenced operation in 1982. From the regulating reservoir on the mountainside in the upper part of the power station, which has an area of 25km2 and depth of 7m (Lake Ruhando), extends an underground pipe with a height difference of 114m and length of 200m that carries water to the turbines, which generate power. In the upper part of Mukungwa Power Station's regulating reservoir is Ntaruka Hydro Power Station (commenced operation in 1959, output 11.25MW), which uses the same water system, and which generates power in the same way by water fed from its regulating reservoir (Lake Burera) with a height difference of 114m.

In addition, downstream of Mukungwa 1 Power Station is the number 2 power station (2.5MW) whose operation commenced in 2 phases, in May 2013 (1.25MW) and December 2013 (1.25MW). The JICA study team was told that while Chinese equipment had been adopted because of its low price, it was often not operating due to equipment trouble, and even at the time of the inspection visit Chinese engineers remained to handle the situation. And further, that there was an issue with equipment reliability. There has been trouble not just the facility itself, but concerning management during construction, it appears that there was an issue with maintenance and repair of the construction site access road cut slope being insufficient.

More that 30 years have elapsed since Mukungwa 1 was constructed. The only spare parts available are those purchased at the time of construction, and procurement of additional items is proving difficult. Meaning that because manufacturer support is unavailable, power station staff have to use their ingenuity in maintenance management. In the operation of the power station, there is a system whereby maintenance staff also participate in operational work so that they can quickly handle trouble if it arises. Technical capability is at a certain level, so that minor maintenance work can be handled by staff working at the power station, and under normal operation there are no problems.

Under current facility conditions, modernization such as through the introduction of automatic control and computers would be difficult. With the introduction of SCADA in 2011, circuit breaker switching only became possible from the Kigali central load dispatching office (NECC).

In the case a power station is constructed at the site proposed for geothermal development, in the northwestern part of the 110kV substation of the Mukungwa Number 1 Power Station, there is a possibility that it would be connected to a transmission line, and it was confirmed that there is installation space here for breakers. Currently, an Aggreko (UK) rental diesel (10MW) is connected at this site.

Source: JICA study team

Photo 2-2.2 Mukungwa 1 turbine room

Source: JICA study team

Photo 2-2.3 Mukungwa 1 transforming equipment

With Gisenyi and Mukungwa 1 having commenced operation in 1957 and 1982 respectively, both facilities have now been operating for more than 30 years. These kinds of aging facilities account for 26MW, or 27% of total domestic installed capacity of 96MW (connected to the transmission network).

To continue power supply in the future using these aging facilities, it is considered essential to improve their soundness through rehabilitation and other measures; however, when such work is being carried out, it is anticipated that it will bring further drops in power supply capacity.

In Rwanda's situation, where procurement of equipment and parts is insufficient because of factors such as frequent changes in suppliers, it cannot be said that the country has a sound supply system, and there is a risk of extended drops in power supply due to shut-downs of generating facilities. To respond to this situation, it is necessary to create an appropriate renewal plan, minimize drops in power supply capacity, and thereby avoid unexpected power supply shortages.

Up until now, responsibility for the development of power stations has been borne by government agencies such as REG and its predecessor EWSA, but currently private-sector-led development such as IPP is very active.

In October 2014, the largest dam-type hydro-power station in Rwanda, Nyabarongo 1 (28MW) commenced commercial operation. Stretching from the power station on the Nyabarongo River a distance of 27km to Kilinda Substation is a 110kV transmission line for the concerned power station, which has been newly installed, and in conjunction with this, augmentation work at the substation was carried out in 2012. Power generated by Nyabarongo 1 is transmitted along a 110kV transmission line from Kilinda Substation approximately 80km east to Gikondo Substation in the capital Kigali. At a total cost of more than US$110million, this national project is 70% loan-financed.

Continuing from Nyabarongo 1, the IPP project FS for Nyabarongo 2 (17-20MW) is soon to be carried out. According to MININFRA, Nyabarongo 2 will be a concrete gravity dam 48m in height with a crest length of 228m, and it is assumed that it will be not just for power generation but be for multipurpose use, including irrigation. Development cost is expected to rise to US$80 million, and because there are issues such as compensation for residents in the surrounding area, the government is now studying whether a private-sector-only development is possible, or whether development should be under a PPP.

Photo 2-2.4 Nyabarongo 1 (28MW) (Source: REG website)

Source: JICA study team

Photo 2-2.5 Kilinda Substation facilities, which were renewed for connection with Nyabarongo 1

Rwanda is pursuing the large-scale development of hydropower stations in partnership with neighboring countries in East Africa. At the Rusumo Falls in the Kagera River Basin located on the borders with Tanzania and Burundi, the 81MW Rusumo Hydro-power Station is now under development. Co-financed by the three countries, according to plans, the main construction will start in 2015, and power generation will commence in 2019. Rwanda plans to import 27MW as one-third output from Rusumo. In addition, Rwanda is planning together with Democratic Republic of the Congo and Burundi to build on the Rusizi River, which flows into Lake Kivu located on the borders between the 3 countries, Rusizi 3 (145MW) and Rusizi 4 (295MW) Power Stations, which are expected to begin operation in 2021 and 2025 respectively.

According to the “Hydro-power Atlas”, a survey carried out in 2008 to determine hydro-power developable sites, within Rwanda 333 sites have been confirmed as being suited to development of small and micro hydro-power (Micro Hydro). Due to the introduction in 2012 of a renewable energy feed-in-tariff (REFIT) for hydro-power of 10MW and under, in recent years small-scale hydro-power development has been progressing. These micro hydro-power facilities should be connected to distribution networks, or otherwise be used to provide power to off-grid districts. Small and micro hydro-power construction plans subject to negotiations for connection to REG distribution networks and negotiations for REFIT and other transaction prices in progress as of

October 2014 are shown in Table 2-2.5. Total output for these projects is on a very significant scale of about 25MW.

Table 2-2.5 Existing small scaled hydro development facilities in Rwanda (as of 2013)

No.	Site Name	Capacity (kW)	Current status
1	Kavumu	380	Construction ongoing
2	Mashyiga	180	PPA negotiations
3	Maruruma	380	FS on going
4	Rubagabaga	400	PPA negotiations ongoing.
5	Nyundo III	4,000	FS approved
6	Mpenge II (80kW) upgrade	300	FS under evaluation.
7	Koko	4,500	FS approved
8	Giciye II	4,000	FS approved
9	NGA-27	500	FS approved
10	Ngororero	2,900	PPA signed
11	Rwaza-Muko	1,940	PPA signed
12	Mpenge I(201kW) & III(750kW)	951	Mpenge III & I FS approved
13	Mushishito	2,000	PPA Signed
14	Kore MHPP	2,400	Pre-FS approved FS is being reviewed
	Total Approx.	25,000	

It is said that Rwanda’s hydro-power has substantial development potential, has relatively small scale, and that with the adoption of run-of-river and regulating reservoir-type power generation, environmental load is small. However, when the JICA study team visited the Gisenyi Hydro-power Station, similar to the above photograph 2-2.2 of Nyabarongo 1 river site, soil-mixed brown-hued water was being discharged, raising concern that it was operating at low efficiency due to pump impeller damage and that the facilities were being impacted. Another issue raised while the team was there, was that even though the power station has more potential capacity, it has not been fully developed since the F/S had not been conducted properly.

2) Diesel

Diesel, which was first introduced in 2004, has become an important source of power supply for Rwanda, which has scarce energy resources. In 2013, diesel was a key power source accounting for 254,946MWh of power generation (51% of total national power supply) and 47MW of plant capacity (43%). As was described earlier, Rwanda aims to maximize its hydropower development potential and has actively developed small and micro hydropower sources from 2010 onwards, however, the hydropower capacity introduced by 2013 still accounted for less than 10MW. Moreover, because hydropower operating conditions are poor in relation to the long development lead-time, high construction costs, and need for environmental countermeasures, hydropower is still no match for diesel, which enables annual load factor and plant utilization rate in excess of 60%, in terms of both peak load and base load. See Table 2-2.5 (Power Gene Diesel, which was first introduced in 2004, has become an important source of power supply for Rwanda, which has scarce energy resources. In 2013, diesel was a key power source accounting for 254,946MWh of power generation (51% of total national power supply) and 47MW of plant capacity (43%). As was described earlier, Rwanda aims to maximize its hydropower development potential and has actively developed small and micro hydropower sources from 2010 onwards, however, the hydropower capacity introduced by 2013 still accounted for less than 10MW. Moreover, because hydropower operating conditions are poor in relation to the long development lead-time, high construction costs, and need for environmental countermeasures, hydropower is still no match for diesel, which enables annual load factor and plant utilization rate in excess of 60%, in terms of both peak load and base load. See Table 2-2.6 (Power Generation Share of Each Power Source (2013)) and Figure 2-2.4 (Daily Load Curve (February 28, 2013)).

Table 2-2.6 Power Generation Share of Each Power Source (2013)

Type	**Generanation(MWh, %)**	
Hydro (60.2MW)	237,239	47%
Domestic(44.7MW)	143,305	29%
Import (15.5MW)	93,934	19%
Diesel (47.8MW)	254,946	51%
Methane (3.6MW)	9,938	2%
Total (111.6MW)	502,123	100%

Source: JICA study team based on data from EWSA

However, diesel incurs a high fuel cost, and because 20MW out of the above 47MW of plant capacity is rental, fixed rental costs are also incurred. Although rental diesel facilities are supposed to be operated as peak or middle demand sources, in reality they are operated at an extremely high capacity factor of 87% on average (97%, 77%) (see Table 2-2.3).

Diesel power has thus become indispensable for Rwanda’s energy security, however, the fiscal burden of providing subsidies to EWSA for diesel operation (government outlays to supplement electricity tariffs) has become a national level issue, and the ESSP (October 2014, Final Draft) has made it a goal to introduce alternative power sources and eliminate diesel by 2018. According to the ESSP, electricity tariffs in Rwanda are around 50% higher than average rates in

Eastern Africa and the sound financial running of power companies is hindered by daily expenditure of US$56,000 on diesel fuel imports.

The study team calculated the diesel power generation costs from the EWSA financial statements for the past three years from fiscal 2010 to 2012 (figures for fiscal 2012 are prior to audit). Looking at the breakdown of generation costs in the financial statement extract shown in Table 2-2.6, the average fuel cost (including lubricating oil for other than diesel uses) for the three years was approximately 39% (approximately 1,400,000 RWF) and the diesel rental cost was 42% (approximately 1,500,000 RWF), which means that diesel accounted for roughly 80% of EWSA power generation costs.

Table 2-2.7 Power Generation Costs and Subsidies according to EWSA Financial Statements (FY2010-2012)

GENERATION COSTS	2013/6/30	2012/6/30	2011/6/30	3 year Avarage	
Chemical products	1,066,851,790	1,512,699,349	1,286,739,940	1,288,763,693	4%
Repairs and maintenance	1,390,579,822	393,491,761	527,822,059	770,631,214	2%
Spare parts and consumables	7,537,780	4,455,335	34,434,738	15,475,951	0%
Fuel and Lubricating oils	21,918,952,024	17,930,879,726	2,325,848,855	14,058,560,202	39%
Variances between physical and book stock	644,001,449	171,074,268	(162,608,963)	217,488,918	1%
Rental of power	12,937,121,146	11,523,175,467	21,910,858,040	15,457,051,551	42%
Capacity charge electricity	2,926,634,386	2,193,261,135	1,260,189,034	2,126,694,852	6%
Purchase of solar energy	7,601,691	15,024,101	13,343,494	11,989,762	0%
Purchase of electricity	2,709,112,635	2,318,147,064	2,427,597,423	2,484,952,374	7%
Generation Cost Total	43,608,392,723	36,062,208,206	29,624,224,620	36,431,608,516	100%
Subsidies received	12,972,816,371	11,845,734,209	12,263,197,041	12,360,582,540	

Source: JICA study team based on data from EWSA

The unit cost of power generation is estimated from the above costs and the amount of diesel power generation over the said three years (accounting term: July 2010~June 2013). In conducting the estimation, facilities are classified into rental diesel facilities that incur rental costs (Aggreko Gikondo (10MW), Aggreko Mukungwa (10MW)) and the diesel facilities owned by EWSA that incur no rental costs (Jabana 1 (7.8MW), Jabana 2 (20MW)). Table 2-2.7 shows the results of estimation.

Table 2-2.8 Unit Cost of Diesel Power Generation according to EWSA Financial Statements (FY2010-2012)

Category	Unit Cost of Generation	Remarks
Rental diesel	234RWF (36 US cent)/kWh	Including rental cost
EWSA-owned diesel	71RWF (11 US cent)/kWh	Not including construction cost, etc.

Source: JICA study team

In the case of rental diesel, the cost is 1.7 times more than the average power tariff in Rwanda

(132RWF/ (20.6 US cent)/kWh), indicating an entirely negative spread. Moreover, on first appearances, the unit cost of EWSA-owned diesel is roughly one-third that of rental diesel or half the power tariff and it seems that economy is secured. However, in this estimation, because data on the construction costs and fundraising costs, etc. of EWSA-owned diesel facilities couldn't be obtained, only the fuel costs are reflected in the generation unit cost. Which out of diesel rental or diesel construction by EWSA incurs the lower introductory cost depends on the procurement capacity of EWSA. Considering that rental operators such as Aggreko are competitive in the extensive African market, it is not certain that rental facilities will be more expensive.

On conducting analysis of EWSA diesel load factors (Table 2-2.3, Table 2-2.4), concerning annual load and daily load, rental facilities are at full operation whereas EWSA diesel facilities are operated to cover peak load. This means that the average combustion efficiency and fuel economy are inferior in the EWSA diesel facilities, however, the rental facilities are thought to have higher variable cost unit rates than the EWSA-owned facilities in reality. Table 2-2.9 shows the scale-separate and load-separate combustion efficiency values for Aggreko.

Table 2-2.9 Combustion Efficiency of Diesel Facilities by Capacity and Load

Generator Rental Sizes	**Voltage** (V)	**Fuel Consumption** Gallons/hour			**Fuel Capacity** (Gross Gal.)	**Overall Dimensions** (L x W x H)	**Weight** (lbs)	
		100% Load	**75% Load**	**50% Load**			**With Fuel**	**Without Fuel**
30 kW	120/40 208/120 480/277	2.0	1.5	1.0	58	8'0" x 3'8" x 5'11"	3818	3410
60 kW	120/40 208/120 480/277	4.6	3.6	2.7	94.6	9'3" x 3'4" x 5'11"	4118	3448
125 kW	120/40 208/120 480/277	8.8	7.5	5.3	184	10'7" x 3'9" x 6'8"	7564	6321
200 kW	120/40 208/120 480/277	12	9	6	275	13'1" x 3'11" x 9'0"	10,326	8378
200 kW (Tier4i)	120/40 208/120 480/277	12.1	9.4	6.3	291	13'1" x 3'11" x 8'2"	10,990	8929
300 kW	120/40 208/120 480/277	18.2	13.7	9.5	277	15'2" x 4'9" x 8'3"	14,748	12,787
500 kW	120/40 208/120 480/277	31.1	23.9	17.3	362	17' x 6'3" x 8'6"	20,550	17,979

Source: Aggreko Website (Available Generator Sizes for Rent)

Moreover, because other generation costs, for example, costs of chemicals, repairs, and spare parts shown in the financial statements (Table 2-2.6), couldn't be distinguished between power sources, they have not been included in the above diesel generation unit costs (Table 2-2.7). Also, administration costs and common costs such as personnel expenses and general affairs expenses at power stations and generation headquarters should also be added to the generation unit costs, however, according to the conventional EWSA accounting policy, these have not been reflected in generation unit costs because they are not linked as activity costs.

If such costs were reflected in the generation cost, it is guessed that the diesel unit generation rate would rise to more than 40 cents per 1kWh, which would be almost twice as much as the power tariff unit rate.

Explanation is given in reference to the estimation procedure. Because information couldn’t be obtained on the facility-separate introduction cost (the rental period and cost in the case of rental facilities, and the construction cost and capital cost in the case of EWSA=owned facilities), scheduled period of use, combustion efficiency, performance curve, other variable costs apart from fuel cost, and other fixed costs, it was assumed that the introduction cost and combustion efficiency are equal for all diesel facilities. Usually, in addition to introduction cost, because the performance of each facility differs according to combustion efficiency, load factor, utilization factor, type of fuel, properties of fuel, temperature and so on, it is necessary to take such factors into account when estimating the generation unit cost. However, since the estimation here is primarily intended to grasp the rough cost level of diesel generation as reference for master plan formulation, all the conditions that couldn’t be acquired were assumed to be uniform. The method for calculating the variable costs and fixed costs that comprise the generation unit rate is described below (see Table 2-2.10).

Table 2-2.10 Calculation table of diesel cost

Name		Aggreko Gikondo	Aggreko Mukungwa	Jabana 1	Jabana 2
Status(MW)		Rental(10)	Rental(10)	REG(7.8)	REG(20)
Year		2005	2012	2004	2009
Type		Diesel	Diesel	Diesel	Diesel(HFO)
2010	Jul	6,623,166		1,758,000	2,226,800
2010	Aug	7,515,180		1,185,600	2,776,500
2010	Sep	7,340,740		972,800.0	4,187,700
2010	Oct	6,142,740		644,800.0	5,807,124
2010	Nov	6,496,250		925,700.0	7,797,598
2010	Dec	6,878,461		957,500.0	9,478,200
2011	Jan	7,351,530		897,200	8,924,840
2011	Feb	6,536,160		653,400	8,363,556
2011	Mar	6,309,870		888,800	11,382,436
2011	Apr	6,249,810		816,100	7,992,588
2011	May	7,314,159		952,700	6,962,248
2011	Jun	7,091,800		911,200	7,276,484
2011	Jul	5,400,962		1,344,900	8,674,148
2011	Aug	7,335,240		1,532,100	7,722,160
2011	Sep	7,131,490		1,242,100	6,922,276
2011	Oct	7,147,711		1,279,700	6,769,472
2011	Nov	6,707,150		637,210	7,870,512
2011	Dec	5,882,189		351,300	8,934,240
2012	Jan	7,305,103		444,700	8,152,232
2012	Feb	6,834,040		533,300	7,654,856
2012	Mar	6,981,720		697,100	8,364,368
2012	Apr	6,846,070		231,400	9,196,112
2012	May	6,748,201		246,500	10,028,552
2012	Jun	5,727,803		581,700	10,018,394
2012	Jul	7,016,330		771,000	9,598,344
2012	Aug	6,420,770		929,600	10,072,912
2012	Sep	6,613,551	0	816,000	7,733,304
2012	Oct	7,276,500	2,451,004	443,100	8,323,704
2012	Nov	7,042,444	2,441,500	405,500	8,937,648
2012	Dec	7,410,240	2,790,300	273,300	8,042,481
2013	Jan	7,353,195	3,566,720	265,500	8,227,516
2013	Feb	6,488,940	4,990,670	654,400	7,143,032
2013	Mar	6,847,053	6,412,360	702,900	7,254,464
2013	Apr	6,720,880	6,261,640	514,200	8,369,616
2013	May	7,275,530	4,890,410	328,700	8,301,208
2013	Jun	7,107,000	5,352,130	494,300	7,497,488
Generation		245,469,978	39,156,734	27,284,310	282,985,113
(MWh)		41%	7%	5%	48%
Fuel cost		17,402,808,305	2,776,050,792	1,934,344,968	20,062,476,540
Rental Cost		39,991,771,161	6,379,383,492		
Unit Cost					
(RWF/kWh)		234	234	71	71
(USD/kWh)		0.36	0.36	0.11	0.11
			FX-Rate(USD/RWF) on End of FY2012		
					642.67

a) Variable costs

- Fuel cost is apportioned according to the share of power generation of each diesel facility (41%, 7%, 5%, 48%), and divided by the quantity of power generation of each facility.

Aggreko Gikondo (10MW)	Aggreko Mukungwa (10MW)	Jabana 1 (7.8MW)	Jabana 2 (20MW)
17,402,808,305 RWF (41%)	2,776,050,792 RWF (7%)	1,934,344,968 RWF (5%)	20,062,476,540 RWF (48%)
71RWF	71RWF	71RWF	71RWF

- The share of Aggreko Mukungwa is low because it only started operation in October 2012. Also, the low share of EWSA-owned Jabana 1 is explained by its small plant capacity (approximately 40%) compared to Jabana 2, and the fact that Jabana 2 uses heavy fuel oil (HFO) which has a relatively cheaper unit cost. Moreover, because it is necessary to increase the operating rate of rental facilities in order to pay for fixed costs, Jabana 1 is thought to have a comparatively low priority of use.

b) Fixed costs

Aggreko Gikondo (10MW)	Aggreko Mukungwa (10MW)
39,991,771,161 RWF (41%)	6,379,383,492 RWF (7%)
163RWF	163RWF

- The rental cost is apportioned according to the share of power generation of each diesel facility (41%, 7%), and divided by the quantity of power generation of each facility. According to EWSA, rental costs for Aggreko are paid according to the annual cost and generated power, i.e. as a unit rate per kWh.

c) Generation unit costs (variable costs + fixed costs)

Aggreko Gikondo (10MW)	Aggreko Mukungwa (10MW)	Jabana 1 (7.8MW)	Jabana 2 (20MW)
234RWF	234RWF	71RWF	71RWF

The relationship between subsidies, which the government reportedly wishes to abolish in FY 2017 (per ESSP draft), diesel cost, and EWSA operating income and expenses is explained in Table 2-2.11. It must be noted that the original statement of earnings on which this table is based was an unaudited draft.

It can be said that subsidies are critical to the extent of being a lifeline for EWSA operation. Without the approximately 12 billion RWF (approx. $20 million) in subsidies, it would become impossible to pay the rental diesel costs, and EWSA operations would no longer be viable. For example, according to the EWSA balance sheet at the end of FY 2012, EWSA's cash and balances at banks amounted to 6.1 billion RWF, which if used in total against annual rental diesel costs, would not cover half of the amount. Shareholders' funds including accumulated profit at the end of FY 2012 were given as approximately 40 billion RWF, this also would disappear to become a net capital deficiency in about 3 years. The point is that whether considered from the point of view of working capital or cash and balances at banks, EWSA is in a difficult situation and would not be able to operate for even 1 year without subsidies. However, operation throughout the year is at almost full load, and rental diesel, which bears around 30% of domestic power availability (based on 2013 power generated) cannot be discontinued, therefore the very continuation of government subsidies supports the stability of the power supply and EWSA's operation.

As shown in the table below, diesel generation costs (fuel and rental costs) amount to 34.8 billion RWF or about 80% of total generation costs of 43 billion RWF, and as noted previously, the capital charges on the investment made by EWSA itself into diesel facilities must also be considered. For these reasons, in carrying out a review of EWSA's cost structure, its issues are not at a level that can be handled simply through the efforts of a private-sector company, by for example improving efficiency or cutting costs, it's a fundamental change of policy based on energy supply and demand from a long-term viewpoint in which government decisions will be crucial.

Table 2-2.11 Subsidies and diesel rental cost in EWSA operating income and expenses

EWSA Income Statement	2013/6/30	2012/6/30
Draft (Unaudited)	Frw	Frw
Revenue	72,438,411,733	58,591,365,431
Cost of sales(Generation Cost)	**(43,608,392,723)**	**(36,062,208,206)**
Distribution costs	(15,678,801,550)	(9,665,315,866)
Administrative expenses	(31,525,405,389)	(26,320,406,612)
Contribution to EARP	(3,947,670,330)	(1,173,563,550)
Profit bfore other income	**(22,321,858,259)**	**(14,630,128,803)**
Other operating income	**15,307,693,520**	**16,688,321,826**
Investment income	58,686,800	149,310,683
Net finance costs	(1,309,394,688)	(603,071,472)
Net profit before Tax	**(8,264,872,627)**	**1,604,432,234**

GENERATION COSTS	2013/6/30	2012/6/30
Chemical products	1,066,851,790	1,512,699,349
Repairs and maintenance	1,390,579,822	393,491,761
Spare parts and consumables	7,537,780	4,455,335
Fuel and Lubricating oils	21,918,952,024	17,930,879,726
Variances between physical and book stock	644,001,449	171,074,268
Rental of power	12,937,121,146	11,523,175,467
Capacity charge electricity	2,926,634,386	2,193,261,135
Purchase of solar energy	7,601,691	15,024,101
Purchase of electricity	2,709,112,635	2,318,147,064
Generation Cost Total	43,608,392,723	36,062,208,206

Almost same value of Rental Diesel cost

Finance, especially for Rental Diesl are sustained by GOR

OTHER OPERATING INCOME	2013/6/30	2012/6/30
Subsidies received	**12,972,816,371.**	**11,845,734,209.**
Other sundry receipts	69,472,886.	91,407,710.
Other income	2,178,269,399.	255,346,362.
Reversal of provisions	0.	440,262,657.
Amortisation of grant	-	4,055,109,867
Variances between physical and book stock	113	
Other equipment sales	87,134,751.	461,021.
	15,307,693,520	16,688,321,826

Source: JICA study team, based on documentation from EWSA

3) Photovoltaic

Effective use of solar light, one of Rwanda's valuable, purely-domestically produced energy resources, is being actively promoted. Currently, the only photovoltaic power station connected to the transmission network is Rwamagana (8.5MW), which commenced operation in 2014. There are plans for two more facilities, Rwinkwavu (10MW) and Nyagatare (10MW), to be constructed by IPPs. In addition, the 0.25MW Jali Solar is connected to the distribution network.

According to MININFRA, the Rwamagana power station installed capacity of 8.5MW is currently the largest scale photovoltaic to have been introduced in East Africa, and the power station's EPC (engineering, procurement and construction) was carried out by Scatec Solar of Norway. Construction funds were provided by developing country investment institutions Norfund and KLP, and business operations are being carried out by Dutch IPP, Gigwatt Global. Photovoltaic generation costs are cheap in comparison to those for diesel and there is no CO_2 emission. For these reasons, MININFRA wants to link photovoltaic with hydro and other renewable energy, and position it as part of the best mix of power sources.

However, Rwanda's power peak time is at night from around 19:00 to 21:00, but photovoltaic does not offer flexible use ready as a standby for this peak. So in contrast to its merits, it is necessary to study equipment to provide backup power sources and stabilization to offset the demerits of its instability of voltage and availability. Therefore consideration is needed on how to balance the aspects of cost and technology. Adoption of photovoltaic must be pursued after its advantages and disadvantages are fully understood. Refer Table 2-2.11.

Table 2-2.12 Advantages and disadvantages of photovoltaic

	Photovoltaic power generation
Advantage	● No problem of resource exhaustion ● No CO_2 emission during electricity generation ● Close to location of demand, so no transmission losses ● Electricity generation during the hours of greatest demand in the daytime ● Short period of construction ● Donor consensus
Disadvantage	● Energy density is low and to obtain the same amount of electric power as from thermal or nuclear power requires a vast area (roughly 130 times as large) ● No electricity can be generated overnight and also the generated output falls on rainy or cloudy days, so it is unstable (General rate of equipment utilization is 12%) ● The cost of the equipment is expensive

Source: JICA study team

Furthermore, with the introduction of photovoltaic there are many technological issues. For example, if measures are taken that incorporate the latest equipment and technology for system control, it must be kept in mind that this will cost a substantial amount of money. Refer Table 2-2.12 below.

Table 2-2.13 Technological issues and measures of photovoltaic

Issues		Responses
Quantit	Insufficient capacity on T&D* lines	Reinforcement of T&D* lines
	Surplus power (Renewables output exceed demand)	Output restriction of Renewables Use of batteries / pumped storage
Quality	Voltage rising in distribution system	Installation of voltage regulating equipment / transformer Electricity consumption in houses
	Insufficient capacity of Frequency adjustment	Use of backup adjustment power source (thermal, pumped storage, batteries)

Source: JICA study team

Source: MININFRA website

Photo 2-2.6 Rwamagana Photovoltaic Power Station (8.5MW)

4) Reduction of indigenous energy resources share

As showed in the table below, according to the increase of diesel (LFO/ HFO), Rwanda's utilization of indigenous generating resources share has been drastically reducing since the first diesel installation in 2004. Although, the government is promoting a variety scale of hydro with private sectors, achievement is not necessarily good at this moment. One of the reasonable measures to increase the affordable power sources might be import. However, if there should be fatal outage related to the interconnector, Rwanda would face the huge energy security risk for a substantial period. Therefore, as the alternative energy of the diesel, unused energy sources in Rwanda, such as peat, methane and geothermal are highly expected in recent years.

Table 2-2.14 Indigenous generating resources share

Source		Generation (MWh, %)	
Indigenous	(48.3MW)	153,242	30%
Import (LFO/HFO)	(47.8MW)	254,946	51%
Import (Hydro)	(15.5MW)	93,934	19%
Total (111.6MW)		502,123	100%

(2) Status of transmission/distribution facilities

In Rwanda, 1,200km of HV line (110kV/70kV), and 3,567km of MV line (30kV/15kV) is currently installed, as of January, 2014. (6.6kV and below is classified as LV line.)

In order to handle the increased power demand and make a reduction in electlicity network loss, there have been conducted some projects for enhancement of the network with support of donnors. As one of the latest implementations, the Project for Improvement of Substation and Distribution Network was completed in March, 2014. This was a JICA's three-year-project to rehabilitate and re-construct old substations as well as to restore and expand distribution network in order to improve a electricity access and supply and coverd the five areas in Rwanda, namely Jabana and Gikondo, Rwinkwavu, Huye and Musha. Since March, 2015, as a following project to the above mentioned, the project for upgrading and new facility installment and of Substation and 110kV HV line in the central area of Rwanda will be started by the support of JICA.

Fig. 2-2.6 shows the transmission line network in Rwanda.

Specifications for types of transmission line follow German DIN standards. For HV lines ASCR 240/40 is used mainly, and for MV lines included within distribution lines ASCR 120/20 is used mainly.

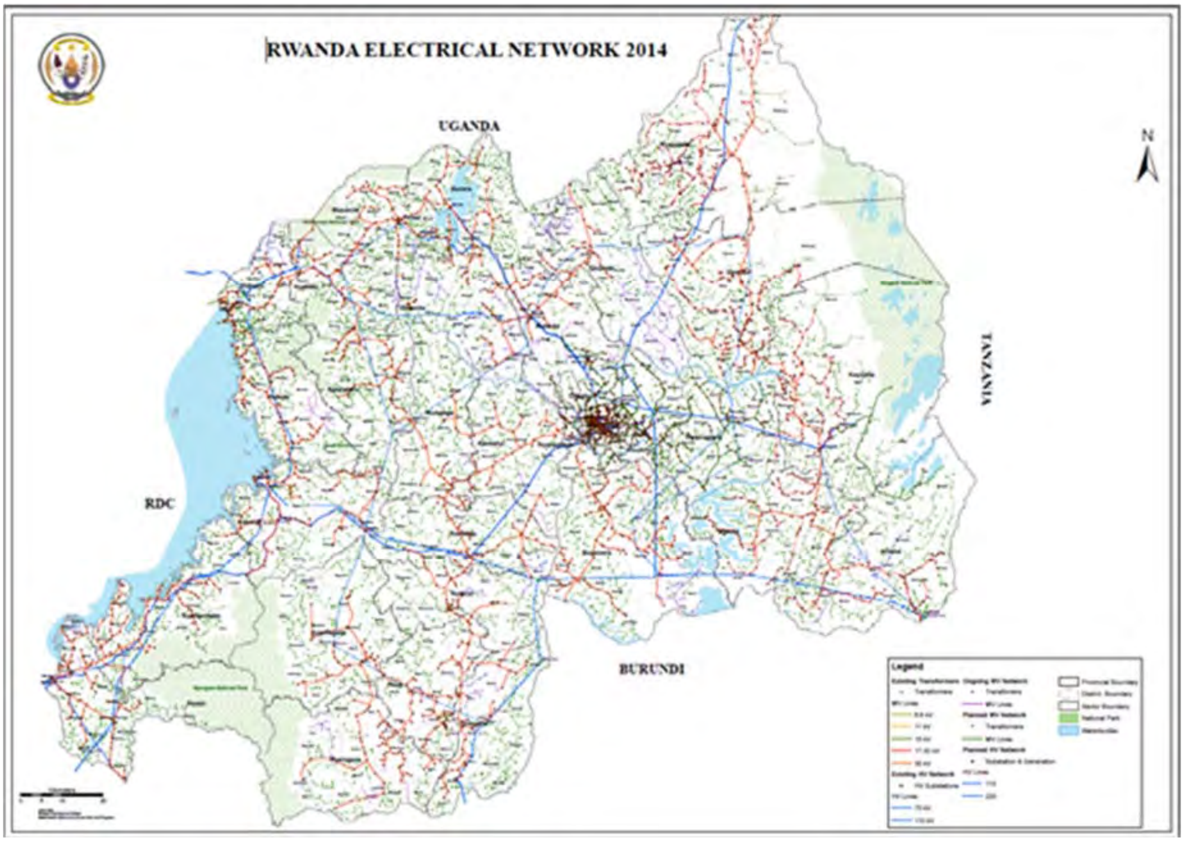
In addition to the lack of capacity in Rwanda's power generation facilities, there is also the issue of resolving transmission/distribution power loss, which at approx. 20% is high. To understand the current status of the transmission/distribution network, through JICA support centered on the district for the capital Kigali, management of the transmission/distribution network that utilizes GIS is now progressing.

Another issue is that Rwanda has no phase modifiers (capacitors). Because there are sections where the power receiving side power factor is approx. 0.8, for which operation is inefficient, it is possible to promote improved efficiency through the introduction of phase modifiers.

In Rwanda, international connection lines are currently connected through 6 grids. However, because Uganda operates with a working voltage of 33kV, which is not used in Rwanda, power is transformed at the Gatuna s/s. In addition, according to data obtained on the results for power interchange via interconnection lines for 2012, power import amounted to approx. 90GWh while export was approx. 0.3GWh, meaning that fundamentally international connection lines are used for the import of power.

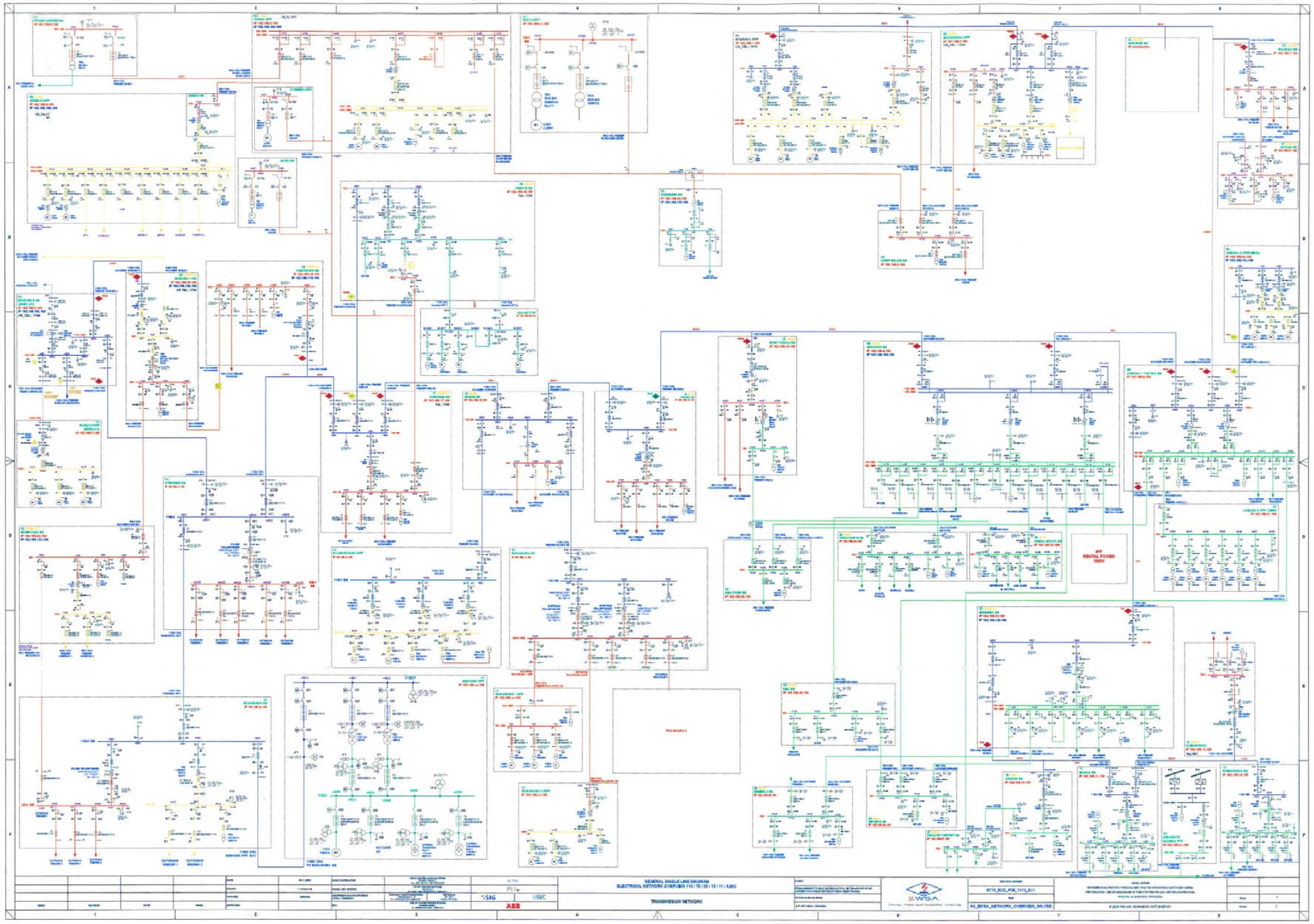
At the load dispatching center (NECC) that coordinates power demand and supply within Rwanda, some feeders are not installed with measurement devices, thus online data collection is not done. It is necessary to increase data collection devices in order to properly coordinate power supply and demand. International connection lines are included among the 220KV transmission lines currently being constructed, and it is planned for 30MW to be imported from Kenya via Uganda in 2015, with the amount imported to be steadily increased thereafter.

There are plans to import 400MW from 2020 onwards, and it is anticipated that these imports will help increase the reliability of power supply in Uganda.



Source: EWSA-GIS

Fig. 2-2.6 Transmission network in Rwanda



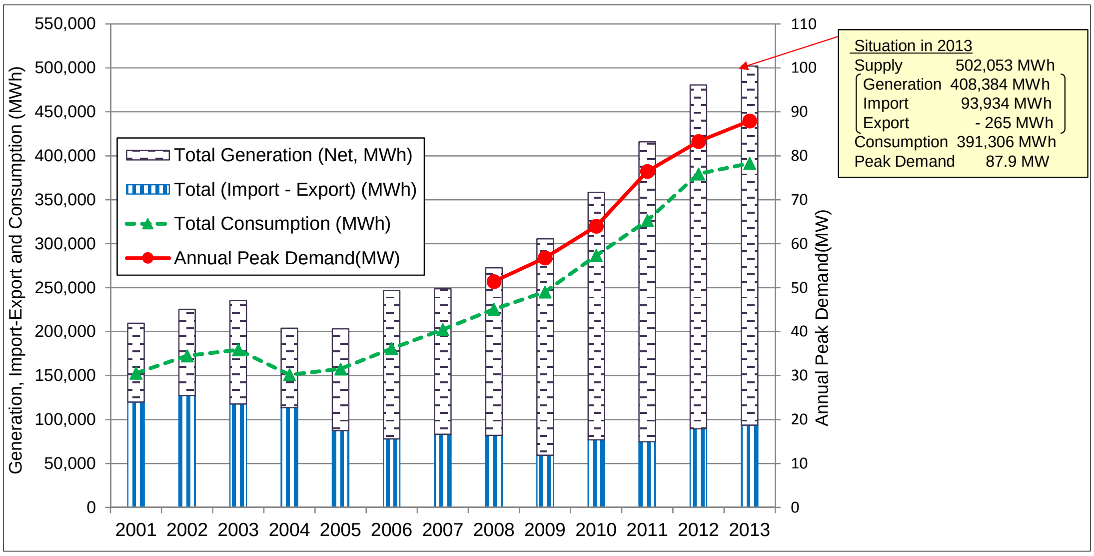
Source: EWSA-GIS

Fig. 2-2.7 Single-line diagram in Rwanda

2.2.2. Electricity Supply-Demand Situation

(1) Supply – Demand

Since 2008, power supply in Rwanda has shown a year-on-year increase of approx. 10%, with power supply in 2013 totaling 502,053 MWh. This is the value obtained by adding 408,384 MWh generated in Rwanda and 93,934 MWh imported from Rusizi 1 and Rusizi 2 hydro-power plants, which are operated jointly with neighbor countries, and then subtracting 265 MWh exported to Uganda and Burundi. Electricity sales in 2013 were 391,306 MWh. The disparity between 502,053 MWh and 391,306 MWh was accounted for by a 22% power loss.

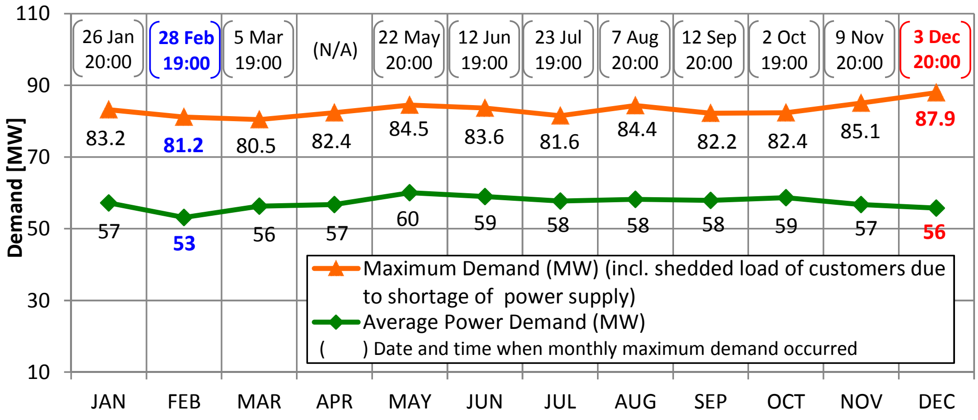


Source: EWSA National Electricity Control Center and Electricity Commercial Unit

Fig. 2-2.8 Transition of yearly supply-demand

The composition of power sources for power supply in Rwanda in recent years is accounted for by: hydro-power of approx. 53 %, including import from Rusizi 1 and Rusizi 2; diesel power of approx. 45%; and methane/solar, etc. of approx. 2%. The ratio for diesel power generation, which uses high-cost fuel, is large.

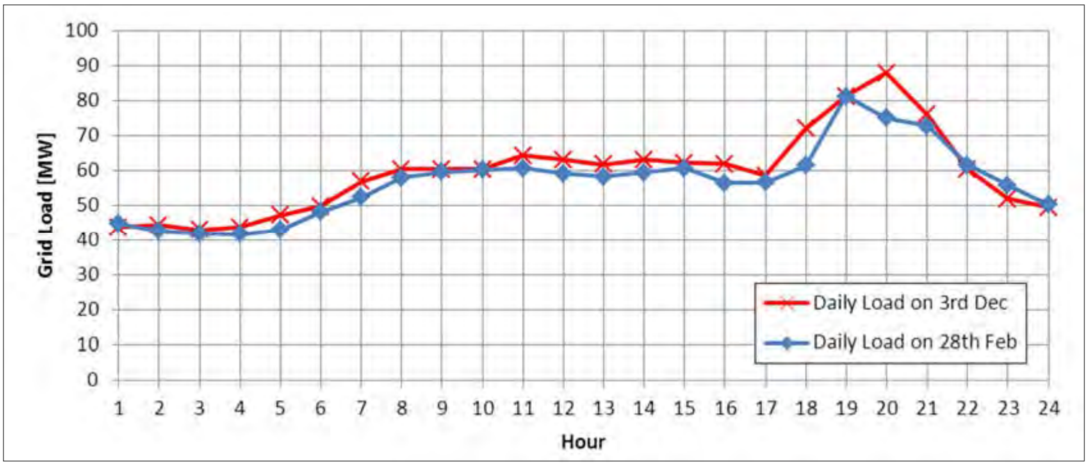
In the same way as power supply, annual maximum demand in Rwanda shows a particularly large rise after 2008. In 2013, a maximum demand of 87.9MW was recorded. Considering monthly power demand in 2013, as shown in Fig. 2-2.9, there is no remarkable tendency of power demand to change according to the seasons. EWSA National Electricity Control Center reports that power supply sometimes cannot meet high demand during the peak period depending on operation of power generation facilities; and to cope with such cases, electricity supply to customers is cut as an emergency measure (Such load shedding occurred during peak periods in Aug, Sep, Nov and Dec. Refer Fig. 2-2.9.).



Source: EWSA National Electricity Control Center

Fig. 2-2.9 Transition in monthly maximum power demand and average demand

Fig. 2-2.10 shows the daily load curve on 3rd December, when the maximum power demand for 2013 was recorded, as well the load curve on 28th February, when the maximum power demand for February, the month showing the smallest monthly power supply, was recorded. On the both days, power demand was maximum during the period from 19:00 to 20:00, when electricity consumed for lighting at households reaches peak demand. Concerning the daily use of electricity, there was no remarkable tendency of power consumption to change according to the seasons.



Source: EWSA National Electricity Control Center

Fig. 2-2.10 Daily load curves

(2) Status of electricity Sales

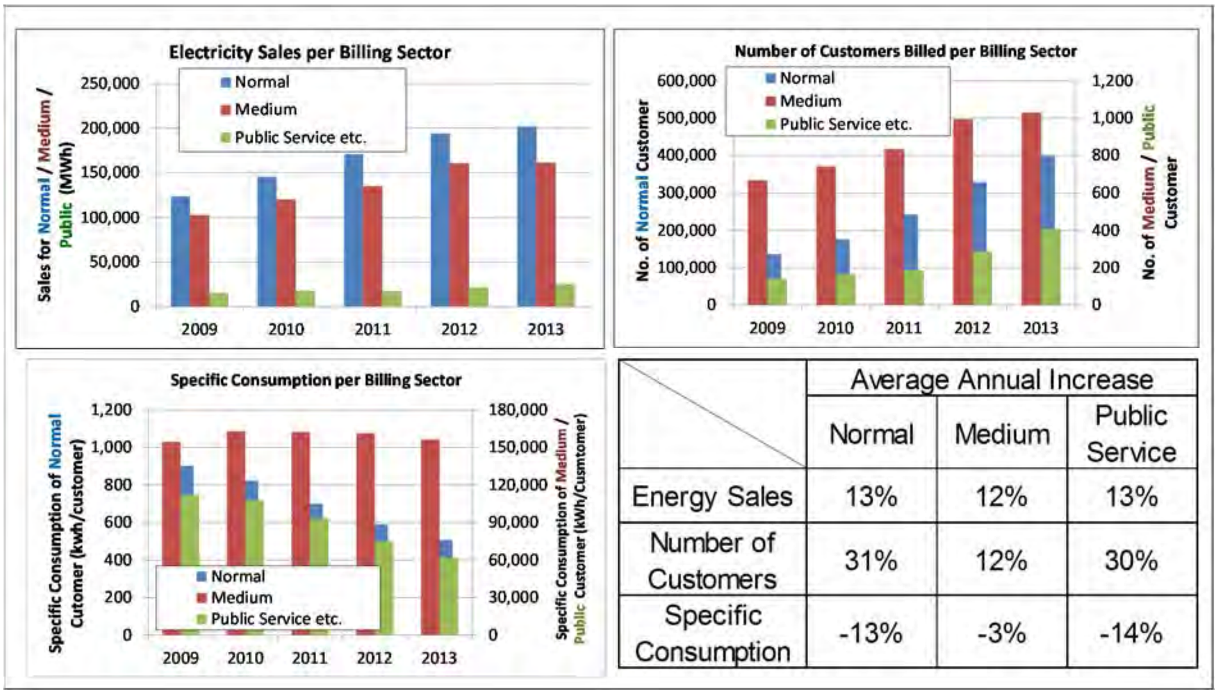
EWSA categorizes electricity sales in three billing sectors below:

- The Normal Customer covers general households
- The Medium Customers covers industrial and commercial facilities
- The Public Service (&Diplomat) Customer includes public facilities such as government offices, public hospitals and schools, as well as embassies

Of the 2013 electricity sales, the Normal Customer accounted for 52%, and the Medium Customer and the Public Service Customer 41% and 7%, respectively.

Fig. 2-2.11 shows the change in the electricity sales, number of customers and specific consumption (the figure obtained by dividing the electricity sales by the number of customers) during 2009 – 2013 for the three billing sectors. The electricity sales have increased by about 13% annually for all the sectors. The number of customers under the Medium Customer increased by 12%, while those under the Normal Customer and Public Service Customer jumped by about 30%. According to EWSA, this large increase was due to the electrification in the rural areas promoted by the national government and EWSA.

As for the specific consumption, it went down by about 13% for the Normal Customer and Public Service Customer. The reason might be that although the number of customers increased significantly due to rural electrification, the rural customers who are newly connected to distribution systems use less power in general than the existing customers; thus compared to the annual average increase in the number of customers (about 30%), the annual increase in power consumption is small (about 13%).



	Average Annual Increase		
	Normal	Medium	Public Service
Energy Sales	13%	12%	13%
Number of Customers	31%	12%	30%
Specific Consumption	-13%	-3%	-14%

Source: EWSA Electricity Commercial Unit

Fig. 2-2.11 Change in electricity sales, No. of customers and specific consumption by billing sector

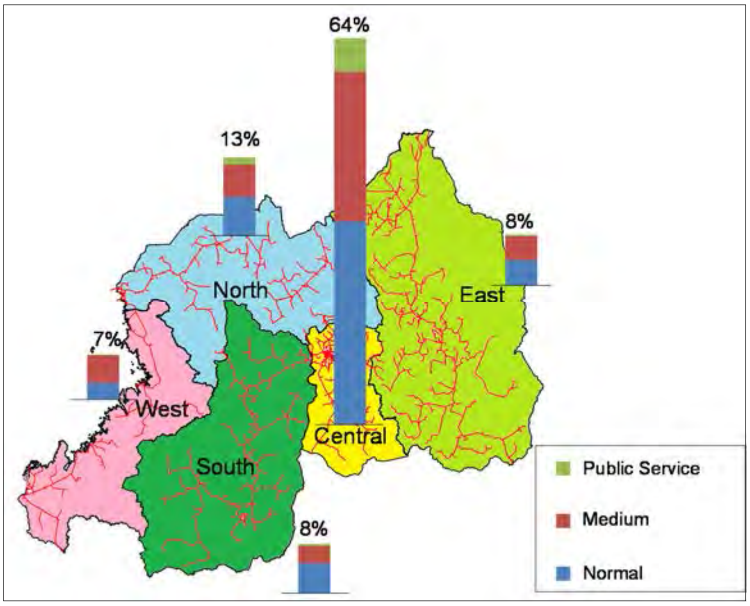
For reference, transition in specific consumption for other African countries from 2009 to 2011 is shown in Table 2-2.15 (for specific consumption, since electricity sales per number of customers was unobtainable, power consumption for the population living in electrified households was used instead). In countries where electrification is progressing, the table shows that specific consumption tends to fall. In contrast, in countries where electrification was not progressing during this period (e.g. Botswana, Eritrea), power consumption by existing customers grew at single-digit percentage rates.

Table 2-2.15 Change in specific consumption for general customers in other African countries

	Electrification Rate (% of Population)			GDP per capita (constant 2005 US$)			Household electricity consumption per person who receives electricity (kwh)			Average change of household electricity consumption per person who receives electricity
Year	2009	2010	2011	2009	2010	2011	2009	2010	2011	
Benin	24.8	27.9	28.2	552	550	554	147	136	135	-4%
Botswana	45.4	45.4	45.7	5,717	6,153	6,476	868	927	962	5%
Cameroon	48.7	48.7	53.7	925	931	945	92	98	93	0%
Cote d'Ivoire	47.3	58.9	59.3	954	958	893	182	158	151	-9%
Eritrea	32.0	32.0	31.9	186	184	194	61	63	63	2%
Ethiopia	17.0	23.0	23.3	214	234	254	83	73	72	-6%
Kenya	16.1	18.1	19.2	558	575	584	369	310	227	-22%
Mozambique	11.7	15.0	20.2	365	381	399	275	250	212	-12%
Senegal	42.0	53.5	56.5	790	800	794	124	109	120	-2%
South Africa	75.0	75.8	84.7	5,595	5,694	5,821	1,040	1,054	939	-5%
Togo	20.0	27.9	26.5	388	393	401	326	237	256	-11%
Uganda	9.0	8.5	14.6	384	393	405	112	126	77	-17%
United Rep. of Tanzania	13.9	14.8	15.0	435	452	466	269	263	270	0%
Zambia	18.8	18.5	22.0	710	741	768	1,070	1,132	935	-7%

Source: JICA study team, based on United Nations, IEA and World Bank data

Next, the trend in power consumption by zone is shown in Fig. 2-2.12. The zones were established based on the method EWSA uses to plan the rural electrification (originally created by Sofreco, a contractor of EWSA) and the country was divided into East, West, South, North and Central to correspond to groups of Medium Voltage Lines. The power consumption in the Central zone (Kigali City and Bugesera district) is the largest, consuming 64% of the country's electricity while other zones use about 10% each. In the West zone with cement and beer factories, the rate of power use by the Medium Customer is greater than other zones.



Source: EWSA Electricity Commercial Unit and EARP Unit

Fig. 2-2.12 Electricity sales by zone and billing sector

2.3. Power Demand Forecast

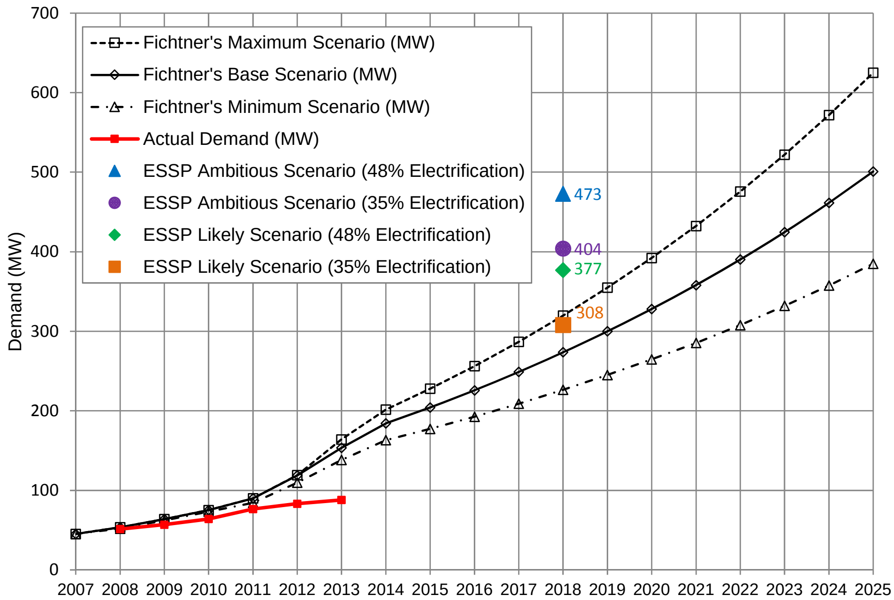
Concerning the forecasting methods applied to arrive at Rwanda's power demand forecast, and the results of forecasting, workshops relating to power demand forecast were conducted at the times of 2nd and 3rd work in Rwanda at which the JICA study team provided an explanation to the counterpart, and to which the counterpart expressed its acceptance.

Photo 2-3.1 Workshops of power demand forecast during 2nd and 3rd work in Rwanda

The methods and results of forecasting are given below.

2.3.1. Existing Power Demand Forecast

Concerning the power demand forecast for Rwanda, Fichtner carried out detailed work in 2009 to forecast future power demand using various socioeconomic data gathered; however, this forecast is not officially authorized by EWSA. Fig. 2-3.1 shows power demand forecast values given in the ESSP (2014 revision) and Fichtner demand forecast, as well as actual power demand recorded from 2007 to 2013.



Source: EWSA National Electricity Control Center, Economic Data Collection and Demand Forecast, Dec. 2009 and Energy Sector Strategic Plan 2013-2018

Fig. 2-3.1 Comparison between power demand forecast and actual demand

Fichtner carried out a power demand forecast, taking into account the number of customers and specific energy consumption by customer type: ordinary consumers, private sector, government sector, Electrogaz sector, diplomats and others. This forecast is based on an electrification scenario based on Vision 2020 and the EDPRS's strategy, such as 350,000 households in total to be electrified by 2012, 35% of households by 2020, and 40% by 2025, as well as GDP growth forecast provided by the Ministry of Finance, and information about future large scale customers. As a result of forecasting, EDPRS's strategic demand of 360MW in 2020 is positioned within the range of the upper and lower limits of the Fichtner forecast scenario. However, actual power demand growth is below the Fichtner forecast minimum scenario for power demand.

Table 2-3.1 shows four sets of power demand forecast for 2017/18 given in ESSP. .

Table 2-3.1 Power demand forecast given in ESSP

Table 7 Demand and supply projections under different scenarios

Demand scenarios	On-Grid Electricity Access Target	
	35% Target	48% Target
Likely Demand	**Supply: 363 MW** Total Demand: 308MW	**Supply: 444 MW** Total Demand: 377 MW
Ambitious Demand	**Supply: 475 MW** Total Demand: 404 MW	**Supply: 563 MW** Total Demand: 473 MW

Source: REG (2014)

Table 8 Assumptions common to both scenarios to 2018

Demand End-User Category	Scenario Dependant Assumptions to 2018	
	Likely Scenario	Ambitious Scenario
Residential and SMEs	Demand by customers increases 5-fold in 6 years.	Demand by customers increases 5-fold in 6 years.
Commercial and Industrial	50 % of large user projects will materialize	100 % of large user projects will materialize

Source: REG (2014)

Source: ESSP

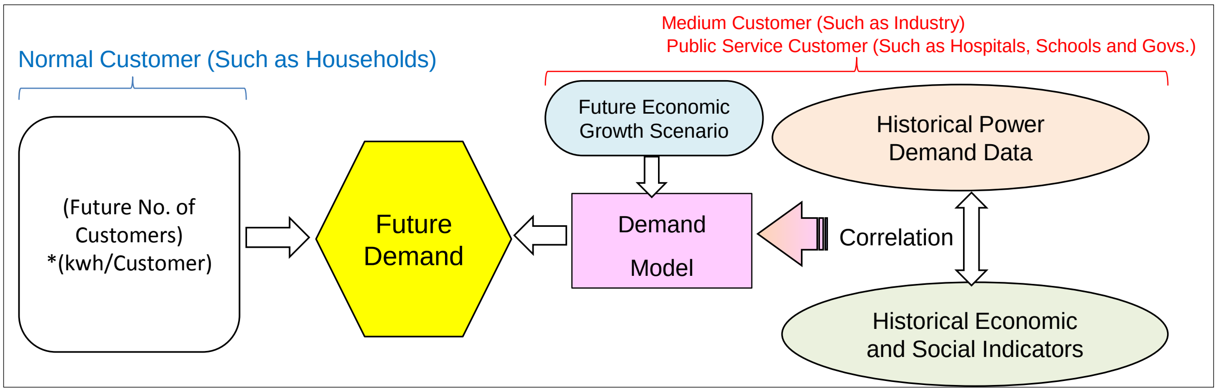
Power grid integration with expanded international interconnection lines is planned for the countries of EAC (East African Community) and the detailed plan is stated in Regional Power System Master Plan and Grid Code Study. In this master plan, each country's power demand forecast is stated; which for Rwanda in 2018, required generation capacity is 205MW and maximum power demand is 165MW. These values are very significantly lower than the targets given in EDPRS2 and ESSP.

2.3.2. Outline of Power Demand Forecast

Two approaches were taken for different billing sectors to forecast power demand, as shown in Fig. 2-3.2.

The first approach was for the Normal Customer such as households, and used a bottom-up method (a product of the future number of customers and specific consumption). Upon forecasting, the rural electrification plan of EWSA was given thorough consideration.

The second approach was for the Medium Customer that includes industrial and commercial facilities and the Public Service Customer, and used a macroscopic method. This method creates a power demand model (approximate formula) based on the correlation between the historical economic and social indicators and power demand, and forecasts the future power demand by entering the future economic and social growth into the model.

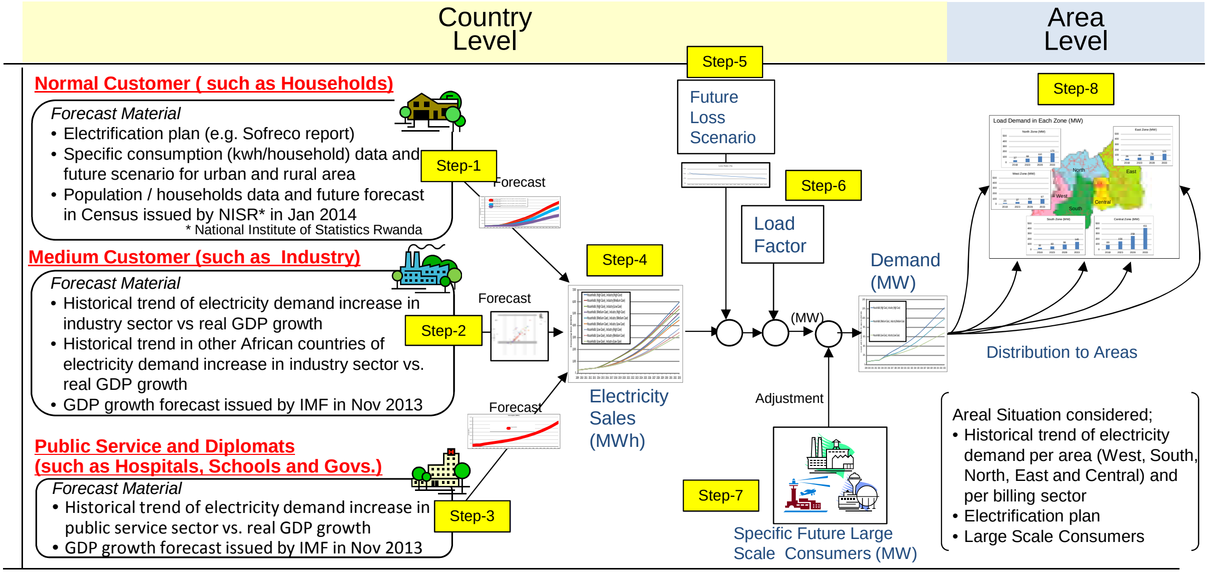


Source: JICA study team

Fig. 2-3.2 Scheme of power demand forecast

The detailed work flow is given in Fig. 2-3.3 and the main steps are described below:

- Step-1 Forecast of electricity sales (GWh) to the Normal Customer
- Step-2 Forecast of electricity sales (GWh) to the Medium Customer
- Step-3 Forecast of electricity sales (GWh) to the Public Service Customer
- Step-4 Calculation of the country-level electricity sales (GWh) by totaling the electricity sales obtained in Steps 1 - 3
- Step-5 Conversion to the country-level generated energy (GWh) using transmission/distribution loss factor
- Step-6 Conversion to the country-level power demand (MW) using load factor
- Step-7 Correction of the country-level power demand (MW) based on the Large-scale Customer information
- Step-8 Division of the country-level power demand (MW) by zones



Source: JICA study team

Fig. 2-3.3 Power demand forecast flow

2.3.3. Details of Power Demand Forecast

The details of power demand forecast are described below for each step listed in the previous section.

(1) Step-1 Forecast of electricity sales (GWh) to the Normal Customer

In order to forecast the electricity sales to the Normal Customer including households, a bottom-up method (a product of the future number of customers and specific consumption [kWh/Customer]) was used.

As for the scenarios of the future number of customers, based on a request from EWSA, a scenario that ESSP's target electrification rate of 48% is achieved in 2017/18 was set as the High Case, and the cases where the target is not achieved were set as the Medium Case (42%), and Low Case (35%) as shown in Table 2.3-2. For the forecast of the electrification rate for each year up until 2017/18, the Combined Design Report of Electricity Access Roll Out Program by Sofreco was used as a reference. The number of new customers for each year after 2017/18 was established based on the assumption that the achievement of 48% electrification rate is delayed by 2 years in the Medium Case, and 4 years in the Low Case (for the number of households necessary to calculate the electrification rate achieved after 2017/18, 3.9%/year was used since the Census issued by the National Institute Statistics of Rwanda in Jan. 2014 forecasted the future increase in the number of households to be 3.9%/year).

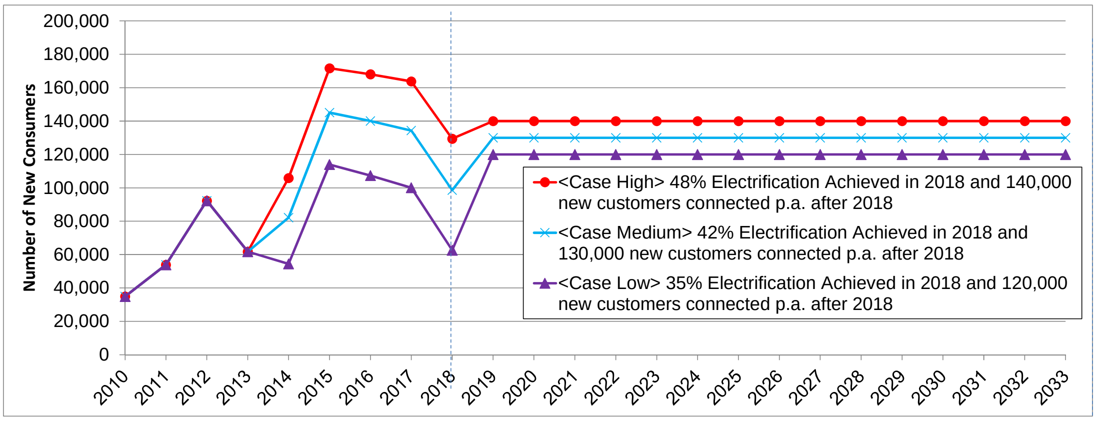
Because future number of customers is calculated based on a scenario under which the ESSP-based electrification rate provided by EWSA will be reached, the effect of future price indices and electricity tariff is not taken into consideration.

Table 2-3.2 No. of customers/electrification scenarios

Case	Electrification Rate in 2017/18	Number of New Customers per annual after 2017/18
High	48%	140,000
Medium	42%	130,000 (2 years delayed to achieve 48% Electrification Rate)
Low	35%	120,000 (4 years delayed to achieve 48% Electrification Rate)

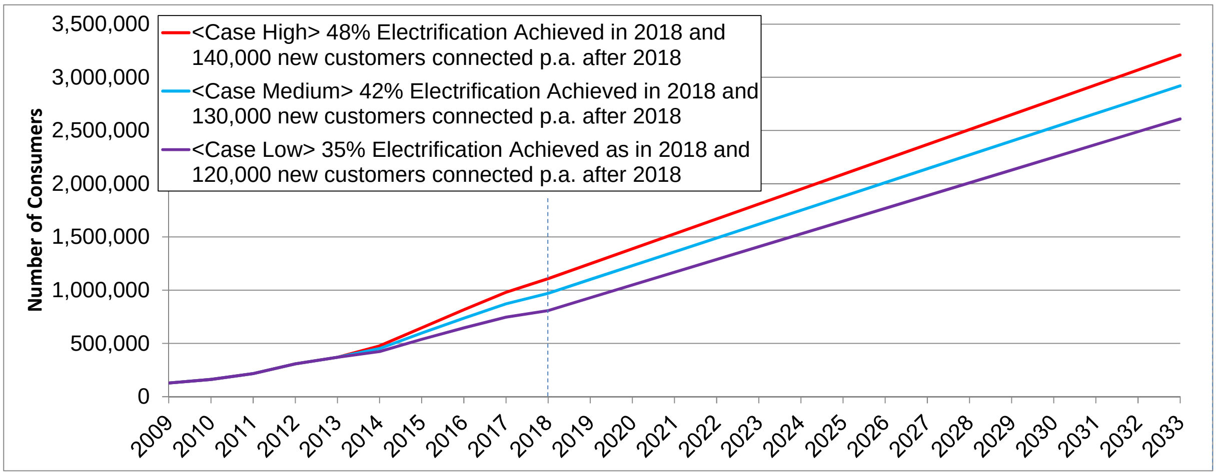
Source: JICA study team

Fig. 2-3.4 below shows the change in the number of new customers, Fig. 2-3.5 that in the number of customers and Fig. 2-3.6 that in the electrification rate achieved.



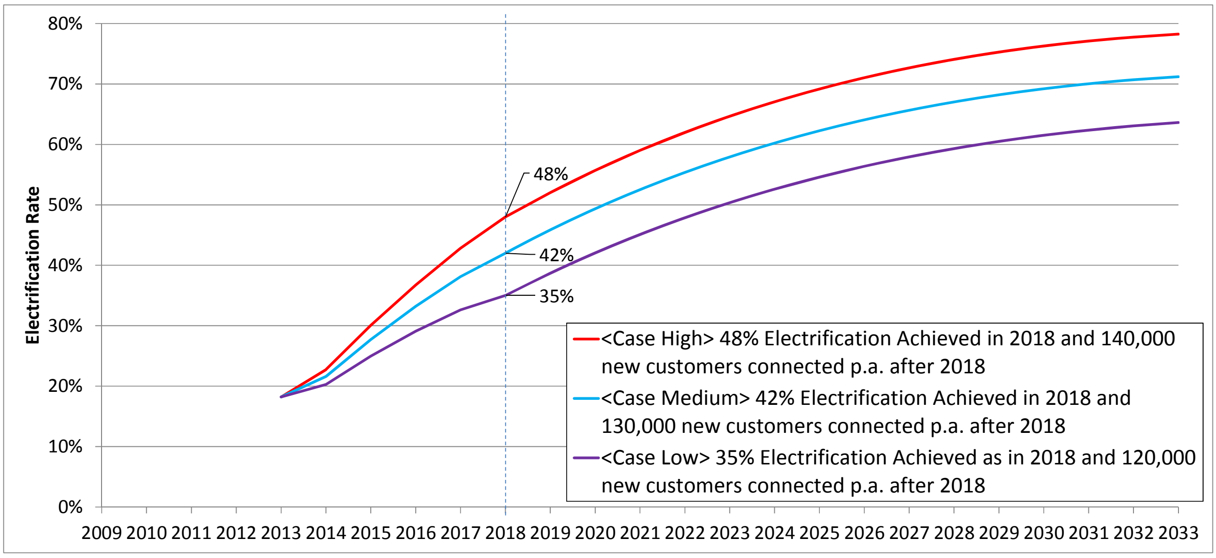
Source: JICA study team

Fig. 2-3.4 Change in the number of new customers



Source: JICA study team

Fig. 2-3.5 Change in the number of customers



Source: JICA study team

Fig. 2-3.6 Change in the electrification rate achieved

Next, specific consumption is covered. In formulating the specific consumption scenario also, the Combined Design Report of Electricity Access Rollout Program created by Sofreco, which was contracted by EWSA to formulate an electrification plan, has been referred (for example: specific consumption growth rate, etc.).

The scenarios to express the specific consumption increase were created for the existing customers and new customers. It is because the specific consumption of the customers who are newly connected to distribution systems through rural electrification is relatively small compared to that of the existing customers. In this forecast, the specific consumption of newly-connected customers is assumed to be smaller than that of the existing customers for 6 years.

Also, the level of specific consumption is different in Kigali City and outside the city; thus two different scenarios were created, increasing the total scenarios to four.

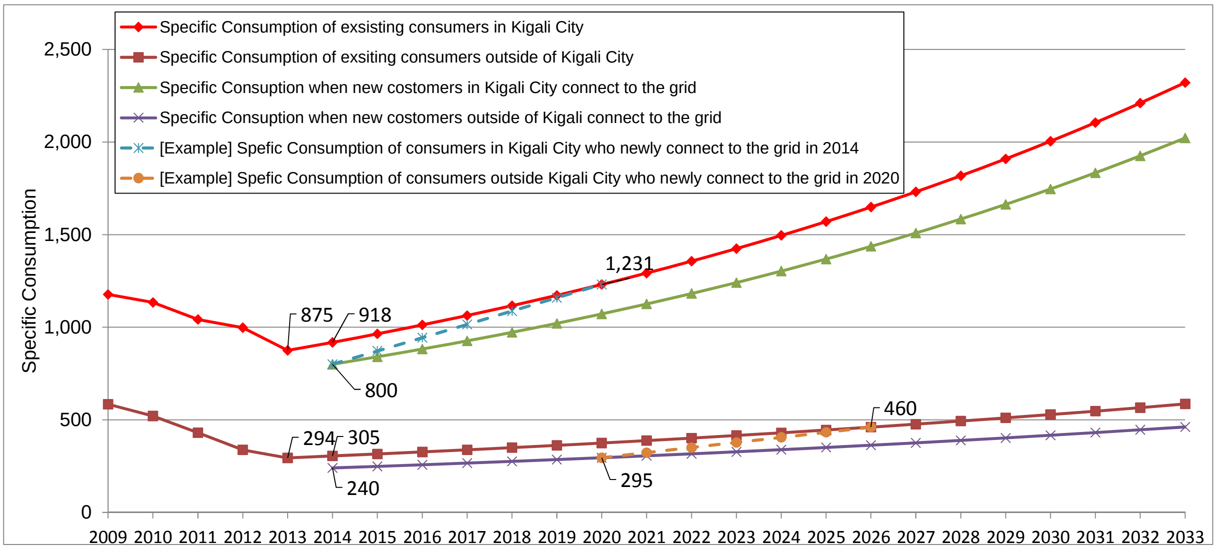
As shown in Table 2-3.3 and Fig. 2-3.7, the specific consumption of 875kwh/ Customer p.a. was recorded in 2013 for the existing customers in Kigali City. The forecast was made that the specific consumption will increase at a rate of 5% a year. For the new customers in Kigali City, 800kwh/ Customer p.a is forecasted for 2014, which is slightly smaller than that of the existing customers, which is forecasted to reach the level of that of the existing customers in 6 years. The specific consumption of the customers newly connected in 2015 and after is forecasted to increase by 5% a year.

Further, outside Kigali City, the specific consumption of 294kwh/ Customer p.a. was recorded in 2013, and it is forecasted to increase at a lower rate of 3.5%. For the new customers outside of Kigali City, the specific consumption is forecasted to be 240kWh/ Customer p.a for 2014, slightly lower than the existing customer level, and to reach the level of the existing customers in 6 years (240kWh/ Customer p.a is 20kWh / Customer per month, and according to ESSP, about half of the total customers have the specific consumption of 20kWh/Customer or less). The specific consumption of the customers to be connected in 2015 or later is forecasted to increase 3.5% annually.

Table 2-3.3 Specific consumption scenarios

	Specific consumption (kWh per annual)	
	Existing customers	Newly-Connected customers
In Kigali	・875 kWh p.a. recorded in 2013 ・Growth rate afterwards 5% p.a.	・800kWh p.a. in 2014 ・Growth rate afterwards 5% p.a.
Outside of Kigali	・294 kWh p.a. recorded in 2013 ・Growth rate afterwards 3.5% p.a.	・240kWh p.a. in 2014 ・Growth rate afterwards 3.5% p.a.

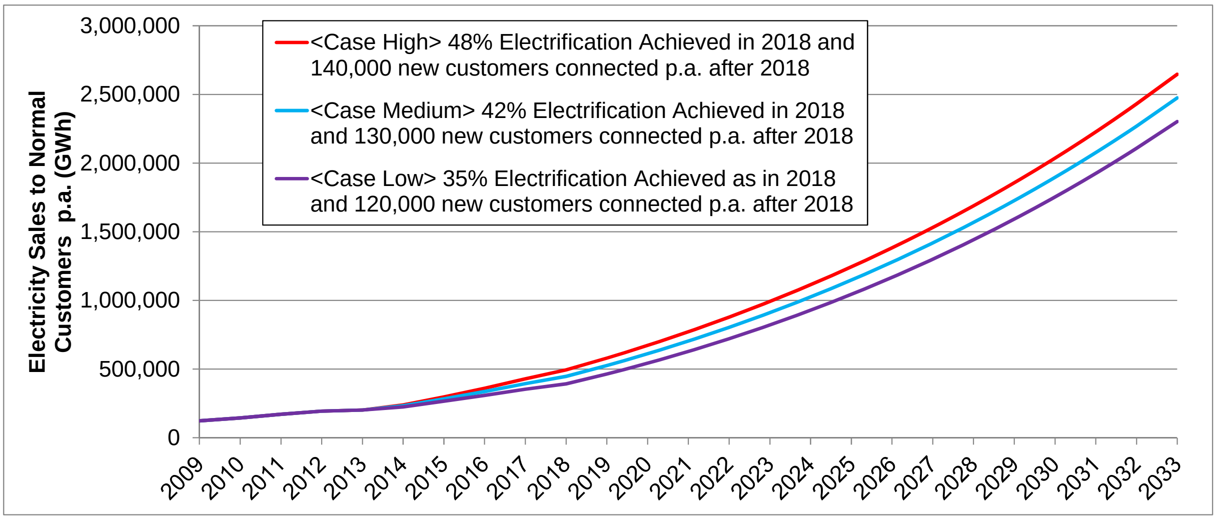
Source: JICA study team



Source: JICA study team

Fig. 2-3.7 Change in specific consumption for existing/new customers inside/outside of Kigali City

Lastly, the forecasted electricity sales to the Normal Customer, which is obtained by multiplying future number of customers by the forecasted future specific consumption, is shown below.

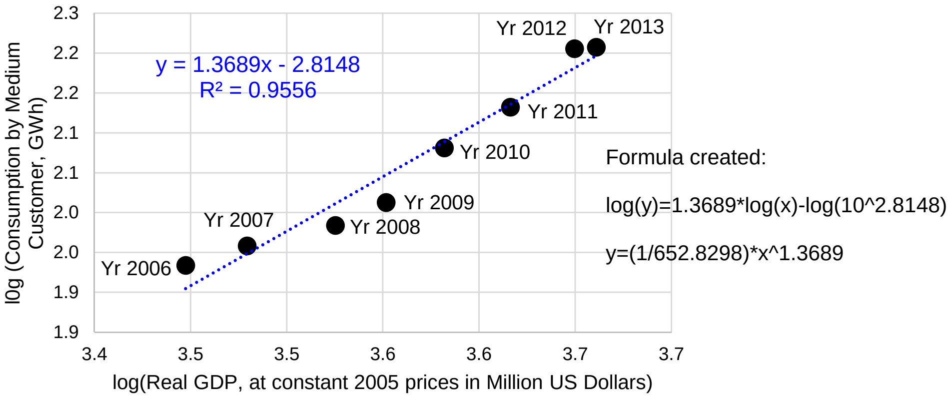


Source: JICA study team

Fig. 2-3.8 Forecasted electricity sales to the Normal Customer

(2) Step-2 Forecast of electricity sales (GWh) to the Medium Customer

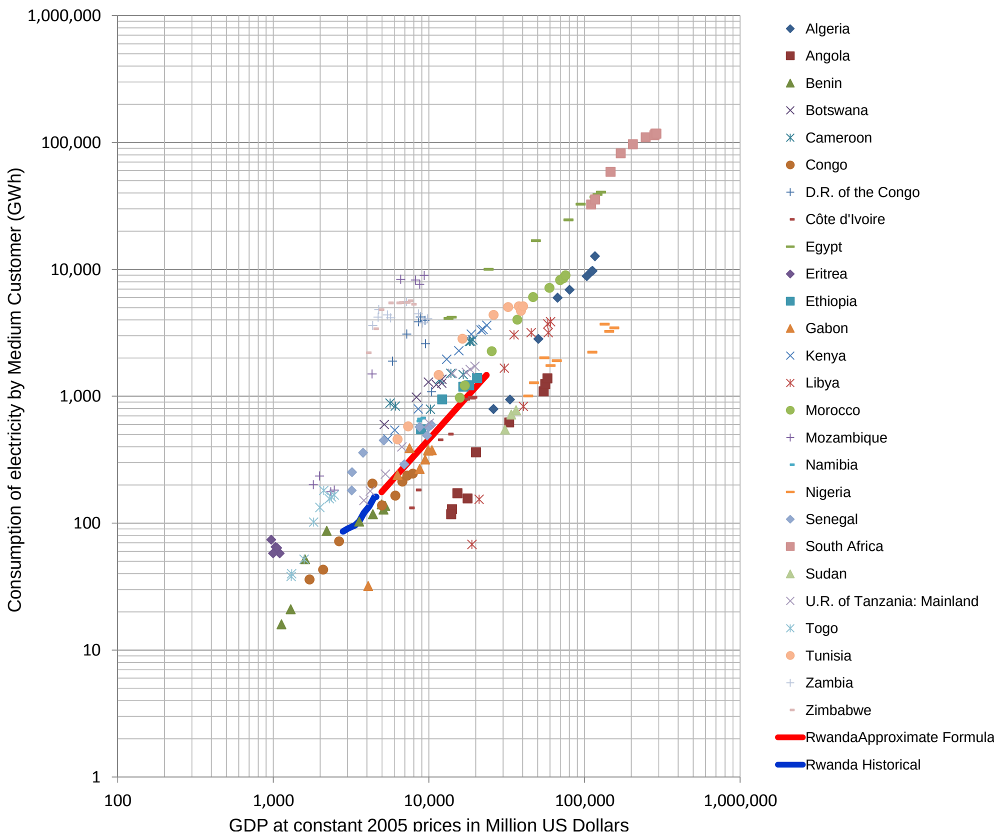
As explained earlier, the forecast used a macro method, in other words, a power demand model was created (approximate formula) based on the correlation between the electricity sales for the Medium Customer (data from 2006 to 2013 owned by EWSA was used) and real GDP, as shown in Fig. 2-3.9. The R2 (Coefficient of Determination) was 0.9556, revealing a high correlation.



Source: EWSA Electricity Commercial Unit and the World Bank

Fig. 2-3.9 Correlation between the electricity sales to the Medium Customer and real GDP

To see if the power demand model (approximate formula) is appropriate, the power demand model was compared to the power consumptions by the industries and GDP status in African nations. As seen in Fig. 2-3.10, the model stayed within the range of other African nations, indicating the validity of the model.



Source: IEA Energy Statistics of non-OECD countries 2012 edition and World Bank

Fig. 2-3.10 Comparison with the power consumptions by the industries and GDP status in African nations

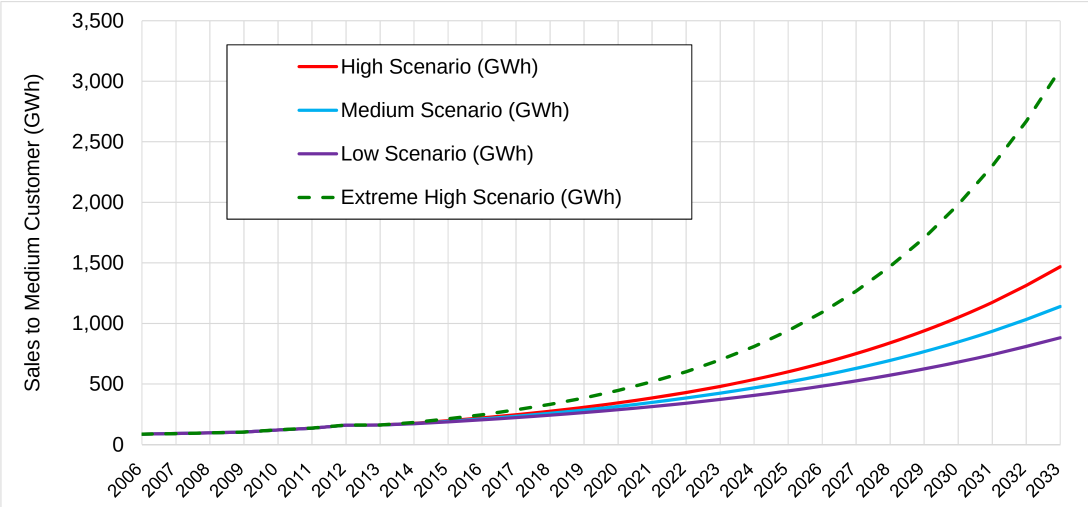
The real GDP scenarios must be entered into the approximate formula. IMF estimates Rwanda's GDP growth rate for the next 5 years to be 7.5%／year in the "Rwanda Seventh Review Under the Policy Support Instrument, Request for a Three-Year Policy Support Instrument and Cancellation of Current Policy Support Instrument" (November 2013) after the coordination and research with Rwanda's government officials and banks. Since there is no data forecasting the long-term GDP growth issued by the government or other agencies, GDP growth scenarios were created for the next 20 years for the forecasting purposes, including the High Case with the growth rate of ＋1.0%, the Low Case with -1.0%, and the Extreme High Case which adopted 11.5%／year, the GDP growth target of the government listed in EDPRS2, as requested by the counterpart.

Table 2-3.4 GDP growth scenarios to be entered into the power demand model (approximate formula)

Scenario	Growth Rate
Extreme High	11.5 % (Government's GDP growth target in EDPRS2)
High	8.5% (+1.0%)
Medium	7.5%
Low	6.5% (-1.0%)

Source: JICA study team

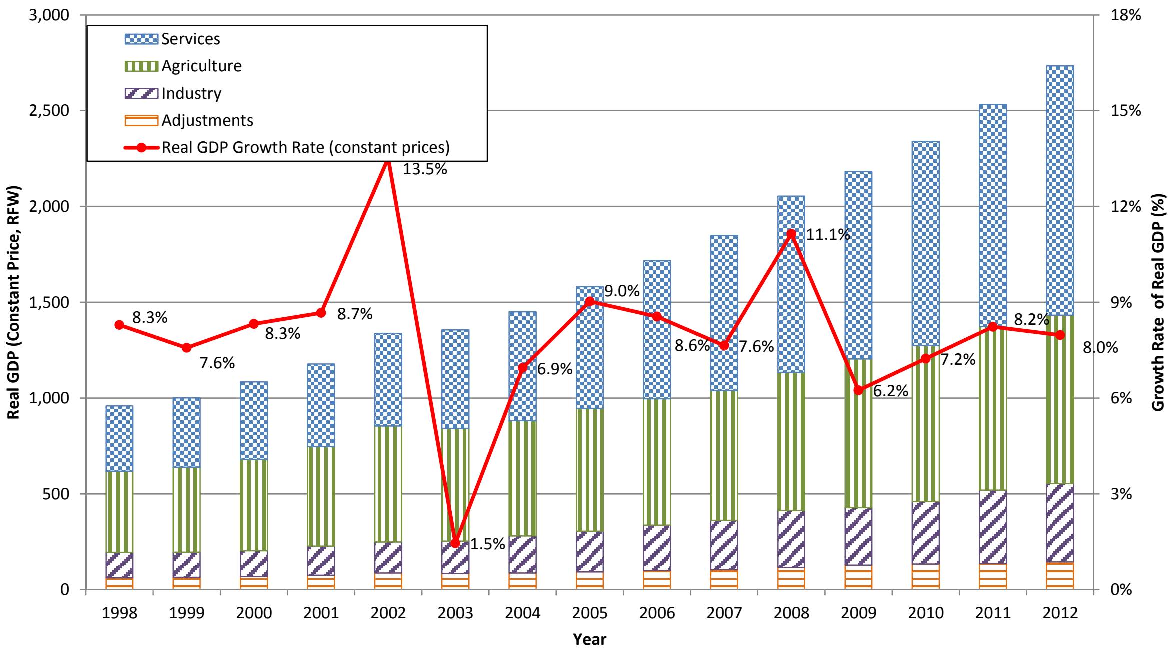
The electricity sales obtained by entering the GDP growth scenarios into the power demand model are shown in Fig. 2-3.11. The Extreme High Case deviated greatly from the High, Medium and Low Cases.



Source: JICA study team

Fig. 2-3.11 Forecasted electricity sales to the Medium Customer

The change in the GDP in the past is shown in Fig. 2-3.12 for reference. The GDP growth rate in recent years is 6-8%; thus the GDP growth rate of 11.5% is extremely high, which in turn raised the forecast in the Extreme High Case.



Source: MINECOFIN

Fig. 2-3.12 Change in real GDP in the past

(3) Step-3 Forecast of electricity sales (GWh) to the Public Service Customer

Since the electricity sales to the Public Service Customer are smaller than that to the Medium Customer, a simpler method, GDP Elasticity, was used for the forecast. The GDP Elasticity is a ratio of power consumption to the GDP growth rate for a certain period of time, and calculated with the formula below:

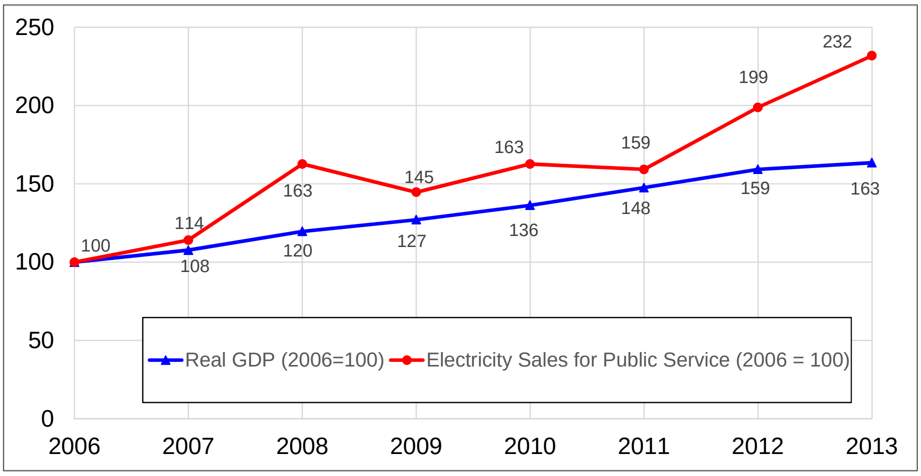
$$GDP\ Elasticity = \frac{Percent\ Change\ in\ Electricity\ Sales\ in\ the\ Term}{Percent\ Change\ in\ GDP\ in\ the\ Term}$$

As seen in Fig. 2-3.13, the growth trend in 2013 was studied by assuming both the real GDP and the electricity sales to the Public Service Customer in 2006 to be 100. The electricity sales had shown a greater increase to 232 compared to that of the real GDP to 163. The trend can be expressed using the GDP Elasticity, as shown in the formula and Table 2-3.5 below:

(GFP Elasticity from 2006 to 2013)

$$= \frac{\left(\frac{232}{100}\right)^{\left(\frac{1}{2013-2006}\right)} - 1}{\left(\frac{163}{100}\right)^{\left(\frac{1}{2013-2006}\right)} - 1} \approx 1.75$$

The annual average growth rate of the electricity sales from 2006 to 2013 was 1.75 times greater than that of GDP.



Source: MINECOFIN and the EWSA Commercial Unit

Fig. 2-3.13 Change in the electricity sales to the Public Service Customer and real GDP in 2006 - 2013

Table 2-3.5 GDP Elasticity between years

From | To	2006	2007	2008	2009	2010	2011	2012	2013
2006		1.84	2.94	1.57	1.61	1.20	1.50	1.75
2007			3.83	1.46	1.53	1.06	1.44	1.74
2008				-1.77	0.00	-0.10	0.69	1.14
2009					1.72	0.63	1.43	1.93
2010						-0.26	1.30	2.01
2011							3.12	3.92
2012								6.29

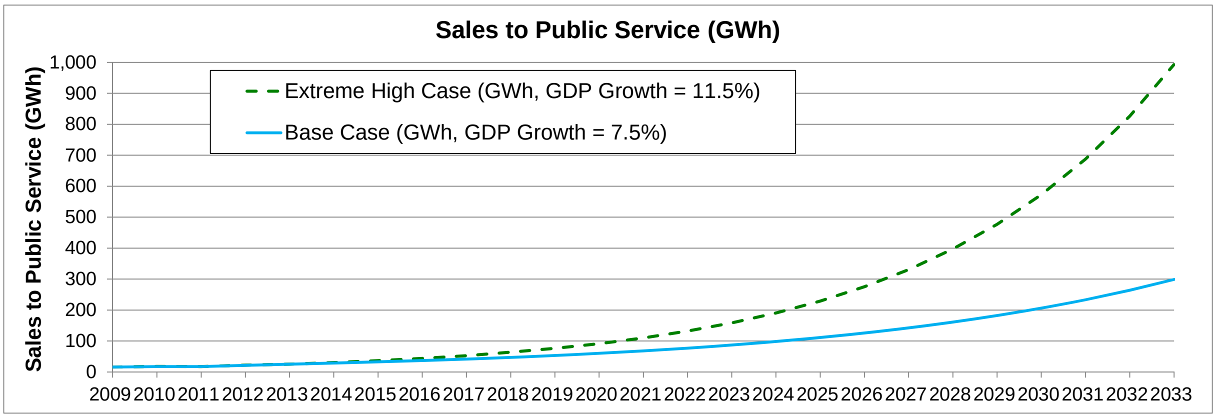
Source: MINECOFIN and the EWSA Commercial Unit

The future electricity sales were forecasted assuming that there will be a correlation between the electricity sales and real GDP similar to that between 2006 and 2013. Thus, the growth rate of electricity sales was forecasted by multiplying the GDP Elasticity (1.75) by the GDP growth scenarios. The GDP growth scenarios were established in a manner similar to the Medium Customer, i.e. the Base Case (annual growth of 7.5%) and Extreme High Case (annual growth of 11.5%). Table 2-3.6 shows the GDP growth scenarios and calculated growth rate of electricity sales, and Fig. 2-3.14 shows the forecasted electricity sales to the Public Service Customer calculated using the growth rate of electricity sales.

Table 2-3.6 GDP growth rate scenarios and calculated electricity sales growth rate

Scenario	GDP Growth Rate	Electricity sales growth rate
Extreme High	11.5 %	19% (11.5%*1.75)
Base	7.5%	13% (7.5%*1.75)

Source: JICA study team



Source: JICA study team

Fig. 2-3.14 Forecasted electricity sales to the Public Service Customer

(4) Step-4 Calculation of the country-level electricity sales (GWh) by totaling the electricity sales obtained in Steps 1 - 3

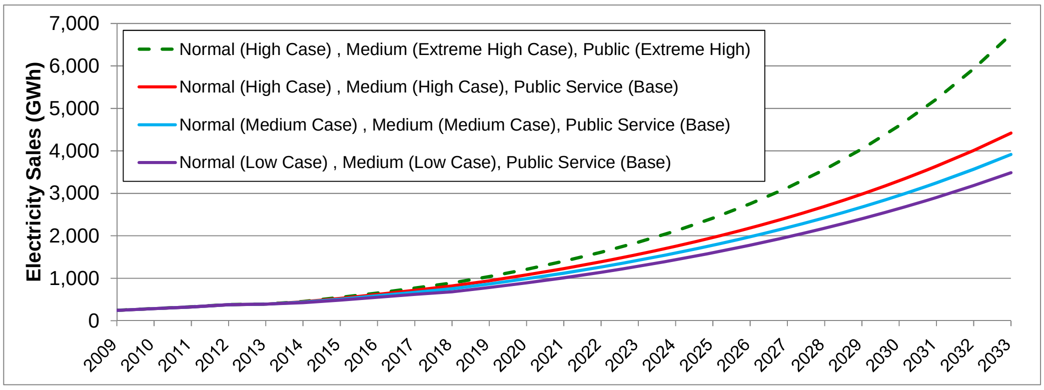
The integration of the electricity sales scenarios for each billing sector calculated in Steps 1-3 produced 3 patterns for the Normal Customer, 4 patterns for the Medium Customer and 2 patterns for the Public Service Customer, with the total of 24 patterns. In order to simplify the following processes, 4 cases were selected as shown in Table 2-3.7.

Table 2-3.7 Selected forecast scenarios

Case	High Case	Medium Case	Low Case	(Reference) Extreme High Case
Normal Customer	High	Medium	Low	High
Electrification Rate in 2017/18	48%	42%	35%	48%
Medium Customer	High	Medium	Low	Extreme High
GDP Growth Rate	8.5 %	7.5%	6.5%	11.5%
Public Service Customer	Base	Base	Base	Extreme High
GDP Growth Rate	7.5 %	7.5 %	7.5 %	11.5 %

Source: JICA study team

The forecasted electricity sales to the Normal Customer, Medium Customer and Public Service Customer for the selected four cases were totaled and shown in Fig. 2-3.15.



Source: JICA study team

Fig. 2-3.15 Forecasted country-level electricity sales

For reference, a breakdown of the electricity sales by billing sector is shown in Fig. 2-3.16 for each case.

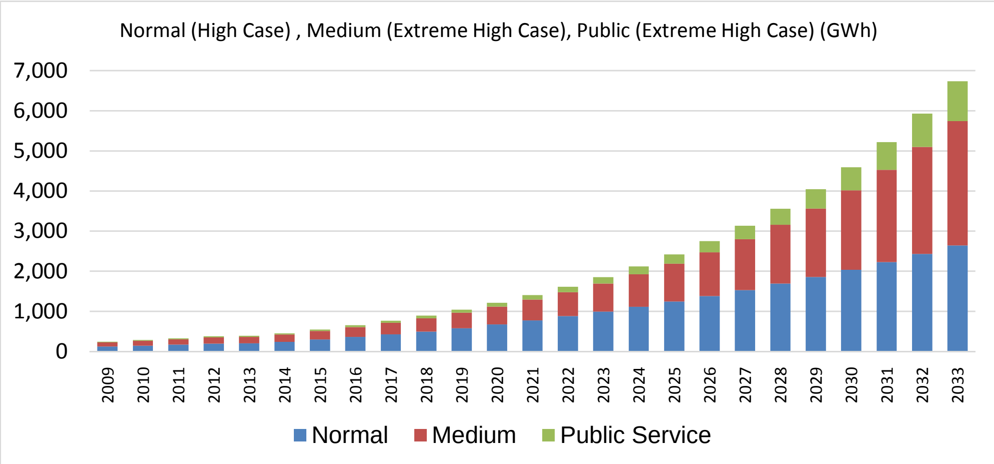


Fig. 2-3.16 (1/4) Breakdown of the electricity sales by billing sector

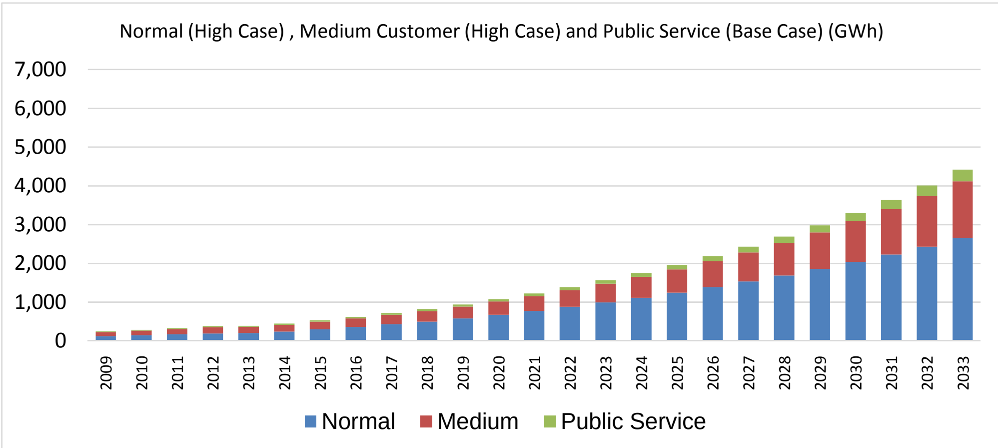


Fig. 2-3.16 (2/4) Breakdown of the electricity sales by billing sector

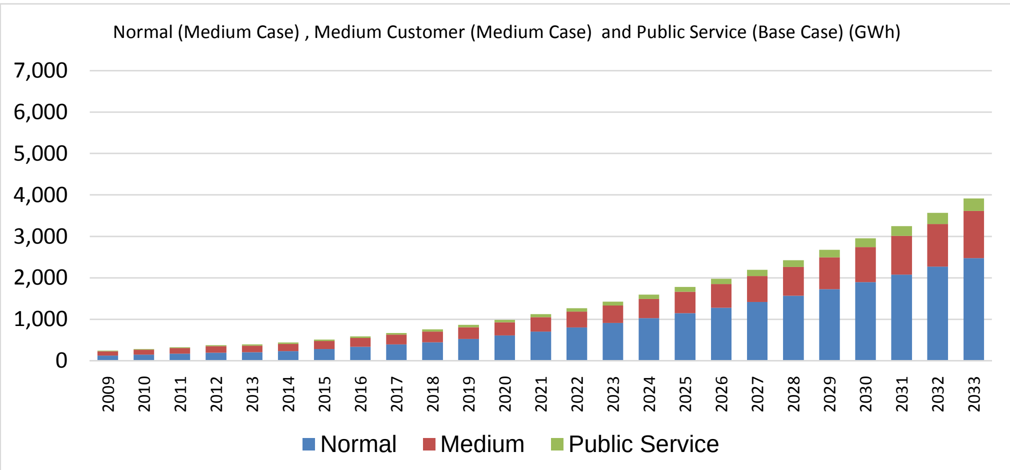
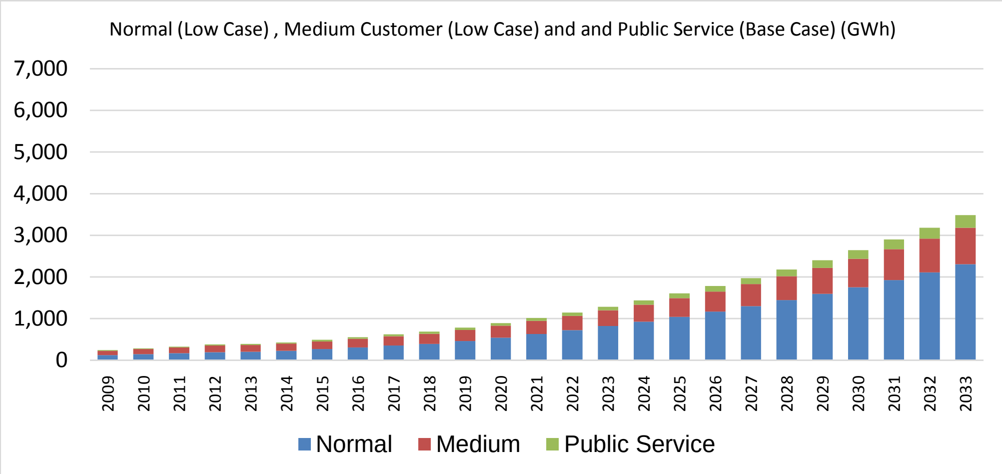


Fig. 2-3.16 (3/4) Breakdown of the electricity sales by billing sector



Source: JICA study team

Fig. 2-3.16 (4/4) Breakdown of the electricity sales by billing sector

(5) Step-5 Conversion to the country-level generated energy (GWh) using transmission/distribution loss factor

To calculate generated energy (GWh) based on the country-level electricity sales obtained in the previous section, the integrated transmission/distribution loss factor for the future is established here. The integrated loss factor is calculated as shown below:

$$Integrated\ loss\ factor = 1 - \frac{Electricity\ sales}{Electricity\ supplied\ to\ the\ grid}$$

When the above formula is applied, Rwanda’s current integrated transmission/distribution loss factor is calculated at approximately 20%. However the loss factor scenario used in this forecast is the scenario provided by the counterpart (“Consultancy services to carry out a loss reduction audit in the Rwandan electricity network” a report originally created by Manitoba Hydro International Ltd. in 2013).

Considering that in Japan it took around 20 years from 1955 to reduce the the integrated transmission/distribution loss factor from 20% to 10%, and that transmission/distribution lines and transformers with lower losses, compared to those at the time, are now being developed and installed around the world, we concluded that the scenarios provided by the counterpart were set at an achievable level.

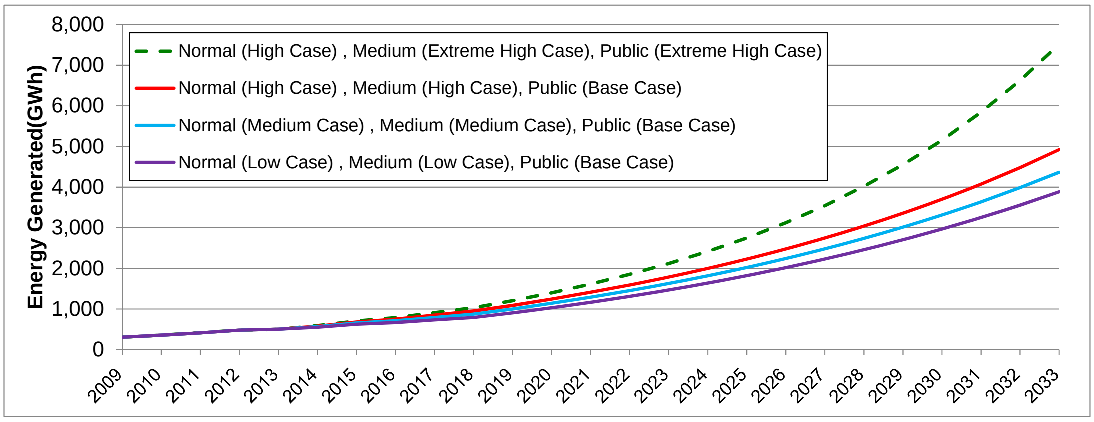
Table 2-3.8 Total loss factor scenario

Actual			Forecast																			
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
22%	21%	22%	22.6%	22.2%	17.3%	15.2%	13.7%	13.5%	13.2%	13.0%	12.8%	12.5%	12.3%	12.1%	11.9%	11.6%	11.4%	11.2%	10.9%	10.7%	10.5%	10.2%

Source: EWSA National Electricity Control Center and MININFRA

Thus, the result of the calculation of generated energy using the formula below and entering the integrated loss factor scenario is shown in Fig. 2-3.17.

Necessary generated energy = Electricity sales / (1-integrated loss factor)



Source: JICA study team

Fig. 2-3.17 Forecast of necessary generated energy

(6) Step-6 Conversion to the country-level power demand (MW) using load factor

For the calculation of the peak load based on the energy generated, the load factor scenario must be established. The load factor is obtained using the formula below:

$$Load\ Factor\ (annual)$$

$$= \frac{Average\ Load\ Demand\ (Annual)}{Peak\ Load\ Demand\ (Annual)}$$

$$= \frac{Annual\ Energy\ (GWh)}{Peak\ Load\ Demand\ * 8760\ hours/year}$$

The confirmation of the recent load factor status revealed a figure of about 65%.

Table 2-3.9 Recent Load Factor

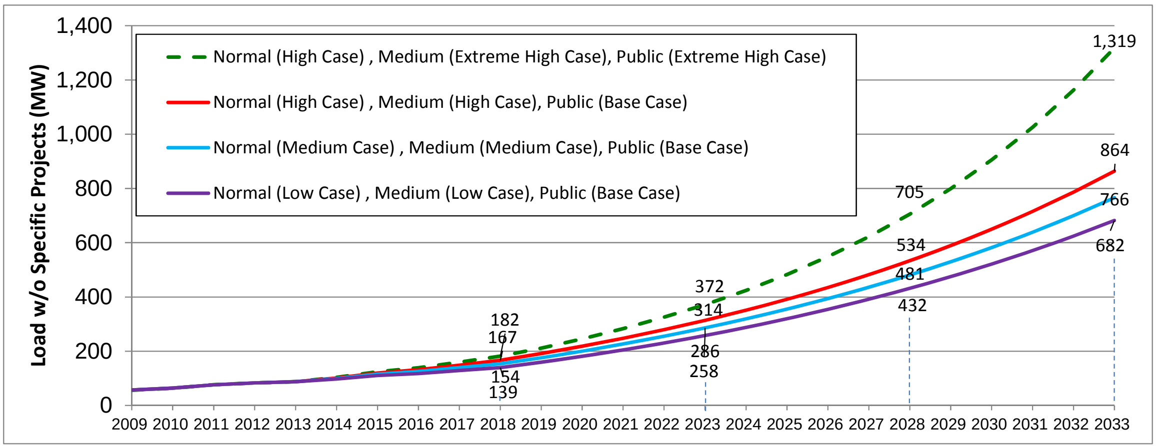
Year	2010	2011	2012	2013
Load factor	64%	62%	66%	65%

[Source] EWSA load dispatching office

The future load factor in the 20 years from 2014 to 2033 will likely go up and down; however, it is forecasted to maintain 65% from a long-term standpoint. For example, if the industry and commerce flourish, power consumption would be high in daytime hours, lowering the load factor. However, load leveling measures (e.g. peak cut, peak shift, energy conservation and bottom up) taken in future will raise the load factor.

Next, the future load was calculated by entering the load factor of 65% to the formula below. The result is shown in Fig. 2-3.18.

$$Peak\ Load\ Demand = \frac{Annual\ Energy\ (GWh)}{Load\ Factor\ (annual, 65\%) * 8760\ hours/year}$$



Source: JICA study team

Fig. 2-3.18 Forecasted load demand (excluding Specific Projects)

(7) Step-7 Correction of the country-level power demand (MW) based on Large-scale Customer information

The forecasted load was corrected based on the information regarding the Large-scale Customer obtained from EWSA (see Table 2-3.10). According to EWSA, the table was prepared by interviewing related ministries and agencies, and the feasibility of each project is high.

However, in making correction, based on the results of discussions with the counterpart, Large-scale customer, which cannot be understood through the macro forecast, are extracted for correction. That is to say, we extracted only large-scale projects such as industrial parks, airport, sports stadium and convention centre now undergoing rapid development, compared to Rwanda's economic growth rate up until now. And taking into consideration the possibility of delays in project development, the 4 development scenarios shown in Table 2-3.11 were formulated, and added to the results of load forecasts shown in Figure 2-3.18.

Demand, after adding Large-scale Customer, is as shown in Figure 2-3.19. For reference, the main premises for each forecast scenario are shown in Table 2-3.12.

Table 2-3.10 Large-scale Customer information by EWSA and data extracted for correction

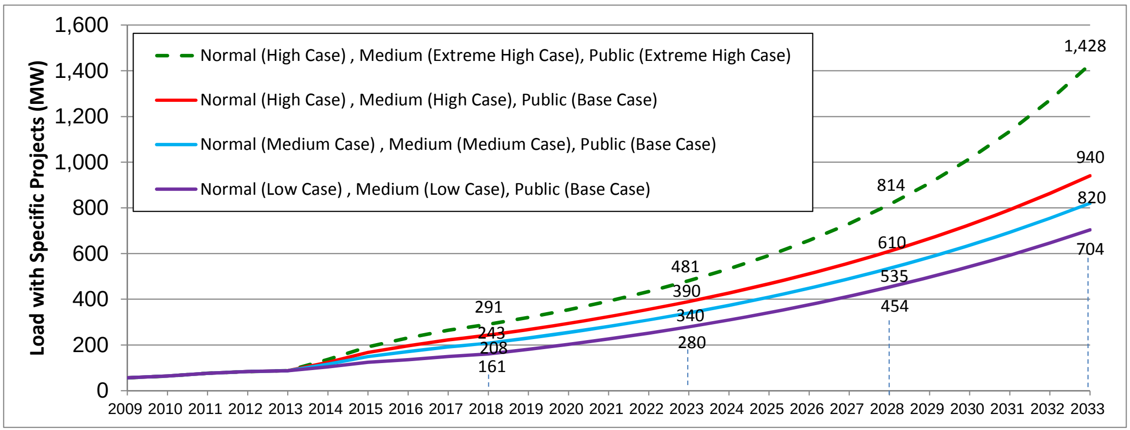
Load name	Year	Demand MW	2014	2015	2016	2017	2018	Load necessary to be added on Demand Model as Large Scale Consumers (Yes=1 or No=0)
Cimerwa	2014	15	15	0	0	0	0	1
Bugesera Steel Industrial Park	2014	10	10	0	0	0	0	1
Bugesera Industrial Park	2015	5	0	5	0	0	0	1
Bugesera Industrial Park	2016	5	0	0	5	0	0	1
Bugesera Industrial Park	2017	5	0	0	0	5	0	1
Rwamagana Ind Park (Steelrwa)	2015	8	0	8	0	0	0	1
Rwamagana Ind Park (AKS Steel)	2015	8	0	8	0	0	0	1
Rwamagana Ind Park	2016	5	0	0	2	0	0	1
Rwamagana Ind Park	2017	5	0	0	0	2	0	1
Rwamagana Ind Park	2018	5	0	0	0	0	2	1
Airport	2016	3	0	0	3	0	0	1
Airport	2017	3	0	0	0	3	0	1
Rutongo Mine	2015	8	0	8	0	0	0	1
Bugarama Ind Park	2016	5	0	0	5	0	0	1
Huye Ind Park	2016	2	0	0	2	0	0	1
Rusizi Industrial Park	2015	2	0	2	0	0	0	1
Nyabihu Ind Park	2016	2	0	0	2	0	0	1
Gahanga Sport Stadium	2016	2	0	0	2	0	0	1
SEZ Free zone Kigali	2015	2	0	2	0	0	0	1
SEZ Free zone Kigali	2016	2	0	0	2	0	0	1
SEZ Free zone Kigali	2017	2	0	0	0	2	0	1
SEZ Free zone Kigali	2018	2	0	0	0	0	2	1
ICC (Convention centre)	2014	6.5	6.5	0	0	0	0	1
Irrigation load Mpanga Sector	2015	2	0	1	1	0	0	0
Irrigation load Mahama Sector	2016	4.8	0	0	4.8	0	0	0
Irrigation load Rusumo Falls	2017	3.4	0	0	0	3.4	0	0
Irrigation load Mugesera Sector	2015	1	0	1	0	0	0	0
Irrigation load Matimba Sector	2014	0.3	0.3	0	0	0	0	0
Irrigation load Kabare Sector		0.486	0	0	0	0	0	0
Irrigation load Kamabuye Sector		6	0	0	0	0	0	0
Irrigation load Kibilizi Sector		0.325	0	0	0	0	0	0
Irrigation load Masaka Sector		0.469	0	0	0	0	0	0
Irrigation load Nasho Sector		0.84	0	0	0	0	0	0
Irrigation load Ndego Sector		0.726	0	0	0	0	0	0
Irrigation load Ngeruka Sector		1.2	0	0	0	0	0	0
Irrigation load Nyamugari Sector		3.45	0	0	0	0	0	0
Loads_for_Mines1		11.8	0	0	0	0	0	0
Loads_for_Mines2		11.8	0	0	0	0	0	0
Loads_for_Mines3		11.8	0	0	0	0	0	0
Loads_for_Mines4		11.8	0	0	0	0	0	0
Nyabihu Tea Factory	2016	1	0	0	1	0	0	0
Rubaya Tea Factory	2016	1	0	0	1	0	0	0
SORWATHE Tea Factory	2016	1	0	0	1	0	0	0
Mulindi Tea Factory	2016	1	0	0	1	0	0	0
Mata Tea Factory	2016	2	0	0	2	0	0	0
Nshili Kivu Tea Factory	2016	1	0	0	1	0	0	0
Pfunda Tea Factory	2016	3	0	0	3	0	0	0
Gisovu Tea Factory	2016	3	0	0	3	0	0	0
Gisakura Tea Factory	2016	3	0	0	3	0	0	0
Kitabi Tea Factory	2016	3	0	0	3	0	0	0
Shagasha Tea Factory	2016	3	0	0	3	0	0	0
Karongi Tea Factory	2016	2	0	0	2	0	0	0
Mushubi Tea Factory	2016	2	0	0	2	0	0	0
Gatare Tea Factory	2017	2	0	0	0	2	0	0
Rutsiro Tea Factory	2017	3.8	0	0	0	3.8	0	0
Muganza-Kivu Tea Factory	2017	3.8	0	0	0	3.8	0	0
Karumbi New tea site	2017	3.8	0	0	0	3.8	0	0
Sovu new Tea site	2018	3.8	0	0	0	0	3.8	0
Rugabano new tea site	2018	3.8	0	0	0	0	3.8	0
Munini new tea site	2017	3.8	0	0	0	3.8	0	0
Kibeho new tea site	2018	3.8	0	0	0	0	3.8	0

Source: EWSA

Table 2-3.11 Large-scale Customer development scenarios

Bulk Load Scenario (Country-Level)							
Case Scenario			2014	2015	2016	2017	2018
Extreme High Case	100%	to be installed as scheduled	31.5	33	23	12	4
High Case	70%	to be installed, comparing with the original schedule	22.1	23.1	16.1	8.4	2.8
Medium Case	50%		15.8	16.5	11.5	6.0	2.0
Low Case	20%		6.3	6.6	4.6	2.4	0.8

Source: JICA study team



Source: JICA study team

Fig. 2-3.19 Forecasted load demand (including Specific Projects)

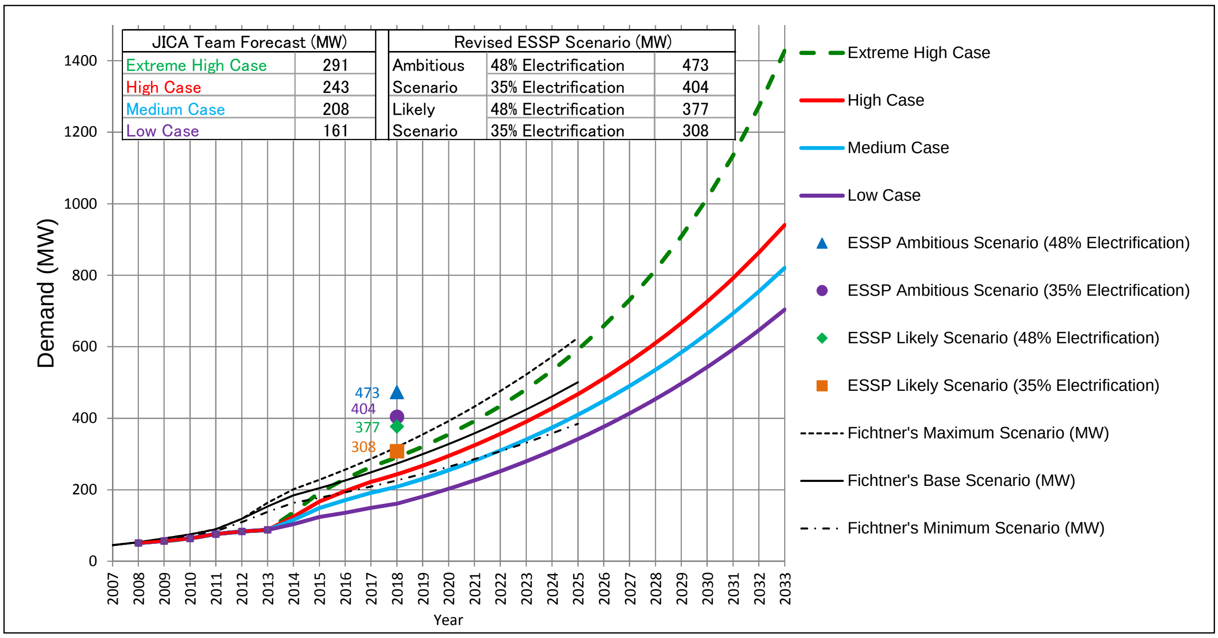
Table 2-3.12 Main premises for each case

Case	High Case	Medium Case	Low Case	(Reference) Extreme High Case
Normal Customer	**High**	**Medium**	**Low**	**High**
Electrification Rate in 2017/18	48%	42%	35%	48%
Medium Customer	**High**	**Medium**	**Low**	**Extreme High**
GDP Growth Rate	8.5 %	7.5%	6.5%	11.5%
Specific Large Scale Consumers load to be on-grid	70 %	50%	20%	100%
Public Service Customer	**Base**	**Base**	**Base**	**Extreme High**
GDP Growth Rate	7.5 %	7.5 %	7.5 %	11.5 %

Source: JICA study team

Figure 2-3.20 shows load forecast results compared with existing demand forecasts. Taking a cross-section for 2017/18, the result is that in every case for 2017/18 the forecasts fall below ESSP scenarios.

In addition, in the long term, the result is that the High/Medium Cases are close to the Fichtner forecast Base and Minimum scenarios.



Source: EWSA National Electricity Control Center Economic Data Collection and Demand Forecast, Dec. 2009, ESSP,

Fig. 2-3.20 Comparison with the existing forecasts

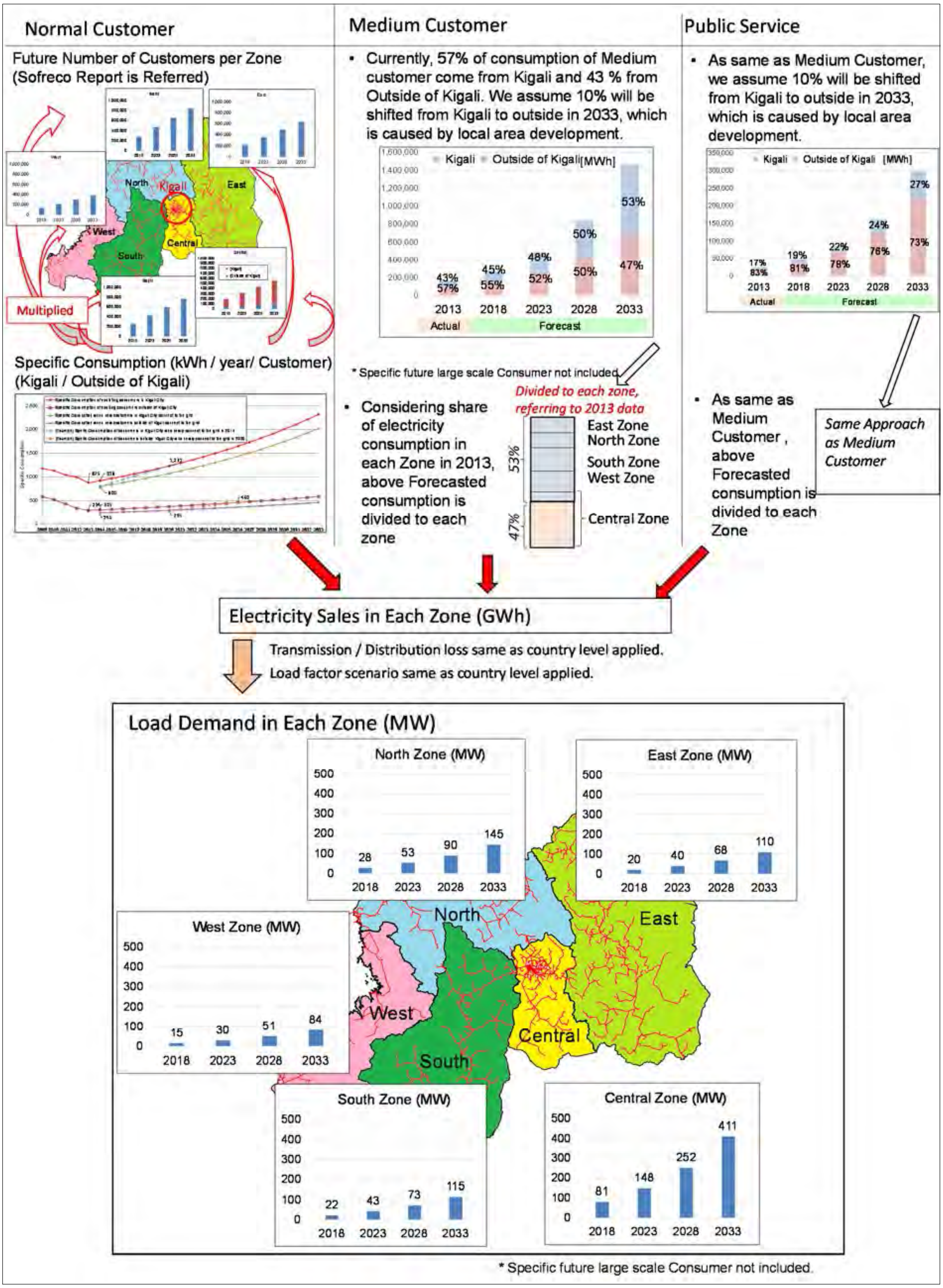
(8) Step-8 Division of the country-level power demand (MW) by zones

Here, among four cases calculated in Step7, the High Case was used to divide the country-level load in 2018, 2023, 2028 and 2033 by five zones of East, West, South, North and Central. The load divided by the zones is used for Power System Analysis and Power Generation / System Planning. Fig. 2-3.21 shows the flow of division and its result.

For the Normal Customer, the demand is calculated by multiplying the future number of customers by Specific consumption scenario for each zone based on the Combined Design Report of Electricity Access Roll Out Program by Sofreco. Next for the Medium Customer, of 2013 electricity sale, 57% is sold in Kigali City and 43% is sold outside of the city; however, 20 years later after the development of local regions, the electricity sold in Kigali City is forecasted to be 47% and that outside 53%, with 10% shift from the city to outside the city. For the division of regional electricity sales by zones (East, West, South, North and Central), calculations were done by referring to their respective share from 2013.

As for the Public Service Customer, the calculations were done in the same manner as those for the Medium Customer. In other words, in 2013, 83% of the power in the country is sold in Kigali City and 17% was sold outside of the city; however 20 years later after the development of the local regions, 73% is forecasted to be sold in Kigali City and 27% outside, indicating 10% shift in sales. The electricity sold was divided to each zone in the same manner by referring to their respective share from 2013.

The division of the load in each zone by substations is further described in Section 2.4-2.



Source: JICA study team

Fig. 2-3.21 Division of the country-level power demand by zones