5 Analysis of Alternatives

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5.1 Project Needs and Objectives

Lack of electricity is a key constraint hampering economic development and livelihood improvement in Burundi, DRC and Rwanda. Current electricity demand by far exceeds supply. Many households rely on biomass for their cooking and heating needs, leading to deforestation and soil erosion. There is consequently a need for improved access to electricity as demonstrated by the figures provided in the table below.

Table 5-1 Access to Electricity in the Region

Country	Access to Electricity (%) in 2016	
	Urban	Rural
DRC (North/South Kivu provinces)	5%	
Burundi	49.7%	1.7%
Rwanda	80%	17.8%

Source for DRC: IRD. 2015. Atlas of the North Tanganyika countries, p146
Source for Burundi and Rwanda: https://www.se4all-africa.org/seforall-in-africa/country-data/burundi/

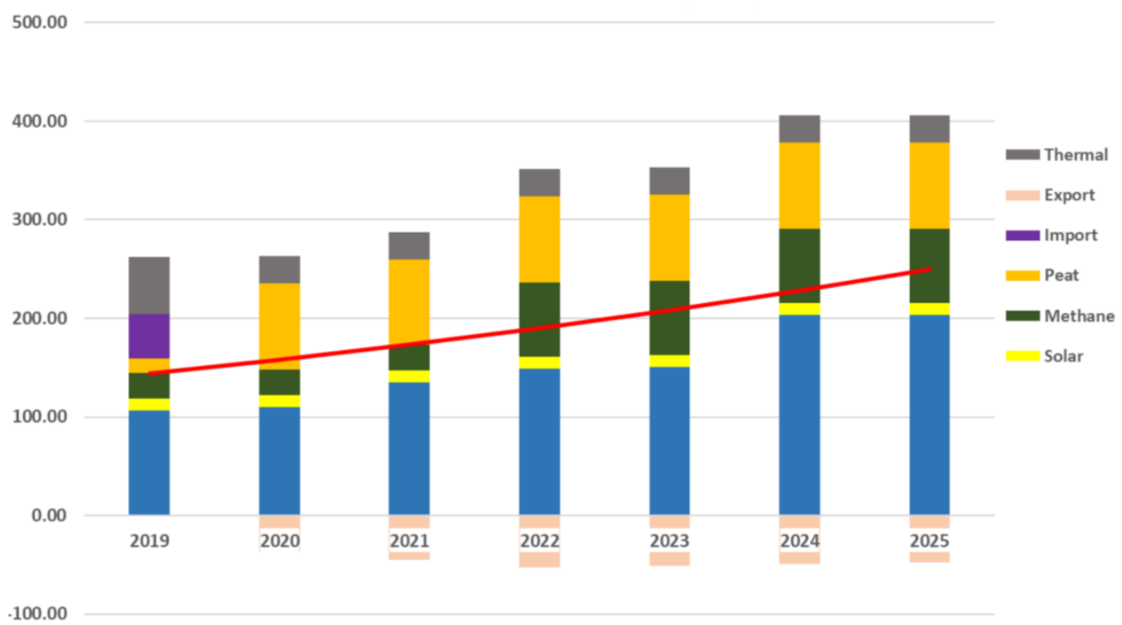
The lack of access to reliable power supply services hampers countries' growth potential, contributes to the poverty and isolation of rural population, and affects provision of other key services, such as water supply, health, and education. It is also a major constraint for commercial and industrial development. The deficit in power supply is rapidly increasing, despite governments efforts. The investments in new power generation plans, transmission/distribution lines and substations as well as the rehabilitation of existing facilities are greatly needed.

5.2 Alternative Power Production Technologies

5.2.1 General

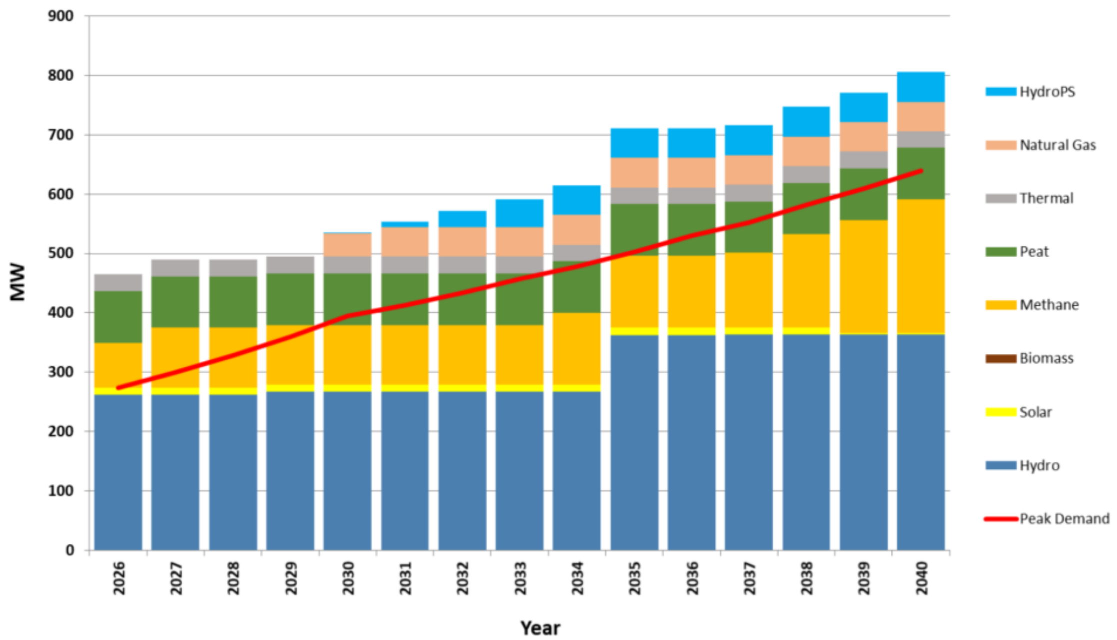
Power generation in Rwanda uses thermal power plants (fuelled with Heavy Fuel Oil (HFO), diesel, methane gas from Lake Kivu, peat, and biomass) and solar power. In DRC and Burundi power is provided mostly from hydropower schemes and from electricity imported from neighbouring countries including Rwanda.

The power strategy in Rwanda is to increase power generation capacity to meet increasing demand using a mix of technologies and making the best use of available resources. Figure 5-1 and Figure 5-2 overleaf illustrate the strategy for the horizon 2040, which comprises increasing hydropower and methane capacity over the next 18 years, but no new projects to generate power from peat, solar, diesel are anticipated. The introduction of natural gas and development of pump storage hydropower schemes are anticipated from 2030.



Source; REG, 2019

Figure 5-1 Installed Power Generation Capacity (2019-2025) for Rwanda



Source; REG, 2019

Figure 5-2 Installed Power Generation Capacity (2026-2040) for Rwanda

5.2.2 HFO - Diesel

HFO and diesel-fuelled thermal power plants use technically mature technology. In 2019, 27% of power in Rwanda was produced with diesel and HFO power plants (REG, 2019).

However, producing electricity with HFO and diesel is an expensive option and currently in Rwanda the HFO and diesel-fuelled power plant are used during periods of peak demand, which result in high electricity tariffs. In addition, the use of HFO and diesel is not in alignment with the Paris Agreement, the 7th Sustainability Goal set by the United Nations and targets for the contribution if renewable energy to the nation electricity production set by Burundi, DRC and Rwanda. As a result of the above, Rwanda does not anticipate investing in additional HFO-diesel power plants and is seeking alternatives.

An HFO/diesel-fuelled power plant with the same power production capacity as the Project would require a project footprint in the order of 200 ha or more on flat terrain with good existing road access, thus requiring land acquisition probably resulting in physical and economic displacement. The plant would probably need to be constructed near Bugarama in order to link in with the transmission line interconnection projects so that power can be shared with Burundi and DRC.

The key environmental issues would be related to GHGs, air quality pollutants, wastewater, hazardous waste and noise. The operation would require important quantities of water. The storage of HFO and/or diesel would represent a technological risk.

5.2.3 Methane

Significant quantities of methane gas are dissolved in the waters at the bottom of Lake Kivu. In 2019, 12% of Rwanda's power production was produced using this methane and the power strategy is for additional power plant to be developed. The methane power production facilities comprise floating offshore facilities to extract the methane gas from the Lake Kivu's waters, submerged floating pipeline to convey the gas to onshore gas-fired power generation facilities.

A single methane gas fuelled power plant with the same power production capacity as the Project would be a major undertaking, and it may be more realistic to develop several smaller projects. Each plant would require a project footprint in the order of 100-200 ha on flat terrain with good existing road access, thus requiring land acquisition resulting in physical and economic displacement. The plant would probably need to be constructed near Kamembe in order to be close to Lake Kivu and additional transmission lines would need to be developed to link in with the transmission line interconnection projects so that power can be shared with Burundi and DRC, thus increasing project cost and incurring additional environmental and social impacts.

The key environmental issues would be related to GHGs, air quality pollutants, wastewater, hazardous waste and noise. The transport and storage of methane would represent a technological risk.

5.2.4 Peat

Large areas of peatland are present in southern part of Rwanda. The peat is harvested during the dry season and dried and then combusted for power generation. In 2019, 7% of Rwanda's power production was produced from peat. However, Rwanda's power strategy does not include developing more peat-fuelled power plants.

A single peat fuelled power plant with the same power production capacity as the Project may not be feasible because of the need for availability of nearby peat resources and it may be more realistic to develop several smaller projects, and these would be situated at suitable locations near to the peat resources to minimise transport costs. Environmental impacts of peat projects include soil damage and erosion, hydrologic impacts, sediment transport and erosion, impacts on water quality, and impacts from disposal of waste ash. Large areas of land would need to be required incurring social impacts. Additional transmission lines would need to be developed to link in with the transmission line interconnection projects so that power can be shared with Burundi and DRC, thus increasing project cost and incurring additional environmental and social impacts.

5.2.5 Other Technologies

Other technologies which are part of the current power generation mix comprise solar energy and biomass, which represent 5% and <1% of the installed power capacity in Rwanda in 2019.

The power generation strategy does not include developing further of wind or geothermal power (see Figure 5-2) because of the lack of wind and geothermal resources. Neither is it planned to develop solar power further because of the following reasons (Rwanda Energy Group, 2019):

- The national power system is still small and annual addition of the generating capacity required to expand the system is still very small. This reduces the ability of the electricity sector to benefit from economies of scale through construction of new large generating units. High specific investments in the construction of small power plants (such as solar power plants) will inevitably lead to high electricity generation costs.
- At present, due to the large share of domestic sector in total electricity demand, the daily peak load occurs in the evening. These hours have the greatest impact on the reliability of electricity generation and on the needs of generating capacity expansion in the system. Solar generation is not available during evening hours, when generating capacity is most required.

A hybrid pump-storage development combining solar with hydropower would allow solar produced energy to be stored and dispatched to the power system using the hydro capacity. This is a future opportunity for the Ruzizi III Project that can be developed when the Contracting States require additional energy sources to meet their demands. At present, the demands are low enough that the hydro can supply alone without the support of energy from solar. However, solar cannot supply alone the energy demand without constructing additional energy storage (e.g., hydro, pumped storage hydro, or battery).

5.3 Alternative Site Layout, Design and Mode of Operation

5.3.1 Dam Type

Alternative dam types are not considered technically feasible because the adopted dam type, a rockfill embankment dam, is considered the best choice when considering the geological conditions and seismic activity of the project location. Rockfill structures are the most robust solutions in areas of seismic activity such as at the project location.

5.3.2 Project Layout and Design

5.3.2.1 Hydropower Component

Project layout and design has evolved over time. The Fichtner 2010 Feasibility Study proposed a dam site, powerhouse and reservoir footprints different from those in the current 2021 design. The dam for the 2010 design was positioned further downstream, but for the 2021

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design it was moved upstream because of landslide risks and in order to increasing the hydraulic head by 45 m. The powerhouse for the 2010 design was positioned 950 m upstream from that of the 2021. The 2021 design moved the powerhouse downstream for geotechnical reasons and create more head, increasing power capacity.

Table 5-2 Key Characteristics of the 2010 and 2021 Designs

Characteristic	Unit	2010 Design	Adopted 2021 Design (the Project)
Dam			
Maximum height	m	39	51.5
Length	m	120	287.6
Reservoir			
Full supply operating level	m asl	1,107	1,145
Minimum operating level	m asl	1,101	1,133
Total Volume	Mm^3	1.68	7.7
Active Volume	Mm^3	0.84	5.1
Reservoir surface area	ha	18	46
Reservoir length	km	0.5	2.3
Headrace			
Length	m	2,840	3,820
Diameter	m	6.7	6.7
Rock excavation volume	m^3	140,000	188,310
Powerhouse			
Design flow	m^3/s	150	150*
Installed capacity	MW	147	204*

* The total power production capacity of the Project (206 MW) is calculated using the formula: Power = Flow rate x net head x efficiency x gravity and including power produced by the mini-hydro unit (2.9 MW) turbining the ecological flow (10 m^3/s), with power produced varying with reservoir water depth.

5.3.2.2 Transmission Line

The selected 7-km-long transmission line takes the shortest distance between the Project's switchyard and the Kamanyola 220 kV substation. The route avoids houses and so no physical displacement is required. Most of the route crosses modified habitat used for agriculture, but there is short 180 m section that crosses an area of hillslope grassland/savannah (natural habitat).

Alternative routes that avoid the hilly slopes and cross flat areas of land would be longer than the selected route and would incur additional construction costs and more households would be affected by economic displacement. This would have no economic or social benefit. However, it would avoid the 180 m of hillslope grassland (natural habitat). However, the environmental gain is expected to be negligible because the transmission line has negligible impact on the grassland habitat – there would be no need for vegetation removal.

Alternative routes that increase the length of the line crossing the hillslope grassland would make no reduction in scale of impacts on economic displacement but would incur higher construction costs as the transmission line would be longer and in length in areas difficult to access would be increased. The impacts on natural habitat would be increased because longer temporary access tracks would be required. Therefore, this alternative has no environmental or social gain.

5.3.2.3 Avoidance and Minimisation of Involuntary Resettlement

To minimize involuntary resettlement impacts, two design changes were implemented. In DRC, the right-of-way for the transmission line was reduced from 50 m to 30 m, which avoided the resettlement of 2 houses and reduced the area to be acquired from 34.5 ha to 21.06 ha. In Rwanda, the width of the access road was reduced, avoiding impacts on about 20 houses and 83 land plots in the outskirts of Bugarama.

The location of quarry sites will be selected when the EPC contract is mobilised. After ensuring quality and quantity of materials in the proposed sites, the EPC contractor will have to submit a list of preferred sites to REL. Based on this list, REL will make a selection with the objective of avoiding and minimising displacement impacts as much as possible.

5.3.2.4 Avoidance of Cultural Heritage Sites

The social baseline survey included identification of tangible and intangible cultural heritage elements potentially affected by the Project. The location of the cultural heritage elements in relation to Project infrastructure and the risk of impacts is assessed in Chapter 11 – Impacts Assessment and Mitigation (section 11.17). The assessment concludes that no significant impacts on the tangible and intangible cultural heritage sites are expected during construction and operation. Consequently, the Project has not explored alternatives to further distance infrastructure from cultural heritage elements.

5.3.3 Mode of Operation

A basic consideration for the selection of the mode of operation of the Project was that the operating mode of the river would not change from the existing situation. The existing Ruzizi-I and -II hydropower schemes operate with a daily peaking mode, where flow is released through the day to match the energy demands from the power system. Ruzizi-III will follow this pattern, although shifting the timing of the peak flow using the storage capacity of the Ruzizi-III reservoir. The Project's peak capacity of 150 m^3/s was specifically selected so that the Project does not cause an alteration to the existing conditions, where Ruzizi-I releases up to 150 m^3/s daily as needed for demand. Ruzizi-II has very little storage so releases the peak flows from Ruzizi-I as it arrives in Ruzizi-II reservoir.

Some consideration was given to a larger installed capacity for Ruzizi-III to improve the economics, but this would increase the daily peaking. This option was rejected on environmental grounds.

5.3.3.1 Run-of-River

The alterative mode of operation would be for the Ruzizi-III scheme to operate as a run-of-river and to turbine the discharges from Ruzizi-II without storing water. This option would avoid creating the reservoir, but in order to be economically feasible the headrace tunnel creating a bypassed reach of Ruzizi River would still be required. This configuration would have approximately 30% less power production capacity (because the hydraulic head would be reduced by approximately 30%) and only a small environmental and social gain compared to the adopted design. Functioning with this mode of operation the Project is probable not economically viable.

5.3.3.2 Regulating Dam-Reservoir

The dam-reservoir could be used to regulate the flow of the Ruzizi River by acting as a buffer reservoir absorbing the peak flows discharged from Ruzizi-II (or Ruzizi-IV once built) and discharging a flow that is similar to that of the natural conditions of the river. This would avoid the negative impacts on hydrology from alternating peak and off peak flows, but will have reduced power production capacity, and would not be able to meet the requirements of peak power demand. Functioning with this mode of operation the Project is probable not economically viable.

5.3.3.3 Peaking Mode

The 2021 Feasibility Study design, which this ESIA assesses, has peak flows of 150 m^3/s. This discharge aligns with the peak flows discharged from the upstream Ruzizi-I and -II hydropower scheme that have been in operation for over 50 years. The 2010 Feasibility Study prepared by Fichtner when EGL was developing the Project also planned for peak flows of 150 m^3/s.

The purpose of the Project is to increase regional power production capacity to meet an ever-increasing power demand, including periods of peak demand. The Project's peak flow rate enables the Project to achieve its full hydropower potential without causing a significant incremental increase to downstream hydrological conditions over and above those caused by the operation of Ruzizi-I and -II.

One alternative to the proposed peak flows would be to design the Project with a capacity to discharge peak flows >150 m^3/s. This would incur additional construction costs but enable peak power production to be higher, but for a shorter period. However, this would expose the downstream river flow conditions to a higher degree of alteration compared to the proposed Project and current conditions. The degree of alteration would be proportional to increase in peak flow capacity. The gain in terms of peak power production capacity would be offset by the reduced duration of peak power and environmental impacts. This configuration has therefore not been considered by the Project.

Another alternative would be to design the Project with peak discharge flows <150 m^3/s. This would result in lower peak power production and reduce the degree of alteration to river flow conditions caused by the existing Ruzizi-I and -II hydropower schemes that have been in operation for over 50 years. However, there would probably not be a significant rapid environmental gain from adopting the lower peak discharge. In the long-term, the river may recover to a certain extent from the impacts caused over the last 50 years by the operation of Ruzizi-I and -II. However, unless Ruzizi-III were to operate as a regulation reservoir, any recovery would be negligible-minor. This configuration has therefore not been considered by the Project.

5.3.4 Hydropower Generation

The Project Agreements with the Contracting States specify that REL is to construct a hydropower generation system comprising 3 generating units.

As part of the Project's power system studies, the impact of an alternative 4 generating units on the transmission grid system (static and dynamic stability analysis of the power flow) was assessed. The 4-unit option would increase the cost of the power station but would not provide any significant improvement in the operating mode for the plant. The 4 units would each be smaller than the 3-unit plant. In some cases this is required because of the variability of flow rate and limits in storage. However, in the case of Ruzizi-III, the 3 units are adequate because of the amount of storage available and the characteristics of the flow available from upstream. The grid system is able to absorb either 3 or 4 units without difficulty.

A 2-unit plant was not studied although this would likely be less expensive. The larger units would have a smaller flow rate range that the 2-unit plant. This would constrain the plant somewhat and require more use of the daily storage capacity (possibly with more on-off peak cycles). The larger units would also be more difficult to dispatch to the Contracting States if the connection to Rwanda were ever interrupted (the systems in both Burundi and DRC are very small for larger units).

With respect to the type of generating units. Francis generating units have been selected as this is the most suitable units for this range of flow rate and generating head. Francis units will also be the least expensive in this range. Pelton units would be well outside their normal operating range and would require a large powerhouse while having lower efficiency. Similarly, the generating head is too high for Kaplan or Propeller units.

5.3.5 Sitting of Facilities

5.3.5.1 Generalities

There are no realistic alternatives to the proposed siting of the facilities other than adopting an alternative layout within the current proposed footprint. This is because facilities need to be sited on flat land that is not exposed to flood risks and landsides, and there are limited areas that meet these criteria.

5.3.5.2 Operator's Village

The location finally selected was determined to ensure that the area is above the 100-year return period flood level in the area while being close to the powerhouse. The Employer's camp location was selected to allow easy access to the dam site in emergency situations. A separate camp is located adjacent to the switchyard in DRC that will house employees working in the switchyard. This site was selected because of its proximity to the yard.

5.3.5.3 Switchyard

The site for the switchyard location in DRC across the river from the powerhouse. The location allows for an efficient arrangement of the transmission lines from the powerhouse to the yard and then on to the Kamanyola substation. The site was selected because it is above the flood level and not used for other high value purposes. This location also allows for the minimum length of the transmission line to Kamanyola.

5.3.5.4 Contractor's Camps and Work Areas

It is planned for Contractor's camps and work areas to be located adjacent to the main works area at the powerhouse because of the availability of sufficient flat land in this area. The lands farther upstream towards the dam site are very steep and unsuited for the large industrial installations needed. A somewhat higher flood risk is accepted for these facilities because of the short period of risk exposure and the consequences of flooding.

5.3.5.5 Roads

Road layouts were selected based on the available topography and for minimization of the total earthmoving requirements. Alignments were tested to reduce the depth of cuts and fills while achieving acceptable geometric design parameters.

5.3.5.6 220 kV Transmission Line Route

The Project's 7-km-long 220 kV transmission line route was originally selected by EGL and included in REL's Project Agreements. The route is located in DRC and connects the Project's switchyard to the Kamanyola substation.

The transmission line route and the siting of the Kamanyola substation (see below) had been selected by EGL with the intention of avoiding technical constraints and minimising social impacts. The route and substation are located on modified habitat and consequently direct environmental impacts have been avoided.

The Project re-examined the transmission line route and made some small adjustments to avoid interference with houses where the line crosses the Kamanyola-Bugarama road. Given that the two end points are fixed there were few degrees of freedom available for route refinement.

The Project's route selection criteria were (i) minimize cost by keeping the line as short as possible, (ii) avoid zones with risk of flooding, (iii) position pylons on land with suitable ground conditions (i.e. avoid ancient alluvial zones), (iv) and avoid residential areas. Other adjustments to the line route would result in increased social impacts.

Avoidance/minimisation of impacts on birds was not a criterion used by EGL for the route selection, or by the Project for refinement of the route. This was because it had been assessed that the line would not have significant impact on birds. In addition, it would be unlikely that alternative routing would reduce any such impacts. However, alternative routes would incur additional cost and additional social impacts because the longer length would cause increase economic displacement.

5.3.5.7 Kamanyola Substation

The Kamanyola substation is an Associated Facility located in DRC and developed, financed, constructed, owned, ensured, operated and maintained by the Contracting States with financial support from KfW (see Chapter 4 – Project Description). The Kamanyola substation is not included in the scope of this ESIA, however, it is mentioned in this Analysis of Alternatives chapter because it is the termination point of the Project's 220 kV transmission line route. The location of the substation has been defined as part of the ongoing development work by the Contracting States with the objective to establish regional power inter-connection. In addition to the being the termination point of the Project's 220 kV line, there will be 3 transmission lines transporting electricity from the substation to the Contracting States. Consequently, the selection of the substation site has required consideration of the technical, environmental and social criteria for the other transmission lines.

5.3.5.8 Quarries and Borrow Areas

Quarries and borrow areas are not included in the scope of the ESIA because the sitting will be defined at a later stage. Chapter 4 - project description provides the locations of potential sites for quarries and borrow areas that have been identified by REL. However, it will be the EPC Contract that selects site locations, and they may correspond to sites identified by REL or alternative sites. Vol. IV - ESMP includes the process for REL's review and approval of the sites proposed by the EPC Contractor so that there is avoidance or minimisation of environmental and social impacts.

5.4 Do-Nothing Alternative

With the do-nothing scenario, the Project is not implemented, and the project's negative impacts can be avoided, but benefits and positive impacts will not be realised. There would be a gap in the power production strategy and a lack of access to reliable power supply services which hampers economic growth and contributes to poverty and isolation of rural population would continue.

5.5 Comparative Assessment of Alternatives

5.5.1 General Comparative Assessment

A qualitative comparison of the magnitude of impacts on the various receptors for each alternative is presented in the matrix overleaf and discussed in the following paragraphs.

The assessment is qualitative and based on expert judgement. This is because the magnitude of many of the impacts of alternative technologies are dependent on the site location and project footprint, and this information is not available.

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Alternative	GHG emissions	Air Quality and Odour	Noise and vibration	Geology and soils	Hydrology	Water quality	Geomorphology and sediment	Aquatic habitats and biodiversity	Terrestrial habitats and biodiversity	Social and economic impacts	Community health and safety	Cultural heritage	Landscape and visual amenity	Positive impacts and benefits
Alternative Technology HFO Diesel	⬤	⬤	⬤	●	•	●	–	–	•	⬤	●	•	⬤	□
Alternative Technology Methane	●	●	⬤	●	•	●	–	–	•	⬤	●	•	⬤	□
Alternative Technology Peat	⬤	⬤	⬤	●	•	●	●	–	•	⬤	●	•	⬤	□
Alternative Technology Solar	•	•	•	●	•	•	–	–	•	⬤	•	•	⬤	□
Alternative Technology Biomass	●	●	⬤	●	•	•	–	–	•	⬤	●	•	⬤	□
Alternative Layout and Design	•	•	●	⬤	⬤	•	⬤	⬤	•	●	⬤	•	●	⬜
Alternative Operation Run-of-River	•	•	●	⬤	●	•	⬤	●	•	●	●	•	●	⬜
Alternative Operation Regulation	•	•	●	●	•	•	⬤	•	•	●	●	•	●	⬜
Adopted Project Design	•	•	●	⬤	⬤	•	⬤	⬤	•	●	⬤	•	●	⬜
No Project	⬤	⬤	–	–	–	–	–	–	–	–	–	–	–	–

Explanatory note

The sizes of the circles in each column illustrate the relative magnitude of impacts from each alternative for the specific receptor/topic. The larger the circle the greater the relative magnitude of the impact.

It should be noted that the size of the circles should not be used to compare magnitude of impacts on the different receptors for a given alternative.

Magnitude of positive impacts and benefits are illustrated using squares, the larger the square the greater to positive impact/benefit.

Figure 5-3 Indicative Qualitative Comparison of Alternatives

Discussion

- **GHG emissions**: The alternative generating the highest emissions is the "no project" alternative, as households in the region without electricity will continue to use firewood and charcoal for household cooking and heating. HFO, diesel and peat - and to a lesser extent methane - have relatively high GHG emissions compared to the hydropower alternatives. The alternative hydropower designs all have the same GHG emission orders of magnitude. Solar power has the lowest GHG emissions.
- **Air Quality and Odour**: The relative impacts of the alternatives follow the same rationale as for GHG emissions above.
- **Noise and vibration**: The thermal power plants will probably generate levels of noise that are similar or slightly higher than for the hydropower alternatives. However, the thermal power plants will probably be located closer to communities because of siting constraints than the hydropower plant's powerhouse. The solar power plant will generate the least noise.

- **Geology and soils**: The hydropower alternatives include tunnelling and major earthworks for construction of the spillway, bottom outlet and access roads. Earthworks for the alternative technologies will probably be required for site preparation and levelling, but on a smaller scale to that of the works for the hydropower alternatives.
- **Hydrology**: The alternative technologies are not expected to have noticeable impacts on hydrology. Whereas the hydropower alternatives (except the regulation dam alternative) will have an operating mode that alters river flow conditions.
- **Water quality**: Hydropower alternatives are not expected to have a significant impact on water quality because the reservoir is small, and the residence time of stored water is less than 24 hours. No industrial effluents are discharged. However, the thermal power plants will generate industrial waste water that will be discharged into watercourses altering water quality.
- **Geomorphology and sediment**: With the exception of peat-fuelled power plants, the alternative technologies are not expected to have noticeable impacts on geomorphology and sediment as impacts on hydrology are not expected. Whereas the hydropower alternatives will trap sediment and cause downstream alteration to sediment loads causing changes to geomorphology. The stripping of peat wetland for peat-fuelled power plant can result in increased soil erosion and sediment loads in watercourses.
- **Aquatic habitats and biodiversity**: Hydropower alternatives are expected to have a significant impact on aquatic habitats and biodiversity because of the alteration to hydrology, sediment and geomorphology. Thermal power plants are expected to discharge industrial wastewaters to surface waters, however, if wastewater is treated to comply with national and IFC wastewater discharge criteria the impact should not be significant.
- **Terrestrial habitats and biodiversity**: All alternatives are expected to have similar orders of magnitude of impacts on terrestrial habitat and biodiversity as much of the project footprints will be predominantly agricultural or modified habitat.
- **Social and economic impacts**: The thermal power plants and the solar power projects are expected to have a greater degree of impact on social and economic environment than that of the hydropower alternatives. This is because the hydropower dam-reservoir project footprint is small compared to the footprint for thermal power plants.
- **Community health and safety**: The hydropower projects probably represent a higher risk to community health and safety because of the dam rupture risk. Which although highly unlikely would affect a much larger number of people than an accident at a thermal power plant. In addition, the variations in river flows from hydropeaking represent a risk of drowning. The thermal powerplant represent a risk because of the storage of large quantities of hazardous substances representing a risk of fire and/or explosion, but these risks can be controlled through including protection and prevention measures in the design.
- **Cultural heritage**: Impacts on cultural heritage are not anticipated for all alternatives.
- **Landscape and visual amenity**. The impact from the thermal power plant and solar power plant are expected to have a higher impact significance than that of the hydropower alternatives. This is because the thermal and solar power projects will be far more visible as they will probably be sited in more populous areas, whereas the hydropower facilities will be located in a deep sided valley which will only be visible to a small number of people.
- **Positive impacts and benefits**: The hydropower project is expected to result in more positive impacts and benefits that the thermal and solar projects, because more unskilled workers will be employed during the construction phase, and there will be more opportunities for economic development such as fisheries.

5.5.2 Comparison of Project GHG Emissions with Alternative Technologies

Cumulative GHG emissions over a period of 30 years for the project and power plants fuelled with diesel, methane and peat producing the same amount of energy as the Project are compared.

Emissions have been estimated using emission factors published by the IPCC. The method comprises estimating the fuel consumption of diesel, methane and peat based on energy requirements and the power production energy efficiency of the different fuels. The calculation is presented in Table 5-3 and the emissions are presented in Figure 5-4.

Table 5-3 – Estimated Annual GHG Emissions from Alternative Technologies

Parameter used in the calculation	Diesel	Methane	Peat	Units
Input				
Plant power capacity	206	206	206	MW
Annual electricity production	1.2×10^9	1.2×10^9	1.2×10^9	kWh/year
Calculated Fuel Requirements				
Conversion factor	3.6×10^6	3.6×10^6	3.6×10^6	J/kWh
Conversion efficiency *	0.35	0.4	0.33	None
Conversion factor	1.0×10^{12}	1.0×10^{12}	1.0×10^{12}	TJ
Fuel requirement	12,312	10,773	13,058	TJ/year
Calculation of GHG emissions				
Emission factor CO2	74,100	56,100	106,000	kg/TJ
Emission factor CH4	10	5	0.4	kg/TJ
Emission factor N2O	0.6	0.1	0.4	kg/TJ
CO2e emissions	0.92	0.61	1.4	MtCO2e/year

* Modern state-of-the-art thermal power plants may have slightly higher efficiencies than those indicated. However, efficiencies used in the calculations are representative values for a wide range of equipment types. Consequently, the estimated emissions indicate orders of magnitude and are indicative of the relative performance of the different technologies in terms of emissions with or without the use of state-of-the-art equipment.

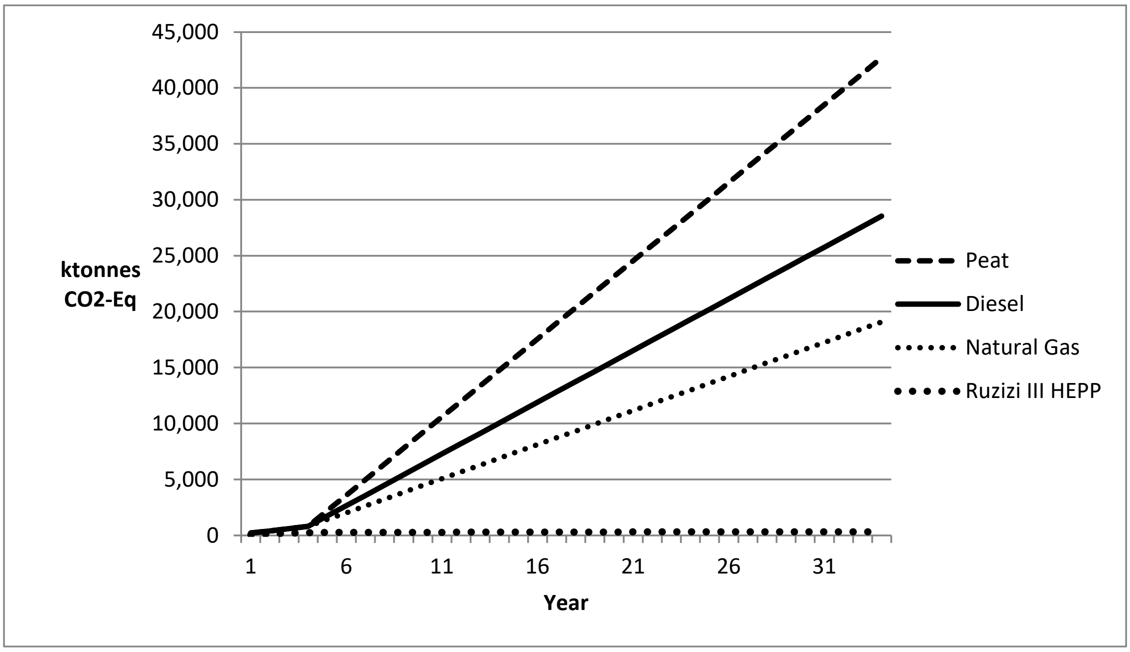

Figure 5-4 Comparison of the Project GHG Emissions with Alternative Technologies

5.6 Selection of the Preferred Alternative

The preferred option is the 206 MW HEPP with hydropeaking mode of operation and the rationale for the selection is that this is the alternative that aligns best with Rwanda's power strategy, is the cheapest technology that is able to produce the forecast peak power demand, results in reduced GHG emissions compared to the thermal power alternatives and offers the best compromise in terms of environmental impacts for energy produced.

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