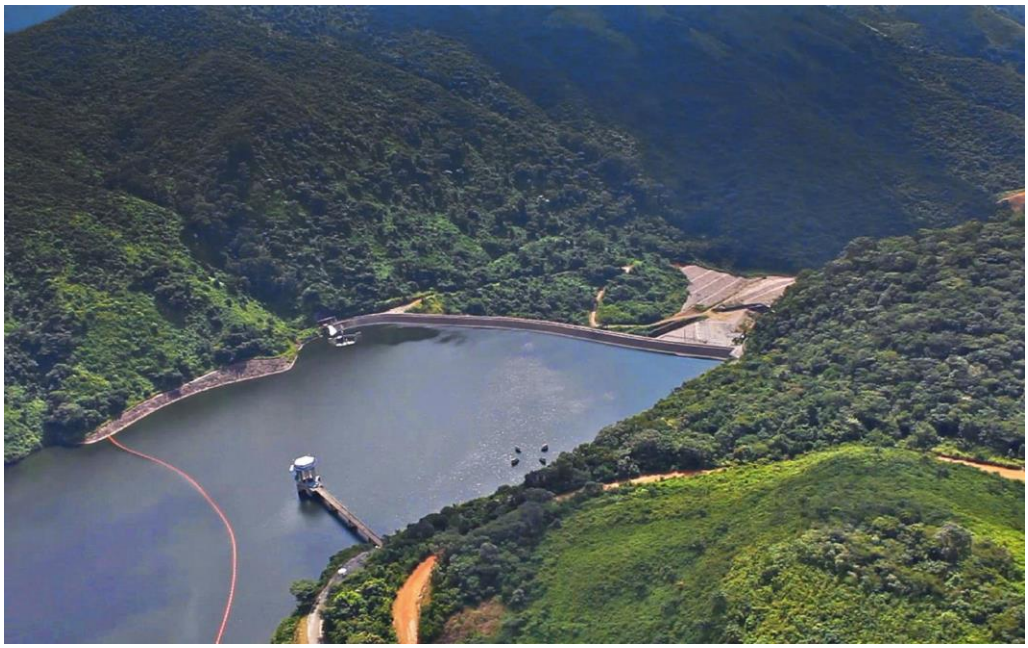
BUMBUNA II HYDROELECTRIC PLANT

ALTERNATIVES ANALYSIS



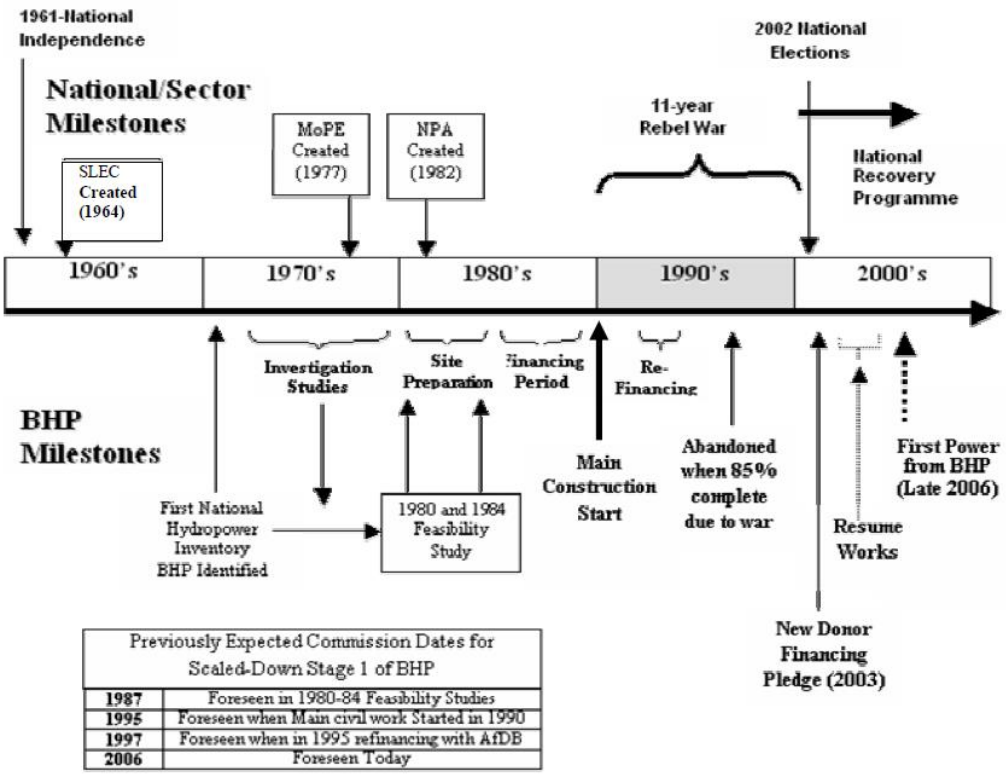
1 BACKGROUND TO THE BUMBUNA II HEP

1.1 INTRODUCTION

This note summarises the process by which the energy potential of the Bumbuna-Yiben hydropower complex (ie Bumbuna I and the proposed Bumbuna II Project) was identified and initially assessed; the policy and strategic framework within which the development of Bumbuna II has been progressed; and various alternatives that have been considered during the design and development process.

1.2 HISTORY

Sierra Leone's effort to develop the Bumbuna HEP has a long history that roughly corresponds to four different periods and events in the history of the country.



The above figure, taken from the Bumbuna I 2005 ESIA, is a simplified schematic showing national events, power sector events and the development of Bumbuna Hydro Power (BHP) in a historical context.

1.2.1 *The 1970 to 1985 Period – Deciding which hydropower project*

A decade after independence in 1961, Sierra Leone's first nationwide hydropower inventory was completed. This was part of a study, "Strengthening of the Sierra Leone Electricity Corporation (SLEC)", undertaken by Moto-Columbus of Baden, Switzerland, financed by the UNDP. 22 potential sites for hydropower were identified

at that time (1970-71) and three sites were identified as warranting detailed investigation. These were:

- Bumbuna Falls (72 MW) - 40 km north east of Makeni in the north east
- Benkongor Falls (15.2 MW) - 40 km west of Koidu in the central east
- Goma (18 MW) - 30 km north of Kenema in the south east of the county

Preliminary design and cost estimates were prepared to rank the sites in order of economic merit.

The Bumbuna site was considered the most attractive of the three sites to supply the Western Area Grid on the basis of hydrology, head, technical characteristics and proximity to the Western Area load centre. From 1973 on, all studies that assessed new supply for the Western Area grid focused on comparing alternative Bumbuna-Yiben construction sequences with equivalent thermal options on imported oil or coal.

In 1972-73, SLEC engaged the Italian consulting firm Carloti as part of a consortium of Canadian and Italian firms to prepare the Bumbuna Hydropower-Development Project Study. The study sought to determine an optimal layout for the Bumbuna site based on economic, technical and hydrological parameters. A second upstream reservoir site at Yiben not envisaged in the 1970-71 study was identified and a staged-development of the Yiben-Bumbuna scheme was recommended, beginning with a seasonal storage dam at Yiben with a 55 MW power station at the base of the dam.

The World Bank (IDA) became involved at that point when the Government requested technical assistance to review the alternatives and explore IDA's interest in financing the project. IDA staff concluded that it was necessary to upgrade the technical and economic studies. Their 12-volume report completed in July 1980 recommended a 305 MW project with five stages. Stage 1 was conceived as a $US192 million (mid-1980 US$ exchange-rates), 74m high dam with a 53.4 MW plant utilizing the 40m head at Bumbuna Falls and a 2.5 km long headrace tunnel. An assessment of the environment effects of the full scheme and the resettlement effects for three different heights of the Yiben dam were prepared, as the Yiben reservoir involved considerably more resettlement than the Bumbuna reservoir.

1.2.2 The 1986 to 1997 Period – Financing and construction delays

The report of the joint UNDP/World Bank ESMAP team (Sierra Leone: Issues and Options in the Energy Sector) was issued. While the report was broadly concerned with short- and long-term issues in the energy and power sectors, the ESMAP team placed special emphasis on comparing the Bumbuna project with other grid supply options. ESMAP concluded that the scaled-down Bumbuna project was economically attractive relative to alternative thermal options (imported coal and oil) over a wide range of load forecast and fuel price assumptions. While the ESMAP team had qualitative concerns that the project was a "lumpy", relatively large investment for the Sierra Leone economy, it concluded that an investment in the scaled-down

version of the BHP would not produce short-term macroeconomic consequences much different than investment in thermal generation with oil imports.

While the ESMAP (1987) team assessed the potential for biomass generation and small hydro to augment diesel-electric supply in isolated provincial networks, it was not until the Master Plan (1996) that more explicit consideration of non-hydro renewable sources for grid supply was provided, specifically for biomass, solar and wind generation.

There was a 3-step process. Initially, all potential energy sources and associated generation technologies were screened. Where the options were deemed technically feasible and potentially economically attractive, the specific energy costs ($/kWh) were determined. Options with attractive specific energy costs were then included in the least-cost simulations. However, no non-hydro renewable options advanced to the final stages because the higher-cost options would not be selected by the least-cost optimisation procedures (They would have to be "forced" - that is, a minimum "portfolio" of biomass generation, for example, would have to be specified as an optimisation criteria).

1.2.3 The Building of Bumbuna I

Following a detailed feasibility study and design development, construction of a 50MW plant (Bumbuna I) commenced at this site in 1986 but was interrupted by the increasing civil unrest in the lead-up to the civil war. Further progress towards completion of the partially-built project was halted throughout the civil war that ended in 2002. Work resumed two years later and Bumbuna I was eventually commissioned in 2009 after further delays due to funding issues. Bumbuna I is, by some margin, the largest power plant in Sierra Leone, providing approximately two-thirds of on-grid generating capacity.

1.2.4 The Current Situation

Throughout any consideration of options for power generation to support social and economic development in Sierra Leone, it is important to remember that for much of the critical period from the early 1990s onwards, the country has been severely disrupted, at times to the point of being a failed state, initially by a prolonged civil war and most recently by the Ebola Virus Disease (EVD). The resulting situation in the country and status of the power sector was summarised by the Overseas Development Institute (ODI) in 2015 (see *Box 3.1*).

It is hard to over-emphasise the critical role that development of power generation capacity, with significant involvement of both development finance institutions and of the private sector, will play in Sierra Leone's social and economic progress in the future; and given the abundant water resource the country has and the significant hydropower potential that this creates, hydropower will play a key part in this.

2 POLICY AND STRATEGIC FRAMEWORK

2.1 GoSL Policy and Strategy

As stated by the Ministry of Energy(1), although there have been various efforts over the last fifteen years Sierra Leone still lacks clear comprehensive policies and regulatory frameworks for the energy sector; these are required to govern the process of energy provision and use in the country. Nevertheless, development of the power sector has been an important thread running through the GoSL's strategy in the aftermath of the protracted civil war, including the following.

- The three iterations of the five yearly Poverty Reduction Strategy Paper (PRSP) that have been part of the process for Sierra Leone to qualify for debt relief, the most recent covering the period 2013-2018 (2).
- The Overseas Development Institute (2015) examined the status of the power sector in Sierra Leone post-conflict and the Ebola outbreak and a summary of this study is presented in *Box 2.1*.
- The strategic priorities and goals for the ten-year period 2006-2015 set out in the Ministry of Energy and Power (as was) document *The Sierra Leone Energy Sector: Prospects & Challenges (MoEP, 2006)*; and
- *Energy Sector Strategy and Action Plan, 2014 -2017 (MoE, 2014)*.

(1) http://www.energy.gov.sl/Energy_Policy.html. Accessed 07 December 2016.
(2)ttp://www.undp.org/content/dam/sierraleone/docs/projectdocuments/povreduction/undp_sle_The%20Agenda%20for%20Prosperity%20.pdf

Box 2.1 Status of the Power Sector in Sierra Leone, 2015

Fewer than 10% of the population has access to some form of power. The power sector in Sierra Leone has been a focus of many development programmes through donors such as DFID and the World Bank who have sought to support the Government of Sierra Leone (GoSL) in reforming the sector. Sierra Leone is one of the world's poorest countries. As of 2012, Sierra Leone ranked 177 out of 186 countries in the United Nations Human Development Index and had an estimated Gross National Income per capita of $580, placing it in the bottom third of countries in sub-Saharan Africa. The largest segment of the population is concentrated in the Freetown area, with one of the region's largest and poorest urban settlements. Poverty is even more severe in rural areas. Gradually, post-conflict recovery has been sustained, characterised by strong economic growth, infrastructure development, improvements in governance and public sector capacity building. Unfortunately, due to the recent Ebola outbreak, many of the development programmes in the energy sector, and indeed in other non-essential areas, have had to take a backseat to the Ebola response. Rural Sierra Leone suffered significantly by isolations posed by Ebola quarantines, which further hampered the gains that had been made before this devastating setback.

Electricity access and demand in Sierra Leone are among the lowest in Africa. Sierra Leone's limited power infrastructure base on generation, transmission and distribution is a major constraint to expanding electricity access. Public electricity services are limited to selected areas. Its sparse coverage and unreliable service exacerbate poverty conditions. The national distribution network extends to Freetown and the surrounding Western Area (Freetown Capital Western Area), covering about 40% of their residents. Two isolated systems (Bo-Kenema and Makeni systems) provide coverage in limited areas in the south-eastern and northern regions. In rural areas, where the bulk of the population reside, electricity access is practically non-existent. Electricity tariffs remain among the highest in Africa, constraining energy consumption…….high tariffs are mostly caused by the reliance on expensive thermal generation and high transmission and distribution losses. The tariff is not cost-recovering and the national electricity utility remains strongly dependent on government subsidies. Low connection rates and affordability issues keep electricity consumption rates among residents very low. Because of scarce supply and high costs, electricity represents only 7% of total energy consumption. The large majority of Sierra Leone's population is forced to rely on inefficient and polluting traditional fuels to meet their basic needs, such as kerosene for lighting and fuel-wood and charcoal for cooking. This results in adverse impacts on personal health and safety as well as on the environment.

Current power generation capacity, transmission and distribution remains inefficient and inadequate to accommodate the country's overall power requirements. Government-owned installed capacity is estimated to be approximately 90 MW, which includes the 50 MW Bumbuna hydroelectric power plant, two thermal power plants at Kingtom (10 MW) and Blackhall Road (16.5 MW), that serve the Freetown Capital Western area. Hydropower from Bumbuna is seasonal, producing less than 20 MW during the dry season often being out of action for days or even weeks. With no availability of a local fuel resource, all the thermal plants are supplied by expensive and imported heavy fuel oil or diesel, which further complicates the electricity supply situation during the dry season. Limited port facility and poor supply chain infrastructure often leads to periods of fuel crises, pushing up the price of diesel and creating fuel black-markets. One of the largest industries in the country, contributing to its economic growth, is the mining sector. This sector relies primarily on self-generation by using large diesel generators to meet its power needs. The power demand of these mining companies is vast and an essential part of their operations, thus not awarding them the flexibility to be able to rely on the (unreliable) national power supply. Other large power consumers who depend on power, such as businesses, also depend on diesel generators as their primary power supply option. This inability to supply industry with its power needs creates a missed revenue generation opportunity for the government. [The lack of] transmission and distribution, together with an appropriate electricity retailing mechanism, to allow for a financially sustainable sector, further exacerbates the situation.

Source: Overseas Development Institute, 2015. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10254.pdf . Accessed 7 December 2016.

All of the above strategic documents have recognised the key role of hydropower in the energy generation mix as Sierra Leone attempts to achieve low carbon economic development; with specific mention given to the importance of Bumbuna II. The MoE's Energy Sector Strategy (2014) identified the components that are collectively

considered within Bumbuna II's ESHIA as fundamental to a stated objective of achieving 1,000 MW of generating capacity by 2017, based mainly on a mix of large and smaller-scale hydropower that it identified to be the cheapest renewable energy source for Sierra Leone. Other renewables and new thermal generation capacity were also identified, but contributing to a lesser extent. Further actions included an enhanced transmission and distribution network and measures to strengthen the capacity of government institutions managing Sierra Leone's power sector. All of the above were part of a comprehensive plan with the involvement of development partners, including *inter alia* the World Bank, African Development Bank, and UK Department for International Development (DFID).

The ambitious objective of such a significant increase in Sierra Leone's generating capacity was immediately behind schedule and was then derailed by two events in 2014:

- the outbreak of the EVD, and the subsequent focus of a major part of donor aid efforts on containing and ultimately eradicating the epidemic; and

- the collapse of the iron ore price on the world market, with its impact on Sierra Leone mining companies' production (and in some cases their ability to survive); the mining sector had been identified as the major purchaser of the increased power planned to be generated.

In July 2015, the President of Sierra Leone announced the country's Ebola Recovery Plan, running from July 2015 to June 2017. The overarching objectives of the Plan set out to eradicate Ebola, restore basic socio-economic services across the country, and lift economic growth rates. The Plan focuses on three sequential steps: (i) getting to and maintaining zero Ebola cases; (ii) implementing immediate recovery priorities, including restoring health services, reopening schools, ensuring food security, and expanding water and sanitation; and (iii) transitioning back into the Agenda for Prosperity (AfP) Plan (2013-2018 – also known as PRSP III). The AfP remains the defining document for the overall development of the country with a set of actions for Sierra Leone to become an inclusive middle income country by 2035, driving towards a low emissions, climate resilient, gender sensitive and sustainable growth trajectory. Also in 2015, the Ministry of Energy, in collaboration with ECOWAS / ECREEE, developed a framework for the deployment and monitoring of National Renewable Energy Plans, National Energy Efficiency Action Plans and the Sustainable Energy for All (SE4ALL) Action Agenda.

The Integrated Resource Plan and Tariff Study (2015) [(1)] identified the prime importance of Bumbuna II in its scenarios for development of generation potential into the mid-term, ie to 2024: "There is considerable undeveloped hydropower capacity in Sierra Leone, most notably in the Bumbuna/Yiben cascade." (*Section 2.4.3*), whilst also noting the severe supply-side constraints that could prejudice Sierra Leone's future potential for strong economic growth. The study considered hydropower to be the most economically viable option for major power generation in Sierra Leone over at least the next decade in comparison with other possible

(1) PPA Energy (UK), submitted to GoSL Ministry of Energy in February 2015

sources (such as coal or oil), considering the other sources either in isolation or in combination with hydropower.

In a recent letter to the World Bank (December 2016), the GoSL confirmed its commitment to Bumbuna II, noting it being part of the Government's "long term sustainable and affordable development plan for the energy sector" and that it was the next Independent Power Producer (IPP) in line following the almost finalised Western Area Power Generation Project (WAPGP), now referred to as the Salone HFO Project), a 57 MW heavy fuel oil (HFO) plant.

The President of Sierra Leone has therefore signalled the importance of energy in the nation's development, declaring energy as one of his highest priorities, with increasing hydropower and other renewable power generation; and improvements in transmission and distribution as key elements. This commitment has been reinforced during 2016 by initiatives such as the "Energy Revolution" and Sierra Leone's active participation in the UK's "EnergyAfrica" program. Sierra Leone also plans to connect to the West African Power Pool (WAPP), through the CLSG Transmission Line, due to start construction in 2017, to provide opportunities to trade energy with neighbouring countries, and to establish feed-in tariffs to harmonise the sale of power into the CLSG from IPPs that develop power generation capacity in Sierra Leone.

In general, development partners' efforts in the energy sector are now focused on three areas: (i) enhanced transmission and distribution to make power more available to the most energy poor, including those in rural areas; (ii) development of small-scale and off-grid generation (eg solar and mini-hydro); and (iii) institutional capacity building to improve management and governance of the sector(1). It is the private sector that will manage the risks and raise the necessary finance for development of larger-scale generation capacity (such as Joule Africa, in the case of Bumbuna II).

2.2 THE POWER SECTOR MASTER PLAN

Sierra Leone's energy generation potential was identified and evaluated in a systematic manner in the Power Sector Master Plan (Lahmeyer International, 1996). The Master Plan considered many options for power development including a wide range of large and small hydropower schemes alongside wind, solar and more conventional thermal power generation. As well as considering many other forms of power generation throughout Sierra Leone, the Master Plan described 27 hydropower sites, each with a potential to generate over 2 MW (approximately 1,200 MW in total across all these sites). Sites with a smaller capacity were not considered.

As part of the Master Plan, six candidate HEPs were considered with a more detailed focus (figure 2).

(1) Development partners involved in supporting power sector development include *inter alia* World Bank, African Development Bank, UK DFID, United Nations Development Program, Millennium Challenge Corporation, Islamic Development Bank and Japan International Cooperation Agency.

Figure 2: Sierra Leone Master Plan (1996) – Assessment of six candidate HEPs

Potential HEP	Guaranteed (Firm) power	Flood Control Potential	Resettlement
Betmai I	4.9 MW	No significant control	One village
Betmai III	23.5 MW	Considerable	Seven villages
Kambatimbo	13.2 MW	No significant control	One village
Benkongor III	5.0 MW	Minor	No villages
Yiben I	48.2 MW	Considerable	One town and nine villages
Yiben II	47.4 MW	Considerable	Two villages

The viability of hydropower generation at some locations was deemed to be compromised to a greater or lesser extent by the extreme seasonality of Sierra Leone's rainfall and the consequent variation in guaranteed power between seasons, but the existence of a number of feasible productive locations for hydropower generation was confirmed. Bumbuna (ie Phase I, already partially constructed at the time the Master Plan was prepared, and the elements now included in Bumbuna II as described in this ESHIA) was indicated as one of the most productive and economically viable projects to generate power for Sierra Leone's future, not only by comparison with other hydropower schemes considered but also when considered against the other options for power generation.

2.3 THE OPTIMAL POWER MIX FOR SIERRA LEONE

The comprehensive assessment of a range of power generation alternatives and sites in the 1996 Power Sector Master Plan was supplemented by the 2015 Integrated Resource Planning and Tariff Study prepared for the Ministry of Energy by PPA Energy (now Ricardo Energy and Environment). This provided a more up-to-date summary of the generation potential of hydropower in Sierra Leone by comparison with other sources of power generation. In the context of Sierra Leone's current situation and potential economic development trajectory over the next decade or more, the study's conclusions can be summarised as follows.

- **Coal**: in addition to noting the environmental impacts of pollutant emissions inherent in coal combustion, for which control technology adds significantly to project costs, PPA Energy also noted that there are no coal sources in the region. As a result, transport costs would be high, which was stated as a reason why there are very few coal-fired power plants in most of Africa. Generation of power from coal combustion is also subject to economies of scale, and Sierra Leone's system would have the capacity to absorb only the smallest viable unit sizes, with extremely high unit costs per kWh compared to units many times the size in other parts of the world where the power market is very much larger.

- **Diesel**: this is not considered practical for more than small generating units of a few MW - at most - and is generally not suited to baseload power generation. More complex technologies have a higher capital cost and O&M complexity and are not, in PPA Energy's opinion, suitable for the developing country context.

- **HFO-fired units:** were considered as a viable short-term solution and as part of a realistic energy mix for Sierra Leone

- **Gas**: although gas-powered plants are operated in several African countries, there is no indigenous gas resource in Sierra Leone and operating such plants on oil is extremely expensive, and subject to price variability and security of supply risks (1) .

- **Solar**: the economics of solar photovoltaic (PV) technology has improved considerably in recent years and is starting to become competitive with conventional generation technologies, in certain instances. The challenges for solar technology in Sierra Leone, however, are that: a) until large mining and industrial loads can be connected,, the system peak will remain during the early evening when solar plants cannot fully generate, and thus solar power could not contribute capacity towards meeting system peak demand; and b) the short-run marginal cost of solar is currently higher than the cost of diesel generation, so it can only have a limited role in the development of an economically optimal plant mix at present.

- **Biomass**: the biomass projects developed in Sierra Leone have generally been initiated by industrial stakeholders from the agriculture sector (eg ADDAX, now owned by Sunbird) to evacuate excess power rather than specifically to fill a gap in the electricity sector, resulting in very limited amount of power evacuated to the interconnected grid. In view of the feedstock supply risk, this seems unlikely to change in the short- to medium-term.

- **Wind**: the wind resource is considered too low to make wind power commercially viable. The challenges of supply-demand balancing too challenging and the resource too intermittent for wind to be a practicable contributor to the energy generation mix in the short- to medium-term.

- **Geothermal** power was not mentioned in PPA Energy (2015) as a possible power generation resource; this is because no potential resources exist within Sierra Leone.

- **Hydropower** development's merits and potential issues were also discussed in the 2015 Integrated Resource Plan and Tariff Study. Amongst various potential issues associated with hydropower development, hydrological seasonality was highlighted as particularly relevant in the Sierra Leone context, where the high seasonality of rainfall results in 'firm' capacity typically being well below the installed capacity. This limits a hydropower plant's utility in satisfying peak

(1) This strategy is generally only employed in countries that have an indigenous gas resource under development, but that wish to build generating capacity to fuel economic development whilst waiting for their indigenous gas resource to come on stream to provide longer-term fuel for power generation.

system demand reliably. Bumbuna I was quoted as an example: although it has a large impounding dam. With an installed capacity of 50MW and the capacity to provide 18MW of power throughout the year, it essentially operates as a run-of-river scheme for a large part of the year, with an output of only a few MWs in the dry season. Yiben was identified as potentially providing Bumbuna as a whole with over-year storage that is more advantageous in contributing towards satisfying peak system demand.

The likelihood of hydropower having high social and environmental costs inherent in the large impoundments necessary to provide year-round flows to overcome high seasonality were described, and it was noted that the resulting unit cost (US$/kW) could be less favourable than in many other countries. However, the 2015 study predates the Bumbuna II engineering design changes and mitigations discussed in the remainder of this alternative analysis notes. These have been developed specifically to reduce environmental and social impacts with the minimum impact on Project cost and operational efficiency, whilst also providing a scheme that offers greater value for money against meeting the current demand estimates for the country.

2.4 THE PLAN FOR HYDROPOWER IN SIERRA LEONE

The GoSL is supporting the development of a range of larger scale Hydro projects to meet the increasing demand in the country. Results from the recent Ricardo - Final Report Financial Analysis of Bumbuna II (2017) indicate that nearly all the hydroplants considered in more detail in the 1996 Masterplan (see figure 3) are now being considered for development – see table below

Name of project	Type of plant technology	Installed capacity	Mentioned in the 2013 IRP	Part of the MoE Energy Sector Strategy[49]	Part of the Electricity Network Investment Plan[50]	Mentioned in the CEPA Report[51]	*Number of sources mentioning the project*
Bumbuna II	Hydro	143 MW	✓	✓	✓	✓	4
Salone Phase I[52]	HFO-fuelled diesel units	57 MW		✓	✓	✓	3
Salone Phase II	HFO-fuelled diesel units	39 MW[53]		✓	✓	✓	3
Salone Phase III	HFO-fuelled diesel units	39 MW[54]		✓	✓	✓	3
Bekongor III	Hydro	160 MW[55]	✓	✓	✓		3
Mange	Hydro	100 MW[56]		✓	✓		2
Betmai	Hydro	25 MW[57]	✓	✓			2
Pepel I	Coal	250 MW[58]			✓		1
Pepel II	Coal	200 MW[59]			✓		1

[48] Source: Ricardo, based on the review of the four documents listed hereafter
[49] Source: Energy Sector Strategy 2014-2017, Ministry of Energy, Republic of Sierra Leone, 2014
[50] Source: Preparation of the Electricity Network Investment Plan: Draft Final Design report, NRECA International Ltd., 2016
[51] Source: Sierra Leone Electricity Market Note, CEPA LLP, 2016
[52] Source : Project Appraisal Document, World Bank, 2016
[53] Source: Energy Sector Strategy 2014-2017, Ministry of Energy, Republic of Sierra Leone, 2014
[54] Source: Energy Sector Strategy 2014-2017, Ministry of Energy, Republic of Sierra Leone, 2014
[55] Source: Energy Sector Strategy 2014-2017, Ministry of Energy, Republic of Sierra Leone, 2014
[56] Source: Energy Sector Strategy 2014-2017, Ministry of Energy, Republic of Sierra Leone, 2014
[57] Source: Energy Sector Strategy 2014-2017, Ministry of Energy, Republic of Sierra Leone, 2014
[58] Source: Preparation of the Electricity Network Investment Plan: Draft Final Design report, NRECA International Ltd., 2016
[59] Source: Preparation of the Electricity Network Investment Plan: Draft Final Design report, NRECA International Ltd., 2016

3 DEVELOPMENT OF THE HYDROPOWER POTENTIAL OF THE BUMBUNA COMPLEX

3.1 BUMBUNA I

The hydropower potential of the Seli River was first identified in 1970, with a suitable initial site for a hydropower plant located 230 km north-east of Freetown at the south-eastern edge of the Sula Mountains, upstream of the Bumbuna Falls.

From its inception, Bumbuna I was always perceived to be an initial part of a complex of developments to utilise the hydropower potential of the Seli River. Bumbuna I's design allowed for successive development of the full potential in one or more later stages without an interruption to generation of power from the original Bumbuna I plant.

3.2 BUMBUNA II

Further development of Bumbuna, which as described above had been envisaged since prior to the start of construction of Bumbuna I in the 1980s, was initiated by GoSL in 2009 with the intention of involving the private sector. Bumbuna II was initially promoted at a Sierra Leone/UK trade and investment conference, and subsequently proposals from interested developers were solicited by the Sierra Leone Investment and Export Promotion Agency (SLIEPA). Following an assessment of competing proposals to develop the project, Joule Africa was named the preferred bidder and a Memorandum of Understanding signed in May 2011, with an independent Pre-Feasibility Study (PFS) undertaken by Lahmeyer International later that year. Development of Bumbuna II was initially overseen by a Steering Committee whose membership was from the GoSL and Joule Africa, and their advisors. More recently, the Energy Strategy Delivery Task Force has had this responsibility. In the period up to the date of this ESHIA, work has progressed through the feasibility stage, design options, EPC procurement, a value engineering study (which has resulted in a considerable cost reduction to the construction costs of approximately 25% with only a small (*circa* 1.1%) impact on the annual average energy) and other steps to create a "bankable" project attractive to potential sources of finance. These steps have included identification and analysis of various alternative configurations, location of components and scheme designs (see below).

The Bumbuna II project as proposed consists of both the further parts of Bumbuna II that had been previously identified in the Power Sector Master Plan and incorporated into GoSL's post-conflict strategy for energy sector development. As described in *Chapter* 2, these components are:

- an extension at the Bumbuna I site to provide additional power generation capacity; and
- an impoundment further upstream at Yiben to generate additional power and regulate flow to the Bumbuna plant.

An associated facility to the new and extended generating capacity consists of the transmission lines needed to evacuate power from Yiben to the Bumbuna I site, and

to connect Bumbuna I to the existing transmission network. This transmission line is being provided by the GoSL as part of a separate project.

3.3 ALTERNATIVES TO BUMBUNA II

3.3.1 The "No Project Option"

As has been described in preceding sections of this note, Sierra Leone is one of the most energy-poor countries in the world. It is in the early stages of an ambitious program to reach low emissions, middle-income country status within twenty years. The development of Sierra Leone's hydropower generation potential is a fundamental part of this plan, and Bumbuna II is the first, most important step to unlock the remaining potential of the Seli River as an energy resource. It carries on the process started with the studies of the Seli River in the early 1970s and the construction of Bumbuna I which started in the mid-1980s. This long-established position at the heart of power sector development justifies Bumbuna II's classification as a major strategic project for GoSL which has the direct support of the country's President.

Bumbuna II's contribution to increasing Sierra Leone's access to electricity will be complemented, but could not be replaced, by small-scale and off-grid renewables generation. Thermal power generation will play a part in the energy mix but over-reliance on imported fuel, the availability and price of which could fluctuate markedly over short periods, would prejudice both GoSL's sustainable growth targets and its energy security. Given that only around 10% of the population has access to electricity, other measures such as demand side management would not be appropriate, nor effective if they were attempted. Under these circumstances, further consideration of alternatives in the remainder of this chapter will therefore concentrate on alternatives within the overall Bumbuna II project concept, and on how environmental and/or social issues have been assessed within different alternatives identified.

3.3.2 Alternatives for the Bumbuna Extension

With the aim of increasing the generation potential of the existing Bumbuna plant, three options were considered in the Bumbuna II PFS (2011). These, as shown on *Figure 3.1,* were:

- extension of the existing powerhouse (Option A);
- development of a new powerhouse on the right bank of the dam toe (Option B); and
- development of a new powerhouse downstream of the existing dam and Bumbuna Falls (Option C).

Extension of the existing powerhouse was not perceived to create any environmental problems, but was ruled out on technical grounds because: a) it would have been necessary to shut down the existing power house for several months, with the resulting severe disruption to Sierra Leone's power supply creating social and economic problems (which would not be acceptable to GoSL); b) the relatively small

additional power generation potential; and c) other administrative and technical problems.

The option of a new powerhouse on the right bank was also discounted, primarily for reasons similar to the above and that a shut-down of Bumbuna I of at least two months would have been necessary.

The third option that was considered takes advantage of the additional generating potential offered by the 40 m head of water over the 2 km stretch of the Bumbuna Falls and rapids downstream of Bumbuna I. It would involve construction of a new powerhouse to release water just downstream of Bumbuna Falls via a tailrace canal of about 2.1 km. The existing powerhouse would then serve as a backup for replacement of generating capacity during scheduled maintenance or forced outage and for generation of secondary power.

The PFS concluded that the third option was preferable on engineering and economic grounds, as it would provide over 50% more firm power (at 99.5% reliability). This significant benefit in terms of energy yield was deemed to override: a) construction taking longer than other options; and b) potential environmental and socio-economic issues associated with loss of land to the tailrace canal that is currently used by local communities for year-round agriculture. The PFS proposed that the loss of communities' access to land, and the resultant impact on livelihoods, could be mitigated by use of the tailrace canal to provide a reliable year-round irrigation water supply to farmers to increase their efficiency and thus yield.

Figure 3.1 Locations of Bumbuna Extension Powerhouse Options

3.3.3 Yiben Dam and Reservoir

As described in *Section 3.2.1*, from early concepts of hydropower generation on the Seli River, the value of maximising the energy yield through development of Bumbuna I and one or more subsequent phases was discussed. Thus, by the time that construction of Bumbuna I commenced in the 1980s, further development of an extension at Bumbuna and an additional component further upstream intended both to generate power in its own right and to regulate flow to Bumbuna to further

increase the energy yield, was considered an integral part of Sierra Leone's power development planning.

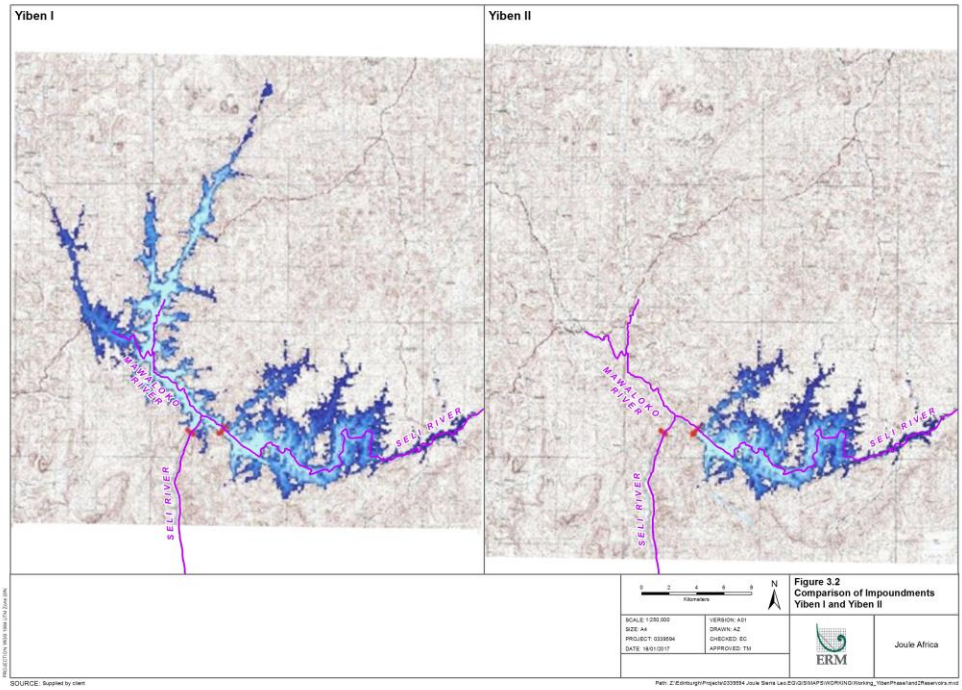
3.3.4 Yiben I vs Yiben II

The PFS assessed two locations for the upstream dam and power plant, both situated near the village of Yiben, on economic, engineering and environmental and social grounds:

- Yiben I (the original option identified in early concepts of feasible development of the hydropower potential of the Seli River) at a location approximately 29 km above Bumbuna I and 1 km below the confluence of the Seli and Mawoloko Rivers; and
- Yiben II, first identified in the 1996 Power Sector Master Plan which is situated about 3 km further upstream (and therefore 2 km above the Mawoloko River confluence).

The siting of Yiben I below the Mawoloko confluence would create a significantly larger reservoir than the Yiben II location (approximately double the size: see *Figure 3.2*), the benefits being to maximise energy yield and regulation of the flow of water downstream to Bumbuna I, thereby providing greater year-round power generation including during the dry season.

Figure 3.2 Comparison of Inundation Areas for Yiben I and Yiben II



Yiben I is therefore a more 'productive' option in economic terms, but as a consequence of the much larger inundation area this option was deemed to cause

significant social impacts. The preliminary analysis in the PFS suggested that 12 major settlements would be affected, of which seven would be completely inundated. Additionally, 14 km of road infrastructure would be inundated along with several paths linking villages. By comparison, the PFS identified that the smaller Yiben II alternative would only inundate one settlement, with a further five affected to some degree and with no impacts on road infrastructure and very few paths affected. The PFS completed a comparative assessment of the Yiben options and concluded that Yiben II was the preferred option due to the lower social and environmental impact.

Yiben I was concluded to be more economically attractive in providing better flow regulation and thus more reliable generation of continuous power as described above, but Yiben II was nevertheless approved as the preferred option by both GoSL and Joule Africa members of the Steering Committee, on the grounds that it would have less social impacts on the communities in the area. Yiben II will still provide an acceptably high regulation of flow to the Bumbuna generation facilities, and will both very significantly reduce socio-economic impacts, and in technical and financial terms, avoid the logistical complexities, potential schedule delays and high costs of undertaking a major resettlement exercise compliant with international standards, compared to the Yiben I option.

It must be recognised, however, that the PFS provided only a high-level study of the social conditions of the Yiben Project area. The more recent, detailed social baseline studies undertaken as part of the ESHIA have yielded more precise information on the number of individuals and households in the Project area (see *Annex H: Social and Cultural Heritage*) which are significantly higher than was initially predicted by the PFS. There appears, however, not to be any reason to assume that the PFS population and infrastructure figures for the Yiben I inundation area are also not underestimates, not least because of the large population in and around the Fadugu area that would be impacted by the Yiben I impoundment.

3.3.5 The "No Yiben" option

As has been mentioned in the preceding sections, the Yiben dam has been considered integral to achieving the full generation potential of the Seli River since prior to the start of construction of Bumbuna I. Yiben was identified in the 1996 Power Sector Master Plan as one of the most feasible options to increase exploitation of Sierra Leone's hydropower resources, even though Yiben is not as economically attractive a development in its own right; rather, its value lies primarily in the regulation of flows to Bumbuna I, plus the Bumbuna Extension, with the incremental power generated at Yiben itself an additional benefit rather than being fundamental to the rationale for the construction of a dam at Yiben.

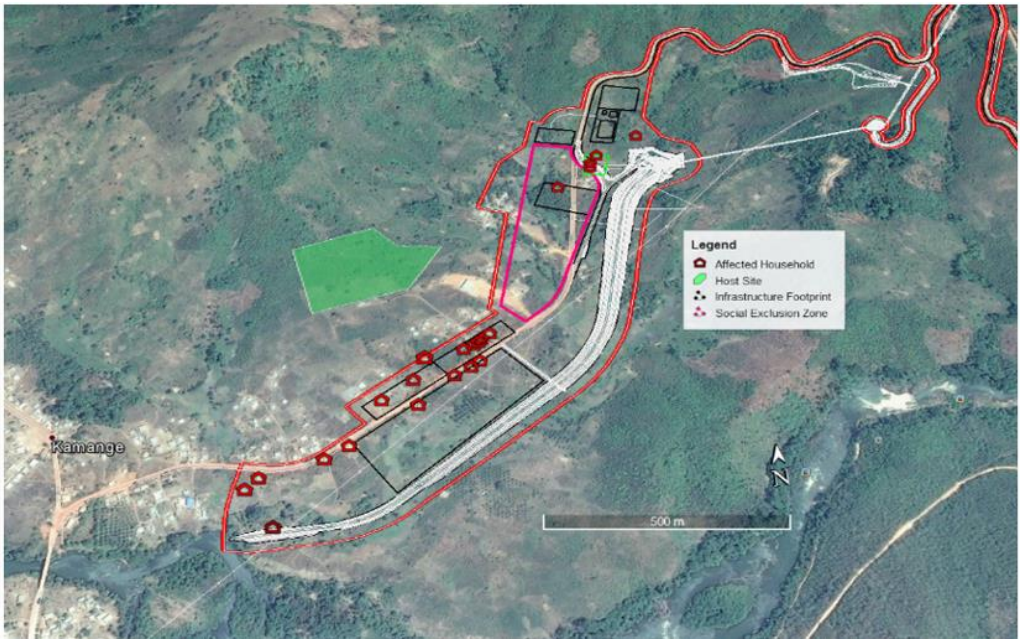
As discussed in detail in the 2016 Value Engineering Study (VES) [(1)] , by regulating the flow of the Seli River, Yiben significantly increases the average energy yield from Bumbuna in comparison to the yield from Bumbuna without a development at Yiben.

(1) See Table 3.3 and supporting narrative in Bumbuna Phase II, Sierra Leone. Value Engineering (Lahmeyer International, 2016).

In the VES, the simulated output at the existing Bumbuna Dam (ie Bumbuna I) averaged around 260 GWh/yr. With the addition of Bumbuna II (including Yiben) the combined generation at Bumbuna I plus the Bumbuna Extension increases to 756 GWh/yr (as per *Table 3.3* of the VES). Thus the generation added at Bumbuna by the Yiben reservoir (and the extension) of almost 500 GWh/yr is much more than the generation at Yiben (305 GWh/yr). Put simply, the flow regulation at Yiben will mean that the energy yield for Bumbuna as a whole will be greater than the sum of the individual parts, and Yiben is therefore considered integral to the viability of the whole Bumbuna II Project.

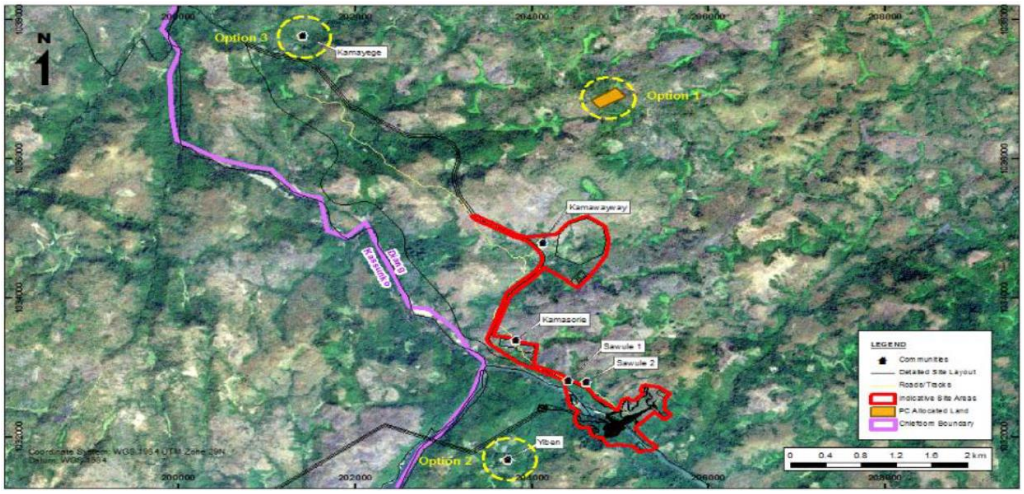
3.3.6 Southern Early Works Area (EWA)

To further reduce the impact, following recommendations in both the ESHIA and subsequently in SRK's Scoping Report, , a 'social exclusion zone' (see pink line in diagram below) was included in the Southern EWA to limit the extent of physical displacement and, importantly, remove the need to relocate the army barracks, church, primary school, and water wells.



3.3.7 Northern Early Works Resettlement Area

The first choice suggested by the Paramount Chief of Diang for the resettlement for the villagers being resettled as part of the Northern EWA development was option 1 (see graphic). However, following an assessment of the ease of access of option 1 (the site is very inaccessible making access to social services difficult) and the impact on biodiversity of an area not yet developed, it was agreed that option 3 (extension of an existing village) should be taken forward.



3.4 OTHER DESIGN CHANGES

Design changes have been considered, and in some cases adopted, as development of the Bumbuna II Project has gone through the normal project development stages over more than five years since the GoSL and Joule Africa signed an MoU. Such changes - for example those proposed as a result of the work carried out through the PFS, FS, and VES - have resulted from a process of considering options (eg for layout, engineering specification, value engineering and operational regime) and assessing them against technical, economic, financial and social/environmental factors. They have subsequently been presented to the GoSL for its review and approval.

Further changes to mitigate impacts of the existing design that have been identified as necessary during preparation of the ESHIA are set out in *Volume II Technical Annexes,* for subsequent incorporation into management plans.