Report No. 63735-LR

Options for the Development of Liberia's Energy Sector

Africa Energy Unit (AFTEG) Energy Sector Policy Notes Series

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October 2011

Africa Energy Unit (AFTEG)
Sustainable Development Department
Africa Region
The World Bank

Executive Summary

In mid-2011, Liberia has possibly the lowest rate of access to public electricity in the world. While the average rate of access to electricity in Sub-Saharan Africa is 28.5 percent, and in neighboring Sierra Leone and Côte d'Ivoire 6 percent and 43.7 percent, respectively, Liberia's rate of access to publicly provided electricity is close to zero. An urban access rate can only be derived for Monrovia: of an estimated 210,619 households, 1,217 are supplied with public electricity (as of late 2010), corresponding to 0.58 percent of Monrovia's population. With the exception of a very limited municipal mini-grid in Gbarnga, Bong County, no publicly supplied electricity service is available outside of Monrovia.

The root cause of this situation is Liberia's civil war. In 2003, at the end of 14 years of warfare, Liberia's power sector emerged seriously damaged. By 2005 what remained had been destroyed by looting. This included the complete destruction of the hydropower plant at Mt. Coffee and Liberia's entire transmission and distribution network. Operations of the Liberia Electricity Corporation (LEC) ceased completely. As a result, Liberia faces the challenging task of fully reconstructing its power system.

In early 2010 the high costs of electricity and low quality of energy services in general imposed a significant barrier to Liberia's long-term economic development. Over 80 percent of Liberia's household energy requirements are met using thermal energy for cooking, and both urban and rural households rely almost exclusively on charcoal and firewood. To maintain annual charcoal production levels of 36,500 tonnes, about 960,000 trees are being cut around Monrovia alone every year, which is fast depleting Liberia's rich forest stock. For lighting, households expend a significant amount of their income on inferior sources such as candles, flashlights, small battery-operated LED lamps, and kerosene or oil lanterns. Production activities, notably agriculture, rely primarily on human power. Some households have small generators of 500 to 900 watts to serve larger processing loads such as rice mills.

While the electricity services available in Liberia are poor, the cost of these services is nevertheless high in comparison with other Sub-Saharan African countries. In April 2010 the price of electricity from the grid was US$0.43 per kilowatt-hour (kWh), possibly the highest in Sub-Saharan Africa. People without access to public electricity pay even more: the use of dry-cell batteries costs US$74.01/kWh, car batteries US$8.43/kWh, candles US$8.27/kWh, generators US$3.96/kWh, and kerosene for lighting US$1.53/kWh.

Since elections in 2006, achievements are clearly visible in the energy sector. The Government of Liberia (GOL) has been working systematically toward the reconstruction of the electricity sector at the urban, rural, and regional levels. A National Energy Policy (NEP), endorsed in June 2009, set clear development goals for the short, medium, and long term. For the first time in Liberia's history, since early 2010, a Rural

and Renewable Energy Agency (RREA) has dedicated its services solely to rural areas, including the rural poor.

By April 2010 the basic functions of LEC had been restored and the supply of electricity to about 2,500 customers in Monrovia established. In July 2010 a management contractor Manitoba Hydro International took over the operation and further build up of the LEC against clearly defined connection targets and timetables. While the LEC's overall financial situation is precarious, its operating revenue growth has been substantial, and it has developed a clientele with comparatively good payment discipline since its early days of operation. Following a complete decline in petroleum fuel use in the 1990s, demand for automotive gas oil and premium motor spirit oil again reached levels seen in the early '80s (during which the Liberian economy was at a high point) in early 2010. This marks the return of economic activity in Liberia.

Yet challenges remain. In the context of the NEP, clear timetables for the implementation of policy recommendations need to be established. These include translating the NEP into a national regulatory framework. The RREA and its Rural Electrification Fund (REFUND) need to become fully operational. At the LEC, average revenue falls well short of the average operating cost, which was US$0.63/kWh in 2009, even though average revenue rose from US$0.42/kWh in 2008 to US$0.45/kWh in 2009. While the LEC's tariff methodology appears appropriate, operating costs, including administrative costs, should be reduced. Customer connections need to increase if the target of 33,000 connections by 2015 is to be met. Under the policies now in place, the NEP targets of connecting 30 percent of Liberia's urban and peri-urban population and 15 percent of its rural population by 2015 seem out of reach.

In the context of petroleum fuels, Liberia does not have any official product specification standards. These are left to oil landing terminals, such as the Liberian Petroleum and Refinery Company's (LPRC's) product storage terminal, to specify. To ensure that safe fuel of satisfactory quality is landed, it is recommended that standards are enforced in accordance with international practices as follows.

Supplying adequate fuel for thermal power plants is a challenge in Liberia. In early 2010 there were no facilities to supply heavy fuel oil (HFO), and diesel fuel supply facilities were in need of repair or replacement. The prices of supplying fuel to Liberia are considerably above the regional average, as suppliers mark their prices up to account for any remaining perceived civil instability, the poor conditions of the receiving terminal at the Monrovia port, and the lack of acceptable international safety standards. The diesel fuel jetty, owned by the National Port Authority (NPA), and the HFO supply facilities have been slated for rehabilitation with World Bank financing, but this is not expected to be completed before 2012.

In an environment of high uncertainty, this paper attempts to lay out an optimal development pathway for Liberia's energy sector between now and 2040. To this end, two main demand scenarios were specified and a set of possible supply options analyzed. Using the linear general equilibrium model called General Algebraic Modeling System (GAMS), a least-cost expansion plan that meets the projected demand was derived. The plan indicates what power facilities should be constructed at what point in time to meet projected demand across five-year intervals until 2040 at least cost. To derive the optimal sector development plan for the medium term, until 2015, an additional bottom-up analysis was performed.

The electricity demand estimate for Liberia has been based on available data, including that collected during Liberia's 2008 census. According to the type of consumption (residential, commercial, public, or industrial), demand is projected using population growth, gross domestic product (GDP) growth, and industry-specific demand drivers. Conservative and high-demand scenarios are distinguished. In the high-demand scenario, economic growth is assumed to be more pronounced and to spur demand for electricity in the commercial and mining sectors. Demand reflects all demand, including suppressed demand.

The supply options under consideration cover all options that appear technically feasible for Liberia in 2010. Among the thermal options, diesel, HFO, and biomass power are considered. Further, construction

of hydropower plants and the import of electricity are also considered and export of excess power is allowed for. Table ES1 provides an overview of all technologies that have been considered. Going forward it will be important for the GOL to update the studies on potential hydropower sites, most of which were prepared in the 1980s. It is also important to consider what additional energy technologies might be used in Liberia in the future.

The bottom-up analysis undertaken for the medium term indicates that in the time frame of 2009 to 2015 a gap in the supply-demand balance will occur starting from 2012. **Measures need to be taken to close this medium-term supply gap.** The emerging gap increases from about 4 megawatts (MW) in 2012 to about 13 MW in 2014. Only in 2015, when the West African Power Pool (WAPP) transmission interconnection for Côte d'Ivoire, Liberia, Sierra Leone, and Guinea (CLSG) is expected to become operational, will the gap be bridged. Assuming that financing is found, construction of an HFO-fired power plant presents a feasible and least-cost measure to close the medium-term gap between power demand and supply by installing 10 MW in 2013, and a further 5 MW in 2014. Further, an HFO plant would provide a stable thermal backup beyond 2015 to make up for the more intermittent hydropower. Due to the small size of the power addition, public financing would be preferred. Advantages of public financing include the flexibility of dispatching power without hampering the financial/economic development of the power system through fixed purchasing power contracts for which dispatch has to be maximized. Further, plant procurement is generally fast once financing is available.

The least-cost modeling suggests that for both conservative and high-growth scenarios, a least-cost expansion plan for Liberia until 2040 would include the construction of a range of hydropower candidate plants, including rehabilitation of the Mt. Coffee hydropower plant by 2015 and construction of the St. Paul River development (SP-1B and SP-2) and Mano hydropower plants by 2020. In addition, the WAPP transmission interconnection of Côte d'Ivoire, Liberia, Sierra Leone,

Table ES1 | Supply Options to be Considered

Power Source	Earliest Possible Commissioning Date	MW Capacity	Total Levelized Cost (US$/kWh)
Diesel existing system	2010	13	0.32
Diesel system, learning curve	2012	1	0.29
Leasing diesel generation	2010	10	0.27
HFO	2012	10	0.16
Core biomass	2012	36	0.21
Biomass benchmarking	2012	31	0.11
WAPP phase 1 Low	2015	28	0.17
WAPP phase 2 Low	2020	23	0.11
WAPP phase 1 High	2015	50	0.17
WAPP phase 2 High	2020	47	0.11
Hydro 1: Mt. Coffee, phase 1	2015	66	0.10
Hydro 2: Mt. Coffee + Via Reservoir	2020	66	—
Hydro 4: SP – 1B + SP2 + Via Reservoir	2020	198	16–23 (11)
Hydro 3: Mano River	2025	90	16–23 (10)

Source: Authors' calculations.

grid through the two above-mentioned WAPP projects. These areas include both urban centers and rural areas. They also include parts of Montserrado County that are just outside of Monrovia. Tables 2.6 and 2.7 show the estimated demand for segment 3 for both low- and high-growth scenarios.

Segment 4: Non-Monrovia industrial demand

The non-Monrovia industry scenario includes the following sectors: mining, agriculture, and forestry.

Mining. Liberia has considerable low-grade iron ore reserves remaining at the sites of the abandoned prewar iron ore mines. Deposits have also been found at Wologisi, Putu Range, Bea Mountains, and Goe Fantro, which have not yet been developed. Liberia's remaining reserves are estimated at almost 3 billion tonnes. The main deposits are found in the Western Cluster, Bong Range, Lofa County (Wologisi), Nimba County, and Grand Gedeh (Putu Range).

Table 2.2 shows the name and size of iron ore mining concessions under discussion. An assessment of the potential energy demand is derived based on the assumption that an expected production volume of 15 to 20 million tonnes per annum will need about 100 MW of power. The lifetime of the mines is assumed to be 25 to 30 years, which fits within the time frame of the analysis.

The estimate for the gold mines is based on information provided by AmLib, which is undertaking feasibility analysis in Bong County. There are also many small mining licenses under discussion that cover a range of minerals. Altogether, the potential mining demand is estimated to be 842 MW.

The potential demand estimate considers two scenarios to be forecast: low and high growth. Both scenarios

Table 2.2 | Estimated Energy Demand for Iron Ore and other Mining

Mine Type and Name	County	Production Volume (tonnes/annum)	Estimated Demand (MW)
Iron Ore			
Western Cluster	Cape Mount, Bomi, Gbarpolu (could be on-grid)	15,000,000	100
Putu Range	Grand Gedeh	20,000,000	100
Kitoma and Goe Fantro	Nimba	15,000,000	100
Nimba	Nimba	20,000,000	100
Wologisi	Lofa	20,000,000	100
Arcelor Mittal	Yekepa (could be on-grid)	15,000,000	132
China Union, Bong Mines	Bong (could be on-grid)	15,000,000	100
Gold			
Bea Mountain/New Liberty	Nimba	Gold	5
Cestos	River Cess	Gold	5
20 potential locations for gold, gems, and other minerals (that is, barite)	Various	Various	100
Total			**842**

Source: Author's calculations.