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Comprehensive Planning for Electric Power Supply in Haiti – Expansion of the Supply for Electricity Generation

Consulting Services CPSC 142/2013, Canadian Cooperation 065/2013

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ACRONYMS

Acronyms	Definition
BME	Bureau des mines et de l'énergie
BME – DSE	Diagnostic du secteur de l'énergie
BME – NEP	National Energy Plan 2007-2017
BMSE	Bureau du Ministre en charge de la Sécurité Énergétique
COS	Cost of Service
EDH	Electrical utility of Haiti
IHSI	L'Institut Haïtien de Statistique et Informatique
INO	Independent Network Operator
IPP	Independent Power Producer
LNG	Liquefied Natural Gas
MCI	Le Ministère du Commerce et de l'Industrie
MDE	Ministère de l'Environnement
MEF	Ministère de l'Économie et des Finances
MSW	Municipal Solid Waste
MTPTCE	Le Ministère des Travaux Publiques, Transports, Communications et Energie
NGCC	Natural Gas Combined Cycle
OLADE	Latin American Energy Organization
PAP	Port-au-Prince
PPA	Power Purchase Agreement
PV	Photovoltaic
ROR	Rate of Return
SIEN	Système d'Information Énergétique National
USAID	United States Agency for International Development

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1.0 EXPANSION OF THE SUPPLY OF ELECTRICITY GENERATION

We present a report with the following items:

- Summary of the best sites for location of new power plants
- Summary for generation expansion plan of short and medium term for the supply of electricity demand
- Summary of electricity simulations of short and medium term to evaluate two scenarios of generation expansion
- Summary of an economic-financial study of two scenarios for generation expansion

1.1 INTRODUCTION

All over the world, 1.6 billion people lack access to electricity. In Haiti, it is more than 8 million. These households "off the grid" spend significant amount in batteries, kerosene, for services that are poor quality. Recycling those expenditures into more efficient solutions is the base of electrification schemes that target these populations with low incomes. However, access to energy services in a multitude of small consumers in a precarious situation presents a double challenge: how to make bankable these investments and how to allocate risks between parties, the seller and the buyer, in a lasting mutual commitment.

Funding of these projects requires combining several resources:

- Equalization between those who benefit from electricity and those who want access
- A significant initial contribution of rural households, thus guaranteeing their commitment
- Grants or concessional loans (ideally long-term loans most often granted via the States to entities providing a responsible asset management)
- Differentiated tariffs from those in urban areas and governmental policies providing rigorous recovery rates required to collect all users' payment capacity.

The question of generating facilities expansion is important to analyze, particularly with regard to Haiti. Indeed, it is clear that the country shows an important generation deficit limiting its economic development. However, this reflection, beyond the identification of potential sites, must also make sure not to only add power but also validate its needs in this area:

- Should we reduce commercial and technical losses before building new power plants, or the process must be done concurrently?
- Who should be in charge of production EDH or private sector?
- What regulating and governmental structures must be put in place to ensure sound management of the electricity sector?

If the financial risks are the responsibility of public entities, commercial and operational risks must be assumed by the operators. Patterns of local management and prepayment have been successfully tested in several countries.

2.0 SUMMARY OF THE BEST SITES FOR LOCATION OF NEW POWER PLANTS

Beyond the information collected, a simple walk in Port-au-Prince makes it easy to imagine how the country would benefit from the production expansion. This expansion is necessary if one wants to achieve the Haitian Government goal in electrification and economic development.

Depending on the country's ability to invest in infrastructure, it's urgent to address energy needs and the type of production that is suitable.

Our analysis leads us to think that infrastructure development should revolve primarily around following findings:

- Some existing electricity generation capacities will be retired, as they will reach their standard lifetime
- Every major energy plant should be built on the main network where reliable interconnection points exist
- Increase in the generation capacity in the short term at the lowest economic cost possible
- Generation tending to a significant increase in the share of renewable energies
- When no interconnection point is close to the energy needs or it is a non-economical option, implement remote islanded facilities adapted to population and industrial's needs

Based on these principles, it is essential to study the various alternatives available in the country.

2.1.1 Heavy Oil or Diesel Thermal Plants

Due to the nature of such plant, it must operate 24/7 to keep low costs. Unless linked with the national grid, it could be located in small industrial parks where customers use energy up to 24 hours per day.

In case of residential consumption only, it requires more management and, alone, is not well suited to this kind of plant.

Location Limitation

- Fuel is delivered to the facility through fuel trunk line, boat or truck. Need of adequate road or rail infrastructures
- Water for all processes is obtained from one of the several available water sources (e.g., municipal water supply)

Haiti's Situation

- This is the type of plant that is mainly used to produce electricity in Haiti. However, the lack of domestic oil production, the importance of pollution generated by these facilities and environmental risks associated with transportation make this solution should be preferable only when other alternatives are discarded.
- In this case, heavy oil should be preferred to diesel to reduce losses.

2.1.2 Coal Plant

Due to the nature of such plant, it must operate 24/7 to keep low costs. Due to scale economy needs, it has to be of a minimum size to operate at reasonable costs and, thus, must be linked with the national grid.

Not suited for residential consumption only.

Location Limitation:

- Coal is delivered to the facility via rail, truck or barge. Need of adequate road infrastructures
- Water for all processes can be obtained from one of a variety of sources; however, water is typically sourced from an adjacent river, when possible
- Wastewater is sent to an adjacent river or other approved alternative
- Typically, significant overhauls on a coal facility occur every six or seven years

Haiti's Situation:

- Haiti has one coal deposit (The Maïssade lignite deposit is located 12 kilometers north-west of Maïssade town, 200 kilometers north of Port-au-Prince, in the central region of the country) which can afford to feed a central adequately. However, this site is too far to connect to existing transmission lines or local consumption sites justifying the installation of a coal plant nearby. Usable site shows a questionable quality of the deposits due to high sulfur and ash levels
- The current deposit would power a 40 MW coal plant for a period of about 17 years (BME-NEP)
- Unless equipped with sophisticated and costly equipment, coal plants are highly polluting and requires near coalfield to reduce costs, which is not the case with Haiti
- Because of the above-mentioned points and our discussion with BME, we don't believe that this alternative is adequate for Haiti's present needs.

2.1.3 Other Thermal Plants

In developing countries, electricity from biomass and cogeneration offers many opportunities. Projects, more complex and yet few, very often suffer from inadequate institutional frameworks and supply infrastructures to enable their integration into national networks.

Due to the nature of such plant, it must operate 24/7 to keep low costs. Unless linked with the national grid, it could be located in small industrial parks where customers use energy 24 hours per day. Residential consumption only is not well suited for this kind of plant.

2.1.3.1 Biomass

Location Limitation:

- The Biomass Combined-Cycle facility utilizes approximately 500 tons per day of biomass (at 25% moisture), or 370 dry tons per day for the production of 20 MW net of electricity.
- Biomass is delivered to the facility by rail, truck or barge. Need of adequate road infrastructures.
- Water for all processes is obtained from one of the several available water sources (e.g., municipal water supply).

2.1.3.2 MSW

Location Limitation:

- The classical MSW facility processes approximately 2,000 tons per day of MSW and produces approximately 50 MW.
- MSW is delivered to the facility via rail, truck or barge. The facility is typically paid a "tip fee" for the MSW delivered.
- Water for all processes can be obtained from one of a variety of sources.

Haiti's Situation:

- These types of plants are considered by many as a green solution and an answer to many waste elimination problems. However, in the case of Haiti, we must take into account some factors:
  - Existing (or non-existing) management of Municipal Solid Wastes
  - Availability of raw materials
  - Ability to organize transport to central locations at avoided costs economically lower than current costs of disposition.
  - State of the road infrastructures
- We find in Haiti many vegetable wastes from coffee, cotton, grain crops and extraction of essential oils. From an energy point of view, these wastes could be used, however, given their high dispersion; it is very difficult to use them where they are generated. In addition, the specificity for each of these waste require the use of special techniques. Farm waste (fying chicken, cow dung, pigs, Cabrits, equine, etc.) as well as city waste

can easily be converted into biogas ready to use. However, the collection problem must be controlled first, mainly for city wastes and in the case of the free breeding.

- The production of urban wastes in metropolitan area (Port-au-Prince) is evaluated at 730,000 tons/year, at 191,000 tons/year for eight other large agglomerations (Cap Haïtien, Gonaives, Les Cayes, Saint-Marc, Verrettes, Jérémie, Port-de-Paix, and Limbé) and at 766,000 tons/year in rural regions and small towns.
- Many neighbourhoods do not have public trash removal services. Some small private services exist, but they are relatively expensive. There is no separation of waste from households, companies, hospitals, and construction debris. Generally, the gathering is done by hand or truck and the removal by truck. The two important landfill sites are located in Truitier, at about 10 kilometers from Port-au-Prince and in Madeline, at Cap-Haïtien. The rate of waste removal is estimated to be less than 30% in PAP. In other cities, they are usually dumped in rivers and ends up on the coasts. Most of the time, these wastes are burnt. However, a little part is used in some areas to produce compost.
- The Haitian legal framework is insufficiently clear regarding the roles of those involved in waste management, particularly concerning PAP and it lacks of technical standards, adequate financial instruments, coordination mechanisms and a true strategy regarding the removal, disposal of waste material and eventual energy recovery.
- Taking into account these factors, we think it would be premature to suggest the introduction of such plants, at least in the short term. However, in the context of the development and the initiation of a national waste management policy, this type of plant could be a very attractive alternative, from both point of views of the efficiency and the environmental contribution (BME – NEP).

2.1.4 Natural Gas Combined Cycle (LNG)

Due to the nature of such plant, it can operate 24/7 to keep low costs but can also serves as a Peek power plant keeping a reasonable COS.

This kind of plant offers more flexibility than an Oil fired plant because of its lower delay and cold start costs.

Unless linked with the national grid, it could be located in small industrial parks where customers use energy 24 hours per day. Residential consumption only is not well suited to this kind of plant.

Location Limitation:

- Natural gas is delivered to the facility through a lateral connected to the local natural gas trunk line.
- Water for all processes is obtained from one of the several available water sources (e.g., municipal water supply).

Haiti's Situation:

- This type of power plant offers a high rate of return while being relatively inexpensive in terms of construction costs. However, it requires a steady fuel supply. Only a LNG terminal with significant infrastructures could allow it.
- The ecological footprint of this type of plant is the lowest of all power plants based on petroleum products.

2.1.5 Hydroelectricity

In developing countries, hydropower is a renewed application. Large projects are often built in cross-border regional infrastructure, and small ones through local mini-plant.

Due to the nature of such plant, it can operate on a 24/7 but can also serve as a Peek power plant while keeping the same COS.

This kind of plant offers more flexibility than any other plant because of its lower delay and cold start costs.

Unless linked with the national grid, it could be located in small industrial parks where customers use energy 24 hours per day. Residential consumption only is not well suited to this kind of plant.

Location Limitation:

- If we do not take into account the need for a watercourse and a significant watershed, since the fuel source for the hydroelectric facility is renewable, the most important off-site requirement is the electrical interconnection to the medium-high-voltage transmission system of the utility. Therefore, the efficacy of such plant would be better if linked with the national grid because of its 24-hour generation capacity.
- Very small plants could also be located in a small islanded industrial park where it would provide energy to business when other renewable energy does not provide regular supply.

Haiti's Situation:

- There is one significant plant (Peligre, 54 MW) that is currently used to produce electricity in Haiti. However, the lack of water resulting from the sedimentation of the watershed and season's hydrological characteristics reduces its power factor by almost 10 times (EDH internal statistics).
- The total energy potential of undeveloped hydroelectric sites in Haiti is estimated to be 153.58 MW. Of this total, 85% (or 130.7 MW) consist of 4 large plants from 22 to 45 MW and the remaining 15% (or 22.58 MW) consist of 27 small plants from 0.10 to 2.57 MW with drop heights from 2.1 to 111.0 meters (BME-DSE).
- A medium size project (central Artibonite, 34 MW) has been under study for several years. However, like any hydroelectric project, its implementation requires about 10 years, significant investment and offers only marginal profitability due to the sedimentation of most watersheds in the country resulting from deforestation which is a hindrance to the development of this type of green energy in Haiti.
- This solution, even if attractive environmentally speaking, should be preferred only when other alternatives are discarded.

2.1.6 Wind Farms

Wind farms are more often developed in mobilizing private investment, especially in China, India and the Mediterranean countries (Morocco, Egypt and Turkey in particular). The same pattern can be seen in North America where national public utilities have mostly decided to leave the development of this kind of energy to the private sector.

Due to the nature of such plant, it can operate 24/7 but since the wind is a variable and non-controllable resource, it can only serve as secondary energy source. It must always be linked with stable energy generation plant which can be stopped when wind turbine operate, about 35% of the time. Globally, it reduces fuel consumption of other generation means but the construction costs need a serious analysis to prove the economical ROE of such generation solution.

Unless linked with the national grid (which is not easily feasible in Haiti at the moment), it could be located in small islanded area.

Location Limitation:

- Since the wind uses a renewable fuel, the most significant off-site requirements are the construction of an interconnection road system and the electrical interconnection to the medium-high-voltage transmission system utility

Haiti's Situation:

- Wind farms are probably the greenest energy but also one of the most expensive. Construction costs are not the only obstacle to the development of this type of energy.
- The generation factor of wind turbines is random and requires a sophisticated balancing system of the network, which is not the case of Haiti.
- Haiti's wind energy potential is mostly concentrated in the northwest, mainly on the north slope of Turtle Island where the winds have an average speed of 5-7 meters per second, which could be interesting for such exploitation (BME – DSE).

2.1.7 Photovoltaic Plant

Due to the nature of such plant, it can operate 24/7 but since solar ray is a variable and non-controllable resource, it can only serve as secondary energy source. It must always be linked with stable energy generation plant which can be stopped when photovoltaic plants operate, about 50% of the time. Globally, it reduces fuel consumption of other generation means but the construction costs need a serious analysis to prove the economical ROE of such generation solution.

Attached to an accumulator system (batteries), it may however present an attractive alternative for small islanded networks or important buildings that require significant amounts of energy. In that case, although the acquisition and maintenance cost are much higher, it can usually operate without other generation means.

Unless linked with the national grid (which is not easily feasible in Haiti at the moment), it could be located in small islanded areas.

Location Limitation:

- Unlike other power technologies discussed in this report, the essential off-site requirements for which provisions must be made on a PV facility are water supply (generally in limited quantities for purposes of module washing, once or twice annually).
- With regard to water supply, some PV facilities purchase water off-site for module washing purposes.

Haiti's Situation:

- Haiti has a good solar energy radiation. According to existing estimates, the average radiation is about 5 kWh/m^2/day. But there is not enough detailed data on the solar potential. Moreover, technical and logistic capabilities to carry out appropriate studies are not in place (BME – NEP).
- Photovoltaic solar energy is still a luxurious product used by the upper class as extra material to supplement power outages in the metropolitan area. A number of photovoltaic installations were carried out with the assistance of international organizations, in rural areas to provide health services to the poor.
- This type of production has many advantages, but suffers from the same problems that affect wind farms:
  - High construction costs (BME – NEP)
  - Relatively unstable rate of production
  - Regular need for network balancing

2.1.8 Interconnections Availability

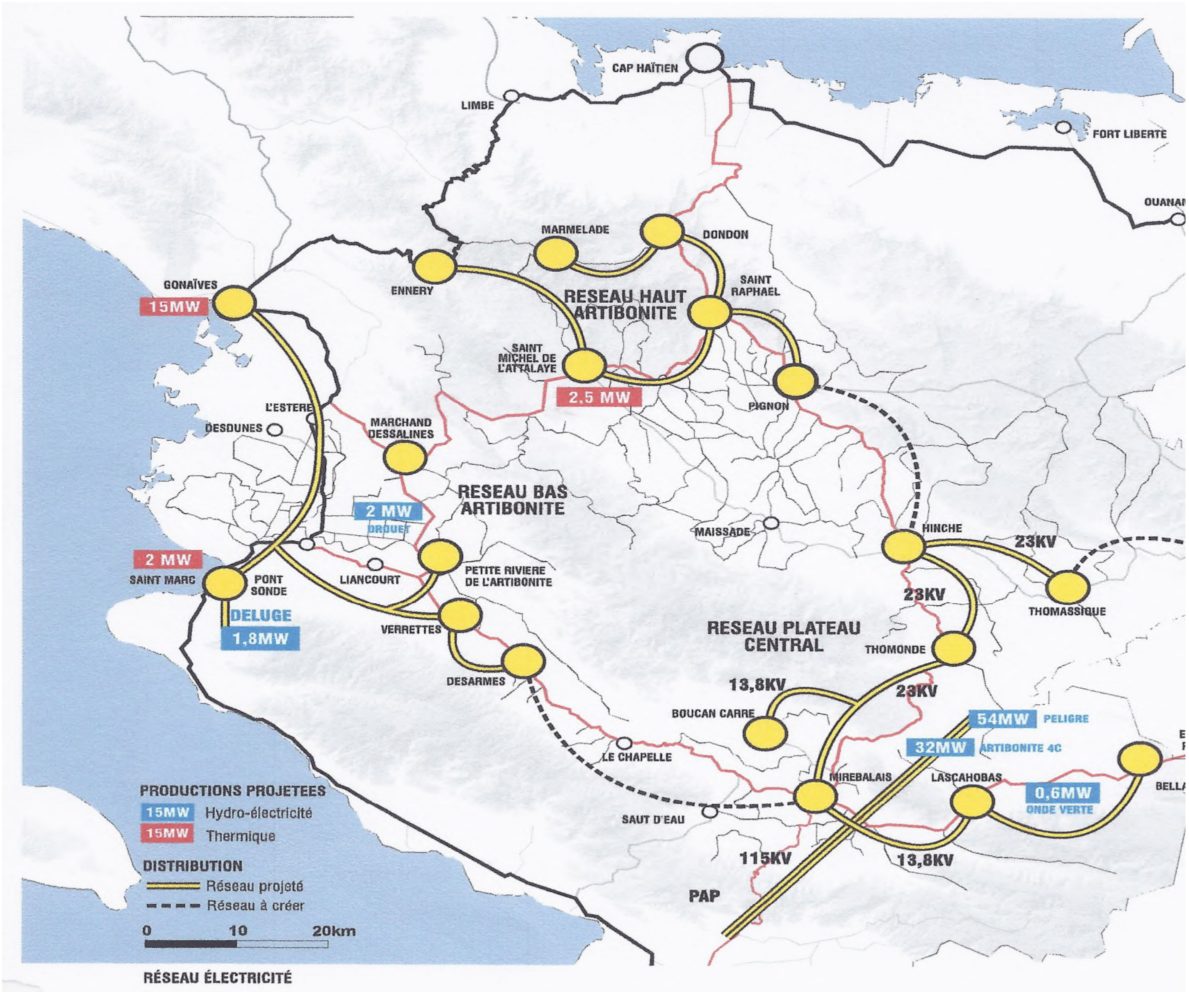
The country has limited interconnection availability and this availability is subject to reliability problems that must be taken into account when comes the choice of a site.

Based on information gathered, the most important efforts supposed to be made in terms of T&D network on the short term would be in PAP region. This network is nearly coming to the end of its useful life and really need major investments.

It is essential, before we go any further, to examine the plans of the Haitian government in the development of the electricity transmission network. The expanding projects allow us to determine some of the areas that can have network for connection to the main network west of the island, at least in the medium term.

This information quickly determines areas that will have to be developed as an islanded network. It will also determine where the future anticipated loop (Artibonite center) would suggest implementation, on the short term, of facilities that may temporarily be islanded but, in a future that has yet to be evaluated, ultimately be connected to the network. (See figure 1)

Figure 1 – Projected Artibonite Centre Buckle



2.1.9 Government's Strategic Plan

In a document named "Plan Stratégique de Développement d'Haïti – Pays émergent en 2030", the government has developed a vision that specifies the siting of power plant projects to be completed between 2012 and 2015. From this extensive list, according to our information gleaned from EDH people, no project has been started. We will anyway follow some of the government proposition to recommend sites for future implantation, but indeedly not for all, such choice being truly unrealistic.

2.1.10 Demographic Evolution

According to IHSI, the rate of urbanization in the country is expected to grow at a constant rate by 2030, from a rate of 42.4% of the total population in 2011 to 55.6% in 2031. The migration will mainly focus in three departments out of the 10 in the country:

- Artibonite: +8.9%
- West (including PAP): +15.7%
- North: +10.2%

These three regions now account for 64% of the total population (2011) and should increase their relative weight to 70% by 2030.

Based on the Strategic plan of the Haitian government, these areas should carve up the lion's share in terms of adding T&D and electricity availability.

The real need for an interconnected network will be for these regions. This was taken into account when we evaluated the best sites to implement power plants.

2.1.11 Other assumptions for siting

Demand Growth

We have elaborated a demand evolution model based on available parameters:

- Population growth (IHSI) and migration movements
- Economic growth (FMI, WB and other expectations)
- Internal demand growth (organic growth)
- Licit and illicit customers consumption anticipated variation
- Reduction of losses (commercial and technical)

This model will be more detailed in the Demand & supply of electricity section to be provided in the next report.

Plant's Type

We have taken into consideration two types of plant equivalent:

- Thermal (Average Utilisation Factor of 80%)
  - This includes all kind of thermal plants even if:
    - NGCC is not yet available but would be the most interesting option
    - Biomass and MSW would be interesting but needed infrastructures to operate that we think are not yet in place
    - Oil / Diesel plant
    - Coal plant
      - If the government really wants to explore this possibility, more analysis will be required in regards to associated cost necessary to engage such production
      - We consider however that such plant would be easy to interconnect on the grid as long as the Artibonite Center buckle was built
- Hydro (Average Utilisation Factor of 60%)

We did not consider Wind Turbine (Grid control non-optimal). We did not propose PV (because of the present cost). We think it could still be an alternate solution but for very small isolated systems, single large building or as soon as the grid is adequately managed to support significant balancing needs.

On Grid or Off Grid

After a significant analysis of the present state of the T&D network, we came to an easy conclusion: the present grid is virtually non-existent outside of PAP and, for the only part outside this area (Peligre Line), it is in such bad condition that some portion of it could fall apart anytime without prior notice (EDH report and TT analysis report).

The government has made a serious exercise on the route and the possible establishment of a dorsal and an interconnecting loop (Artibonite Centre), which could help bring electricity in areas known to show the fastest growing activities. We have based part of our analysis on the route of the loop. However, given that it is not yet under construction, all plants will have to operate for a while on an islanded mode.

We are aware that many agglomerations could benefit from the installation of a power plant. However, we had to make a trade-off between the dispersion of the active production and the concentration of such generation requiring the installation of distribution lines (our primary choice given the easiness of maintenance and logistics of the power plants).

- The need for additional power of every borough has been evaluated. If the cost to implement the needed power plant exceeded the approximate cost of the implementation of a distribution line from the closest generation center, we choose to concentrate the additional power units in this generation center.
- Our research led us to evaluate the cost of implementing a 23 kV distribution line to between $100k and $150k per km, the cost depending on a set of factors too large to be listed. Certainly, in-depth studies are required to validate these hypotheses, but in the context of a preliminary report, we evaluated approximately $125k per km the cost of establishing a line and used this data to analyze the relevance of focus or not the power in regional centers.

One of the problems we faced came from mini-hydro run-of-the-river dams that display a lower and less constant utilization factor than thermal power plant. To stabilize it, these dams could be supported by generators during the drought and planned outages. However, we did not take that possible complementary power into consideration in our analysis.

We did not prioritize one region at the expense of another. This choice does not belong to us and must be made according to government guidelines or EDH in his potential new role.

Artibonite Hydroelectric dam

Artibonite hydroelectric project has been one of the government's plans for over than 10 years. However, according to information provided by EDH, it remained at a standstill for a long time due to lack of financial resources for its development.

The contribution of infrastructure of this type with a national transport network would be extremely valuable because of its reliability, its low operating cost and the environmental friendly nature of this type of production in relation to energy requiring fossil fuels. However, in the absence of a dorsal to spread electricity across regions lacking energy, this expensive project proves to be less profitable as mobilizing significant resources to reach mixed results in terms of electrification level progress.

If the government's goal was to reduce the share of fossil fuels in the overall generation of electricity, this project would present a great value. But since the main objective is to maximize the socio-economic impact of electrification, we believe that this project should be shelved pending the developments of the transport capacity of networks.

PAP Region

Considering the generation units serving the area of the national capital, the transfer of these assets to IPPs favoring the improvement of their utilization factor, and the recent refurbishment of the Peligre hydroelectric complex (still underway), PAP region should not suffer any shortfall in production until about 2025, according to our calculations.

However, in the absence of a reliable T&D network, it is impossible to supply other regions with current surplus generated by the West administrative region. Production units could therefore be laid off depending of the needs and kept in reserve in case of unplanned outage or unexpected peek in demand.

2.2 PROPOSED SITES FOR POWER PLANTS

Figure 2 – Proposed Sites for Power Plants

Years		2016	2021	2025	2030
ARRONDISSEMENT					
Artibonite					
	Gonaïves	12 MW (T)	5 MW (T)	8 MW (T)	
	Gros-Morne				
	St-Marc	2 MW (T)	1.6 MW (H)		
	Dessalines		2 MW (H)		
	Marmelade		2.5 MW (T)		6 MW (T)
Centre					
	Hinche	14 MW (T)	3 MW (T)		
	Mirebalais				2.5 MW (T)
	Lascahobas		0.6MW (H)	3 MW (T)	
	Cerca-la-Source				
Grand Anse					
	Jérémie				
	Anse d'Hainault				
	Corail		5MW (T)		
Nippes					
	Miragoâne	6 MW (T)			
	Anse-à-Veau		3 MW (T)		
	Baradère				
Nord					
	Cap Haïtien				
	Acul-du-Nord				
	Grande rivière du Nord	8 MW (T)	8 MW (T)		
	St-Raphaël				
	Borgne				
	Limbe			4 MW (T)	
	Plaisance				
Nord-Est					
	Fort-Liberté			3 MW (T)	
	Ouanamithe				
	Trou-du-Nord	8 MW (T)			
	Vallières				

Years		2016	2021	2025	2030
Nord-Ouest					
	Port-de-Paix	6 MW (T)	5 MW (T)	2MW (T)	3 MW (T)
	St-Louis-du-Nord				
	Mole St-Nicolas	6 MW (T)		2MW (T)	
Ouest					
	Port-au-Prince				
	Léogâne				
	Croix-des-Bouquets				
	Arcahaie				
	Gonâve				
Sud					
	Cayes	15 MW (T)	2 MW (T)	3 MW (T)	
	Port-Salut				
	Aquin				
	Coteau				
	Chardonnières				
Sud-est					
	Jacmel	5 MW (T)	3 MW (T)	3 MW (T)	
	Bainet				
	Belle-Anse	3 MW (T)			
TOTAL	**165 MW**	**85 MW**	**41 MW**	**28 MW**	**11 MW**

This plan is based on assumptions included in the financial model built to evaluate the demand growth, expansion of the generation and implementation of the new structure of governance and management of the Haitian electricity sector presented in the Regulatory and institutional section of the complete report.

As already disclaimed, we evaluated the needs without regards to the budget availability. Priorities must be set forward by the responsible ministry and available funds allocated as per these priorities. At this point, we do not express any opinion on these choices.

3.0 SUMMARY FOR GENERATION EXPANSION PLAN OF SHORT AND MEDIUM TERM FOR THE SUPPLY OF ELECTRICITY DEMAND

The most important thing to remember in this title regards the words “short” and “medium”. We have taken the most admitted definition for both terms:

- Short term means less than a year
- Medium term means between one and five years

Indeed, we cannot plan to expend the generation park without taking into account the fact that on a short and medium term, we cannot envisage to implement large hydroelectric, biomass or MSW thermal plants. These choices require too much time to be implemented within the next five years.

- Large hydroelectric plants need an average of eight years from geotechnical studies to the final start-up. Thus, this could not be considered on the short or medium term.
- For MSW plants, this type of power generation requires the development of policies and important means for the collection of waste supply. These policies, although necessary, are not in place and do not allow this type of production to start quickly.
- With regard to the biomass, the collection of culture residual material could be organized so as to locally supply a nearby station. However, the challenges posed by the required level of organization of target communities are significant. The effort in this type of production is typically that of a private producer. It is not totally excluded but operationally very difficult.

Even though this would probably be our favored overall solution, we also have to consider the fact that no LNG terminal or port is built or near completion. This excludes Combine Cycle Gas fired facility.

Coal plants are not an option on the short and medium term since no coal deposit is available to supply such generation unit and the construction of such plant would require road or rail infrastructures that Haiti does not have at the moment. Even if some projects are studied in the Government’s Strategic Plan; the main efforts would be oriented, based on the document, to rehabilitate the current network instead of building new access roads. This orientation is not sufficient to cover the needs for such kind of plant.

The operation limitations of wind farms and photovoltaic plants would not be a short-term solution except for very limited projects, mainly islanded area.

- Even if wind maps of the country exist, they would have to be verified and confirmed before implementing such wind farms.
- The utilization factor of a wind park is rarely over 35% and requires a sophisticated balancing system if linked on the main network to absorb generation modulation. The Haitian network is not presently adapted to manage such complexity (based on EDH’s seniors comments), and its current reliability does not allow this situation to be corrected shortly.

A photovoltaic plant suffers from the same limitation of a wind farm in terms of utilization factor. However, a battery supply could enable it to extend this factor but linked to the network, it would require the same complex balancing system. Therefore, such system could be better adapted to islanded area where all other systems would not be adequate and/or network extension would not be an economical acceptable choice.

3.1 OPTIONS

Haitian government’s options on the short and medium term are not very diversified. The time to put in place most of the best solutions, either economically or environmentally, cannot be envisaged at such short notice.

To increase the generation in rural areas where electricity is not present, many choices are offered in terms of isolated network:

- Solar + Diesel

- Solar + batteries
- Diesel only
- Very small dams + Diesel

In terms of interconnected generation, on the short and medium term, it leaves Haitian government with only three major choices:

- Increase thermal plants generation, along with micro-hydroelectric dams where it is possible
- Reduce commercial and technical losses to reduce the need to implement additional generation units on short term
- A combination of the two above-mentioned choices

We think that the latest proposition should be privileged. It will be demonstrated in the next two sections.

It is very important to think that, for the remote solutions that are not linked with the national grid, a budget must go along with every project to secure the maintenance of each unit, including an informational part related to a strong program aiming to discourage theft and vandalism of the units.

3.1.1 Long-term Options

Although not in the mandate, we write these few lines to confirm that on the long course, LNG plants are probably the most affordable, environmentally sound, viable and the best economic choice for further development of the electricity generation in the country.

We were informed that a LNG terminal project is under review by a local promoter in the PAP northern area. We suggest, based on well-known economic models and worldwide experience, that such project, in the interest of the country, be strongly encouraged by the government energy policy. Not only could it tremendously support Haiti's economy but would also help to accelerate the conversion of other combustion fuel to less polluting solution which is one of the most favored solutions of the government to the deforestation problem of the country.

Every thermal plant reachable by this infrastructure could easily be modified to use this fuel instead of heavy oil or diesel improving the environmental footprint and reducing COS significantly.

4.0 SUMMARY OF ELECTRICITY SIMULATIONS OF SHORT AND MEDIUM TERMS TO EVALUATE TWO SCENARIOS OF GENERATION EXPANSION

We have built a mathematic model simulating the evolution of the electricity demand based on:

- Expected population growth (based on IHSI data)
- Economical expected growth (based on past expected growth as determined by FMI and WB)
- Projection of the result of the struggle to reduce losses (as already met in other emerging countries and estimated by TT in a former mandate in Haiti)
- Natural electricity demand growth due to the intensification of the electrification efforts by many governmental agencies, as well as improvement of the economical overall condition due to government initiatives. Results are estimated comparable to other emerging countries who implemented regulation reforms in the past (Algeria, Morocco, Senegal, Ghana)

Here is a short resume of the assumptions used in all models:

- Economic growth (GDP) would start from a 3.3% increase in 2014 to reach 6% in 2030
- Total population is projected to be at 10.9M people in 2015 and 13.35M in 2030
- Technical losses will be reduced from 15% (estimated by EDH) in 2014 to 10% in 2025 and after
- Commercial losses, due to the implementation of government policies and designated units among EDH and police services, will be brought down from 57% in 2014 to 5% by 2027 and after. The expected schedule could move in time due to delay that could be incurred in the implementation of the new regulatory and institutional structures indispensable to reform Haiti's electricity sector
- Organic growth of the demand is expected to reach 3% per year during the next 15 years (based on previous experiences in Africa and South America

As everywhere in this report, we use 2016 as the starting year for the purpose of the analysis. This could not be considered as a fixed milestone as we are not responsible for the government's action plan implementation schedule.

We present the table with slices of four or five years. Surpluses are expected to decrease significantly over the years between the reference years.

4.1 SCENARIO 1

Here are the specific assumptions of the scenario 1

- No large hydroelectric project (Artibonite)
- Three small hydroelectric dams as anticipated in the Strategic plan
- No large T&D investment (no Artibonite buckle), only small distribution efforts in region
- No LNG available, neither biomass, coal or MSW plant
- No PV plant, neither Wind farm
- Only heavy oil/diesel thermal plants
- We cover all demand wherever it is
- We do not give priority to any region
- All regional units are on an isolated mode with small distribution network around

Figure 3 : Scenario 1

Electrical Power generation		2016	2021	2025	2030
PAP					
IPP					
Gasoil / Diesel	MW	150.4	150.4	150.4	150.4
Hydroelectric	MW	27	27	27	27
New thermal generation	MW	0	0	0	0
Reserve PAP	MW	-50	-24	0	0
New Hydroelectric generation	MW	0	0	0	0
Total used generation power		**127.4**	**153.4**	**177.4**	**177.4**
Provinces					
IPP					
Gasoil / Diesel	MW	48.5	39.9	37.9	37.0
Hydroelectric	MW	3.3	3.3	3.3	3.3
New thermal generation	MW	85	122	150	161
New Hydroelectric generation	MW	0	4	4	4
Total generation power available		**136.8**	**169.2**	**195.2**	**205.3**
Total installed capacity	MW	264.2	322.6	372.6	382.7
Expected Annual maximum energy - PAP region	GWh	845.5	1027.7	1195.9	1195.9
Expected Annual maximum energy - Other region	GWh	952.9	1169.1	1351.3	1422.1
Expected annual generation	GWh	**1798.4**	**2196.8**	**2547.2**	**2618.0**
Peek need	%	20%	20%	20%	20%
Peek need (GWh)	GWh	248.0	311.8	357.1	417.1
Estimated demand	GWh	1240.2	1559.1	1785.6	2085.3
Total estimated demand (including peek)	GWh	1488.3	1870.9	2142.7	2502.3
Expected surplus	**GWh**	**310.1**	**325.9**	**404.5**	**115.7**

4.2 SCENARIO 2

Here are the specific assumptions of the scenario 2

- Large hydroelectric project (Artibonite) is implemented for 2025
- Three small hydroelectric dams as anticipated in the Strategic plan implemented for 2021
- Large T&D investment (Artibonite buckle) is realized and completed for 2021. PAP region is now able to distribute its surplus through the dorsal and the Artibonite buckle
- LNG available in the PAP area by 2021 (Heavy oil and diesel plant converted at 50%)
- No biomass, coal or MSW plant. No PV plant, neither Wind farm
- In region, additions are only heavy oil/diesel thermal plants
- We cover all demands wherever it is. We do not give priority to any region.
- Most of the northern regional units are on an isolated mode with small networks around until 2021.
- All generation units in South and Grand Anse work in isolated mode but develop small distribution network around.

Figure 4 : Scenario 2

Electrical Power generation		2016	2021	2025	2030
PAP					
IPP					
Gasoil / Diesel	MW	150.4	75.4	75.4	75.4
Hydroelectric	MW	27	27	27	27
New CCGN generation	MW	0	75	75	95
Reserve PAP	MW	-50	0	0	0
New Hydroelectric generation	MW	0	0	0	0
Total generation available power		**127.4**	**177.4**	**177.4**	**197.4**
Provinces					
IPP					
Gasoil / Diesel	MW	48.5	39.9	37.9	37.0
Hydroelectric	MW	3.3	3.3	3.3	3.3
New thermal generation	MW	85	97	102	122
New Hydroelectric generation	MW	0	4	36	36
Total generation available power		**136.8**	**144.2**	**179.2**	**198.3**
Total installed capacity	MW	264.2	321.6	356.6	395.7
Expected Annual maximum energy - PAP region	GWh	845.5	1261.6	1261.6	1419.3
Expected Annual maximum energy - Other region	GWh	952.9	993.9	1155.1	1288.9
Expected annual generation	GWh	**1798.4**	**2255.5**	**2416.7**	**2708.2**
Peek need	%	20%	20%	20%	20%
Peek need (GWh)	GWh	248.0	311.8	357.1	417.1
Estimated demand	GWh	1240.2	1559.1	1785.6	2085.3
Total estimated demand (including peek)	GWh	1488.3	1870.9	2142.7	2502.3
Expected surplus	**GWh**	**310.1**	**384.6**	**274.0**	**205.9**

5.0 SUMMARY OF AN ECONOMIC-FINANCIAL STUDY OF TWO SCENARIOS FOR GENERATION EXPANSION

In terms of growth scenario, we used assumptions based on the implementation of recommendations included in this report. We consider several factors, including:

- The application of these scenarios could, for all, see a temporary decrease in consumption and short-term electricity production in Haiti due to the intensification of the struggle for technical and commercial losses.
- The implementation of the reform measures would allow EDH a gradual and steady increase cash flow enabling it to improve its financial situation and potentially alleviate the problems arising from the human resources level.
- We believe that the cost of energy to the end user will increase over time to reach a level in line with the economic cost of production to enable EDH sustain itself financially, and even begin to pay annual dividends to the Government within a period of 15 years. The increase would be gradual and accompanied by temporary measures to support households with lower incomes.
- We estimate it will take about five years before recording a significant increase in residential consumption in line with the country's economic growth. Industrial and commercial sectors should see their consumption increase more rapidly over the next 10 years and then stabilize at GDP growth thereafter.
- We believe that the implementation of this reform could be spread over a period of three to five years. This would be necessary to put in place the structures that do not exist, modify the structures that will change vocation, and vote on tax and regulatory measures that would support this reform.

Figure 5: Scenario 1

Summary - Scenario 1			
		TOTAL	
Power added (MW)		165	
Power added in Thermal unit		161	
Power added in Hydro unit		4	
Total energy generated		11 843 520	
Capital cost Thermal	$ Current	142 353 947	$
Capital cost Hydro	$ Current	10 536 303	$
Operation cost Thermal	$ Current	85 588 354	$
Operation cost Hydro	$ Current	519 636	$
Cost analysis			
		NPV	
Capital cost Thermal	(154 MW - $ 2014)	107 687 120	$
Capital cost Hydro	(4 MW - $ 2014)	7 229 346	$
Operation cost Thermal	(154 MW - $ 2014)	40 919 285	$
Operation cost Hydro	(4 MW - $ 2014)	205 366	$
Energy generated	MWh (14 years generation at PV)	7 886 200	
Cost per MWh	PV	19.79	$

Figure 6 : Scenario 2

Summary - Scenario 2			
		TOTAL	
Power added (MW)		158	
Power added in Thermal unit		122	
Power added in Hydro unit		36	
Total energy generated		10 301 760	
Capital cost Thermal	$ Current	107 533 208	$
Capital cost Hydro	$ Current	94 931 051	$
Operation cost Thermal	$ Current	68 075 361	$
Operation cost Hydro	$ Current	2 830 861	$
Cost analysis			
		NPV	
Capital cost Thermal	(102 MW - $ 2014)	81 649 300	$
Capital cost Hydro	(36 MW - $ 2014)	52 789 945	$
Operation cost Thermal	(102 MW - $ 2014)	34 777 084	$
Operation cost Hydro	(36 MW - $ 2014)	814 936	$
Energy generated	MWh (14 years generation at PV)	6 947 932	
Cost per MWh	PV	24.47	$

5.1.1 Assumptions

We used a TT – economic - financial model to perform calculations in regards to the hypothesis. In both scenarios, even if new power plant were supposed to be established by 2030 (included in the total installed power), we didn't take into account their CAPCOSTS neither their COS because of the period of analysis which was between 2015 and 2030. These are the main hypothesis of the model used for both cases:

- Financing rate: 5%
- Expected ROE: 12%
- Financing ratio: 70%
- Inflation: 1.8% per year
- Nominal Actualization rate: 7.10%
- Net Actualization rate: 5.21%

Although we do have the capability to do it, we didn't take into account the new Artibonite Centre Buckle's cost since we didn't have enough data to calculate it. Such information should be available and additional analysis shall be performed before final decision.

We didn't take into account the conversion cost of the Heavy oil / Diesel plant to GNL because unknown in regards to Haiti's equipment present condition. We expect however these costs to be relatively low in regard to the overall scenario 2 costs. In the short and medium term, it is not pertinent because no GNL terminal is in place.

6.0 CONCLUSION

The expansion of production is necessary but should be done in conjunction with other measures, many of which have already been the subject of a report in connection with the reform of the institutional and regulatory sectors.

In the current context of Haiti, greener solutions, such as solar-and wind, are not in the short or medium term at least, easily applicable and certainly not on a large scale because of the costs and usage factors. We therefore chose the contribution of thermal and hydroelectric power as generally offering higher yields and releasing a best quantity / cost ratio.

The shift towards greener energy is certainly important but not at the expense of accelerating the electrification of the country.

Our knowledge of the Haitian electricity sector, its issues and generation changes required, as well as the information collected might allow us to deepen this report with, in large part, what we have in hand. If this is the desire to OLADE, BPR will be happy to discuss it.

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