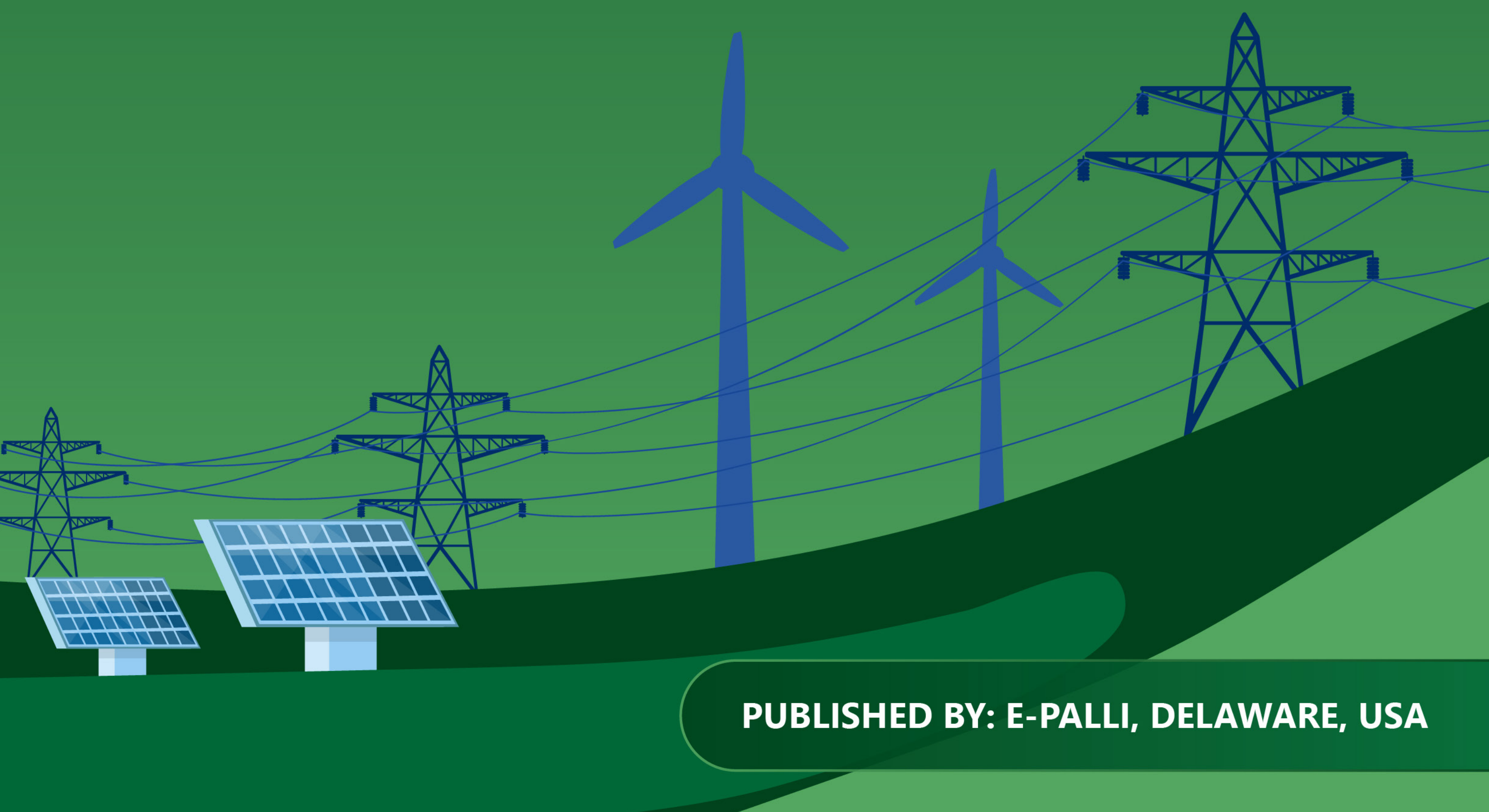
e-palli

AMERICAN JOURNAL OF ENERGY AND NATURAL RESOURCES (AJENR)

VOLUME 1 ISSUE 1 (2022)

Indexed in

doi | Crossref | Google Scholar | Directory of Research Journals Indexing DRJI



PUBLISHED BY: E-PALLI, DELAWARE, USA

American Journal of Energy and Natural Resources (AJENR)
Volume 1 Issue 1, Year 2022
https://journals.e-palli.com/home/index.php/ajenr

Technical-Economic-Institutional Diagram of a Micro-Hydroelectric Power Station in Electrified Areas: Case Study in the Lingang-Foto Site of Cameroon

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Article Information

Received: October 05, 2022

Accepted: October 16, 2022

Published: October 22, 2022

Keywords

Institutional Scheme, Micro Hydro Power Plant, Production Area, Rural Electrification, Technical Parameters

ABSTRACT

Access to electricity, reliable energy supply, and environmental protection are key elements that support economic development around the world. In most of Sub-Saharan African countries, the production deficit is a key issue. In addition, the network is made of long distance power lines, leading to huge voltage drops and frequent power cuts in remote electrified areas. Most of these areas offer a wealth of micro hydro power potential. It hence happens that the development of such project in an environment not prepared should address many issues from the technical, the economic and the institutional point of view. The aim of this paper is to examine how we could contribute to the design and development of such a project while taking into account the related constraints. From the findings and the literature review, we have suggested for each core aspect how we might overcome some difficulties. Given the similarity of the network architecture in remote areas in Africa, we have focused on one 148 kW case study in Cameroon to illustrate the implementation of the results. We got a 6.5$cents/kWh cost-effective project from an initial investment of 480 509USD with the need to use robust and simple equipment and the need to adjust the regulations. Since power cut is harmful and a hence issue for a grid connected plant, we have also designed an architecture to address this issue of load shedding from the grid.

INTRODUCTION

Access to energy is one of the essential aspects of development and economic growth in the world. However, it is increasingly clear that current energy systems are not able to provide energy to the entire population under sustainable conditions and at affordable prices. Thus, renewable energies are intended to ensure a more sustainable and secure energy supply, in order to underpin economic growth and promote the achievement of the Millennium Development Goals. Indeed, renewable energies (or RE) designate a set of means of producing energy from theoretically unlimited sources or resources, available without a time limit or which is renewed more quickly after consumption. Thus, micro hydroelectric power station is a type of hydroelectric power that typically produces 20 kW to 500 kW of electricity using the natural flow of water. Micro hydropower plants have proven to be suitable for providing energy and sanitation services to isolated communities with some hydropower potential. It should be noted that many countries have developed aspects that make it possible to enhance the value of micro-power plants in their country in order to provide quality energy services to isolated communities with exploitable hydroelectric potential; we can cite among others:

- Peru, where (Lillo, 2015) have developed a new management model for small hydropower projects and have proposed a new method for assessing sustainability concerning technical, economic, social/ethical, environmental and institutional/organizational dimensions;
- India, where the government of Himachal Pradesh (HP) (Sinclair, 2003) set up the HP Energy Development Agency to encourage private sector investment in small hydropower projects (3 MW and less) and to assist developers by facilitating the project approval process;
- Nepal, where (Adhau, 2009) described the macroeconomic, financial and institutional arrangements that seem important for scaling up investments in micro hydro.
- Greece, where (Kaldellis, 2005) have done the systematic investigation of the techno-economic viability of SHP stations. He concluded the study by a sensitivity analysis properly adapted for the local market financial situation, in order to enlighten the decision makers on the expected profitability of the capital to be invested.

It should be noted that all this work does not deal with the specific problems of the Cameroonian context, which are in particular linked to the difficulties of access to financing and the weak supervision of this sector by the laws of the country; as is the case in Nigeria, where (Mohammed, 2017) did suggestions as to how to pursue certain socio-political, technological, investment and legislative issues with a view to the efficient development of small hydropower plants in the country;

Electricity production in Cameroon is largely of hydroelectric origin and despite the increase in the rate of access to electrification from 61% in 2017 to 63.5% in 2020 (ENEO, 2020), the production deficit remains significant and frequent power cuts in electrified areas; gold according to studies made by Invest'Elect (MINEE, 2014), Cameroon has enormous potential in electrified areas for the development of micro-hydroelectric power stations. However, it should be noted that most of these potential sites for the development of micro-hydroelectric power stations are within the scope of the

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ENEO concession (scope within which it has exclusive distribution and sale of electricity as required by law (MINEE, 2009). However, the institutional framework prohibits the development of commercial energy production there, hence the need to revisit the texts in force at the technical, economic and regulatory level. This is how this work aims to establish "a technical-economic-institutional plan of a micro hydroelectric power station in an electrified zone" in order to promote this renewable energy technology in Cameroon. The study will be organized in several stages. First, we will describe the site for our case study, then we will describe the MH (Micro Hydro) system, then an analysis of the system of the area will be made, finally we will present the results obtained.

METHODOLOGY

An assessment has been conducted to understanding the micro hydro system in generally; and we collected data in order to describe the general environment of the Lingang-foto site in Cameroon identified for the case study. We collected the specific data in the field to have topographical and hydrological details; and to determine the energy needs of the locality and the power situation of the site; we analyzed data to find the reasons for poor quality of electrical energy in electrified zone and developed solutions. A rigorous and balanced analysis was finally made to highlight the political implications of our subject.

Description of the MH (Micro Hydro) system

Block diagram of the system (short description)

Nozzles direct water jet against a series of spoon-shaped buckets mounted around the edge of a turbine. The system ensures the hydraulic energy transformation into mechanical energy. The wheel of the turbine is coupled to a generator which transform the mechanical energy into electrical. The general diagram of this system is represented in Figure 1 below (Chennani, 2008).

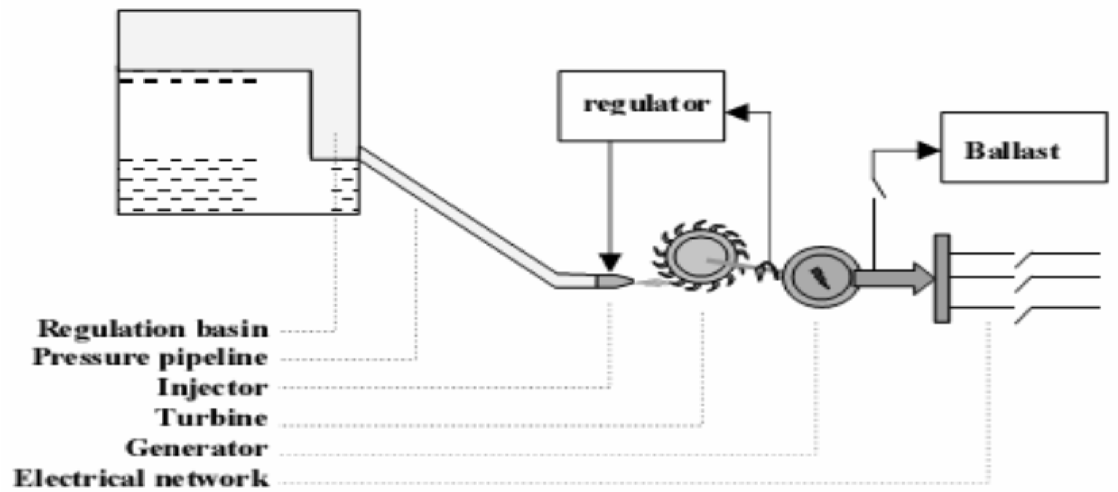

Figure 1: Synoptic diagram of a hydroelectric development

The water is captured from the reservoir (quantity of water upstream of the dam) by an intake structure whose function is to derive the quantity of water necessary for the operation of the plant during flood periods as well as during periods of flooding low water. It is transported to a sedimentation basin in which it will be cleaned of any element that could be harmful to the turbine. It then continues to the charging chamber which ensures that the penstock always has water. By passing through the penstock, the water acquires hydraulic energy under the effect of the fall, thanks to which it will turn the turbine. The latter will provide the mechanical energy necessary to run a current generator which will in turn produce an alternating current.

Summary table of the MH system (Micro Hydro)

Micro hydroelectric power stations are power stations with installed power between 20 and 500 KW (Kaldellis, 2007); they differ according to the geography of the site, the flow rate, the height of fall and the type of turbine suitable. The summary component of the micro hydro system is in table 1 below.

Table 1: Summary component of the MH (Micro Hydro) system.

Classification of hydroelectric facilities	Characteristics	Development component
Lake or high fall power plants	high mountain sites, low flow, very high difference in height, drop greater than 300 m, Pelton type turbines	• Civil engineering works (dam, diversion structure, power plant building)
Lock or medium power plants fall	Mid-mountain sites, average flow, fairly steep drop, drop between 30 and 300 m, Francis type turbines.	• Hydro mechanical installation (the turbine, valves)

Run-of-river or low-head power plants	located on the course of large rivers or large rivers, very high flow, low drop, drop of less than 30 m	• electromechanical installation (alternator, coupling element between turbine and alternator) • Electrical Installation (control system, regulation system, distribution system)

System analysis of the area

Technical analysis

For us, it will be a question of determining the energy potential of the study area. The annual energy is evaluated by taking into account the variation in flow rates during the year. It is therefore a function of the variation in the efficiency of the turbine and the efficiency of the generator (PACER, 1995).

$$E = \rho g\left(\sum_{i=1}^{365} \eta i \; \eta g \; Qi \; Hn \; Ti \right) / 1000 \quad / \quad (1)$$

With: P the density of the water (1000 kg/m^3);

g The acceleration of gravity (9.81 m/s^2 ;

H_n the net height of fall in m;

Qi The rate of flow i in m^3/s ;

Ti the time for which the Qi rate is reached in hours;

Ean the energy produced annually in kWh;

ηi The efficiency of the turbine at flow i;

ηg The efficiency of the generator.

The calculation can be done by considering the output of the generator ηg constant. Only the variation in the efficiency of the turbine is considered.

The net height of fall

The net head represents the effective energy available to the turbine, measured between the inlet and the outlet of the machine.

It is practically calculated by deducting from the gross fall:

- The pressure drops upstream and downstream of the ΣHL turbine;

- The residual kinetic energy which is lost at the outlet of the $v^2/2g$ turbine.

The gross head represents the total energy available between the entry and exit of the facility. It is given by the difference in altitude between the water levels at the water intake and downstream of the power plant. This is topographic data measured on the ground or on the map (as we said above, topographic studies had already been made for our site and the gross height of fall is estimated at 42m). The exact downstream level to consider depends on the type of turbine.

The available net fall is therefore:

$$H_n = H_b - \sum H_L - V^2/2g \qquad (2)$$

H_n: Net height of fall; Hb: Gross height of fall; H_L: pressure drops; residual kinetic energy $V^2/2g$.

In a preliminary study of a small hydropower plant, the loss of residual kinetic energy is most often neglected. However, it can take on significant importance in low-head installations.

The efficiency of the turbine at flow i ηi

The yield varies greatly with the flow. It is given by the constructors in the form of curves like those of figure 2 (PACER, 1995): Order of magnitude of maximum yields ηmax (PACER, 1995)

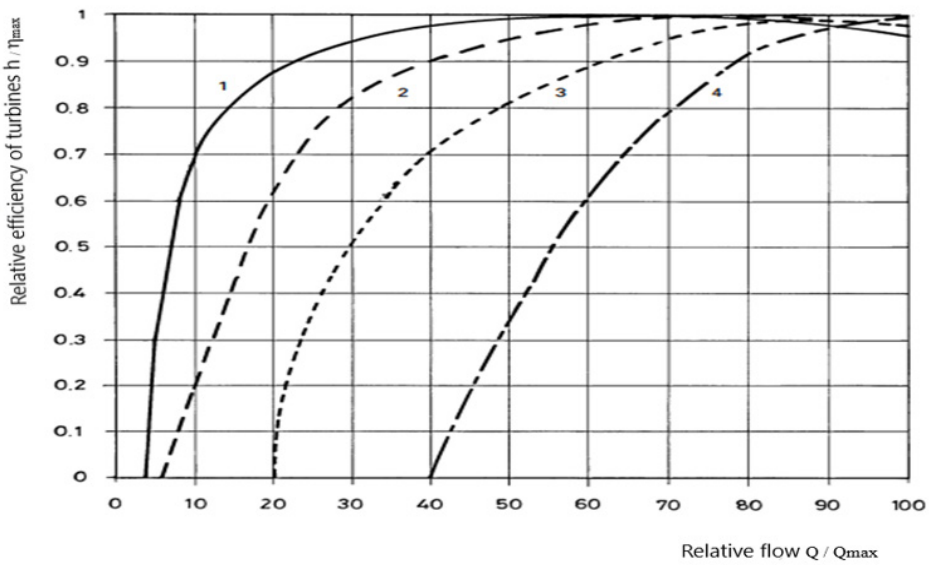

Figure 2: Shape of efficiency curves of different turbines for variable flow rates

Order of magnitude of maximum yields ηmax (PACER, 1995)

Table 2: Characteristics of the different types of turbines, the higher values of the efficiencies concerning large turbines

Curves	**Turbines**	**Type**	**ηmax**	**Min flow Turbinal**
Curve 1	Pelton turbine	Action	84 - 90%	10% of Qmax
	2-cell crossflow	Action	78 - 84%	20% of Qmax

Curve 2	Kaplan turbine	reaction	84 - 90%	20% of Qmax
Curve 3	Francis turbine	reaction	84 - 90%	30% of Qmax
	1-cell Crossflow turbine	Action	78 - 84%	20% of Qmax
Curve 4	Reverse pump	reaction	75 - 90%	Fixed flow

The maximum efficiency is reached for a flow between 60 and 90% of the maximum flow. The value of ηt for Qmax is generally less than ηmax.

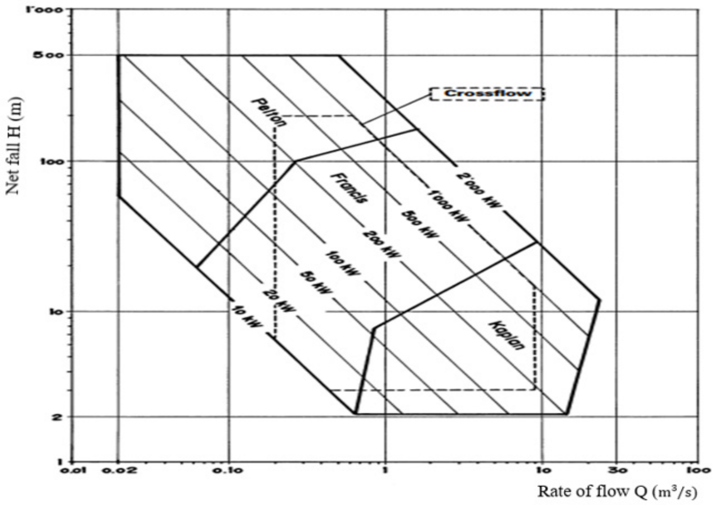

Figure 3: Field of use of the different types of turbines (net head, flow, power)

The output of generators ηg

The transformation of mechanical power into electrical power leads to losses. As with turbines, part of the power is dissipated in the form of noise and heat.The indicative values for the outputs of the generators are in table 3 below (PACER, 1995)

Table 3: Generator efficiency

Fully charged		At partial load	
Pél [KW]	ηgmax	Pél / Pelmax	ηg/ηgmax
1 to 5	80% _85%	> 50%	100%
5 to 20	85% _90%	25%	95%
20 to 100	90% _95%	10%	85%
> 100	95%		

Economic analysis

After the technical characterization of the supply systems, it is necessary to integrate all the costs associated with the expected payments from consumers. Economically evaluating the hydroelectric development will amount to calculating the cost of the energy produced and comparing it with the expected payments from consumers according to the decision N°0096/arsel/dg/dcec/sdct of May 28, 2012 fixing the sales tariffs excluding tax electricity applicable by the company ENEO Cameroon (Engo, 2019). For consumption less than or equal to 110 kWh, the tariff is 50 FCFA/kWh. It takes into account the depreciation cost of the development, the financial charges according to the financing of the project and the operating charges. By setting our break-even point at 20% below the official rate, the development will be profitable if the cost per kilowatt hour is less than or equal to 40 F CFA. The cost per kilowatt hour is therefore calculated as follows:

$$Ckwh=D/Ean \qquad (3)$$

With: D the annual expenditure in FCFA;

E_{an} the energy produced annually in kWh

The annual expenses D or annual cost of the development depend on the annuity factor a, the investment I and the annual expenses A.

They are obtained by the relation

$$D=aI+A \qquad (4)$$

With a: annuity factor;

I: investment in FCFA;

A: annual operating expenses in FCFA

Annuity factor a

The annuity factor determines a constant annual amount (amortization + interest) for the entire duration of the investment. It is calculated based on the payback time and

Table 4: Annuity factor a

Amortization period in years	Adjusted interest rate (daily rate minus inflation) 2%	3%	4%	5%	6%	7%
10	0,111	0,117	0,123	0,130	0,136	0,142
15	0,078	0,084	0,090	0,096	0,103	0,110

20	0,061	0,067	0,074	0,080	0,087	0,094
25	0,051	0,057	0,064	0,071	0,078	0,086
30	0,045	0,051	0,058	0,065	0,073	0,081

the annual interest rate. For each amortization period and real interest rate, table 4 below gives the annuity factor a, in % per year (J. Levet, 2021).

Investment I

It represents all the financial means for the acquisition of durable equipment. It is generally very high in hydropower plants. It is obtained by evaluating the costs various facilities (dams, buildings, etc.) and various equipment (turbines, generators…). But roughly, we can assess it using relationships empirical. The cost of electromechanical equipment can be determined by the relationships in board 5 (I. R. E. Agency, 2012).

The cost of the electromechanical equipment having been made, we can estimate the cost of the other structures with the help of figure 4.

Table 5: Electromechanical equipment costs of the Small Hydro Power (SHP)

Turbine type	**Electromechanical equipment costs in function €/KWH**
Pelton	$C=17693P^{-0,3644725}\ H^{-0,281785}$
Francis	$C=25698P^{-50135}\ H^{-0,127283}$
Kaplan	$C=33236P^{-0,58338}\ H^{-0,113901}$

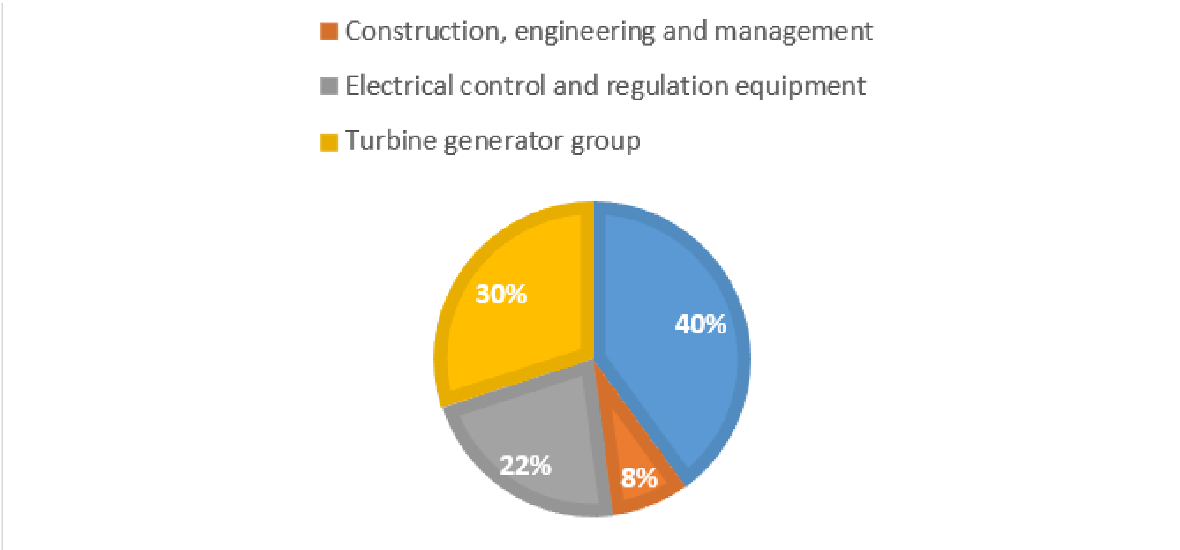

Figure 4: Investment Distribution of a Small Hydro Power (SHP)

Table 6: Estimated values of annual costs for the operation and maintenance of small power plants

Types of costs	**Annual fee rate**	**Reference for calculating costs**
Turbine and electrical part	3 à 6%	Investment for the components concerned
Dam, water intake and penstock	1,2 à 1,6%	Investment for the works concerned
Plant building and associated facilities	0,4 à 0,6%	Investment for the works concerned
Taxes, taxes, insurance, administration	0,8 à 1,5%	Total investment

Institutional analysis (institutional diagram and description of laws and regulations)

In the context of this analysis, the institutional framework will reflect not only the vision that the company has for the development of the electricity sector but also the way in which it intends to bring the various actors into play for this development.

The institutional framework is considered here as "a set of rules established for the satisfaction of collective interests relating to electricity in all its forms; and all the bodies that are created to apply these rules and meet these interests". This is how the administrative and land use planning procedures that PCH project developers must follow are presented below.

Regulation of energy production-water rights

It is stipulated in its article 3 (1) of the law n ° 2011/022 of December 14, 2011 (« Law n°2011/022 of 14 december 2011 governing the electricity sector in Cameroon Lc-doc », 2021)that the storage of water for the production of electricity, constitutes the public service of electricity. It is also stipulated in article 6 of Decree n° 2012/2806/PM of September 24, 2012-09-28 (" Decree n° 2012/2806 /PM of September 24, 2012", 2021) implementing certain provisions of law n° 2011/022 of December 14, 2011 that it is the Administration responsible for electricity (MINEE) which grants production, sale, import and export licenses, including those relating to a sale of surplus electricity, and production and distribution authorizations, as the case may be, on the basis of the files sent by the Agency.

The selection criteria for granting concessions, licenses and authorizations are described in Article 12 (1), and are awarded by competitive bidding. An order of the Minister in charge of electricity determines, after consulting the Agency, the composition of the concession, license and authorization application files as well as the scale of the related costs.

It is written in article 17 (2) that the administration in charge of electricity may decide to grant concessions and licenses for the production of electricity without a call for tenders in the following cases: In the event of an emergency that does not allow for a call for tenders, in particular in circumstances of serious electricity shortage or danger to the safety of persons or electrical works. If commitments already made or agreements already concluded by the Republic of Cameroon prior to the publication of this decree provide for the principle of granting such concessions or licenses to certain companies.

Environmental procedures

Since the 1970s, environmental integration has become an important part of PCH projects and therefore environmental protection is included in most of the laws in force in member countries. The country has a precise legal arsenal in relation to environmental and social management. In this regard, Law n° 96/12 of 5 August 1996 (« Law N° 96/12 of 5 August 1996. Relating to environmental management InforMEA », 2021) on the framework law relating to environmental management makes it compulsory to carry out an Environmental Impact Assessment (EIA) for any project that is at risk due to its dimension, its nature, to damage the environment. Decree n° 2013/0171/PM of February 13, 2013 (« Decree 2013/0171/PM of 14 February 2013 fixing modalities for carrying out Environmental and Strategic Impact Assessments - Decree 2013/0171/ PM of 14 February 2013 fixing modalities for carrying out Environmental and Strategic Impact Assessments Resourc, 2021) defines the methods of carrying out environmental impact studies: among other things, the decree explains the different procedures to be followed for a project, initiated by a promoter, can obtain a favorable opinion from the competent administration for a certificate of environmental compliance. These procedures provide for the participation of beneficiaries through public consultations and public hearings for projects subject to a detailed EIA.

Order n° 00001 / MINEPDED of February 08, 2016 (« Ministerial Order 00001/MINEPDED of 08 Feb. 2016 related to different categories of operations subjected to strategic and environmental impact assessment Ministerial Order 00001/MINEPDED of 08 Feb. 2016 related to different categories of operations , 2021) sets the different categories of operations whose performance is subject to a strategic environmental assessment or an environmental impact study.

Construction specifications

According to law N ° 2004/003 of April 21, 2004 (« Law n°2004/003 of 21 april 2004 to regulate town planing in Cameroon | Lc-doc »., 2021) governing town planning in Cameroon, it is the town planning authorities which issue a building permit separately from the water right. The authorization request often includes a landscape study of the site and the integration of the project into the environment. The administrative department in charge of the project must verify its conformity with the town planning documents.

Network connection

Connection to the network is also a different procedure from water law. A request to ENEO which is the authority in charge of the network concerned is necessary. Indeed, according to law n ° 2011/022 of December 14, 2011 (« Law n°2011/022 of 14 december 2011 governing the electricity sector in Cameroon Lc-doc », 2021), ENEO has the obligation to purchase electricity from renewable energy sources and yet the energy services it offers is not of good quality. We therefore believe that the State should open the scope of ENEO to other producers because injection improves the quality of service even though the network is good.

Due to the country's effort to develop renewable energy sources, utilities have received a significant increase in demand for connection of decentralized power generation facilities. As a result, the connection capacity to the local network may be saturated. In this case, it is necessary to strengthen the network, an operation more expensive than a simple connection. Likewise, it is also necessary to know the connections to be made in order to avoid reinforcing the network.

Other procedures

You may also be asked to follow other procedures such as:

Clearance authorization: Authorization is required to carry out clearing work, depending on the legal status of the forest. This authorization is set by Law N ° 94/01 of January 20, 1994 ("Cmr4845.pdf"., 2021) governing forests, wildlife and fishing. The authority to be contacted is the one in charge of agriculture and forestry.

Agreement with the Ministry of Cadasters and Land Affairs: A PCH developer is not always the owner of all of the land used. He may have to build a penstock, an access road or part of a waterway on neighboring land. The promoter will have to find an agreement with the owners concerned by the project. Where the municipality is the developer, it often has additional rights and powers over the private developer, which it is able to exercise freely. If no agreement is reached, the municipality can take advantage of the public interest, which is not the case for a private developer.

Site description

Geographic location

We are going to use the Lingang-Foto site (5.48179167 North, 10.0260167 East) which is a fall on the cliff of Dschang (mountain region, at 1400 m altitude on the south-eastern slope of the Bamboutos Mountains), tributaries of the Menoua which belongs to the Wouri basin.

Socioeconomic situation

The main income-generating activity of the locality is agriculture. It is practiced both in rural and peri-urban areas. The crops are diversified there (coffee, arabica, corn, plantain, beans, tomatoes, cabbage, potatoes, cassava, macabo, taro etc.). Small-scale breeding of pigs, poultry and cattle is also frequent in the arrondissement. However, it is practiced in a traditional and semi-modern way. One of the activities that affects all layers of society is the trade in food, handicrafts and manufactured products. The industrial sector, on the other hand, is not sufficiently developed. We only meet agrifood industries, the most important of which are modern and artisanal bakeries.

Energy situation of the area

Lingang-Foto is partially covered by the ENEO network; and we note in the area the presence of lines of 17.3 Kv. The distance between the site and the nearest national grid point is currently estimated at 1.6 km. The populations who benefit from the ENEO electricity network deplore the poor quality of service (significant voltage drops and untimely power cuts). Also, although they are in the area covered by ENEO, some still do not have access to electric power. We can cite those in the Mefet and Tsenlah districts, which have about 150 and 80 houses respectively. The figure 5 above shows the electrical situation of the lingang site.

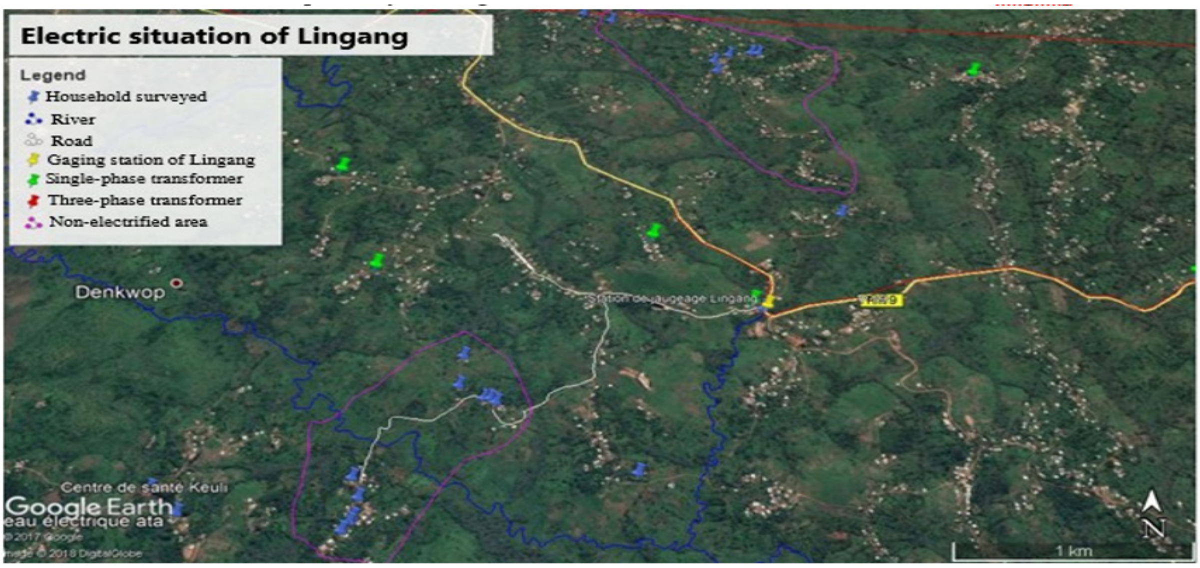

Figure 5: Lingang's electrical situation (Source: Google Earth)

Water resource

The Lingang site was selected because the detailed topographic and hydrological survey was available. In fact, the daily flow values over 365 days were obtained by gauging during the low water period by the method of exploring the velocity field using an electronic current meter.

This allowed us with the rainfall and evapotranspiration data to simulate the daily flows at the outlet of our watershed. At the end of these studies, we obtained the gross height of fall of 42 m by reading the topographic plans. We made the choice of the equipment flow rate by carrying out technical-economic studies, the value retained was 0.469 m3/s. Figure 6 below shows the curve of classified flows from the lingang site.

Energy needs of the locality

The collection of data relating to the local electricity needs is divided into three main groups of users or customers. These are households (lighting, distraction, small household appliances, food preservation, communication); community places (public lighting, drinking water supply, lighting for schools and health centers, food preservation); and productive activities (lighting for stores and shops, processing of agricultural products, administration).

The maximum power demand and the daily energy consumed by the locality must be determined in order to carry out the sizing of the electrification infrastructure. The locality's average hourly load curve must be estimated. This is sometimes difficult to characterize given the lack

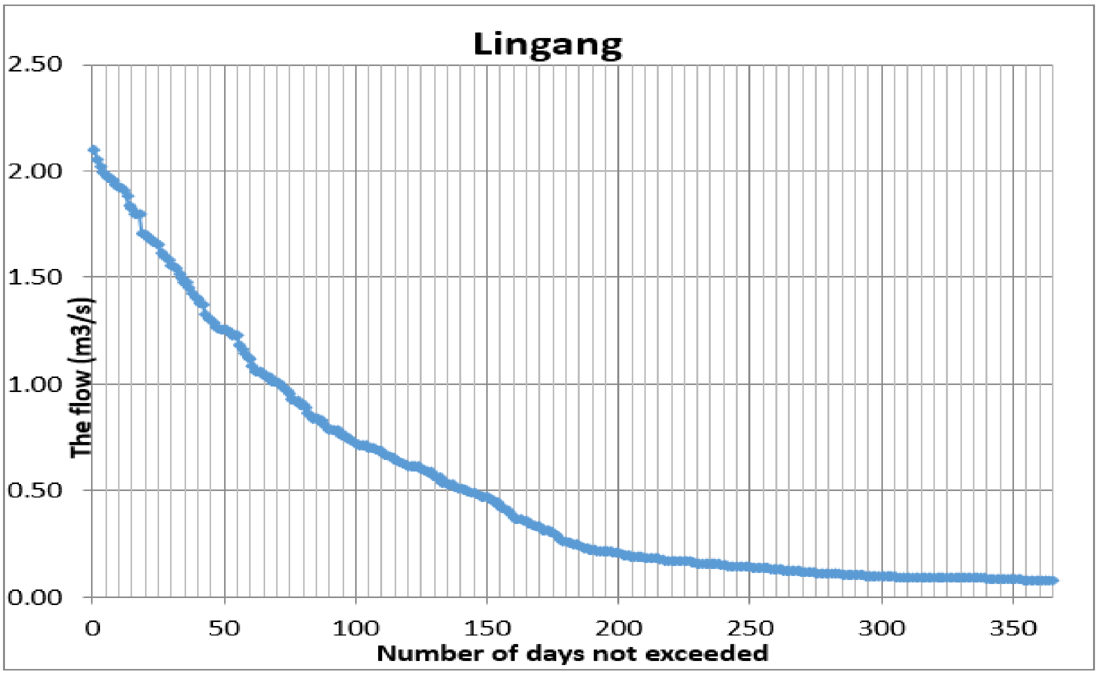

Figure 6: Curve of classified flows of the Lingang site

of historical data and the number of influencing technical and socio-economic parameters. Assumptions can be made in order to assess the energy needs of the villagers. The locality load curve will be evaluated from these data. We will also define different types of standardized electrical services. The characteristics of the devices used in these services must also be defined. Knowing the income and needs of the village makes it possible to estimate the distribution of the various services offered. Finally, the cross-checking of these different data makes it possible to determine the load curve adapted to the village.

RESULTS AND DISCUSSION

Needs of the locality and hydroelectric potential of the Lingang site

The Table 7 presents the energy needs of the locality and the hydroelectric potential of the site:

Table 7: Local needs and hydroelectric potential of the Lingang site

Needs of the community	76 KW		
Hydrological and topographical data			
Design flow	0.469 m^3/s		
Gross head	42 m		
Turbine			
Choice of type of turbine		Francis	Crossflow
Operating Parameters	Rotational speed (rev / min)	1500	1000
	runaway speed (rev / min)	2700	1800
	specific speed (rev / min)	186.27	124.18
Generator			
Type		asynchronous generator	
Electric power		148 KW	
Apparent power		250KVA	
power factor		0.8	
nominal voltage		400 / 660V	
Ampere		360.8 A	
Frequency		50HZ	
Rotation speed		Francis: 1500 rev / min Crossflow: 1000 rev / min	
Yield		0.95	

Builder	SIGENTIS
Pole pairs	Francis: 2 Crossflow: 3
Transformer	
Apparent power	250 KVA
Operating mode	Riser
Grid frequency	50HZ
primary voltage	400V
secondary voltage	15 KV
Yield 100% of the load and power factor = 0.8	0.98
Builder	France transformer
The annual energy	
Francis turbine	1398 525.18 KWh
turbine Crossflow	1293 181.80 KWh
Connection to Network	
Line length	1.6 Km
technical instruction	

Suitable type of power plant and proposal for the layout of the power plant

The site characteristics allowing us to determine the suitable type of plant are as follows:

- Geographic location: Mountain region, at an altitude of 1400 m on the south-eastern slope of the Bamboutos mountains;
- Type of stream: a low flow rate of 0.469 m3 / s
- Drop height : 42m
- Power : 148.58 KW
- Turbine type : Francis.

In view of its characteristics, we have to do with a micro hydroelectric plant (because power between 20 kW and 500 kW) of medium head or lock plant (height of fall between 30 and 200 m and Francis turbine).

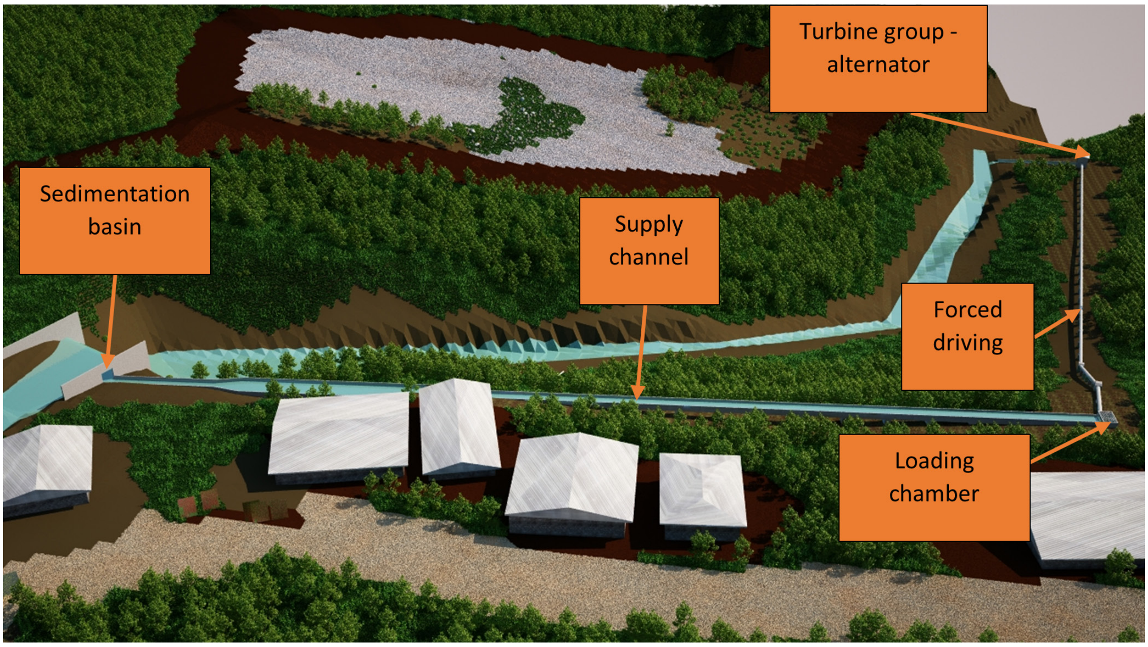

Figure 7: 3D diagram of the medium head hydraulic power plant at the Lingang site

We have the intake structure which captures the necessary flow; the collected water is decanted in the sedimentation basin and is sent to the loading chamber via the inlet channel. The charging chamber ensures that the penstock is always full, and also helps to mitigate water hammers. Once in the charging chamber, the water is conveyed under pressure in the penstock at the level of the Francis turbine which it will turn and which will in turn drive an alternator thus producing electricity.

Stakeholders and institutional plan proposed for the micro-hydro

Our project concerns the development of a low-power hydroelectric generating facility which is part of a regional development strategy. The lingang site corresponds to the "central connected to an existing network" scheme because it is close to the south interconnected network (RIS), more precisely near the 17.3 KV outlet which supplies part of the city of Dschang. Figure 8 below shows the different stakeholders and institutional diagram of the project.

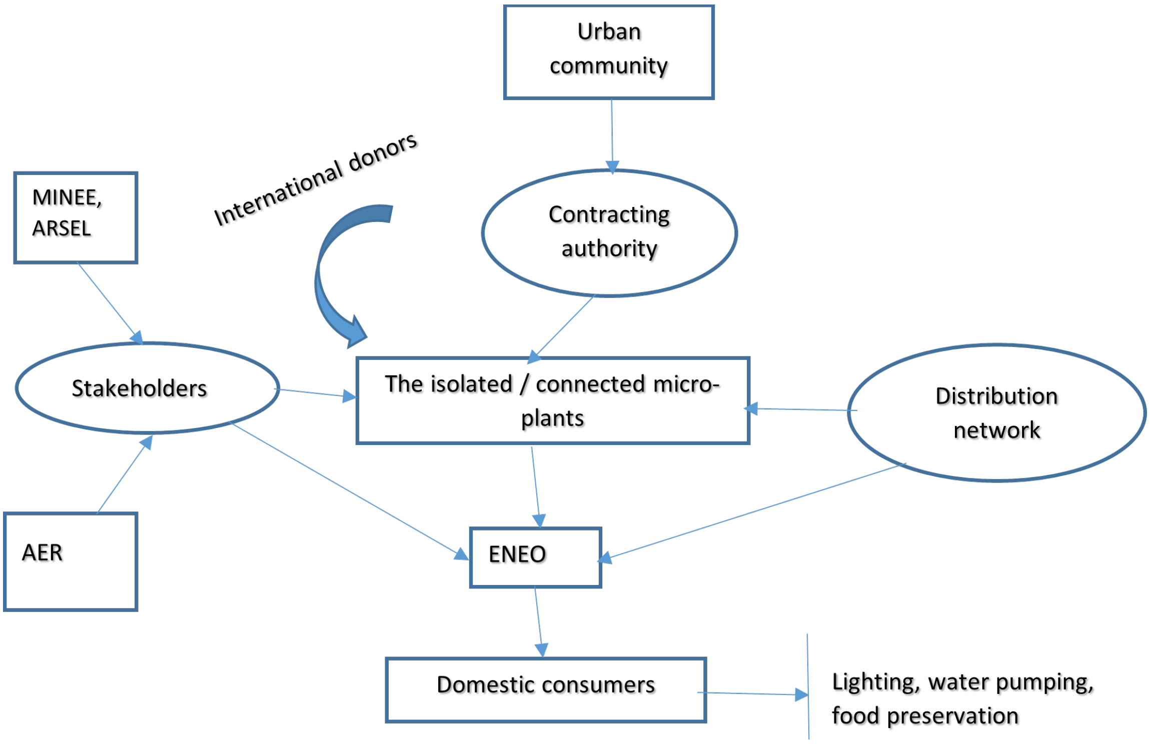

Figure 8: Stakeholders and institutional plan of the Lingang micro-power plant

We want to build a micro hydro power plant on an isolated site to connect to the electricity grid, but this site is within the ENEO concession area. It is normally forbidden to develop commercial energy production there, however load shedding, brownouts and other operating difficulties force ENEO to encourage this type of solution. We will therefore produce and inject into the network with the agreement of the latter, respecting the connection conditions (voltage and frequency equivalent to that of the network), and economic (selling price per KWh below the profitability threshold) in order to improve the quality of service for domestic consumers. This type of project can be financed by international donors with the urban community as the contracting authority. The project stakeholders will therefore be:

- The Electricity Administration (MINEE) which grants production, sale, import and export licenses, including those relating to the sale of surplus electricity, and production and distribution, as appropriate, on the basis of the files transmitted by the Agency;
- The Electricity Sector Regulatory Agency (ARSEL) to ensure compliance with the regulations in force;
- Rural Electrification Agency (AER) works to promote and develop electricity in rural areas.

Proposal for an electrification plan for the linfang-foto site

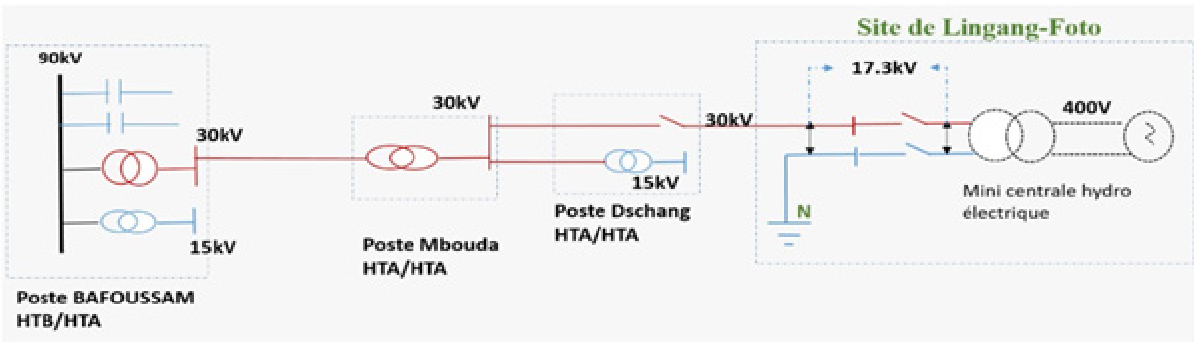

Figure 9: Electrification plan for the Lingang site

The Lingang micro-hydroelectric power station produces low voltage (0.4kv) and will be connected to the 17.3 kV single-phase network in order to comply with the voltage and frequency rules required for connection to the existing network.

Economic evaluation

We evaluated the project with different parameters, namely:

- **CKWH** = 39.59 FCFA> 40 FCFA (Break-even point that we have set ourselves so that the price is competitive with respect to the current price);
- **NPV** = 317 995 330FCFA Positive
- **IRR** is close to 18%> 12% (Discount rate)
- **the updated return time is 10 years**

According to these values, the project is profitable and attractive, hence a contract is possible with ENEO for the realization of the connections and the operation of the plant in compliance with the procedure of newly conceded goods, in accordance with the article 7 of the specifications of the framework concession contract binding the Cameroonian State to ENEO. This will be a win-win objective, both for the local authorities who will see in it the achievement of access to electricity for their population and for ENEO which will benefit from new subscribers.

Potential environmental impacts

We have assessed the potential environmental impacts of our project and we have proposed mitigation measures in table 8 below:

Table 8: Assessment of the environmental impacts of the project.

Sources of impact	Impacts	Reduction measures
Construction of the dam and penstock	Deforestation and loss of vegetation	-optimize the project to minimize the loss of vegetation -Reforest in excavation and construction areas
	Use of agricultural areas	Compensate owners
Changing the volume and flow of water	Bank erosion, sediment transport	-Construction of dikes in areas of residual flow to increase the water level in the bypassed section -Stabilization of the banks by vegetation or rocks Natural filtering of sediments by planting plants on the banks
Water stagnation	Appearance of insect vectors of diseases	Eliminate suitable habitats for insects by maintaining a constant flow
Passage of heavy vehicles	Dust emanation	Water the roads
Toxic product spill Waste from workers and construction activities	Soil contamination	-Recycle oils to local businesses -Incinerate solid waste -Recycle solid waste.

CONCLUSION AND POLICY IMPLICATIONS

Having reached the end of this work where it was a question of establishing “a technical, economic and institutional diagram of a micro hydroelectric power station in an electrified zone”, it emerges that the micro hydroelectric power station is a profitable energy solution capable of solving the problems of energy for the populations of electrified areas; it is enough just to imagine a model of institutional and commercial framework in order to encourage the modification of the texts in force.

To this end, in this manual we propose an institutional arrangement for the marketing of low voltage electrical energy obtained from micro hydroelectric power stations in electrified zones; then, we show how to determine the type of power plants that will be suitable in order to perform a reliable sizing of all the elements of the development. At the institutional level, we have defined an institutional framework model for the sites that are within the scope of ENEO; and finally, we showed how to assess the profitability of such a project in the Cameroonian environment.

As part of the implementation of this technical, economic and institutional plan for micro hydroelectric power stations in electrified areas, we have tested a practical case in the lingang site in Dschang.

Indeed, Dschang is an electrified area where all the populations who have access to electricity complain about the load shedding. We therefore made an analysis of the energy demand of the locality which was76 kW about; a value lower than the exploitable electrical power of the site, which is approximately 148 kW. As a result, the lingang site will also be able to solve the region’s load-shedding problems on board after connection to the network. Then, we made an economic analysis which confirmed us on the profitability of the project in real time.

This study therefore underlines the importance and the need for multifaceted policies to promote and develop green energies in electrified areas in order to overcome the problem of access to electricity that our society is underminig. The results presented above provide relevant knowledge for the design of future informative policy measures for micro hydropower plants. This study has important implications for power sector policy.

- Energy management policies should be reviewed to encourage investors to take an interest in the field, and to increase independent production of electricity for commercial purposes to improve the quality of service offered by the entity in charge of production and distribution of electrical energy;

• The government should also ensure that proposed policies and regulations are implemented to facilitate the development of the sector.

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