ASSESS CURRENT APPROACH FOR PLANNING AND IMPLEMENTATION OF THE EXPANSION OF THE POWER SECTOR IN CAMEROON AND PROPOSE IMPROVEMENTS BASED ON BEST PRACTICES IN INTERNATIONAL EXPERIENCE ON COUNTRIES WITH GROWING DEMAND

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<u>Document Revision History</u>

Revision Number	**Revision Date**	**Nature of Revision**
1	March 21, 2024	Updating performed following discussion and Client's feedback during the workshop
2	March 28, 2024	Updating following the need for further synchronization between the English and French versions

1. Executive Summary

The electricity sector in Cameroon has evolution within the last three decades, with the most recent reform in 2011 by which generation, transmission and distribution functions were unbundled. This change in the electricity market model went from a vertically integrated market model to a single buyer model. Naturally, the electricity sector planning assessment framework was expected to evolve accordingly.

Power sector development in Cameroon is approached from two angles: on-grid projects development for the centrally connected electricity infrastructure, and off-grid and rural projects developments aiming at providing electricity access to communities far away from the network. Following the approval of the Electricity Law reform in 2011, the Government of Cameroon developed an Electricity National Master Plan known as PDSE2030, which was produced in 2014. The primary objective of the PDSE2030 was to provide the Government of Cameroon with an investment roadmap in generation, transmission and distribution assets to sustain the country's economic development over the 2014-2035 planning horizon. The plan was later supported by additional initiatives such as in the form of a Rural Electrification Master Plan developed in 2016 with the intent to provide a roadmap for rural electrification, and a National Development Strategy developed in 2020 articulating the government's vision for the energy sector over the period 2020-2030.

Unfortunately the country experienced some economic stress which undermined the materialization of economic expectations, from an expected optimistic 6.05% GDP growth rate over the 2014-2023 period to an actual average of 3.87% over the same period. A consequence of that economic stress was that the retained electricity infrastructure investment roadmap as planned could not be implemented neither timely nor as planned. Generation projects delays and non-adherence to infrastructure maintenance programs led the energy sector to the state of resource inadequacy crisis and failing infrastructure reliability while the country has continued to face increasing demand. Structurally throughout this period there has been no formal standard review or updates on the Master Plan in the light of the changed environment. Operationally, the aging infrastructure performance degraded resulting in poor service quality through severe power outages and unstable service reliability, forcing the government to adopt at times non-optimal and costly temporary remedial initiatives. This has occurred within the context of subsidized tariff regulation which along with increased debt to service utilities has created a sustainability risk for the sector.

Aware of these challenges and despite this difficult context, the Government of Cameroon has nevertheless worked on addressing the situation with initiatives such as supply resource adequacy in the form of Natchigal hydropower project development, some network reinforcements programs and recently with the development of a short-term electricity sector recovery plan estimated at 820 Billion FCFA. While encouraging, these initiatives have yet to tackle why and how a systematic review of the power sector planning approach in the country is needed.

In the course of our work, an assessment of the current sector planning approach and its implications was performed for several areas of activity within the power sector in Cameroon. These areas are: included hydropower resources planning on the Sanaga river, integration of Natchigal hydropower into the grid, coordination across the generation-transmission-distribution functions, the concessions agreements between the government and the distribution and off-taker utility, the monitoring mechanisms and information systems regarding utility performance, grid code and charges, merit order procedures, and strategies for hybridization.

Through our assessment, betterment opportunities have been identified and turned into recommendations to consider in supplement of an already existing improvement program, all while strengthening the foundations of the decision making process. This strong foundation when included in a systematic integrated approach will ultimately impact positively the operational and financial performance of the sector, as demonstrated in the best practices herein described.

The recommendations discussed in Chapter 5 of this report are listed below. Each one intends to improve the operational framework of the sector as much as its institutional aspect. These combined perspectives provide for a more efficient strategic planning environment.

Recommendations	***Primary Impact***	***Implementation Timeline***
Generation Assets Maintenance	*Operational*	*Immediate*
Transmission & Distribution Assets Maintenance	*Operational*	*Immediate*
Assets Outage Management	*Operational*	*Immediate*
Water Supply Management	*Operational*	*Medium Term*
Thermal Fuel Supply Management	*Operational*	*Medium Term*
Demand Forecast	*Institutional*	*Medium Term*
SCADA, AGC Infrastructure Expansion and Energy Management System	*Operational*	*Immediate*
Transmission Line Monitoring System	*Operational*	*Immediate*
Energy Balance Report and Sector Performance Data	*Institutional*	*Medium Term*
National Water Reservoirs Management	*Institutional*	*Long Term*
Grid Code Improvement	*Institutional*	*Medium Term*
Transmission & Distribution Assets Reinforcements	*Operational*	*Immediate*

Off-Grid and Rural Electrification: Harmonization and Communities Economic Development	*Institutional*	*Immediate to Medium Term*
Infrastructure Security	*Institutional*	*Immediate*
Revenue Collection Improvement, Public Consumption Management and Smart Distribution Digitization	*Institutional*	*Immediate*
Sector Financial Stability	*Institutional*	*Immediate*
Hydropower-Solar Hybridization	*Operational*	*Long Term*
Power Sector Planning Through an Integrated and Coordinated Framework	*Institutional*	*Medium Term*
Power Sector Planning: a Need for Capacity Building	*Institutional*	*Medium Term*

Table 1: Recommendations List

Note that the implementation timeline in Table 1 is provided on an indicative basis.

In conclusion, the recommendations provided in this report are cognitive of a power sector in development that can, with the consideration of the government's sector recovery plan and articulate implementation, transform its on and off-grid architecture into a modern grid to address the country's growing demand, all the way from planning to systems operations and financial performance.

1. Introduction and Project Background

Over the last twenty years, the Government of Cameroon (GoC) has spearheaded a series of structural reforms to improve sector efficiency and attract private investments in the electricity sector. Despite these reform efforts and huge hydropower potential, significant challenges remain in the energy sector such as inadequate planning with uneven access rates linked to insufficient distribution and transmission infrastructure. Electricity access rate in Cameroon stands at 65 percent with significant disparities between urban (94 percent) and rural (25 percent) areas. The National Development Strategy-30 elaborated by the Ministry of Economy Planning and Territorial Development (MINEPAT) sets an access target of 80 percent by 2025 with the aim of achieving universal electrification by 2030.

Through its ongoing engagement, the World Bank aims to support the preparation of crucial planning tools for the sector to support the development of the electricity sector and meet future demand, in line with international best practice. In light of serious shortcomings in implementing power sector expansion, the World Bank is undertaking an upstream assessment of the current approach to planning and implementing the expansion of the power sector in Cameroon.

In the 1990s and first half of the 21st century several countries in Latin America and other regions carried out comprehensive reforms in the power sector. In all the cases, the main driver of the reform was a deep operational and financial crisis in the electricity sector. The implemented reform was a market-oriented one, based on the separation of the roles of policy making, regulation and provision of electricity service, unbundling of generation, transmission and distribution, establishment of a competitive wholesale market and private participation as main instruments to increase efficiency, ensure sufficient and reliable power supply and improve the government's fiscal position.

State-owned companies were restructured and privatized or capitalized, generation prices were deregulated, and a spot energy market was created to promote competition among stakeholders, as well as independent institutions responsible for sector regulation and monitoring and market administration. The sector's Ministry remained responsible for policy making.

This first market-oriented reform was in general successful to improve performance of the electricity companies, in particular in quality of services provided to existing consumers. All the successful cases were characterized by the sustained improvement of the operational performance and the recovery of the financial viability of the incumbent distribution companies. However, mixed results were observed in the expansion of installed generation and transmission capacity. Even in the successful cases, private developers did not receive the right signals for long-term expansion of generation capacity to meet increasing demand. As a consequence, most of the countries with significant share of hydropower in the generation mix (Brazil, Chile, and Colombia) faced situations of energy rationing during dry periods.

Security in energy supply has emerged as a very relevant issue at the time of defining the mechanism to promote competition at wholesale level, and its importance is likely to increase in those countries where the electricity demand is expected to grow at significant rates over the next decades. It is necessary to recognize that no serious agent will carry out high investments required to build new facilities without a consistent flow of revenues assuring recovery of those investments and a fair return on them. And this implies long term contracts with financially viable off-takers (the distribution companies serving final consumers).

Addressing supply adequacy of electricity as an objective of high priority for a country requires direct involvement of the Government in planning the expansion of the power sector. This does not imply that state-owned companies become directly involved in the construction and operation of the facilities needed to expand the sector. However, the Government must design and put in place mechanisms to ensure that the optimum expansion projects identified in the development of the planning process are implemented at the least cost for the country. This requires carrying out competitive processes to award long-term power purchase and transmission services agreements between the distribution companies serving end users and the successful bidders in those processes.

In this context, our Project (or Activity) has consisted of performing an assessment of the current approach for planning and implementation of the expansion of the power sector in Cameroon, and propose improvements based on best practices in international experience from jurisdictions with growing demand. Our methodology, approach, findings and recommendations are presented in the remaining chapters of this report.

2. Methodology and Approach

The report, in accordance with the Activity's Terms of Reference discussed with our technical counterpart in the Government of Cameroon, the Ministry of Water and Energy, has been divided into three (3) parts.

2.1. Part I: Assessing the Current Approach for Planning and Implementation of Expansion of Power Sector in Cameroon:

In this part of the Activity, we have reviewed and analyzed the current planning framework for power sector planning in Cameroon, from the standpoint of two angles:

- In the first one, we undertook a comprehensive examination of the existing institutional and operational frameworks within Cameroon's power sector. This includes scrutinizing the allocation of roles and responsibilities in power system planning among various key players: ministries, ARSEL, ENEO, SONATREL, EDC, AER, and Independent Power Producers.
- Next, we have conducted an analysis identifying both barriers and opportunities inherent in the present methodology, with a focus on integrated resource planning, least-cost planning, and other ongoing strategic initiatives vital to the power sector. We have paid particular attention to the following areas:
    - Hydropower resources planning for the Sanaga river
    - Integration of the Nachtigal hydropower into the grid and investment in distribution to meet the rising industrial demand
    - Coordination across the generation, transport, and distribution functions
    - Concession arrangements between ENEO, IPP and government
    - Monitoring mechanisms and information system regarding utility financial and operational performance
    - Merit order dispatch procedures
    - Applicable grid code and charges
    - Strategies for hybridizing solar and hydropower

2.2. Part II: Providing a Gap analysis with Best Practices in International Experience on Planning and Implementation of the Expansion of the Power Sector in Countries with Growing Electricity Demand:

Here, we have identified jurisdictions that offer valuable experience and insights, aiming to improve Cameroon's current approach against best practices in international experience analyzing in detail the following topics for two (2) selected cases:

1- Sector structure

We have scrutinized and compare the overarching organizational and operational architecture of the power sector.

2- Approaches to ensure a cost-effective balance between supply and demand resource adequacy for the country:

a. Planning: we have assessed institutional arrangements, exploring roles and responsibilities of government agencies, regulatory bodies, and operating companies; and scrutinizing implementation arrangements which include stakeholders' roles, consultation process, and dissemination strategies, etc.)
b. Implementation: we have evaluated how the outcomes of the planning process are implemented through market and policy instruments.
c. Results achieved: we have assessed the efficacy and outcomes of the strategies and implementations.

3- Main lessons learned

Based on the above, we have drawn lessons the Government of Cameroon could benefit from in its planning framework implementation

Afterwards, we have integrated the results from the country case studies and summarize the main lessons learnt from the international experience and their main relevance for Cameroon.

2.3. Part III: Proposed Improvements to Current Approach in Cameroon:

We will in this part, based on lessons learned, recommend improvements to the current approach in Cameroon aimed at a systematic adoption of least-cost planning principles for the power sector's expansion and a cost-effective execution of the outcomes of the planning process across the electricity sector value chains. We will also propose a roadmap for the implementation of these recommended improvements.

Our assessment for the completion of this report has relied on various inputs. In addition to our experience and subject matter expertise, our work has been performed on the basis of publicly available information including the Stratégie Nationale de Développement 2030, the 2015 Energy Balance, exclusive information from the World Bank, and discussions with experts from the MINEE, EDC, SONATREL and AER.

3. Outcome - Part I:

Assessing the Current Approach for Planning and Implementation of Expansion of Power Sector in Cameroon

3.1. System Energy Planning: Foundation to Building a Modern Grid

From a national perspective, System Energy Planning (SEP) can be defined as the roadmap by which policies and related processes and infrastructure framework are defined to help guide the future of the national energy system. Such a roadmap needs to take into consideration the various factors impacting its implementation, such as the economic environment, the market and technology trends. Planning requires the input of all the actors in segments identified for the targeted commodity value chain. In its simplest form, energy system planning can be described as shown in Figure 1.

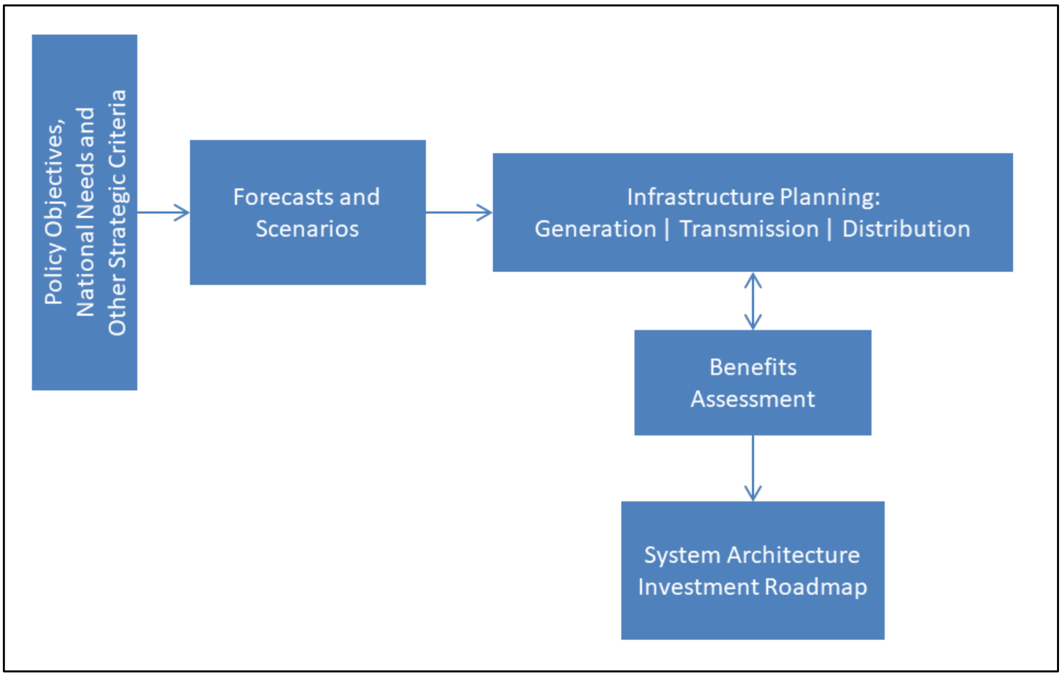


Figure 1: Generalized System Energy Planning Framework

In the power sector, the objective of system planning is to identify supply and demand resources, and related infrastructure required to satisfy current and anticipated electricity needs in the least cost manner, and subject to financial, technical, social, environmental and sometimes political constraints. This process results in a roadmap of suitable investments to make over a defined planning horizon. Next, the roadmap is presented to and discussed with decision makers. In a context where decision-making in the sector remains the government's responsibility, the approved roadmap should translate into a national implementation plan with clear roles and functions for all involved stakeholders.

In an environment with low uncertainty, system energy planning involves low-level intricacy within and interactions across the processes and components involved. Conversely, the components dependency amongst the various actors and processes must be understood and expanded when undertaking system planning in an environment subject to considerable uncertainty factors, including those created by investment commitment and operational risks.

In reality, the electricity industry landscape has been changing drastically over the last twenty (20) years, as demonstrated by the technology advances which permit the transformation of electric grids into smart ecosystems and the increased role of variable renewable energy. Such transformation requires decision makers to approach planning from the perspective of building a modern energy grid system with the following attributes: flexible, reliable, secure, resilient, affordable and sustainable. These attributes, as defined in Figure 2 below, demand that each process or system infrastructure considered in the planning process aligns as best as practical with strengthening all of them.

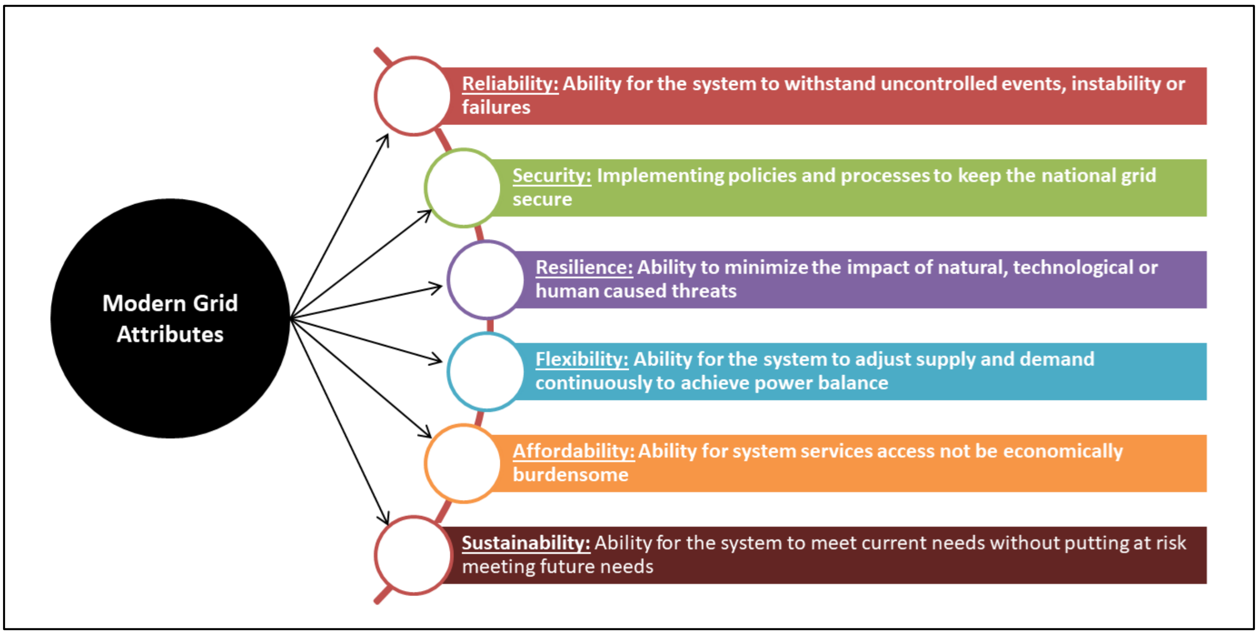


Figure 2: Attributes of a modern electric grid

All grid planning initiatives in advanced energy systems have embraced the principles articulated in these attributes with success. Their proven foundations are now serving a guide to energy systems development across the world including in emerging economies and low-income countries.

3.2. Cameroon's Power Grid at a Glance

Cameroon is a country in Central Africa with a population of about 28.9 million, covering an area of 475,650 km^2 and a population growth rate of 2.60%. With a population density of 60.7/km^2, the country is sparsely populated and like most developing countries, is characterized by a large population found in urban centers: the Douala and Yaoundé metro areas account for more than 30% of the country's population.

In sub-Saharan Africa, Cameroon has the third largest hydropower development potential, estimated at over 12,000MW across the country. This potential is mostly concentrated in the south of the country, namely in the Sanaga river capturing 75% of that potential estimate. Currently, the country's electricity generation mix is dominated by hydro resources (55%), with gas (16.8%) and oil generation (25.7%) and marginally by other renewables (2%) with 30MW of recent PV solar park commissioned in the northern part of the country. The Government of Cameroon intends to achieve universal access to electricity by 2035 and increase its generation capacity by a least 3,500MW through hydro projects, implement transmission and distribution network reinforcements as well as various off-grid initiatives, thus reducing its dependency on expensive fossil fuel generation, accelerating the decarbonization of its generation portfolio, strengthening its security of supply, becoming a potential exporter and a competitive player in the region and boost its national economy.

Concerning electricity transmission, Cameroon's on-grid infrastructure consists of a high voltage network system that consisted until November 2022, of three (3) isolated networks covering its ten (10) regions: the Southern Interconnected Subsystem (Réseau Interconnecté Sud or **RIS**), the Eastern Interconnected Subsystem (Réseau Interconnecté Est or **RIE**) and the Northern Interconnected Subsystem (Réseau Interconnecté Nord or **RIN**).

- The Southern Interconnected Subsystem covers the following regions: Littoral, West, Centre, South, North-West and South-West. This network is the largest of all three and comprises voltage levels of 225 KV and 90 KV. The network installed generation capacity is estimated at 1 400 MW
- The Eastern Interconnected Subsystem covers the following region: East. This network comprises a voltage level of 30 KV. The network's installed generation capacity is 42 MW (30 MW from hydro generation capacity and 12 MW of thermal generation capacity)
- The Northern Interconnected Subsystem covers the following regions: Extreme Nord, Adamoua, Nord and Extreme Nord. This network comprises voltage levels of 110 KV and 90 KV. The network's installed generation capacity is 102 MW (72 MW

from hydro generation through the Lagdo river, and 30 MW of recently commissioned hybrid PV generation capacity).

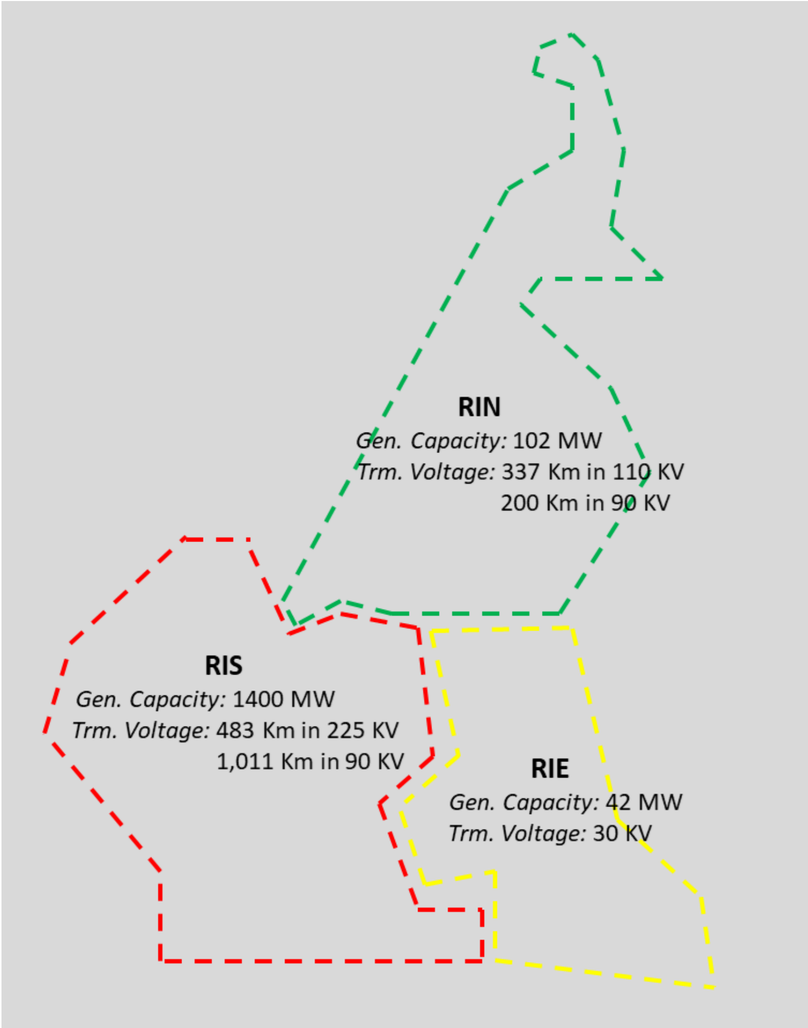


Figure 3: Cameroon's Electric Grid Networks Map, as of November 2022

Prior to November 2022, the distribution network also consisted of three isolated networks, each embedded within their corresponding Interconnected Network. Overall, the distribution network comprises voltage levels of 30 KV, 15 KV, 0.38 KV and 0.22KV.

Since November 2022, the RIE got connected to the RIS through the Abong-Mbang-Bertoua medium voltage transmission line. However, there are reliability concerns over this interconnection as its current configuration lacks stability and weakens the interconnection between these two networks. This instability prevents the phasing out of expensive thermal generation (estimated in 2020 at 200 FCFA/KWh) located in the eastern part of the country which could have been substituted with cheaper hydropower generation (less than 50 FCFA/KWh) coming from the southern region or from the still awaited LomPangar hydropower plant production. The situation is further exacerbated by the fact that intra-connections within the eastern region are unstable, causing major power outages within the region's main load center, the city of Bertoua. The absence of a robust interconnection between the two networks creates a situation of suppressed demand in the eastern region of Cameroon, which in turn results in economic lost opportunity as it prevents the timely development industrial projects in that part of the country rich with mining-related potential.

Finally, it is worth noting that there are end users that get their electricity supply outside the mentioned electricity subsystems, such as through rural electrification initiatives and auto-production.

Cameroons intends to emerge as an industrialized powerhouse in Central Africa. With its current population growth rate and non-electrified population statistics, there is an urgency for the country to develop an electric grid capable of meeting these and anticipating the future needs. While the estimated electricity access rate is 65.4%, it is worth pointing out that there is a disparity in electricity access between urban and rural/remote areas: the electricity access rate in urban (resp. rural/remote) areas is estimated at 94.7% (resp. 24.8%), for an urban population of 15.81 Million and a rural population of 11.83 Million.

An analysis in 2019 estimated that Cameroon had about 5.5 million people without access to electricity: the majority of that population lives outside of the perimeter of utility distribution network, as illustrated in Figure 4 below.

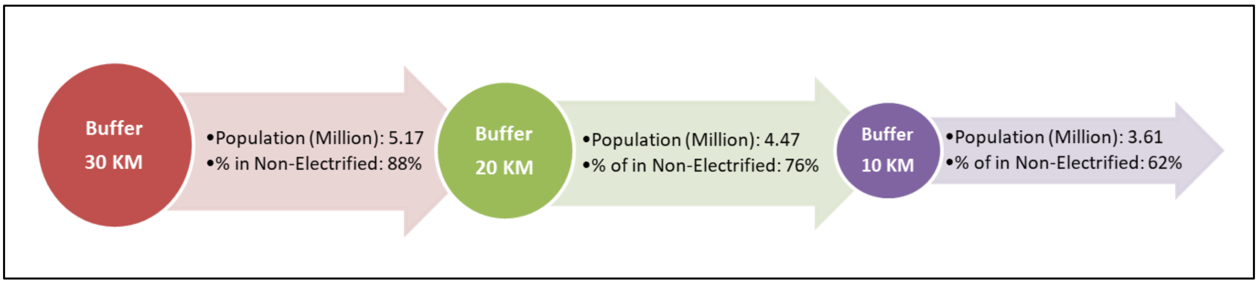


Figure 4: Cameroon's Non-Electrified Population Proximity to the Grid (source: USAID)

Based on recent population growth statistics putting the country's population at 34 Million by year 2030, a status quo in electrification efforts could put the estimate for population without access to 11.78 Million, a situation which can negatively impact the country's economic development.

The GoC is aware of these challenges and eager not only to reduce the electricity access disparity between urban and rural settings, but also meet its universal access timeline economically through a sound energy transition. The road towards these objectives consists according to the GoC, of a concurrent approach. Part of the national electrification strategy intends to expand the on-grid infrastructure in the segments of production, transmission and distribution. The other part consists of developing off-grid electrification initiatives in rural areas or communities too far from the distribution network and for which the distribution utility will not provide network connectivity.

3.3. Cameroon Institutional Power Sector Institutional and Operational Framework

The Government of Cameroon relies on the following key objectives guidelines to foster the roadmap of the above described strategy:

- National Development Strategy (SND30 - Stratégie Nationale de Développement à l'horizon 2030)
- Electricity Sector Development Plan (PDSE2030 - Plan de Développement du Secteur de l'Electricité, last updated in 2016)
- Rural Electricity Development Plan (PDER - Plan Directeur de l'Electrification Rurale, last updated in 2016)

To implement its strategy, the Government of Cameroon relies on an institutional and regulatory framework, defined by the existing Electricity Law. It is worth noting that the institutional and regulatory landscape of the electricity sector in Cameroon has evolved over the last three decades, with the most recent development being the adoption of the Electricity Law of 2011 (Loi n ° 2011/022 du 14 Décembre 2011 régissant le secteur de l'Electricité) and by which amongst others, the transmission and distribution functions were unbundled.

In practice, the power sector in Cameroon comprises several actors participating in the government's implementation of its strategy from the standpoints of policy, technical oversight, financial and regulatory oversight, and in the electricity delivery structure through the generation, transmission and distribution segments:

- At the policy orientation level, the Ministry of Economy, Planning and Regional Development (**MINEPAT** - Ministère de l'Economie, de la Planification et de l'Aménagement du Territoire) is the main actor that defines the objectives for the electricity sector,
- At the technical orientation level, the Ministry of Water and Energy (**MINEE** - Ministère de l'Eau et de l'Energie) is the actor in charge of coordinating the implementation of the national strategy objectives,
- At the regulatory level, the Electricity Sector Regulatory Agency (**ARSEL** - Agence de Regulation du Secteur de l'Electricité: created in 1999) is the institution in charge of monitoring the sector, including tariff structuring and approval, customer rights protection and granting licenses and/or concessions. This public institution is under the technical oversight of the MINEE and the financial oversight of the Ministry of Finance (**MINFI** - Ministère des Finances)
- To address rural electrification needs, the Rural Electrification Agency (**AER** - Agence d'Electrification Rurale: created in 1999) is the actor in charge of developing and

implementing projects aimed at reaching electricity universal access. This public institution is under the technical oversight of the MINEE and the financial oversight of the MINFI. It is worth mentioning that since its reorganization decree in 2022, the AER missions have been redefined as to:

   a) Promote rural electrification, including collecting data and information suitable for investment opportunities in rural electrification as well as electrification with all energy sources
   b) Ensure rural electrification development, including assisting the GoC in drawing up plans for rural electrification in collaboration with the concerned administrative entities such as decentralized territorial collectivities (DTC)

- The Rural Electrification Fund (**FER** – Fonds d'Electrification Rurale: created in 2009) is intended to be the principal program financing vehicle for rural electrification for the country, with contribution of the GoC and development partners. The Fund must ensure the sustainability of rural electrification programs and projects developed in Cameroon, is directed to be used by AER
- The financial support for ARSEL and AER is guaranteed by the MINFI, while the Electricity Sector Development Fund (**FDSE** - Fonds de Développement du Secteur de l'Electricité: created in 2020) is intended to accompany the Ministry of Water and Energy (MINEE) in its mission to execute the government's policy in the sector,
- For the on-grid electricity sector framework, the electricity market model in Cameroon can be considered to be a modified Single Buyer Model with a:
   a) Generation segment composed of a dominant actor, Energy of Cameroon S.A (**ENEO**: created in 2014), a public-private partnership with 44% shares owned by the GoC, 51% shares owned by Actis and 1% shares owned by employees. This actor has a contractual obligation to supply industrial customers ALUCAM, SONATRAL and CIMENCAM. ENEO's generation portfolio installed capacity is 993 MW, which accounts for more than 68% of the country's installed generation capacity. The remaining other suppliers which have a power purchase agreement (PPA) by which their production output off-taker is ENEO:
      - Kribi Power Development Company (**KPDC**). It is an independent power producer (IPP) created in 2013, with 44% of its shares owned by the GoC, 56% shares owned by Globeleq, and 1% shares owned by its employees. KPDC generation portfolio installed capacity is 216 MW
      - Dibamba Power Development Company (**DPDC**). It is an IPP created in 2009, with 44% of its shares owned by the GoC, 56% shares owned by Globeleq, and 1% shares owned by its employees. DPDC generation portfolio installed capacity is 88 MW
      - Maroua Guider Solar Company (**MGSC**). It is an IPP created in 2022. MGSC generation portfolio installed capacity is 30 MW of solar PV in the northen region of Cameroon
      - Electricity Development Corporation (**EDC**). It is a public company created in 2006 that contributes to the power generation space

through its companies Memve'ele Hydro and Mekin Hydro. EDC is a public institution under the technical oversight of the MINEE and financial oversight of the MINFI. EDC generation portfolio installed capacity is 226 MW

- Natchigal Hydro Power Company (**NHPC**). It is an IPP created in 2016 with 40% shares owned by EDF, 20% shares owned by the GoC, 15% shares owned by Africa 50, 15% shares owned by STOA, and 10% shares owned by IFC. Its projected generation portfolio installed capacity by 2024 is 420 MW

b) Transmission segment consisting of one actor, the National Electricity Transmission Company (**SONATREL** - Société Nationale de Transport d'Electricité: created in 2015). A public company, SONATREL acts as the national Transmission System Operator (TSO) and is in charge of developing and managing the HV (≥ 90 KV) national transmission assets.

c) Distribution segment under the management of one actor, ENEO acting as the Distribution Utility, responsible for the development, maintenance and operation of the national MV/LV distribution network (< 90 KV).

Figure 5 below provides a relational description of the energy sector institutional relationship between the actors described earlier.

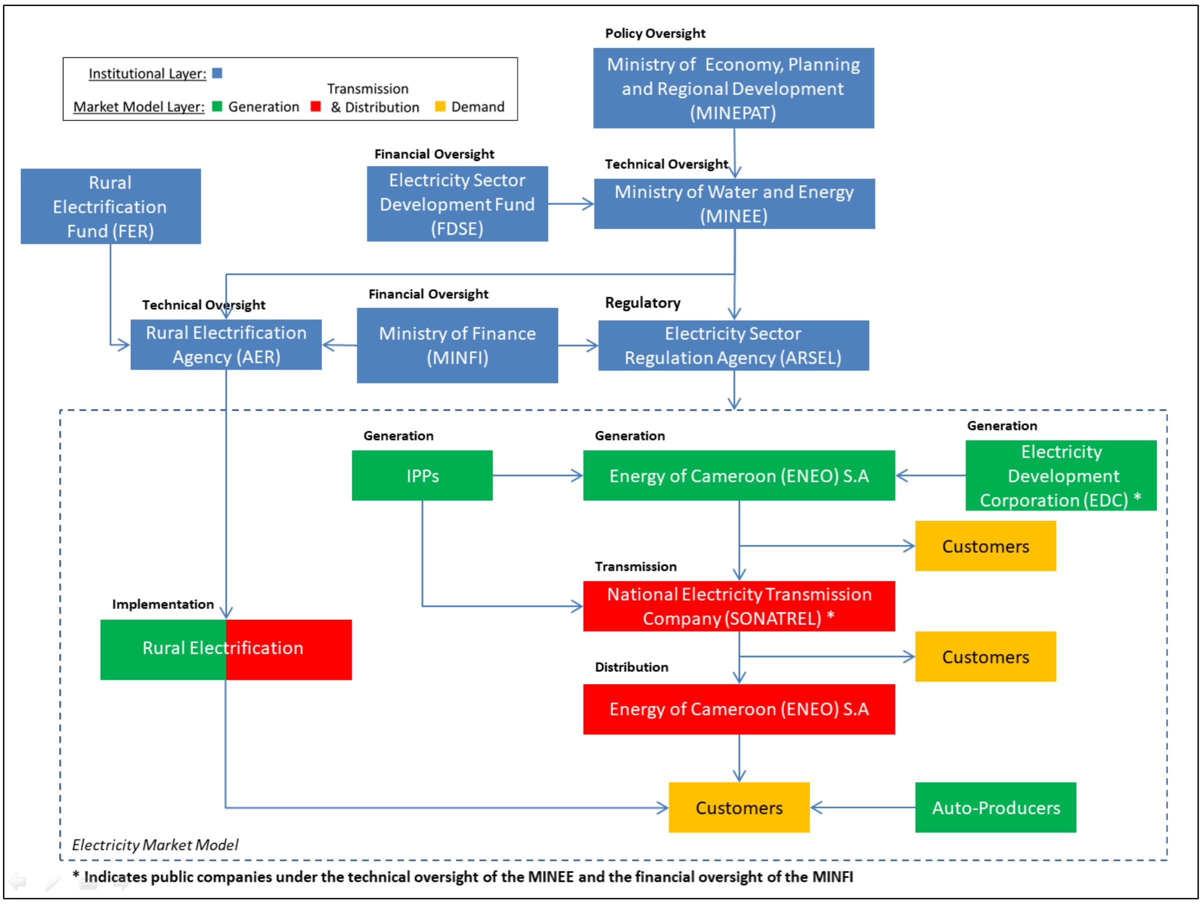


Figure 5: Institutional and Market Model Architecture of Cameroon Electricity Sector (*adapted from the World Bank*)

The semi-public company ENEO S.A. holds a 20-year license in the electricity sector and the three (3) following concession contracts:

- Electricity Generation Concession
- Electricity Distribution and Sale License for Medium/Low Voltage
- Electricity Sale License

While the various institutional decrees do not always explicitly attribute responsibilities in system planning, some collaboration amongst these actors is required in order to strategize the implementation of the government's policies: this is also true when it comes to system energy planning.

To the institutional layer presented above, it is important to note that the power sector in Cameroon also benefits from the financial and technical assistance of international donors, supporting on-grid and off-grid initiatives. It is the case with The World Bank, who supports the operationalization initiative of the National Transmission Network Operator and the increase in access to electricity in underserved areas.

3.4. Power Sector Planning and Implementation in Cameroon

In Cameroon, power sector planning remains the responsibility of the government. The articulation of the current Electricity Law identifies the various several stakeholders (see Figure 5) that are impacted by decisions made in the planning process.

At the heart of the power system planning process in Cameroon is the SND30 (Stratégie Nationale de Développement à l'horizon 2030), a document produced in 2020 that sets the framework for the country's development objectives for the period 2020-2030. One key goal of the strategy contained in the document is to have Cameroon become one of the new industrialized nations by 2035. As such, industrial development is identified as a key driver to the economic and social development of the country. Borrowing from the document, Cameroon intends to produce 5000MW of installed generation capacity by 2035 through the diversification of its supply energy mix with resources from hydroelectricity, natural gas, solar and biomass.

To support this vision, the GoC had relied on the foundations of a Resource Adequacy Master Plan (**PDSE2030** - Plan Directeur du Secteur de l'Electricité), developed in 2014 and lastly revised in 2016. The PDSE2030 covers a planning horizon of 2035 and has set national demand growth and energy export assumptions to develop a program of possible generation resource capacity and transmission investments needed meet these goals. The technical structure of the PDSE2030 consists of four study components:

- A Demand Study: this component aimed at producing an electricity demand forecast for the country. It resulted in three demand scenarios: a low growth scenario, a medium growth scenario and a high demand scenario,
- A Resource Supply Study: this component aimed at establishing an inventory of existing and planned supply resources along with their expected commissioning timeline. Then based on the retained demand scenarios, proposed resource supply development sequences are developed on the least-cost basis and established reliability criteria for the system,
- A Transmission System Study: based on the retained resource supply plan, this component aimed at assessing the robustness of the transmission network and identifying which reinforcements and upgrades are needed to meet desired reliability criteria and planned interconnections,
- An Economic and Financial Evaluation Study: this component aimed at assessing the economic cost of the resource supply and associated network components infrastructures retained to meet the demand scenarios, evaluate its financial viability and propose them as investment plans to meet the sector country's objectives over the planning horizon.

In order to reach its intended generation capacity target, Cameroon plans to invest in the following additional generation portfolio technology capacity: 3300 MW of hydro, 350MW of gas, 130 MW of PV solar, 40 MW of Wind and the retirement of 347 MW of existing LFO/HFO. Such as stated, the needed generation capacity investment must bring up commissioned generation capacity of more than 3000 MW within the next six (6) years and reach the following capacity mix ratios: 85% of utility-scale hydro generation, 10% of gas fired generation and 5% of other renewable generation.

While the PDSE2030 primarily addresses on-grid power sector development, there exists a rural and off-grid power sector development program component, which is articulated in the Rural Electrification Master Plan (**PDER** - Plan de Développement d'Electrification Rurale). The PDER approach to power sector planning for rural and remote areas relies on the concept of communities clustering with the purpose to define localities that can become candidates for electrification and thus help the GoC meet its goal of electricity universal access. The localities can be grouped as either falling within the contractual perimeter of the distribution utility and in which case their electrification remains its responsibility, or otherwise in which case the electrification responsibility technically belongs to the AER entity according to which about 9,000 localities in the country remain without electricity. Under the latter, electrification can occur through a scheme aiming at main grid connectivity or otherwise, depending what's most practical. It is in that context that a 1,000-localities electrification project between the GoC and Huawei has been launched in 2016, of which 350 are close to completion. Similar initiatives are under way by another actor in this field, Renewable Energy Innovators Cameroon (REI-C) who operates 8 mini-grids in the country. With the growing interest in solution suppliers for rural and off-grid electrification, the GoC should consider local grid architecture and tariff schemes that will 1) accelerate the electrification footprint expansion and 2) provide financial sustainability for the implemented systems and foster the communities' economic development.

Cameroon's last Resource Master Plan was developed for a planning horizon 2013-2035. The plan considered an economic growth framework of three scenarios: a high growth scenario of 6.53%, a medium scenario of 6.05% and low growth scenario of 3.81%. In the development of the proposed investment plans within the PDSE2030, the low growth scenario was discarded for reason of being too pessimistic. As such and following the investment plans development approach characterizing the PDSE2030 study components, the resource adequacy and transmission network upgrade investment plans only covered the medium demand growth and high demand growth scenarios.

To date, some of the projects initially decided and treated as an input to the PDSE2030 have not materialized. In the medium demand growth scenario which was the one retained as the most likely, some of these projects for the:

- RIN include the hydropower generation project of Bini Warak (61.5 MW expected by 2018), the MBinjal hydropower generation project (83 MW), the hydropower project generation project of Mbam Amont Phase 1 (84 MW), the solar power generation project of Maroua I (60MW expected by 2014). Regarding the latter and other solar generation contribution in the RIN, it was further assumed that they would not participate in mitigating the evening peak, a condition that nowadays could be addressed with adequate energy storage investment and sizing,
- RIS include gas-fired generation project extension at Kribi (114MW expected by 2016), the hydropower generation project at Menchum (84 MW expected by 2017),
- RIE (now RIS) include the thermal generation project at Colomines (18 MW expected by 2020).

Furthermore, the medium demand growth scenarios considered that the interconnection projects Cameroon-Nigeria and Cameroon-Chad links would be in service by 2013 and 2015 respectively. These and a considerable amount of other planned industrial projects did not materialize per the expected timeline.

Conversely, historical data of Cameroon's economic growth indicate that its GDP has reached an average of 3.87% over the last decade. Similarly, the projected GDP average over the next five years is estimated at 4.4%, as illustrated in Figure 6.

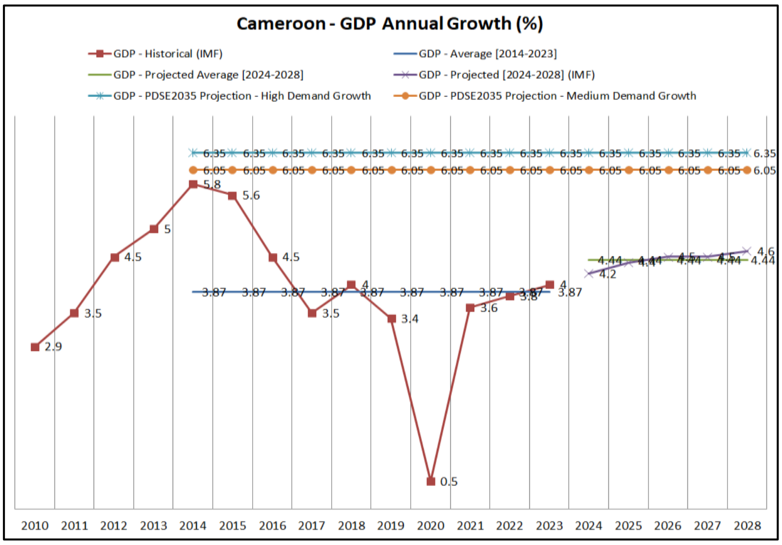


Figure 6: Cameroon's GDP Annual Growth: Historical and Projected (sources: IMF, PDSE2030)

A direct implication of the historical indicators is that some of the assumptions made in the elaboration of the PDSE2030 have not materialized, and might still be difficult to achieve in the medium term based on current projections. An implied consequence is that the derived resource adequacy and transmission network expansion program could not be implemented, leading to a situation whereby electricity resource supply shortages would be severe and exacerbated by economic conditions that altogether would leave the power grid in a state of poor infrastructure health, unless resource and an overall energy system planning reassessment would take place. While this might have been the case, it appears the GoC has nevertheless started rethinking its timeline in infrastructure investments in some areas and reassessing its steps towards the SND30 and Vision 2035 goals. One indication of such includes the commitment and construction of Natchigal Upstream at 420 MW soon to be completed in 2024. Another one is the recently completed RIS-RIE transmission link in 2022 albeit not optimally, a project that was initially excluded in the PDSE2030 recommendations.

Over the years, there has been no formal revision of the PDSE2030 nor the PDER. Nevertheless, ad-hoc workshops and meetings between sector stakeholders have taken place. This is what has led to the 2023 published Cameroon's Electricity Sector Recovery Plan (**PRSEC** - Plan de Redressement du Secteur de l'Electricité au Cameroun) identifying about 820 Billion FCFA of sector investment needs for the period 2023-2027. The PRSEC focuses its investment priorities on seven (7) areas: shifting the energy production mix towards a less expensive portfolio, electricity networks reinforcements and expansion, electricity sector financial stability, improving electricity sector actors performance, increasing electricity access rate, increasing electricity industrial demand consumption, and capacity building and local skills development.

The next sub-sections will look into topics that can help us understand the current approach to power sector planning and implementation in Cameroon. The assessment can also provide betterment opportunities insight through gap analysis based on our experience and best international practices. The topics are: hydropower resources planning for the Sanaga river, integration of the Natchigal hydropower into the grid, coordination across the generation, transmission and distribution functions, concessions agreements between the GoC and some entities, monitoring mechanisms and information systems for utility and financial performance, grid codes and charges, hybridization of solar and hydropower, and merit order dispatch procedures.

3.4.1. Hydropower Resources Planning for the Sanaga River

As noted, Cameroon plans to capitalize on its hydroelectric potential for its energy supply mix target. As articulated earlier, this comes from the fact that Cameroon's water ways are richly fed by four bassins: *Congo* Bassin, *Lac Tchad* Bassin, *Niger* Bassin and *Guinea Golf* Bassin. Further, the Sanaga within the Guinea Golf Bassin is the river in Cameroon with the highest hydroelectricity potential. In fact, the current installed hydro capacity of the country sits mainly on the Sanaga River: Edea run-of-river hydro generation plant at 276 MW and Songloulou Generation plant at 384 MW, Long Pangar Usine de Pied at 15 MW.

As mentioned earlier, a 420 MW of run-of-river hydropower generation capacity upstream on the Sanaga river will be commissioned in 2024, at Natchigal in the Lékié Division. Additionally, other sites defined on the river have gained further interest from the government and are becoming serious candidates to hydropower development on the Guinea Golf basin in the near-term. Such sites/projects include:

- Kikot run-of-river hydropower project estimated at 450-500 MW capacity range. This project is expected to have technical and environmental studies started in 2022, and construction to begin in 2025, with an expected commissioning year of 2030,
- Grand-Eweng run-of-river hydropower project initially estimated at 1,800 MW capacity. A letter of intent on this project had been signed in 2019. We are learning that construction is expected to begin in 2024 for full commissioning in 2028, albeit with a revised generation capacity of 810 MW.

Knowing the hydro generation capacity potential on the river Sanaga, the GoC had initiated a program to look into hydropower resources planning potential on the river Sanaga. The ongoing study should help decision makers in Cameroon get a refined perspective on how to best initiate investments in hydropower generation on the river Sanaga. From a planning standpoint, while the study will assess the MWH-potential on the river, it will also take into consideration how changes in climate would impact such estimates, a condition not currently assessed in spite of the observed climate circumstances. One would also expect for social and environmental implications in the affected localities to be assessed and mitigation solutions proposed.

The potential hydro generation sites identification on the Sanaga river dates from the early 1980s (see Figure 7). In 2014, a study indicated that it is unlikely that hydropower generation energy on the Sanaga river wouldn't decrease more than 20% due to climate change. Additionally, water regulating capability infrastructure completed in 2016 was added on the river in the form of the Lom Pangar dam, with the intent to mitigate the water availability variability associated with the SongLoulou and Edea hydropower facilities.

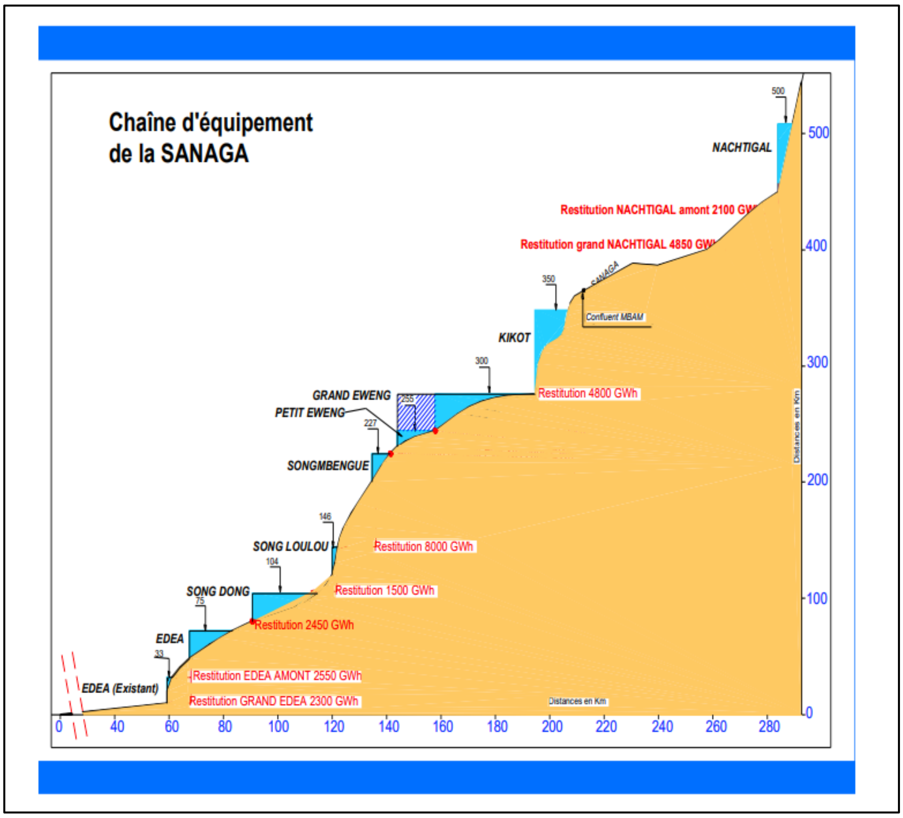


Figure 7: Estimated HydroPower Energy Potential on the Sanaga River (source: Sebastien Tchuidjang Tchouaha, HydroPower in Cameroon)

It is important to understand that while nine (9) potential sites have been identified on the Sanaga river, and mainly in the form of run-of-river projects, the GoC should undertake a systematic update of the study on hydro generation alternatives potential on the river. Such study update should take into considerations the major developments in climate change understanding for the region and the country, specifically with regards to water availability, predictability and hazards water-related events may cause.

Within the last half-century, the hydrological pattern in Cameroon has changed and continues to do so, as illustrated in Figure 8. Undoubtedly, the increased hydrological variability observed could impact the reliability of the river flows, thus impacting the available capacity not only of existing river-based hydropower plants but also that of future considered plants or those in the projects pipeline.

Anecdotally, the National Observatory on Climate Change has issued warnings for the upcoming dry season (source: ONCC Bulletin Saisonnier de Previsions Climatiques Pour les mois de Decembre 2023, Janvier 2024 et Fevrier 2024), characterizing it as a very harsh dry season. The harshness could result in high temperatures, describing the drought risk the country will face during the upcoming dry season. This seems to resonate with the international community assessment that southern Africa will face in the next decade an increased exposure to climate hazards, characterized by prolonged and severe droughts seasons.

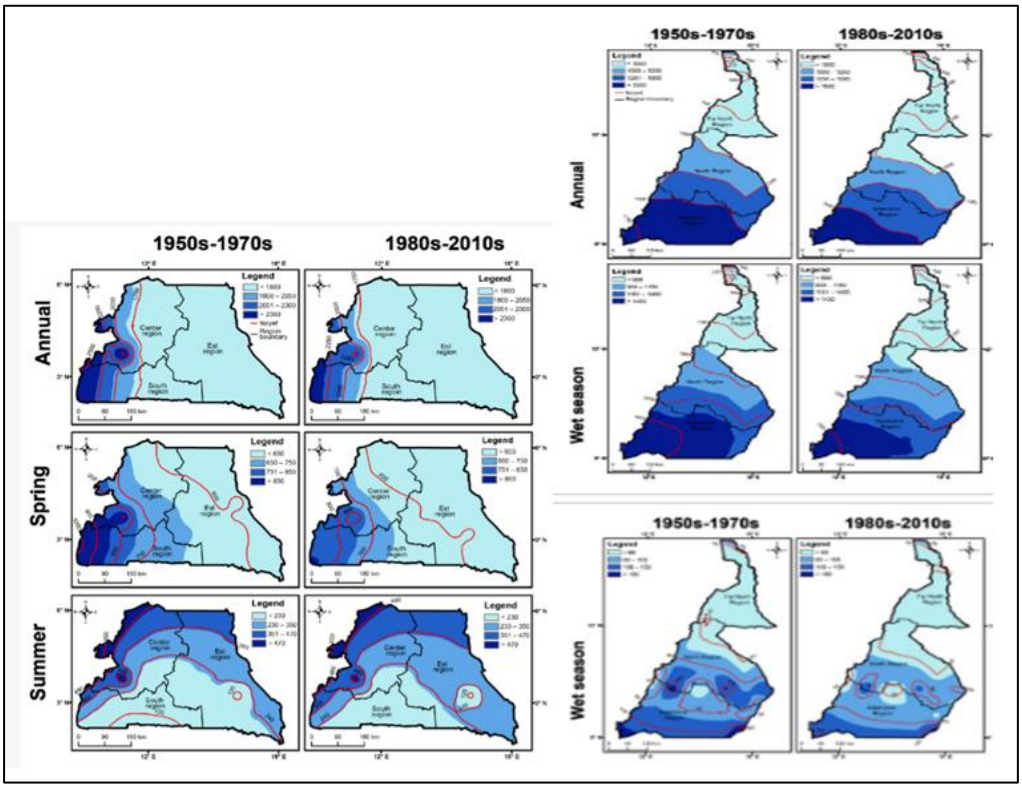


Figure 8: Spatial Distribution of Mean Rainfall for the Southern and Northen Region of Cameroon (source: Ebode, Analysis of the Spatio-Temporal Rainfall Variability in Cameroon over the Period 1950-2019)

The Water Law in Cameroon has not been updated since 1998, and there seems to be conflicting interests between water supply and energy, a lack of communication amongst stakeholders. Our review has found that there is no active River Basin Management Plan from a comprehensive standpoint. Simply put, water resources management in countries like Cameroon, must be initiated and continuously monitored to include an Integrated Water Planning Program that systematically and for each river/basin, looks into how water resources should be allocated competitively and economically for the households, commercial and industrial needs which include hydropower electricity. Our findings indicate that there is no active Water Resource Management (IWRM) program accounting for water planning comprehensively.

3.4.2. *Integration of the Natchigal Hydropower Into the Grid and Investment in Distribution to Meet the Rising Industrial Demand*

Natchigal Hydropower is the latest hydropower project currently in construction on the Sanaga River in Cameroon. The project was initiated by GoC, EDF and IFC in 2013: these three entities jointly own the project at 30%, 40% and 30% respectively. The project was subsequently identified as a generation supply option in the 2014 Master Plan. Technically, the Natchigal Hydropower plant is estimated at 420MW: it is built downstream the Lom Pangar regulating dam, thus mitigating water variability risk for the infrastructure. Current progress on the construction is estimated at 95% and the plant will be operated under an IPP framework. As planned, Natchigal Hydropower will boost the generation's capacity by 30%, contributing to a reduction in energy capacity deficit in the country. With that capacity increase and the improved water regulating capability it should benefit from, the situation in generation outage and operations costs is expected to improve. Notwithstanding, the availability of the generation plants of the country's generation portfolio must continue to improve: the ageing generation infrastructure and somewhat then neglected maintenance program have led to higher generation unavailability and supply inadequacy, in contrast to the installed capacity.

Naturally, the power generated from Natchigal should replace more expensive generation sources (e.g. rental and operational costs associated with HFO/LFO generation units) during dispatch operations, assuming network constraints do not impede the process, thus resulting in lower system operational costs. However, there remains a general concern that having 80% of the generation capacity's projection as hydro in the supply mix introduces an additional layer of risk, due to climate change and as observed within the last decade.

Natchigal's generation capacity was initially supposed to be absorbed by industrial demand, part of which unfortunately did not materialize. Such projects included the Bauxite exploitation project tied to the Kribi Deep Sea Port and Alucam's extension plant planned for 2021. Similar concerns on other non-materialized industry-demand inspired generation projects (e.g. RTA Aluminum Factory and the Song-Mbengue Hydropower project on the Sanaga River) are creating challenges from a planning standpoint, as they produce an environment by which generation projects materialization certainty is questioned. It also brings up questions around the transmission and distribution networks readiness to absorb the energy coming from these generation projects.

In its current configuration, Cameroon's transmission network cannot immediately absorb the projected full power to be injected by the Natchigal hydropower plant, without risking the reliability and security of the system. It is likely that concerns of transmission lines overloading over a system already characterized by low security margin materialize. As such, network upgrades must be identified in coordination with a gradual capacity expansion for the considered generation sites under development. These upgrades typically consist of network reinforcements (e.g. substations transformers upgrades) or the construction of new transmission lines towards existing load centers or new ones to be identified. This approach in the sequential implementation of a generation-to-transmission-to-distribution infrastructure development allows for the mentioned segments to study the network impact of the considered infrastructure and coordinate the investment deployment sequence needed to address the identified issues. Thankfully, this seems to be the approach taken by the national Transmission System Operator which has identified a couple of network upgrades that should be undertaken to allow for an increased hydropower participation in the country's energy dispatch procurement. Failure to proceed as such could result in the non-full utilization of the Natchigal generation capacity, continued dispatching of more expensive generation supply resources or even load shedding for purposes of system network security.

3.4.3. Coordination Across the Generation, Transmission, and Distribution Functions

With the unbundling of the generation, transmission and distribution functions in Cameroon, the framework of the national system operations has known several challenges. In fact, all the actors in their respective segment are dealing with either a missing or an ageing infrastructure that has not undergone coherent maintenance program nor bold modernization initiatives.

3.4.3.i. The Generation Function

Concerning the generation segment, Cameroon's approach to resource adequacy can be described as consisting of the management and development of three portfolios: the on-grid generation portfolio, the off-grid generation portfolio and auto-producers portfolio.

3.4.3.i.a. Grid-Connected Generation

With a total grid-connected installed generation capacity closer to 1,600 MW as illustrated in Table 2 below, Cameroon's net available capacity still falls short the country's demand.

Network	Genration Location	Fuel Type	Installed Capacity (MW)
RIS	Kribi	Gas	216
RIS	Dibamba	HFO	86
RIS	Limbe	HFO	85
RIS	Oyomabang 1	HFO	24.4
RIS	Oyomabang 2	HFO	24.4
RIS	Logbaba 1	LFO	5.4
RIS	Logbaba 2	HFO	12
RIS	Logbaba 3	Gas	30
RIS	Edea	Hydro	276
RIS	SongLoulou	Hydro	384
RIS	Memve'ele	Hydro	90*
RIS	Mekin	Hydro	15
RIS	Ahala	LFO	21
RIS	Bamenda	LFO	20
RIS	Bafoussam	LFO	9
RIS	Mbalmayo	LFO	10
RIS	Ebolowa	LFO	10
RIS	Bassa 2&3	Gas	20
RIN	Lagdo	Hydro	72
RIN	Djamboutou	LFO	20
RIN	Ngaoundere	LFO	1
RIN	Maroua 1	LFO	10
RIN- isolated	Kousseri	LFO	2.8
RIN- isolated	Poli	LFO	1.2
RIN- isolaed	Touboro	LFO	0.9
RIN	Maroua-Guider	PV	36
RIN	Aggreko-Maroua	LFO	10
RIE (now RIS)	Bertoua	LFO	9.6
RIE (now RIS)	Lomie	LFO	1.9
RIE (now RIS) - isolated	Garoua-Boulai	LFO	0.3
RIE (now RIS) - isolated	Yokadouma	LFO	0.1
RIE (now RIS) - isolated	Betare-Oya	LFO	0.1
RIE (now RIS)	Aggreko-Bertoua	LFO	5
RIE (now RIS)	Lom Pangar	Hydro	30

Table 2: Installed Generation Capacity in Cameroon (2023) (*) (**)

(*) Initially a 211 MW, the site can only produce 90 MW out of its 211 MW installed capacity because of a lacking transmission line to export the power from the facility

(**) Natchigal not being counted and auto-production excluded

Contrasting the current installed generation capacity to the installed capacity projections in the SND30, the gap between the desired generation capacity and the achieved installed generation capacity is expected to be around 2,000 MW by 2025. Meeting the SND30 generation capacity target will require developing about 3,000 MW of generation projects within a 6-year timeframe (see Table 3), which could be extremely challenging. As such, there is a risk that the current approach to resource adequacy planning timeline might not be met.

2024 Commissioning of Natchigal: almost certain

	2016 [Baseline]	*2020*	*2025*	*2030*
SND30 - Projected Installed Capacity (MW):	1,401	1,650	3,500	5,000
Likely (To Be) Installed Capacity (MW):	-	1,581	2,001	?
Missed Capacity Target (MW):	-	69	1,499	?
Missed Capacity Target (%):	-	4.18%	42.83%	?

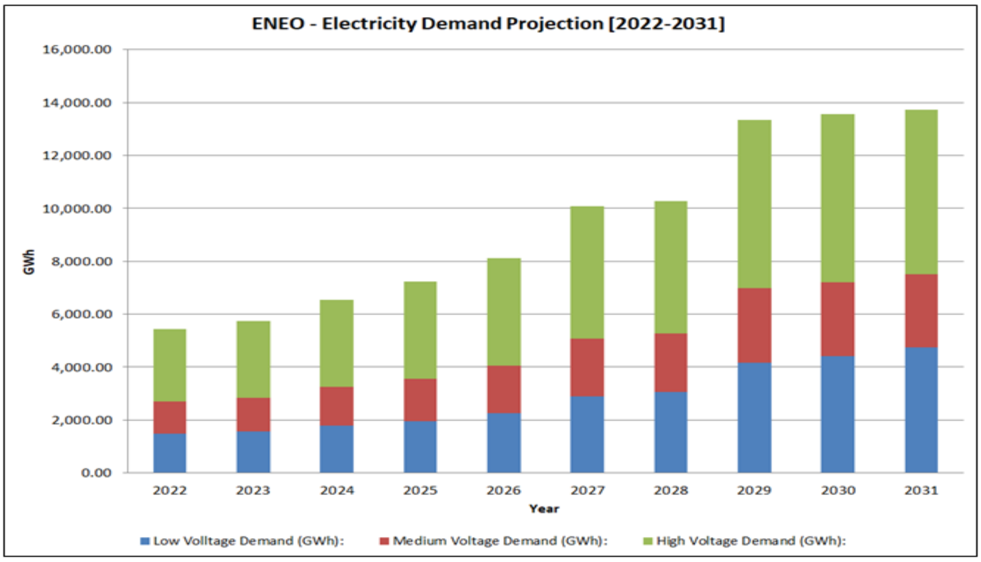
GoC Proposed Generation Projects to Meet 2030 Capacity Target

Project Name	*Expected Installed Capacity(MW)*
Limbe: Gas-Fired Plant	350
Bini A Warak: Hydropower Plant	75
Kikot: Hydropower Plant	500
Grand Eweng: Hydropower Plant	1080
Menchum: Hydropower Plant	72
Ngoila: Hydropower Plant	84
Katsina-Ala: Hydropower Plant	285
Chollet: Hydropower Plant	600
Northen Regions: Solar PV Plant	250

About 3,000 MW to develop within 6 years

Table 3: Installed Generation Capacity Expectations (source: MINEE, SND30)

Factors such as the country's difficult economic context, tardiness in projects execution, missing or delayed demand, inadequate projects structuring leading to the inability to secure financing or reach financial closure and the country's internal conflicts can explain this situation. On the other hand, the impact caused by this supply resource inadequacy on the country's economic growth must foster a healthy debate on how to better structure the grid's resource adequacy and transport-distribution planning and implementation framework to meet the projected increasing demand. On the latter, one can observe that demand projections based on the PDSE2030 did not materialize; they are also far from recent estimates by the Distribution Entity (see Figure 9). These observations, coupled with the economic growth statistics presented earlier further stress the need for the planning process in Cameroon to be reviewed and updated frequently.



PDSE2035 Projected Demand (GWh)

	2015	2020	2025	2030	2035
Medium Growth - Total:	6,357	10,126	14,922	20,525	24,413

Figure 9: [2022-2035] Cameroon's Projected electricity Demand (sources: ENEO, PDSE2030)

3.4.3.i.b. Small Hydro and Variable Renewable Energy

In addition to its large hydropower potential, Cameroon is also known for a non-negligible small hydropower (SHP) potential. This potential is estimated at 970 MW for sites with up to 10 MW-capacity. To date, only one such site has been developed in the country, at Mbakaou (1.5MW) in the Adamawa region: we can thus consider that the country's SHP potential is untapped. Figure 10 below shows the progress in SHP potential assessment and projects development over the last decade.

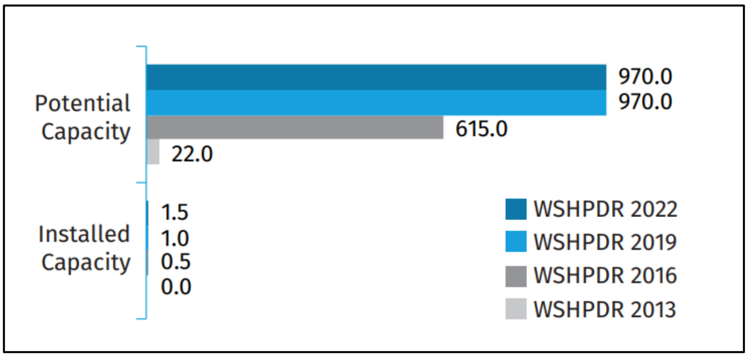


Figure 10: Small Hydro Power Assessment and Installed Capacity in Cameroon [2013-2022] (source: UNIDO 2022 Report)

We are not aware of ongoing SHP planning or project development In Cameroon by AER, the public entity responsible for rural electrification managing the SHP sub-portfolio of sites of up to 5MW-capacity. Notwithstanding, the GoC through the MINEE intends to develop fifty small hydropower projects throughout the country.

Regarding variable renewable energy, Cameroon is slowly moving towards solar PV projects implementation, such as recently seen with the commissioning of the Maroua-Guider 36MW PV plant. Studies have shown that Cameroon has a decent PV power potential. As can be seen in Figure 11 below, the northern part of the country can provide a daily average in the [4.4 – 5.0] Kwh/Kwp range. Similarly, the western part of the country in the RIS network is estimated at a [4.0 – 4.40] Kwh/Kwp range. In the northern part of the country, that potential could be used to further strengthen the supply capacity within the RIN network.

Overall, Cameron's PV power potential could be used to complement its hydropower's current and planned generation infrastructure, thus offering energy supply alternatives for the RIS or RIS-RIN integrated network. Moreover, this solar power potential is becoming a credible supply option to consider both at utility and non-utility scale in light of the technology advances in the solar PV industry and continuing declining costs. In an environment where the RIS and RIN networks are connected and an integrated transmission network becomes the country's grid configuration, the natural complementarity between the RIS network that is dominated by large hydropower generation infrastructure and the RIN network abundant solar power should be considered. Such complementarity offers further benefiting options whereby an additional water regulating framework for hydropower generation is provided, faster deployment in modular generation resources could be implemented, additional energy storage capabilities could be developed for capacity-strained areas, and savings on otherwise more expensive network extensions or generation expansion from a status quo scenario (i.e. not pursuing solar power development initiatives) could be achieved.

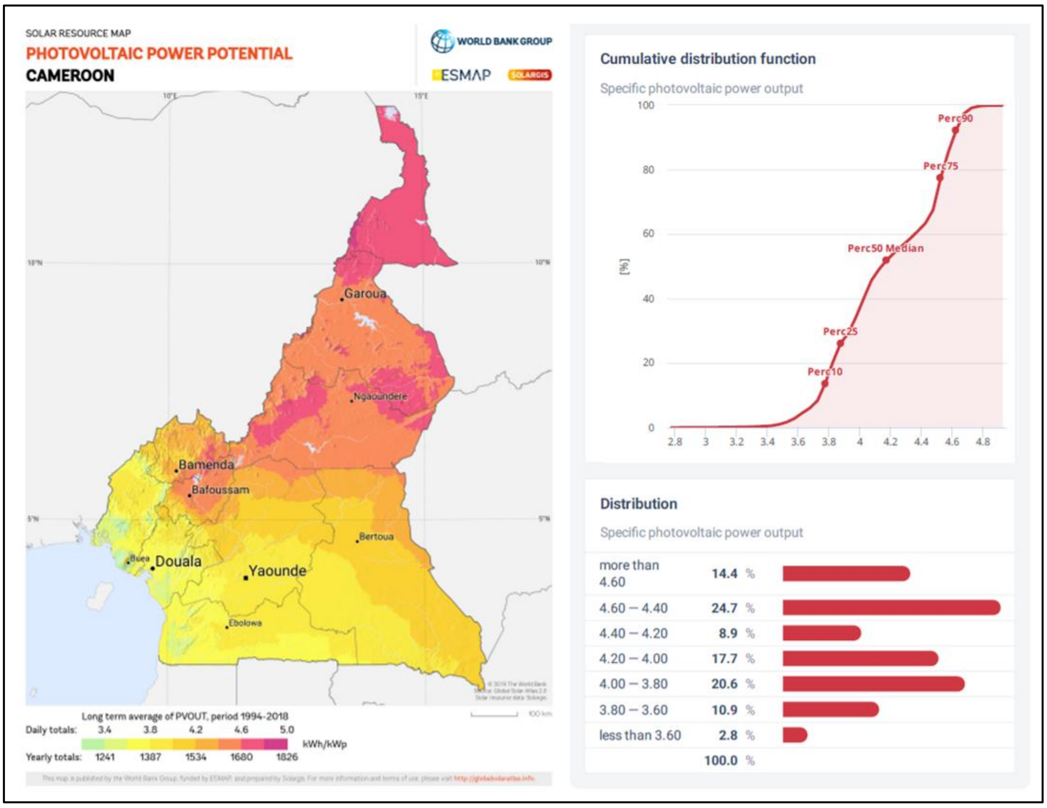


Figure 11: Cameroon Solar Power Potential (source: WorldBank-2018)

We have learned that the GoC has recently launched a Cameroon 2020 Photovoltaic Power Project by which off-grid energy consumers and on-grid unserved energy consumers could be reached with a projected 500MW-installed PV capacity in two phases of which the first, has already begun and is 37% under completion will help develop a 110MW solar PV sub-portfolio as illustrated in Table 4 below.

Network	*Site*	*Projected capacity (MW)*	*Status*
RIS	*Sangmelima*	*5*	*completed*
	Meyomessala	*2*	*completed*
	Mengon	*1*	-
	Nkilzok	*2*	-
	Yingui	*1*	-
	Ebengbis	*2*	-
	Kyeossi	*6*	-
RIN	*Maroua I*	*60*	-
	Maroua II	*30*	*completed*
RIE (now RIS)	*Mbalel, Oum*	*1*	-

Table 4: Cameroon 2020 Photovoltaic Power Project – Phase I Portfolio (source: UNIDO)

Cameroon is also said to have some wind, geothermal and biomass energy potential.

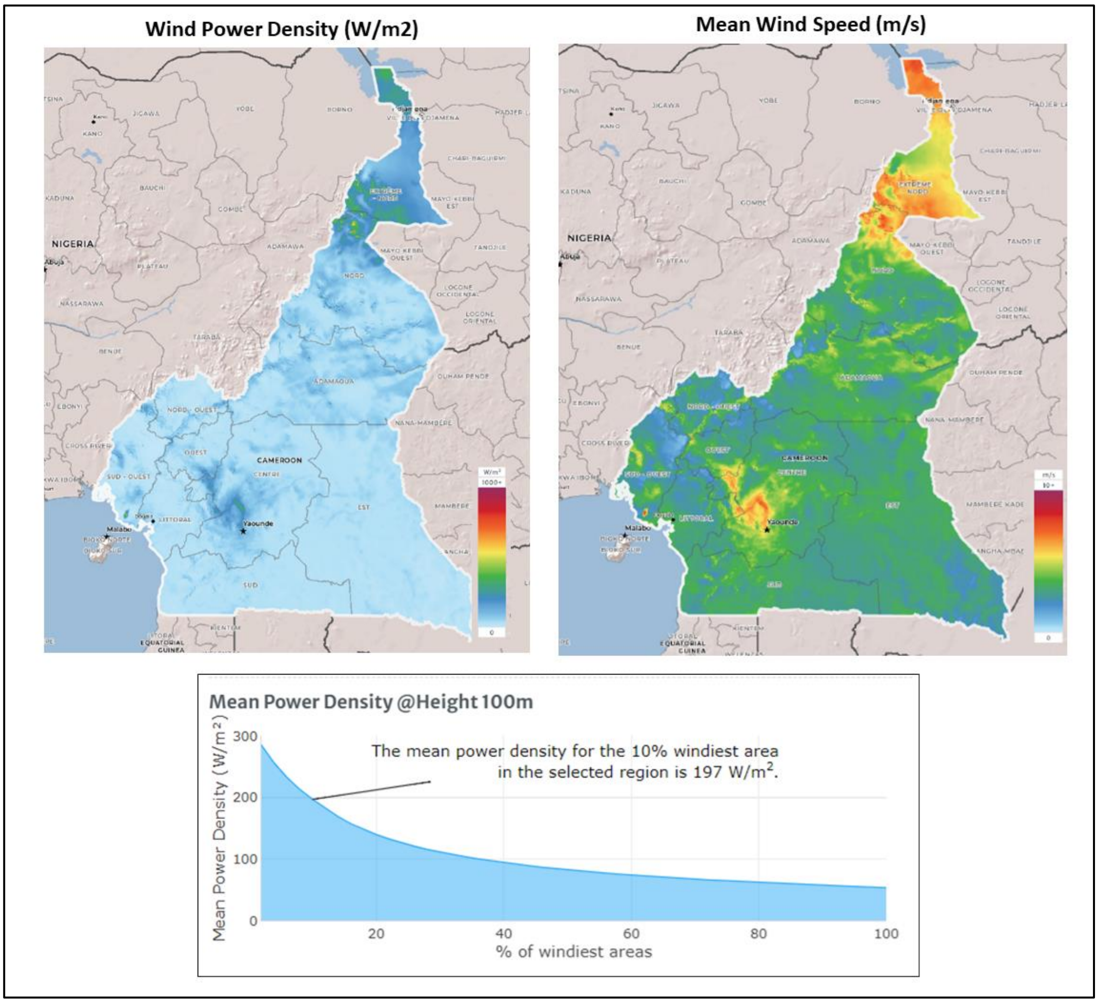


Figure 12: Wind Power Potential (source: Global Wind Atlas)

Preliminary data as shown in Figure 12 indicate that the areas with adequate wind potential in Cameroon are the Centre, North and Far North regions. While there is no wind generation portfolio program or existing infrastructure in Cameroon, we have learned that there is a 42 MW wind PPP - based project to be constructed (unknown commission date) at Bamboutos, in the West region of the country.

There is no known energy used of geothermal resources. Biomass is used extensively and predominantly in rural areas. Notwithstanding, there is no major extensive study or robust data atlas that provide MW-potential for these energy sources in Cameroon for the moment.

Naturally, a planning power sector expansion strategy that includes solar power development will contribute to the Nationally Determined Contribution (NDC) goals to help Cameroon meet its 2035 renewable energy mix diversification consisting of 11% in small hydro (for infrastructure-capacity no greater than 5MW), 7% in biomass, 6% in solar and 1% in wind energy resources. Other areas of NDC commitment include more hybridization of thermal power plants with solar energy and better electricity demand management.

3.4.3.i.c Off-Grid and Rural Electrification

With the concern on emissions reduction, energy transition, meaningful potential in small hydropower and solar irradiation, off-grid and rural electrification programs will have to migrate form small thermal solutions to more renewable-based infrastructures. The recent operational decree amendment on AER functions has recentered its priorities on the promotion and development of rural electrification. Thankfully, the AER is moving towards greater collaboration with the CTDs to better develop programs for meaningful local electrification. One expected outcome of this collaboration should be an inventory of targeted areas whose electrification is deemed vital for the communities. This approach which has the merit of engaging directly the concerned communities must fit within a strategic rural electrification planning component derived from an integrated sector planning framework.

The strategic planning component previously mentioned should lead to a coordinated action plan of rural electrification implementation encompassing design, construction, operations and maintenance. It must all take into consideration ongoing initiatives such as the Huawei electrification project and advise on how best to include future initiatives by other private developers for the purpose of a coherent rural electrification scheme. However, the success of such implementation at full scale requires sufficient human talent, adequate technical infrastructure and processes, and funds to support the related activities.

In reality, there is a timid development of SHP, variable renewable energy projects and biofuel-based generation projects in the country. From a sector and network expansion standpoint, this is slowing the deployment of efficient off-grid and rural electrification programs in general, and of distributed energy resources solutions in particular. Some reasons for this weakness can be attributed to the:

- Lack of coherent renewable energy (i.e. outside of utility-scale hydropower or solar generation) master plan due to the multiplicity of renewable energy projects initiatives from various entities, such as of renewable energy programs developed by ANAFOR, MINFOF and Decentralized Territorial Communities, and sometimes other ministries such as MINEPAT or MINDEVEL. Added to the inadequate information sharing and collaboration between them, conflicts of interest tend to impede projects planning efficiency, as each entity approaches the planning process with its own objective. As a result, roadblocks to the implementation of renewable energy projects and the cohesiveness of a comprehensive renewable energy program exist. The absence of a Renewable Energy Master Plan (REMP) constitutes a planning challenge.
- Absence of an adequate policy and regulatory framework encouraging the promotion and development of renewable energy projects, including long-term financial support mechanisms for their implementation and deployment.
- Absence of an harmonized regulated tariff structure for deployed distributed energy solutions in the country (outside of the contractual perimeter of the distribution utility). One could observe that the tariff structure private sponsors deployed mini-grids is sometimes higher (100 FCFA/KWh for Huawei, SolKamTech) than the

distributed utility LV 2nd tier tariff (79 FCFA/KWh). The tariff articulation for rural electrification is further concerning when noticing that while tariffs for AER projects are determined by the MINEE, there is no such determination concerning projects from private developers. And with the previously mentioned example, this situation presents a rural electrification long-term sustainability concern, especially knowing that these electrification solutions target an economically disadvantaged portion of the country's population,

- Need for trained expertise in the subject to boost the vulgarization of renewable energy technologies,
- Absence of local capacity expertise for manufacturing electromechanical equipment, the installation, the operation and the management of the deployed renewable energy infrastructure,
- Absence of technical standards in the development of rural and off-grid projects, with the consequence of possible non-harmonization and challenges towards future distribution network anchoring,
- Absence of practical industrial research and development to look into the practical substitution of thermal fuels by biofuels, and the creation of a market for derivative products
- Inadequate functioning of AER funding. As the entity responsible for the promotion and implementation of rural electrification projects, the AER has not been successful in raising funds, further leaving its activities coordination difficult.

The PDSE2030 from which the National Master Plan was derived in its approach to energy supply options had mainly focused on large hydropower, gas-fired plant projects and other thermal options. As the majority of the sites for SHP, Solar PV and wind are likely located in semi-rural or rural areas, strategies must be developed to build distributed energy resources (DER) in co-existence with the backbone network expansion. Overall a coordinated approach to planning for demand-side, grid-based integration of renewable energy in general and variable renewable energy in particular is needed. Further, as a country rich with renewable energy potential, the option for distributed energy resources, economically competitive and operationally more efficient, connected to the distribution network can provide options for transmission asset or centralized generation resources investment deferral. Such options must be assessed in conjunction with the others from an integrated standpoint in the development of a robust power sector planning.

The imbalance in supply-demand capacity in spite of considerable efforts by the GoC to address the resource adequacy problem coupled with an ageing and poorly maintained infrastructure have led to a degradation of the quality of service for end users. That degradation is experienced by frequent load shedding events, unserved energy (also known as energy not distributed) in the form of prolonged power outages or energy supply capacity deficiency in some areas, and unstable power quality both in terms of voltage and frequency. Statistics back in 2015 estimated that more than 81% of estimated 60^{+} GWh in unserved energy was caused by both infrastructure failure and the need for energy rationing.

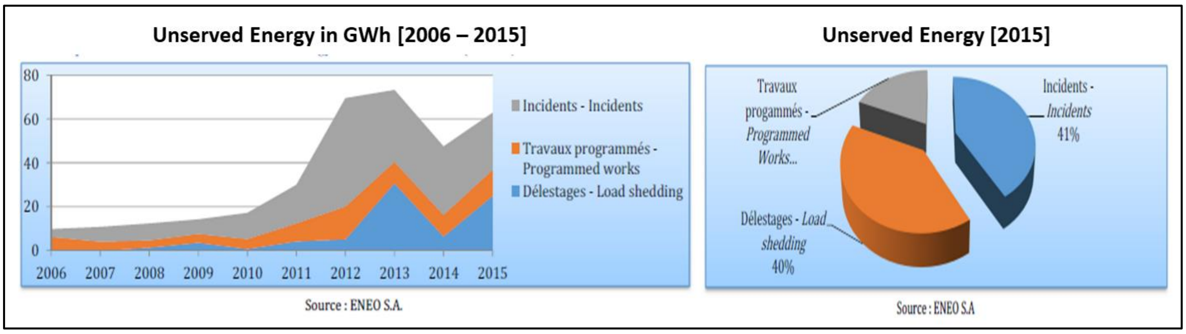


Figure 13: [2006-2015] Estimated Unserved Energy (source: MINEE- 2015 Energy Balance)

Updates to these statistics should be made available and computed to help assess the current situation. Further, as the economic cost of unserved energy is not reflected in the study that has led to the 2014 Master Plan, it should be considered and accounted for going forward in the planning process. Some end-users needing to have a better quality and continuity of service have invested in their own generation options. The size of this production segment which was estimated at 450MW in 2021, a 68% increase from its 2013 estimates, attests to the challenges associated with reliable and secure energy delivery.

As a system with low capacity reserve margin, Cameroon's grid operational planning must continuously monitor and improve generation plants reliability indicators. These indicators defined in the industry allow generation management to focus on how to better prepare the generation assets for operations, and anticipate on the maintenance programs needed to meet their operational efficiency targets. In Cameroon, generation operators are assigned availability targets and mandated to provide information regarding their achieved availability (see Figure 14) over a certain period. This information is then used by the regulating entity to take appropriate actions for the targets to be revised or for the infrastructure operations to be improved.

ENEO's production segment over the planning period 2026-2031 is accounting for 75% of CAPEX in the area of reliability improvement, namely the improvement of the availability of the production units under its management. This is an encouraging initiative as generation management overall should be directed to work on improving their plants net availability rate by reinforcing maintenance and rehabilitation programs in order to reduce their plants failure and forced outage rates, especially in context of low generation capacity margin.

KPI	K2021	R2021	K2022	R2022
Generation				
Songloulou availability rate	82.5%	94.30%	82.5%	93.46%
EDEA availability rate	82%	81.47%	82.10%	89.53%
Lagdo availability rate	66.1%	85.00%	66.6%	97.55%
Availability rate of connected thermal power plants	93.73%	70.71%	93.73%	73.83%
Remote thermal power plant availability rate	83.73%	71.77%	83.73%	82.38%
Hybrid power plant availability rate	90%	75.04%	90%	85.39%
Fuel stocks for remote thermal power plants	10	7.99	10	6.87
Access to electricity				
Connections-first access (u)	43 800	95 234	57 300	130 297
Regularisation connections (u)	33 700	126 230	37 100	65 091

KPI = Key Performance Indicator ou Indicateur Clé de Performance

K2021 = Objectif ou résultat attendu par l'Etat en 2021

R2021 = Résultat réalisé par Eneo en 2021

K2022 = Objectif ou résultat attendu par l'Etat en 2022

R2022 = Résultat réalisé par Eneo en 2022

Figure 14: Generation Availability Rate - ENEO 2022 Annual Report

3.4.3.ii. Thermal Fuel and Water Supply Management

Similar to the hydrology considerations for electric power generation capability on the Sanaga river addressed earlier, hydrology changing conditions have affected the availability and operations of other hydro generation plants in the country. This situation, which could be described as a fuel management problem is affecting two major generating infrastructures: Memevele'e in RIS and Lagdo in the RIN. In the RIN, the Benoue river which feeds the Lagdo power plant has experienced within the last three years instances of severe drought that have reduced the plant's capacity to 25% of its nameplate capacity. In the Ntem river which feeds the Memvele'e power plant, low water periods can sometimes reduce the available plant's capacity to 30-40 MW. Concurrently and in the absence of a water regulating mechanisms for these plants, the combined RIS and RIN networks could have lost up to 225 MW in generation capacity availability, difficult to cover with the other resources already close to maximum availability or stressed because of the same conditions. In conclusion, hydrology conditions can affect the net capacity availability of hydropower plants in the absence of regulating infrastructure or longer term solutions.

System planners must also develop a plan for fuel procurement to thermal generation plants. In Cameroon, this thermal fuel portfolio consists of natural gas, heavy fuel oil (HFO) and light fuel oil (LFO). The current approach to this thermal fuel portfolio management in Cameroon is to:

- reduce the dependence on HFO/LFO generation plants because of their high heat rate and expensive fuel costs. Concurrently a HFO/LFO generation substitution program relying on intra-country interconnections (e.g. recent RIE-RIS linkage, ongoing RIS-RIN interconnection project), more contribution from hydropower and variable renewable energy (e.g. Maroua-Guider 30 MW PV program) is proposed and currently implemented. Albeit ongoing, the substitution program cannot immediately terminate HFO/LFO plant generation, and as such a HFO/LFO fuel supply management requiring generation operators to guarantee at minimum a certain MMbtu runtime equivalent of fuel must be put in place. Typically, the required levels are determined on the basis of the anticipated generation profiles, and should be adjusted as needed. In Cameroon, HFO/LFO generation operators are assigned a certain amount of fuel inventory to carry and report on the actualized quantities (see Figure 14). It should be noted since the HFO/HFO is imported, the fuel procurement process is subject to a market risk in the form of international market prices fluctuations,

- develop and implement a plan for gas procurement to gas-fired generation plans. The responsible entity for providing gaz to the Logbaba Power Plant is Gaz du Cameroun (GDC) from the Logbaba field, while the Societe Nationale des Hydrocarbures (SNH) is responsible for providing gas to the Kribi power plant from the Sanaga South field. Gas is supplied to the plants through a gas pipeline network. Contrary to the LFO/HFO, there is no explicit market price risk since the primary resource is harnessed locally, but there remains an availability risk if the identified gas source fields are not explored optimally or constraints on the gas network hamper delivery to the generation plants. The lack of gas supply, according to the African Development Bank seems to be the reason for the non-expansion of the Kribi gas-fired generation plant.

3.4.3.iii. Transmission and Distribution Functions

With an estimated average demand growth of 4% through 2040 according to UNIDO, it is critical for sensible and pragmatic planning in the sector to be put in place. Beyond structural and functional attributions, the planning interaction between the segments of electricity power production, transmission and distribution and other relevant sectors must be reinforced in an environment with so many stakeholders' entities.

From a systematic viewpoint, an assessment of the infrastructure robustness for each of the segment must be performed continuously, in order to identify their operational vulnerabilities. Next, the linkage between each of these segments requires stronger coordination, especially in an energy system with low reliability and security margin. A sometimes overlooked aspect of such coordination is the establishment of an infrastructure planned outage program over a short, mid- and long term perspectives. Non-adherence to infrastructure maintenance programs has also weakened the grid, as illustrated by the need to rehabilitate the Edea and Songloulou turbines back in the early 2010s and the Limbe Power Plant in 2016. Similarly, regular incidents on the transmission network such as weather-triggered transmission tower collapses (Edea/Kribi transmission line in 2022) or fire-caused substations damages such as in Logbaba and Bonaberi in 2022) remind us of the importance to plan infrastructure design with the attributes of a modern grid in mind.

Transmission projects development has been undertaken by both the MINEE and SONATREL. Our understanding of SONATREL's mandate is that it remains the entity in charge of the national grid transmission planning and operations, a responsibility inherited from the transmission and distribution functions unbundling. As such, it must develop a long-term plan for the adequacy and reliability of the national grid. The developed plan must reinforce the grid and provide a response to transmission expansion growth in terms of integration of new supply and demand resources, as well as requests for long-term transmission services.

Network interconnections in the context of national power sector growth or regional power pool integration require a set of institutional, regulatory and operational tools necessary for the participating countries to maximize their participation. In such a context, the existence of a comprehensive Grid Code both at the national and sub-regional levels is essential for regulating electricity exchange and power expansion planning internally and across the border. Thus, an integrated network within Cameroon will require tools and processes to better monitor and operate its grid. And the presence of variable renewable supply sources will increase system management complexity in control areas where they could be dominant.

Network interconnection will also bring challenges to grid synchronization which, depending on the desired network agility configuration, must require some level of investment in control areas reliability independence. Additionally, investment in transmission elements reinforcements are needed for an ageing and highly constrained network such as Cameroon's. To date, SONATREL is addressing some of these challenges by adopting a project-driven infrastructure reinforcement program, such as the stabilization required investment in the Yaoundé and Douala control areas. We have found however that SONATREL is not equipped with some of the critical tools, such a demand forecast platform or a control room with SCADA/EMS system preparing it for the evolving grid's needs. In fact, SONATREL cannot optimally monitor the behavior of its assets, a situation that leads to issues of grid performance. These issues are often exacerbated by inadequate generation unavailability planning coordination, all which should be part of its daily responsibilities. Aware of these challenges and others, the national TSO (SONATREL) has developed a 10-year investment plan of 948 Billion CFA with 39.5% of it allocated to the national network integration and interconnection with neighboring Chad. Overall, the investment plan intends to improve the network reliability and security, and contributes to its growth so as to allow the interconnection of future generation plants, and the country's electrical system linkage to neighboring countries. The existence of an investment plan for the transmission segment speaks to the fact the GoC understands that there needs to be a strategic action plan over a short, medium and long term timelines for grid expansion. This action plan must be built around critical pillars such as Studies for Network Planning activities.

Concerning SONATREL and ENEO, each develop an investment plan according to its respective mandate. From a planning standpoint, the coherence in the country's transmission and distribution investment roadmap first requires coordination in the development of each function in the short, medium and long term horizons.

One instance where that coordination is essential is in the ongoing development of the interconnection between Cameroon and Chad (**PIRECT** - Projet d'Interconnexion des Résaux Electriques du Cameroun et du Tchad), expected to be completed in 2027. On the Cameroon side, that project will first link the RIS network at the Natchigal substation to RIN network at the Hourou Oussoua substation through a 514km-225KV line, ultimately transforming the transmission network into an integrated one. The project will then proceed with linking Cameroon's integrated network with Chad, through a 800 km of transmission line construction. Similarly, the GoC announced in 2020 a project to interconnect Cameroon with Nigeria (expected in 2030) through a 400 KV line between Natchigal and Bafoussam within Cameroon, and from Bafoussam to Nigeria. With these intra-regional connecting projects, Cameroon will become an electricity hub, for the West African Pool (interconnection with Nigeria) and the Central African Power Pool (interconnection with Chad). Naturally, the question of how rural or poorly energy served areas could benefit from these initiatives is of interest, further coupling axes of grid technology developments, energy access and economic development. Thankfully, reports indicate that the Cameroon-Chad interconnection project will help provide electricity to 409 localities in Cameroon and 69 localities in Chad.

Another area essential for planning coordination is the development of the transmission and distribution demand forecasts, and the needed networks reinforcement initiatives at each level, including protection and automation. In that regard, there is some encouragement in that a 2024-2027 country's additional industrial demand projection (total: 574.8 MW) has led to the identification of investment needs for both transmission and distribution infrastructures. Through that exercise, SONATREL and ENEO have found that they can meet only 43% of that MW-infrastructure with on-going projects. Looking into the PAK (Port Autonome de Kribi) demand portion of the projected industrial demand, SONATREL and ENEO can only meet 47% of the T&D infrastructure needs. Out of the 326 MW T&D infrastructure needing estimated financing of 57.8 Billon FCFA, 152.6 MW have yet to be turned into projects proposals.

While the T&D needs assessment seems to satisfy firm upcoming industrial demand, looking into it separate as such from all other impacting factors demand could lead to incremental T&D investment proposals not optimal, from a comprehensive integrated planning standpoint. Nonetheless, failure to timely satisfy that explicit industrial demand summarized in Figure 15 will present risks for 1) suppressed industrial demand in the country, 2) increased in embedded generation, and 3) non full utilization or non-development of generation projects, all potentially affecting the GoC's economic growth negatively, and causing delayed or non-economical on-grid network expansion.

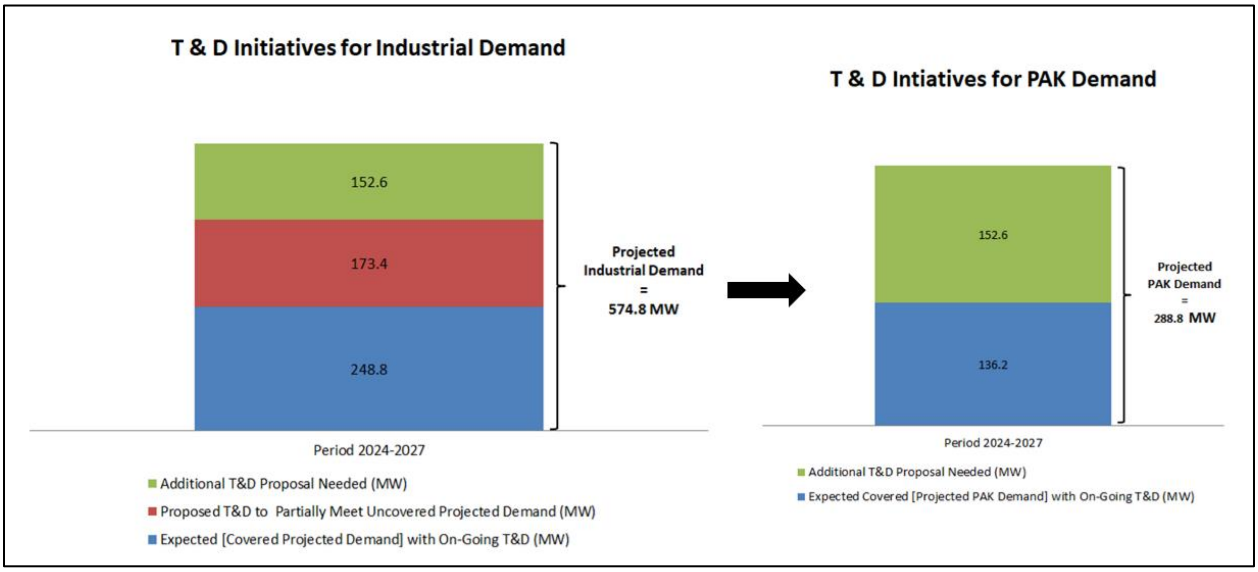


Figure 15: T&D Initiatives for 2024-2027 Projected Industrial Demand (source: SONATREL & ENEO)

Unfortunately, there is a concern about the timely execution of T&D projects reinforcements, as illustrated by the low progress status (38%) on the World Bank sponsored transmission network reinforcement project (**PRRTERS** - Projet de Remise à Niveau des Réseaux de Transport de l'Electricite et de la Réforme du Secteur) which was expected to complete in 2022.

In Cameroon, the functions of load-serving entity and distribution provider are performed by the same organization, ENEO also known as the Distribution Utility (DU). While the SONATREL is responsible for the reliability of the transmission network, the reliability at the end-user and local distribution level are the responsibilities of ENEO. As such, ENEO ensures the expansion growth and reinforcement of the distribution network based on distribution reliability and security criteria: consequently, grid distribution projects are its direct responsibility. Off-grid and rural initiatives remain mostly under the responsibility of AER. Based on recent DU statistics, the distribution efficiency rate had been below 70% through 2016-2019 period, and seems to have improved since then even tough still below 80%, as illustrated in Figure 16. below.

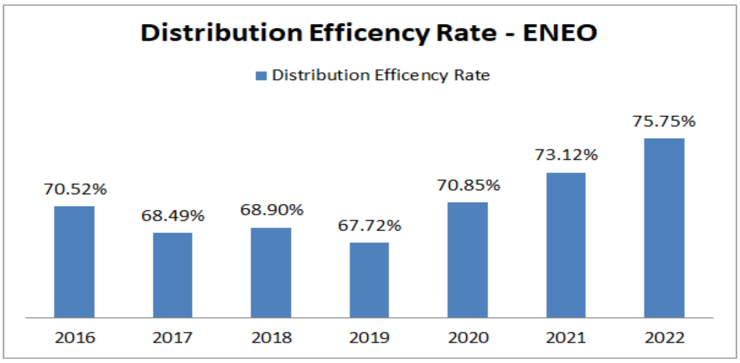


Figure 16: Cameroon's Distribution Utility Historical Efficiency Rate (source: ENEO)

The distribution efficiency rate is far below international standards, expected around 88% and above. It indicates high inefficiencies with the distribution network. These inefficiencies can be categorized both in terms of technical and non-technical losses. Further, there is a quality of service (voltage and frequency) is not satisfactory to most end users. Both of these were primarily caused by the inadequate investment in distribution automation, repeated transformers overloading, non-adherence to distribution infrastructure maintenance programs, and the systematic and adaptive planning program in the distribution infrastructure. Efforts by the distribution utility to tackle these problems must include network technical reinforcements and modernization, fraud (which was estimated at more than 60 Billion FCFA for 2020) reduction, and revenues collection improvements. The absence of a robust electricity consumption management infrastructure negatively impacts the sector development in that incurred revenue losses by the distribution utility delay distribution investment, and wasted energy consumption such as uncontrolled public lightning unnecessarily divert energy production for an already low reserve margin system.

Thankfully, efforts such as smart meters deployment and related technology platforms such as prepaid programs, in an effort to modernize the infrastructure, curb fraud, better measure energy consumption and improve revenues collection are underway. The distribution utility has reported that more than 630,000 smart meters were deployed in 2022, and that as of the first quarter in 2023 about 32% of ENEO household customers are expected to use the equipment. The GoC has also begun looking into linking public lightning infrastructure to smart metering in an effort to better manage its use: it has been reported that about 18,000 points of connections have been identified. Unfortunately, the distribution utility has indicated in 2023 that more than 50% of the household deployed smart meters have been purposely tampered, resulting in revenue loss and creating concern over adequate revenue collection. This situation brings to light the need to treat the electricity system in Cameroon as a critical infrastructure and design it accordingly both from physical or cyber security perspectives.

Conversely, the low inefficiency rate could also be seen as an opportunity for system planners introduce DER such as demand side management within the distribution planning framework.

With the intent to improve the reliability aspect of its segment, the Distribution Utility has budgeted at least 60% of its planned investments over the next 5 years on the distribution network reinforcement centered mainly on maintenance, while 30-40% would account for distribution network growth.

Overall, the total distribution utility projected investment of about 222 Billion FCFA francs should contribute to the improvement of Key Performance Indicators (KPI), some of which include SAIDI, SAIFI and generation plant availability rate (as part of its generation portfolio).

In a system subject to seasonal weather variability that impacts energy systems operations, generation and transmission-distribution planning should direct their efforts to improve their systems whenever possible with seasonal performance targets in mind. Indicators with seasonal granularity allow a better targeted focus on the planning and operational responses that are needed for the reliability and security of the system.

An aging infrastructure, resource adequacy challenges caused by increasing demand and more recently sub-regional network interconnection initiatives have been some of the catalysts to electricity sector reform and investments in Cameroon, as indicated by the CAPEX projections from both SONATREL and ENEO. While the approach is essential to stabilize the integrated grid infrastructure, there needs to be a recognition that other factors are becoming central to rethinking the planning framework that should support the development of these and future investment plans. Some of these factors include the need for:

- infrastructure resiliency, as the infrastructure can become subject to adverse physical and technological stress,
- adopting technology advances that make possible quick deployments of distributed energy resources, both allowing for improved energy access and grid architecture modularity,
- the modernization of the infrastructure to accommodate the integration of systems, tools and processes advances in the management of electricity systems,
- assessing and implementing grid flexibility options as more variable renewable energy is introduced in the supply mix,
- operational and system data continuous monitoring to better understand, control and respond to system events. This information should ultimately lead to a better re-architecting of the grid,
- more comprehensive demand-side programs to complement the resource adequacy part of the sector expansion planning,
- the implementation of adequate packaging and pricing formulation for the grid services that are needed to operate the energy system (both for on-grid and off-grid connectivity), and keep it financially sustainable.

3.4.4. *Concession arrangements between ENEO, IPP and Government*

ENEO acts as the electricity distribution entity in Cameroon for low voltage, medium voltage and high voltage customers. Tariff for these customers is determined through n concession agreement between ENEO and the GoC that had initially been structured over a three 5-year period starting in 2001 as defined by the Master Agreement between the two parties (or GoC and legacy entities of ENEO), and recently extended through a third concession amendment. Within that amendment and post-third 5-year phase, the defined customer tariff for ENEO provided energy services is regulated on the basis of the entity's received revenue associated with its mandated activities of electricity sale to low and medium voltage customers under 1 MW-capacity, electricity distribution and generation production for the said electricity sale. That revenue, further capped by a maximum allowed revenue amount leads to an average tariff computation described as in Equation (1) below.

$$\mathrm{AT_t} = \frac{\mathrm{Min}\ [\mathrm{RR_t}\ , \mathrm{ARmax_t}]}{\mathrm{EA_t}} \qquad (1)$$

Where:

t: time period for which the activity's assessment is performed

$\mathrm{AT_t}$: average tariff for period t

$\mathrm{RR_t}$: received revenue for period t

$\mathrm{Armax_t}$: maximum allowed revenue for period t

$\mathrm{EA_t}$: Energy accounted for during period t

Conditions for tariff revision are contained within the concession or license agreements. In general, tariff determination is subject to mandatory revision every five years or exceptionally should substantial circumstances that could impact its values occur. All these activities are performed by the sector regulator.

Similarly, the utilities KPIs targets are determined by the sector regulator and are embedded within the concession or license agreements. In Cameroon's context, actual utility performance can be rewarded or penalized depending on whether the targets are met or not. With concession agreements spanning decades, setting KPIs targets over a long term period with little revision flexibility could be a challenge for grid reliability investment acceleration. The balancing exercise of setting KPIs targets over a long term requires a thorough understanding of the existing architecture as well as what its planned future state should be, and the timeline needed to achieve it. An example of Distribution Efficiency Target between 2021 and 2022 shows a difference of 0.9 on the basis of 71.5% in 2021, while the reported performance for both years was 73.12% and 75.75% respectively. In the absence of a retrospective analysis, it could be difficult for the sector regulator to determine whether the indicators were optimally determined.

KPI	K2021	R2021	K2022	R2022
Distribution and Quality of Service				
SAIDI (Day/customer/year)	74.1	84.05	65.9	57.6
SAIFI	25.1	24.42	23.00	19.8
Distribution efficiency	**71.5**	**73.12**	**72.4**	**75.75%**
Availability of MV lines per feeder	82%	75%	84%	89%
Deadlines for replacing MV/LV substation transformers				
- - Metropolitan (hours)	12	27	12	16
- - Urban (hours)	12	37	12	14
- - Rural (hours)	72	310	72	66
Sample of LV customers equipped with smart meters	1.2%	1.42%	1.5%	1.63%
Sample of MV/LV substations equipped with smart meters	5%	1%	7.5%	1%

KPI = Key Performance Indicator ou Indicateur Clé de Performance

K2021 = Objectif ou résultat attendu par l'Etat en 2021

R2021 = Résultat réalisé par Eneo en 2021

K2022 = Objectif ou résultat attendu par l'Etat en 2022

R2022 = Résultat réalisé par Eneo en 2022

Figure 17: Distribution Utility KPIs Values for 2022 (source: ENEO)

Note that no concession information was provided for IPPs.

3.4.5. Monitoring Mechanisms and Information System Regarding Utility Financial and Operational Performance

Actors in the electricity sector should operate in an environment that promotes confidence and ensure the sector's sustainability. Adequately, utility operational indicators should translate into financial equivalent to help assess the sector's viability.

Based on the institutional architecture of the sector in Cameroon, the MINEE through its Department of Renewable Energy and of Energy Management (**DERME** - Direction des Energies Renouvelables et de la Maîtrise de l'Energie) is the unit responsible for collecting electricity related data from the standpoint of production, transport, distribution and consumption. Conversely, the entity responsible for tariff computation and dispute resolution in the context of market operations, ARSEL, should rely on its Department of Studies and Regulatory Information Systems (**DESIR** - Direction des Etudes et du Système d'Informations de Régulation) for harnessing utilities operational and cost data.

Concerning the MINEE, there exists an established process by which a yearly Energy Balance (EB) report should be produced. The report, which provides a comprehensive view of electricity consumption, transport and production establishes a sound operations-based informed platform on utilities performances. This platform further indicates areas of performance challenges and of sector expansion opportunities. In its last publication, for the year 2015, the EBS report rightly pointed out that " *…It provides an analysis of energy flows, and highlights indicators that are essential to draw up the national energy strategy. Apart from providing information, this document is a real tool for decision-making…* " . For instance, the document had illustrated then that public administrations electricity bills had been increasing, as shown in Figure 18. It is unlikely that this situation has changed, and therefore calls for an adaptive response in terms of smart energy demand management, including the National Energy Efficiency program application and monitoring.

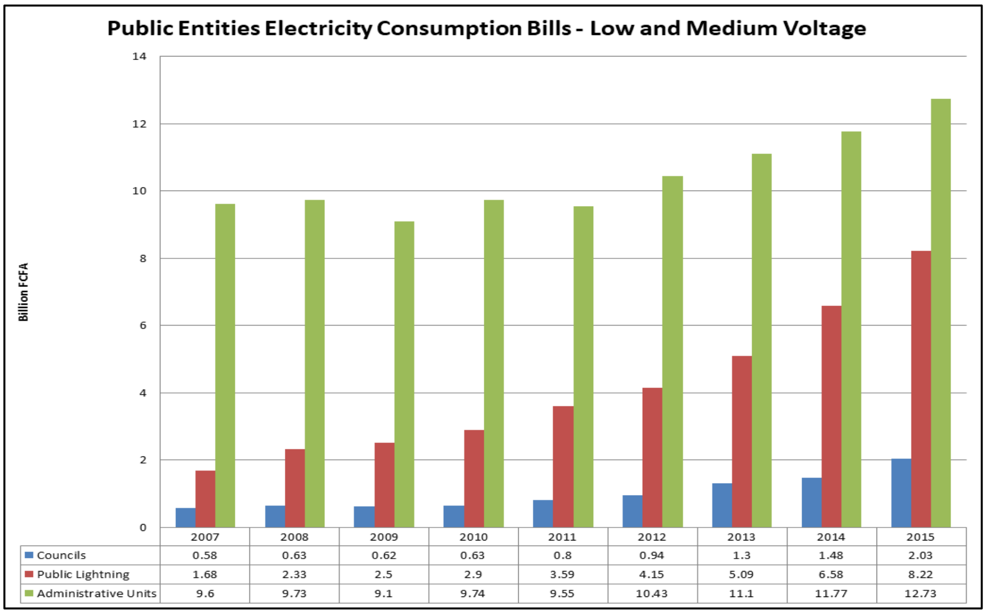


Figure 18: [2007-2015] Electricity Consumption Bills (*adapted from the MINEE 2015 Energy Balance*)

Valuable assessment of energy consumption trends and possible energy substitution options to electricity could be inferred, providing insight into the sector demand growth, as illustrated in Figure 19.
Similarly, the assessment of historical electricity generation energy produced offered an insight into the resource mix utilization, and possible replacement alternatives to consider on the basis of desired policy targets, technology advances and associated costs, and other related considerations. An example of such trends can be seen in Figure 20.

As with unserved energy and energy consumption data previously described, the updating of these statistics and others presented in the report should be made for adequate analysis of the sector and utilities performance. For instance, the report next versions could be enhanced with the inclusion of infrastructure historical unavailability information, further completing the overview of the sector and operating participants.

At the MINEE, the data collection effort needed for the preparation of the EBS report is described as burdensome. The burden comes from the fact that there exists no centralized electronic data exchange and communication platform that allows for these data to be remotely and seamlessly transmitted. In fact, the process thus far had been manual and consisted mostly of sending personnel out with printed data forms to be filled by the participants and returned for processing, with no systematic guarantee of participants collaboration or error-free in forms filling. Mitigating that process inefficiency required repetitive participants' solicitation, further increasing the cost of producing the report. Over time, the non-consumption of allowed budgets provision for this activity because of other administrative contingencies has unfortunately caused this important toolkit to be cancelled.

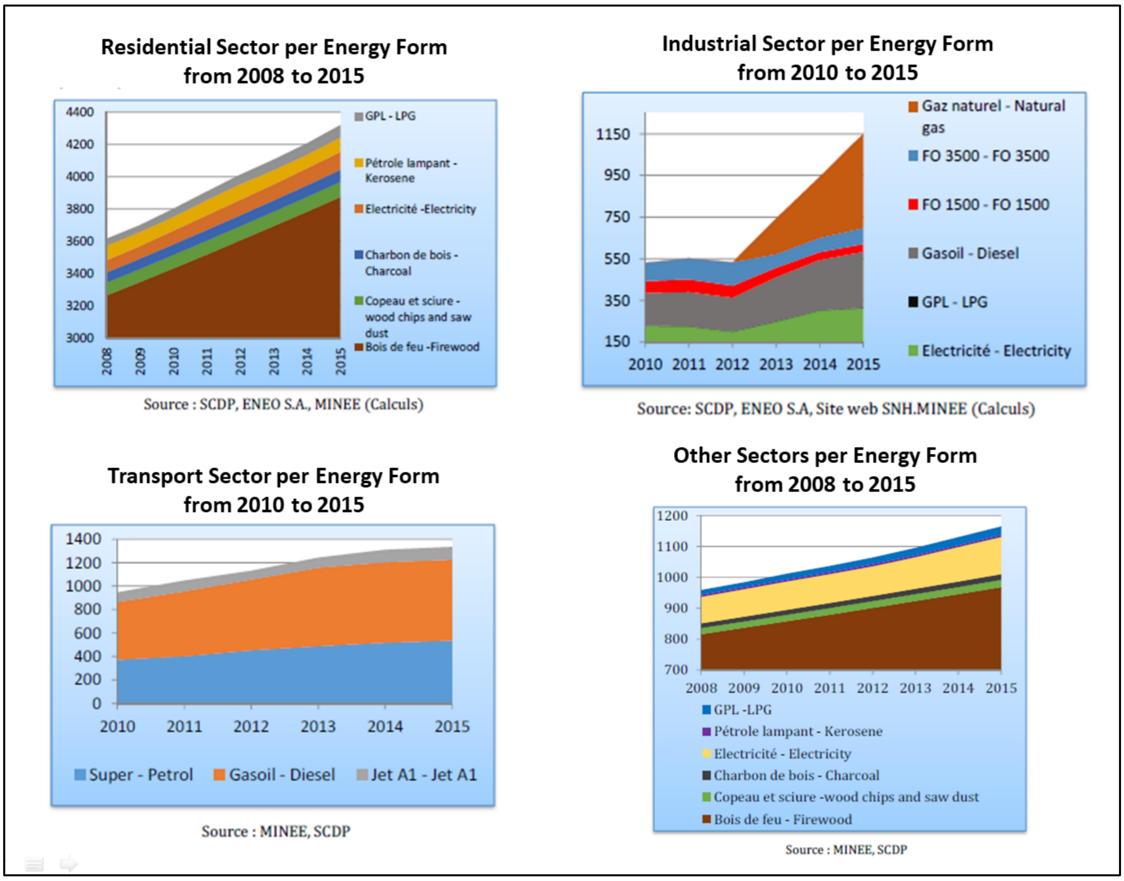


Figure 19: [2008-2015] Energy Consumption Trends, in Ktoe (source: MINEE)

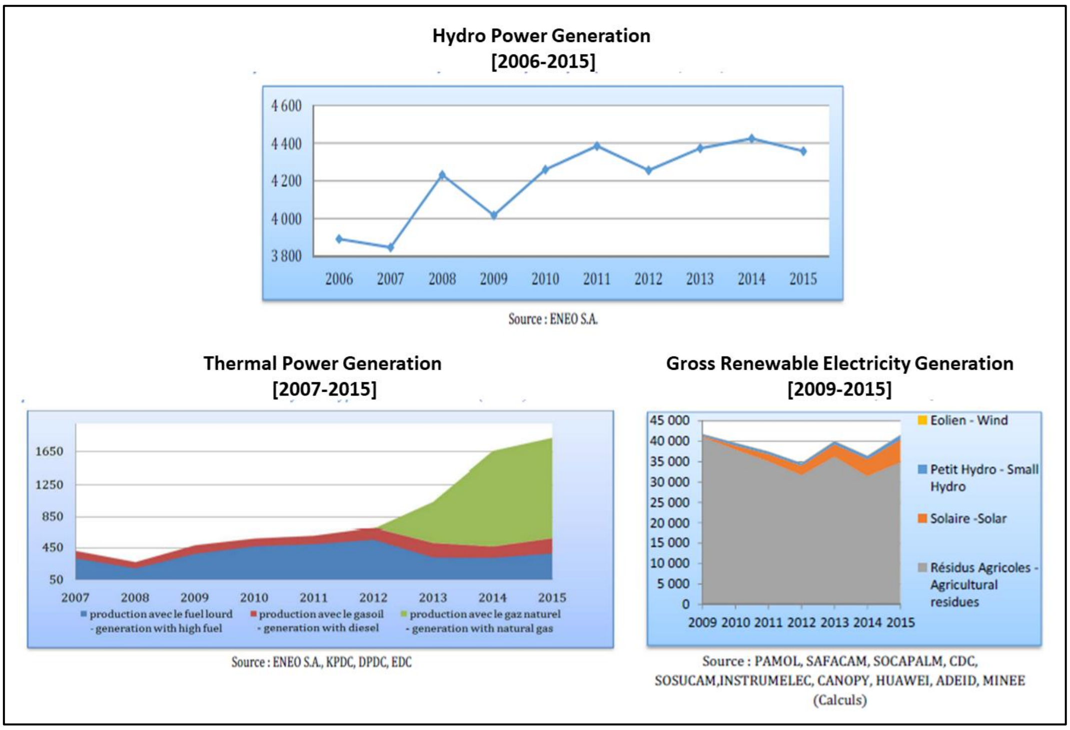


Figure 20: [2006-2015] Produced Generation Energy Trends in MWh (source: MINEE)

For the power sector regulator, operational data from supply and demand resources, load serving entities, transmission system operators must be made available to monitor the entities performance and evaluate the sector's operational robustness and financial sustainability. As such, ARSEL in Cameroon should report regularly on the sector activities as a sector monitoring entity in the absence of a such officially defined one. In practice, ARSEL conducts tariff workshops every three (3) months with segment actors to collect information and discuss regulatory concerns. In fact, ARSEL's yearly activity report indicates that some operational data such as the monthly generation availability rates and fuel delivery (be it water for hydropower plants, HFO/LFO or gas for thermal generation plants) amounts are provided for its review.
In the interest of information coherence and data processing efficiency, public monitoring entities such as ARSEL or MINEE-DERME could benefit from a common data collecting platform, and thus creates synergies and costs savings in the energy data management process (e.g. Data Warehouse) associated with their mandate. Naturally, such a platform should be designed so that data collection discrimination on the basis of confidentiality can be implemented (e.g. participants' operational costs might be needed for ARSEL but not for MINEE-DERME).

3.4.6. Merit Order Dispatch Procedures

The energy supply resource mix in Cameroon has predominantly been dominated by run-of-the river generation, with little or no participation of gas, LFO/HFO or variable renewable generation. In these circumstances, system dispatch could be simplified as each network (RIS, RIN and RIE) had its own configuration, was relatively small (except for the RIS) and required its own methodology for generation dispatch. With the RIE now as part of the RIS, the country's system dispatch procedures can be considered as a collection of the two sub-systems dispatch procedures largely treated each independently. Currently, the dispatch procedures remain under the responsibility of ENEO due to the fact that that SONATREL is not ready to take over this responsibility for lack of adequate infrastructure. The RIS system is dispatched through a SCADA/EMS system configured for hydro-thermal coordination, while the RIN is dispatch procedure is simplified and manual. Notwithstanding, Cameroon's grid is changing and moving to become an integrated network and an electricity exchange hub in its sub-region, likely with higher DER network integration and energy storage solutions, and an increased generation diversification (see Table 5).

There is an acknowledgement that the current approach to system dispatch must evolve, and that improved unit commitment, dispatch and generation control tools are needed. Indeed within such a transformational grid's configuration environment, short-term operational planning and real-time control of energy resources must be performed with modern decision tools framework that is adapted with modern network configurations. Such typical framework consists of investing in the modernization of the DCS architecture of the transmission network, Supervisory Control and Data Acquisition (SCADA), full deployment of Automatic Generation Control (AGC) capability and Energy Management Systems (EMS) taking into consideration DER control and variable renewable energy, modern demand forecasting technology, distribution control areas configuration optimality through Distributed Management Systems (DMS) platforms with D-SCADA technology, and national control rooms primary and backup centers. Such investments, once studied and justified should be implemented. They will allow grid operators to achieve greater operational savings over the short, medium and long terms.

Generation Capacity par Fuel Type	*2000*	*2012*	*2022*
LFO/HFO:	*20%*	*32%*	*23%*
Solar:	-	-	*1%*
Wind:	-	-	-
Gas:	-	-	*14%*
Hydro:	*80%*	*68%*	*62%*

Table 5: [2000-2022] Generation Capacity Mix Trend (source: MINEE)

3.4.7. Applicable Grid codes and Charges

In a structured market environment, the institutional and operational framework requires participants to interact with the market under regulated guidelines. These guidelines are meant to promote indiscriminately fair access to the grid, and participate to the competitive procurement of reliable and secure energy services for end users. The guidelines by which participants interact is contained in a technical documentation framework known as the Grid Code, which serves as a reference for market participation. The Grid Code consists of several components, each providing specific guidelines with respect to technical responsibilities associated with grid operations. It allows Transmission System Operators (TSO) to interact with participants in operational matters. Typical Grid Code components include: Connection Code, Metering Code, Market Code, Settlement Code, Planning Code and Operations Code. As the entity responsible for the transmission network growth, the Transmission System Operator must provide network infrastructure development plans. That responsibility which requires input from all transmission users must be coordinated through procedures and criteria defined in the Planning Code. This code component ensures a dynamic stakeholders involvement that should lead to investment proposals coherent with all relevant inputs.

In Cameroon, two Grid Code components have been developed: The Connection Code and The Market Code. Both code components have been officially adopted and approved for implementation in 2019. The absence of approved Planning Code or Operations Code components in the current Cameroon's Grid Code is problematic for the reasons mentioned above. The unknown participatory involvement having led to SONATREL's investment plan, coupled to the fact that the plan was mostly inherited in 2018 from ENEO's then legacy TSO-DSO role requires caution with regards to: 1) coordinated operations procedures and standards for generation, transmission and distributions operators, 2) network reliability and security criteria for the plan's robustness, and 3) the unknown frequency recalibration process taking into consideration the previous concern given the long-term horizon of the proposed investment plan.

Regarding tariff, it is worth mentioning that there is no tariff rule for off-grid electrification. This situation creates a concern for tariff harmonization between provided on-grid and off-grid energy services. Such concern can further impact the development of off-grid electrification initiatives negatively.

3.4.7.i. Distribution Utility Financial Performance

The electricity tariff structure in Cameroon is not reflective of the costs borne for the service delivery. In a subsidized system which has known frozen tariff since 2012, the Distribution Utility which has been facing increasing costs (both in investments and operations) to meet its concessions and licenses agreements must rely on the GoC to be made-whole in an already stranded economic environment. Further, some of the DU customers with large accounts arrears are public entities (e.g. administration, public lightning), some of which with poor demand management incentives.

On the basis of the existing tariff structure, the distribution utility ENEO financial performance can be seen to have improved in 2022, with a 58% liability-to-asset ratio. The company has also seen a net operation income improvement of 45 Billion FCFA. A look at the company's balance sheet indicates that while its equity has increased, its account payable situation has worsened (see Table 6). The cumulative debt of the distribution utility was estimated at 700 Billion FCFA for the year 2022, while its solvability indicator was very low, around 7.4%.

	2021	**2022**	**Relative Difference**
Net Income (Million FCFA):	*-35,521*	*10,028*	*-128.23%*
Suppliers and Account Payable (Million FCFA):	*283,489*	*336,444*	*18.68%*
Total Liabilities (Million FCFA):	*888,406*	*940,121*	*5.82%*
Total Assets (Million FCFA):	*677,164*	*1,617,284*	*138.83%*
Liabilities / Assets Ratio:	*131.20%*	*58.13%*	-

Table 6: Distribution Utility's Financial Performance Excerpts (source: ENEO)

Altogether, this situation creates an environment whereby cash flow tensions render mid and long term capital investment decisions uncertain, and sometimes creates conflicts between the distribution utility and its suppliers. One example of such of situation can be seen with Globeleq shutting down power delivery (almost 20% of the nation's installed generation capacity) to the distribution utility in October 2023 for cause of cumulated non-payment on power delivery, not unlike what occurred in with the Emergency Thermal

Program (**PTU** - Programme Thermique d'Urgence) units shutdown in Decembre 2012 through February 2013, a situation which then caused several prolonged power interruptions and power supply rationing in several regions of Cameroon such as Centre, Littoral and West. According to public reports from November 2023, the biggest portion of the 700 Billion CFA owed to the distribution utility comes from the government and its affiliates.

Aware of the sector collapse risk caused by this financial instability, the GoC has committed to address the following: improve transport and distribution efficiency rates, update the tariff methodology to reduce the gap between the administered tariff and the cost of service delivery, better electricity consumption management for public administrations and lightning, pay its debt towards the distribution utility, and improve revenue allocation and make-whole and revenue allocation. To date, while the GoC has established a payment mechanism to clear what it owes to the distribution utility, the situation regarding the GoC's affiliates (e.g. CRTV, Alucam, Camwater) indebted to ENEO has yet to improve and remains a concern. This said, on the distribution utility side, actions towards improving service quality and revenues collection are underway. On the production side, actions towards improving the performance of the generation portfolio and reduce operational costs (e.g. reducing reliance on HFO/LFO generation and accelerate thermal units hybridization) are targeted.

3.4.8. Strategies for Hybridizing Solar and Hydropower Generation

Hybridization in power systems can be performed locally from a facility standpoint or from a system's perspective through intra-connectivity at the national level or regionally with countries inter-connectivity when the adequate energy resources exist and can be connected adequately.

From a facility configuration standpoint, power plant hybridization is relatively new in Cameroon. In fact, the hybridization experience in the sector had begun with ENEO's solar-thermal commissioning in 2018 for a dual 186 KwpSolar/1,115 KW solar-thermal capacity at Djoum whereby both components could inject power into the grid during daytime. Next, ENEO followed up 2020 with another solar-thermal of 125-KWp the site at Lomie, and recently in 2021 at Garoua-Boulai. In the three completed sites, one cannot be seen as full energy substitution mechanisms since the added solar capacity to each plant represents a fraction of thermal counterpart. However, building on its relative success, the company has decided to increase its solar-thermal hybrid portfolio by 4MWp with projects eastern, central and northern regions of the country. It is worth mentioning that thermal-solar hybridization is one of the strategies the GoC through the MINEE intends to contribute to its NDC.

On solar-hydro hybridization, there is no known active project of sort in Cameroon. In fact, Ghana's BUI hydro-solar power generation facility is the first utility-scale infrastructure of sort in the West and Central Africa regions. In Cameroon, a country with significant hydropower and good solar potential, the solar-hydro hybridization potential in the country when developed as a program (i.e. extended beyond the concept of a single facility implementation) could provide a mechanism for better regulation of hydropower generation. Hydropower production fluctuations during the course of the day and during the dry seasons could be complemented or substituted by solar power generation during the day, while procuring electricity could be produced by hydropower generation or other energy storage solution during evening peaks. In an environment where such resources complementarity exists such as Cameroon, an integrated network with vast solar power potential in the northern regions and rich hydropower potential in the southern regions, a hydro-solar hybridization program could be a viable infrastructure planning scheme for medium and long term perspectives.

3.4.9. *Other Structural Challenges*

The current approach to power sector planning in Cameroon is characterized by a differentiation in supply resources development programs, off-grid and on-grid electrification development frameworks, all with the unbundling of the generation, transport and distribution functions. This has materialized into costly investments and operations the creation of entities responsible for developing plans to meet the government's objectives, each in their respective segment over an aging and not optimally maintained capacity-short infrastructure. In principle, these segmented attributions are sound and adequate. Beyond the attributions of various specific missions and goals, the biggest value in the establishment of a coherent planning framework requires an intricate and dynamic collaboration amongst all stakeholders, as they are all part of the organizational and market operational structure of the sector. We have also noticed that little is discussed in addressing effective demand side participation in the power sector.

The process structurally coordinating these missions and mandates from a sector planning standpoint is not defined, and these entities increasingly face internal capacity and structural challenges. Some of the key challenges they face are mentioned are below.

A first challenge comes sometimes from the interpretation of the mandates received by the various entities. An example would be how off-grid rural electrification planning should be performed and which of the entities between the in line ministry or the public agency in charge of rural electrification programs should manage it. Such confusion leads to issues of process ownership and could possibly create collaboration inefficiencies.

A second challenge is the missing official process by which frequent mandated updates by circumstantially trigger-based of the several developed plans are performed. This happens to be the case with the 2014 National Master Plan that has not undergone a formal review process.

A third challenge comes from how well structured the stakeholders entities are, both from a human talent capability and adequate process/systems infrastructure to perform their missions. This happens to be the case for SONATREL who is lacking a modern demand forecast capability. It is also the case with the MINEE that has been unable to produce an Energy Balance report since 2016 for reasons mentioned previously, the absence of a Planning Code guiding the application of reliability and security criteria in the development transport and distribution plans and their updates, and the unclear coordination in functional operational complementarity for an optimal TSO-DSO operational framework efficiency.

A fourth challenge comes from how well the stakeholders' inter-dependencies are understood and their inputs dynamically reflected in a Master plan that should ultimately capture all the attributes of a modern power grid. This happens to be the case with the integration of hydrology and related impacts for the need to further balance supply capacity with the introduction of demand flexibility, or better assessing of the hydro-solar hybridization potential of the country. Further the absence of an integrated approach to planning fails to create the needed synergies information gathering, sharing and knowledge transfer for an effective structural information process leveraging throughout the development of various investment plans.

A fifth challenge is the shortage of human talent in the power sector. This issue raised by the GoC, could become a sustainability risk for the sector development.

An unintended consequence for not concurrently tackling these challenges, the poor operational performance and the technical issues of the sector is a risk of adopting a myopic power sector planning approach. Such approach is not only reactive because if fails to coherently anticipate how to best adapt to uncertainties or fully address the infrastructure problems. Further, it doesn't fully integrate the needed interactions among all relevant stakeholders, nor dynamically meets the sector needs for adequate tools, processes, or sound investment infrastructure decision-making in an evolving industry.

4. Outcome – Part II: Best practices in International Experience on Planning and Implementation of the Expansion of the Power Sector in Countries with Growing Electricity Demand

4.1. Ghana

In Ghana, the total electricity consumption has increased on an average rate of 10.3+%, reaching 21.4 thousand GWh in 2021. Similarly, energy generation has reached more than 22 thousand GWh in 2021. Installed capacity (including embedded generation) has increased from 5.2 GW in 2019 to 5.4GW in 2021, while system peak demand has increased from 2.7 GW in 2019 to 3.2 GW in 2021. These statistics, summarized in Figure 21 are an illustration that Ghana is a country with increasing electricity demand.

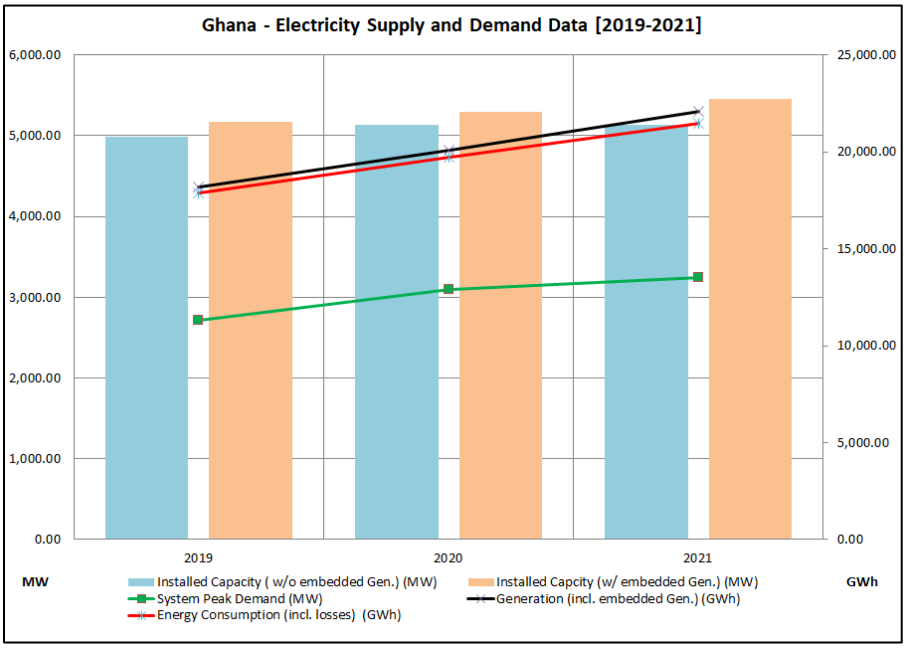


Figure 21: Ghana's Electricity Supply and Demand [2019-2021] (source: Ghana Energy Commission)

Based on the Ghana's Energy Commission's projections in 2021, peak demand and installed capacity (w/o embedded Gen.) was expected at 3.5GW and 5.4 GW respectively for 2022. The generation capacity mix in 2022 was estimated at 68.47% of thermal generation, 29% hydropower and 2.6% in other renewable energy.

Ghana's installed generation capacity in 2022 is estimated at 5,481 MW, with the thermal share being 3,753 MW (68.47%), hydropower 1,584 MW (28.90%) and 114 MW (2.63%) from renewables. However, the amended renewable energy bill redefines hydro as a water-based energy system that produces electricity, placing all installed renewables at 1,639 MW (30.99%)

The power sector in Ghana is under the supervision of the Ministry of Energy (MoE). The ministry is responsible for formulating, implementing and monitoring the development of an energy service at minimum cost and which should be deemed reliable and high quality. The electricity market model is characterized by the unbundling of the generation, transmission and distribution functions:

- Operating entities in the generation segment include private IPPs, and the state owned utilities Volta River Authority (VRA) and Bui Power Authority (BPA) both managing a 2532 MW and 454 MW generation portfolios respectively. BPA initially created with a mandate to manage Bui Hydroelectric power project has seen its mission expand to assume the function of the Renewable Energy Authority. It is in that context that the 250 MW solar-hybridization project at the BUI enclave has come into existence,
- The transmission function in Ghana is under the responsibility of the state-owned entity Ghana Grid Company (GRIDCo). GRIDCo is in charge of administering the electricity market, operating the Network Integrated Transmission Service (NITS) for lines above 36 KV and acting as an independent system operator (ISO),
- In contrast to Cameroon where there is only one distribution entity in the power sector, Ghana is home to several distribution companies. These actors include the state-owned entities Electricity Company of Ghana (ECG) and Northern Electricity Distribution Company (NEDCo), and a private entity Enclave Power Company (EPC).

There are two power sector regulators in charge of activities monitoring in Ghana: The Energy Commission (EC), and the Power Regulatory Utility Commission (PURC):

- The EC is he the entity mandated for power sector planning in Ghana. It prepares, reviews and updates periodically indicative national plans to ensure that all reasonable demands for energy are met. In addition to enforcing performance standards for the utilities, the entity also grants licenses for the implementation and operations of all transmission, wholesale electricity supply and distribution assets. Other responsibilities include regulating and managing the development and utilization of energy resources in Ghana as well as to provide the legal, regulatory and supervisory framework of all providers in the country
- The PURC manages the regulation of utility services in the electricity and water sectors. It also oversees regulation for gas supply, transportation and distribution services in the gas sector.

The power sector in Ghana has an organizational structure similar to Cameroon, in that the Ministry of Energy is responsible for the government policies strategy implementation. It also provides technical oversight to the unbundled electricity market model operating entities in the segments of production, transport and distribution. The electricity market itself consists of a deregulated wholesale component and a regulated distribution market component under the supervision of the PURC.

Ghana's approach to power sector planning has known a significant improvement in the mid-2010s, not without previously experiencing a severe power crisis, but also with the recognition that the process as it was then implemented had significant shortcomings. Back in 2012-2015, Ghana was plagued with a severe power sector resource adequacy crisis that crippled the country and significantly hindered its economic growth. That crisis not unlike what we are witnessing in Cameroon was caused in part by technical operational challenges, lack of fuel supply security, experienced low water levels at the country's water reservoirs, and shortage of gas supply. Other causes included a misguided strategic investment plan failing to adapt to changing project financing environment or other exogenous factors. Facing urgency to resolve to the supply shortages, the government of Ghana (GoG) responded by contracting expensive mobiles PPAs all while projects developers were solicited in non-adherence to the established procurement process, a parallel and uncoordinated approach that led to medium term generation capacity oversupply. Recognizing the shortfalls and facing these challenges, the GoG decided to improve its approach to power sector planning, moving away from its standard Integrated Resource Planning (IRP, Ghana's IRP was similar the GoC's methodology leading to the development of the PDSE2030) which was inadequate to capture the increasing evolving and dynamic uncertainties associated with the sector.

While the nature of the IRP process itself appeared a limitation to the successful implementation of developed investment plans because of its inability to respond to evolving sector conditions in the country, the GoG also realized that there was a need to address the following realities within the national environment:

- The entities involved in the various segments of the production, transport and distribution in power sector were not working cohesively and the poor collaborative environment impeded the planning process efficiency. As a result, one key driving aspect of the revised planning approach was to transform it as a stakeholders-driven process. This was achieved by first identifying key decision makers which then would define relevant strategic and technical elements. Furthermore, the identified stakeholders are required to engage with the appropriate government entities to solidify the governance and regulatory foundation of for the plan's success. Some of the key stakeholders include the Energy Commission (EC) responsible for the development of the Grid Code and the Resource Master Plan, the Transmission System Operator (GridCo), the Distribution Companies (PDS, NEDCo), the entity responsible for 1) Execute renewable energy projects on behalf of the State and, 2) Undertake its own renewable energy activities and 3) Undertake clean energy alternatives in the country (BUI Power Authority), the Public Utility and Regulatory Commission (PURC), the main generation supplier in the country (VRA), all under the technical oversight of the Ministry of Energy (MoE).
- The revised planning process takes under consideration in its development the vision and priorities of the sector's key stakeholders. The development was put under the

responsibility of a Technical Committee supervised by a steering committee, both filled with key staff from the concerned stakeholders entities

- Develop the human talent and expertise needed to perform the associated planning activities, including program and project management as well as the project's related technical tasks
- Facing evolving markets (including access to capital), climate, regulatory and technological conditions, produced investment plans must be reviewed and revised so as to reflect the last planning horizon expected environment. A review and update program on every 2-year frequency was adopted
- Understanding the planning context requires both data coherence and standardization effort so that all parties have access to it transparently and with the same quality. That effort expanded to the identification and adoption of tools and models to be used collaboratively in planning activities
- The impacts of climate change have demonstrated the need for taking into consideration an explicit component of climate risk. This risk further directed system planners to add a component of climate resiliency in the planning process
- The presence of several entities and involvement required some strategic organizational structure regarding reporting and authority. As such a Power Planning Technical Committee was created as the power sector planning body responsible to update the ISMP every two-three years. Committee was the must be further included in the planning process

The improved planning process, known as the Integrated Resource and Resilience Planning (IRRP) has become the process in use for the development of Ghana's Integrated Power Sector Master Plan (IPSMP). As a collaborative and stakeholder's driven process, its outputs reflect the vision and objectives of the sector's main actors. It is supported by a workflow integrating their contribution as described in Figure 22. Note that besides common features with an IRP process, one key difference is the *risk and resilience analysis* component in the IRRP process reflecting the potential impacts of risk drivers through explicit assessments.

The infrastructure investment roadmap the IPSMP derives integrates and helps better mitigate the risks associated with various uncertainties such as hydrology variability, climate change impacts, fuel supply and their prices. Planners benefit from an framework built as an adaptive process that supports proposals for resilient power system infrastructure. The IPSMP serves as the foundational basis to the development of the sector's medium to long terms Transmission Master Plans, Distribution Master Plans and the Annual Supply Plans taking into consideration on-grid and off-grid systems. As implemented, the IPSMP provides studies recommendations for its future updates, and can also be used as support to the development of request for proposals (FRP) for infrastructure assets. Finally, recognizing the dynamic nature of the power sector, the IPSMP is expected to be reviewed and updated every 2-3 years, allowing system planners and decision makers to react with more efficiency to factors that can impact the implementation of the country's electricity related policies.

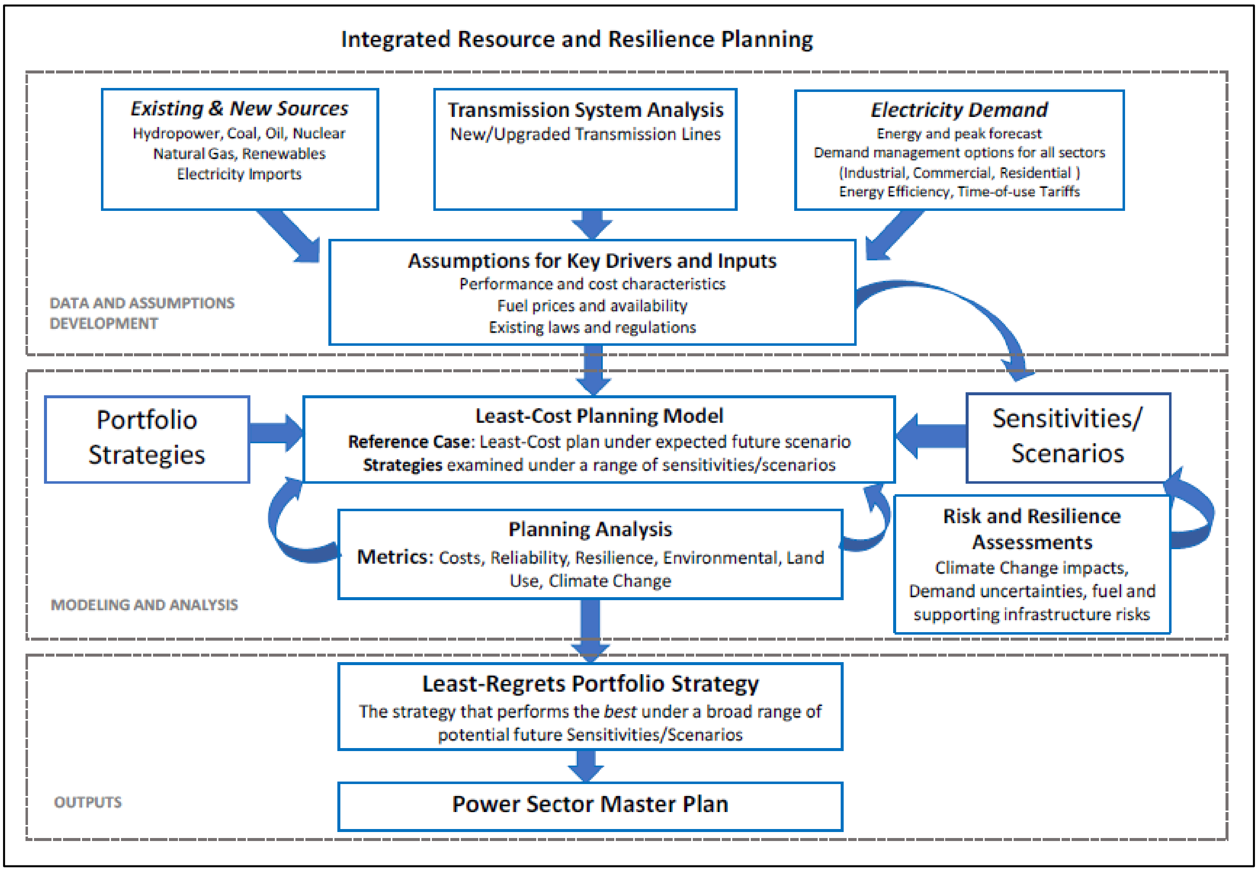


Figure 22: Ghana's IRRP Framework Workflow (source: USAID)

4.2. Brazil

Brazil is the largest electricity market in South America, enjoying more than 97% in universal access rate for reliable electricity. Its energy generation mix is dominated by large hydropower at an estimated 65%. Because of its reliance on hydropower generation, Brazil's grid's reliability has been challenged over the last two decades due to the impacts of climate change characterized by continuous drought conditions and man-made deforestation.

Back in 2001-2002, Brazil suffered a major energy crisis caused by 1) several previous years of drought in a electricity system then dominated by more than 80% in hydropower, and 2) delays in the commissioning of expected generation projects. The Government of Brazil (GoB) responded to the crisis with a program to bypass established bidding procedures for the purchase of new generation options and reduce electricity consumption, with some success. Although proving that demand side management options could work, the crisis affected the country's economy negatively, prompting the country in 2004 to continue sector reforms with the objective of securing expansion in the generation, transmission and distribution segments and a stable supply of electricity in the country. The reform concurrently focused on achieving universal access, targeting fair return on investment and implementing tariff adjustments to reflect cost of service. A key component of the reform led to the introduction of energy auctions, a process by which generation projects are competitively evaluated up to five years in advance of the delivery date. As a result of the various reforms, Brazil has enjoyed large private capital investment in the power sector.

The power sector in Brazil is under the supervision of the Ministry of Energy and Mines (**MME**). The ministry is responsible for setting the policy in the electricity sector. The electricity market model is characterized by the unbundling of the generation, transmission and distribution functions:

- The generation segment consists of federal, state dominated companies and IPPs, all totaling about 150GW of estimated installed generation capacity in 2020. The largest generation companies are Electrobas (federal entity – 42 GW portfolio), CESP (state entity – 7.4 GW), Tractebel enrgia (private entity – 6.8 GW) and Cernig
- The national system operator (**ONS** – Operador Nacional del Sistema) created in 1998, whose function is to coordinate and control generation and transmission operations within the integrated national grid. The transmission grid in Brazil (**SIN** – National Interconnected System) with more than 140,000 km of HV transmission lines consists of four (4) interconnected networks: the southern network, the northeast network, the southeast central-west network and the northern region network,
- The distribution segment consists of more than fourty (40) distribution companies, public and private entities. The most important ones include Enel (private entity) covering the city of São Paulo, CPFL (private entity) covering the Sao Paolo state outsieed the city of São Paulo and Cernig (public entity) covering the state of Minas Gerais,

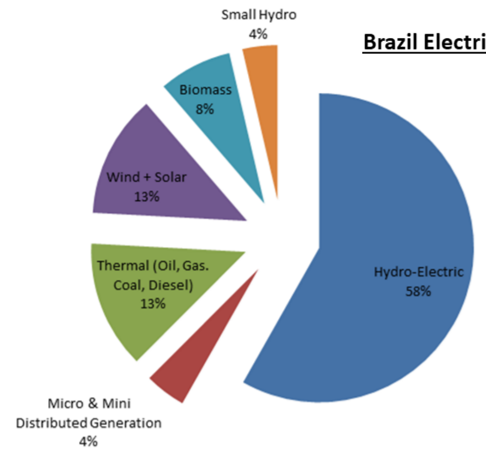
Other actors in Brazil's institutional power sector include:

- The Electricity Regulatory Agency (**ANEEL** – Agencia Nacional de Energia Electrica) created in 1996, whose responsibility is to regulate the generation, transmission, distribution and commercialization of electricity in the country according to the legislation and policies defined by the federal government
- The national market operator (**CCCE** – Cámara de Comercialización de Energía Eléctrica) created in 2004 as a successor the **MAAEE** (Mercado Atacadista de Energia Electrica*)*, is responsible for promoting the electricity commercialization activities in Brazil. Through its operations, the CCCE ensures that the electricity market is competitive, sustainable and environmentally safe through the trading activities, including ensuring the smooth market functioning and fostering discussions about the evolution of the power sector market. Amongst others, it monitors the sale and purchase of electricity, and verifies the differences between contractual amounts and physical amounts
- The National Council for Energy Policy (**CNPE** – Conselho National de Politica Energtica) created in 1997, a federal government entity in charge of advising the Presidency of the Republic and elaborating policies in energy matters including the electric sector for Brazil. Its membership includes experts in energy, state government representation. CNPE also serves as an advisory body to the MME,

- The Electricity Sector Monitoring Committee (**CMSE**) – Comite de Monitoramento do Setor Eletrico) created in 2004, whose primary responsibility is to permanently monitor and evaluate the continuity and security of the electricity energy supply for the country.

Concerning planning, the Energy Research Company (**EPE** – Empresa de Pesquisa Energitica) created in 2004 is the entity with the specific mission to produce the integrated long-term planning documents for Brazil power sector. The EPE management and operations team is diverse. It membership draws from several ministries, production, transmission and distribution companies, as well as consumers and regions representatives. EPE areas of research and studies also cover oil and gas. EPE's work serves as input for the MME's actions for strategic planning and implementation steps in the power sector in the formulation of the national energy policy.

Brazil generation mix consists of 87% in renewable generation as illustrated in Figure 23. Over the years, Brazil has been pursuing significant variable renewable energy development, mostly in the form of biomass and wind power. This comes as a response to both policy initiatives encouraging renewable energy development in a context of fewer large hydro projects in the pipeline. Acknowledging the supplemental risk that these resource options could bring in term of security of supply in a system already challenged by hydrology variability, the GoB has moved towards the development of thermal generation projects (mostly gas fired generation) with the purpose to regulate hydropower generation and provide flexibility to the variable generation sub-portfolio.



	Installed Capacity (MW)
Hydro-Electric	108,903
Micro & Mini Distributed Generation	8,013
Thermal (Oil, Gas, Coal, Diesel)	25,027
Wind + Solar	24,027
Biomass	14,329
Small Hydro	6,830

Figure 23: Brazil's 2021 Electric Generation Mix (source: Brazil MME)

The National Energy Plan (**PNE** - Plano Nacional de Energia) and the 10-Year Expansion Plan (**PDE** - Plano decenal de Expansão) and are two key instruments used in the power sector planning in Brazil. Both are produced by the EPE and are meant to guide policy and implementation in the sector and address sector expansion.

Brazil's PNE serves as the equivalent of the sector Master Plan. It is developed as a reference for long term strategic decision making in the energy sector. It consists in a set of studies that support the country's long-term strategy with respect to the expansion of the energy sector. The PNE is made of three pillars: the National Strategy Design, the Strategy Implementation in the form of recommendations and an action plan, and a Monitoring Component tracking of development and its impacts. Based on its conception, the PNE is reviewed every 4 years or whenever critical circumstances could affect the government's strategy design or its implementation.

PNE2030 (National Energy Plan through 2030) is the first developed National Energy Plan of Integrated planning of energy resources in the GoB and prepared by the MME. Recently, a revision was made which led to the development of PNE2050 (National Energy Plan through 2050), the latest version. PNE2050 builds on the foundation of its predecessor PNE2030 and works on the basis of a multi-sector agencies collaboration in the development of the integrated54 planning process. Where the PNE2030 followed a traditional IRP approach within which the main generation sources are assumed, PNE2050 explicitly acknowledges circumstances that can disrupt the energy sector including generation projects assumptions, thus further reflecting that the future is unpredictable beyond scenario analysis. As a result, the PNE2050 aims its recommendations towards flexibility and diversity of choices, and technology bias avoidance. As can be found in the PNE2050, axes for long term strategy design include uncertainty impact assessment. Some of these axes, also relevant for the power sector planning in Cameroon include: hydropower projects development realization, energy demand, viability of a generation portfolio made of more than 80% in renewable sources, climate change, increase penetration of variable renewable generation, technology changes, distributed generation and energy load management. Further the strategy must be developed with the intent to improve the legal and infralegal framework suitable to the attraction of private sector capital in the power sector expansion: technological neutrality, promotion of competition, predictability, efficiency, isonomy, simplicity, transparency, coherence, sustainability and caution/adaptability.

On the other hand, the PDE is produced annually and covers a planning horizon of 10 years. It aims at providing perspectives of expansion in the power sector from an integrated framework perspective for the various energy segments, based on the methodology of the Brazilian Energy Balance and recently within the context of its energy transition and achieving lower carbon economy model. The PDE remains the reference document guiding short and medium term sector implementation. Its process articulation is described in Figure 24. Through that process, system operations provide feedback to planning analysis and the reverse is also true, stressing the cyclical interactive nature of the process.

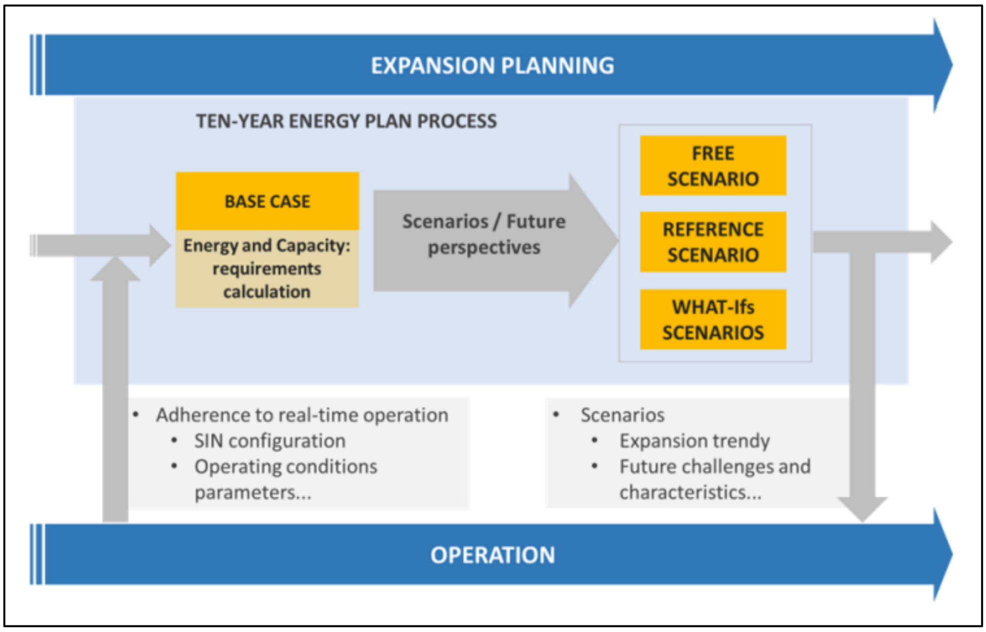


Figure 24: Brazil's PDE Planning Process (source: Brazil's MME)

As produced, the 10-Year Expansion Plan serves as the government's instrument for on-grid medium-term planning, taking into consideration energy planning guidelines from the PNE, demand forecast, and implementation schedules of generation and transmission projects.

One important aspect of the Brazilian's approach to power sector planning in meeting its electricity growing demand shown in Figure 25 is the hydrology variability risk management that its hydropower generation sub-portfolio might cause in terms of resource adequacy and security of supply. The associated risk which in the past had created concern, has recently in 2021 being exposed with the country recording one of the most critical inflows in a 91-year history within a 6-month period, exacerbated by the water storage levels found at times at 32% in some of its largest reservoirs at the beginning of the dry season. With a growing concern of climate change trends indicating longer droughts and lower water reservoir availability, Brazil has taken steps to reflect these conditions in its planning process with the objective to providing structural improvements leading to long term implementable solutions that avoid rationing measures and blackouts, both of which negatively impact the country's economic growth.

While pessimistic scenarios in hydrology analysis have been the default consideration for its associated risk mitigation, it would often lead to recommendations of long term generation contracting, some of which excessive and causing additional economic stress in the form of higher tariff. As an improvement to the approach and in response to a need for planning adaptation, the MME is focusing efforts in a better assessment of the possible structural changes in hydrology inflow regimes and in the availability of basins' water inflows, all used as inputs to hydropower generation inflexibility representation and availability considerations within the planning process. In practice, that assessment is expected to be deployed gradually over three timespans: short term, medium term and long term initiatives. Short-term actions will focus on the recalibration of hydrology time-series forecasting based on recent climate change collaboratively with the National Water and Sanitation Agency (**ANA** – Agência Nacional de Aguas e Saneamento Básico), medium term contribution will encourage the development of studies in climate change scenarios with other institutions in the context of the Intergovernmental Panel on Climate Changes's (IPCC) assessment reports, and the long term will target discussing with analytical models suppliers improvements in the consideration of uncertainties and climate variables, as well as their impacts on forecast of future hydrology scenarios, demand growth and other renewable sources as well.

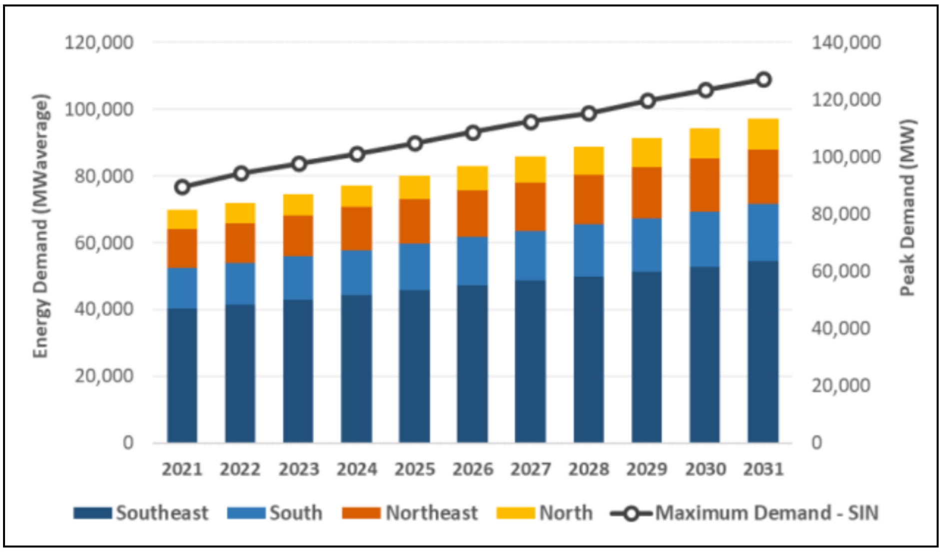


Figure 25: Brazil's Expected Electricity Demand Growth (source: Brazil MME)

With a power system dominated by hydropower generation (62% estimation in 2021 and 55% projection in 2031) and in anticipation of growing demand within the next decade, the GoB has taken steps to develop a planning strategy focusing on innovation and resilience. While pushing for further integration of renewable energy in the supply mix, the GoB takes a proactive approach in its planning strategy that aims to reflect and mitigates the impact of climate change in the investment plans recommendations of its power sector infrastructure, both learning from its past experience and building on best international practices with the objective to keep the power sector reliable, sustainable and resilient.

In conclusion, both Brazil and Ghana have implemented a framework to develop their power sector planning instruments with their countries technical expertise, acknowledging the importance of growing organically capacity building in the sector for future initiatives.

5. Outcome – Part III: Proposed Improvements to Current Power Sector Planning Approach in Cameroon

Our review of the power sector in Cameroon has shown the country is rich in diverse energy sources. Some of these sources are used for the production of electricity and to meet other energy needs. This is the case with natural gas being used in industrial chemical fertilizers factories and as fuel supply to gas-fired generation plants. It is also the case for water in the Sanaga river being used for the network distribution of water in the Centre region and for production of electricity use in the various hydropower generation plants on the river. Further and based on high hydropower potential, Cameroon has approached its power sector planning from the perspective of capturing that potential as much as practical, leading to the development of Master Plan centered around large hydropower generation capacity as currently and in the future.

In practice, the implementation of the needed electricity infrastructures and programs has not been executed as per the recommendations contained in the National Master Plan nor as initially planned. This in part has been caused by the degrading economic situation the country has experienced, but also because of a non-adequately coordinated approach to system planning and implementation, the inability to modernize the existing infrastructure and optimize its maintenance, a slowly evolving regulatory landscape and finally and the inability of performing a structural comprehensive review of the sector planning paradigm in an environment facing financial stress and increasing uncertainties.

Based on our review of the sector's planning approach and topics discussed in the previous chapters, the recommendations below are intended to improve the sector planning approach overall and can also serve as additional support to the initiatives outlined in the PRSEC. Some of the recommendations which appear more operationally centric remain relevant in the context of sector planning as their articulation comes from an observed planning implementation limitation.

Ultimately, the recommendations herein presented are part of the nexus [policy-to-planning, planning-to-operations, operations-to-performance, performance-to-benefits and benefits-to-policy], which shapes the sustainability of electricity sector (see recommendation 5.1.18). The recommendations are further characterized by:

- Impact: where values can be *Operations* indicating that the impact is primarily felt in systems operations, or *Institutional* indicating that the primary impact is elsewhere in the planning process
- Timeline: where values can be *Immediate* indicting the possibility for completion within a year, *Medium Term* indicating the possibility for completion within 2 years, and *Long Term* indicating the possibility for completion with 3-4 years

Finally, the proposed recommendations do not represent an exhaustive list of possible improvement initiatives, but rather a collection of improvement opportunities from which additional ones could be derived.

5.1. Recommendations

5.1.1. Generation Assets Maintenance

Re-adhere to the manufacturers' maintenance and replacement programs of for existing generation assets. A maintenance program of the assets must be developed, inventoried along with maintenance risk impact matrix to better prioritize the timing of its implementation. This should ideally apply to all generation assets in the system, and more specifically in areas facing critical supply risk

- *Impact*: Operations
- *Timeline*: Immediate

5.1.2. Transmission & Distribution Assets Maintenance

Re-adhere to the manufacturers' maintenance and replacement programs for existing transmission and distribution assets. Similar to the recommendations on generation assets maintenance, the program must provide inventory, continuous monitoring and maintenance risk impact matrix.

- *Impact*: Operations
- *Timeline*: Immediate

5.1.3. Assets Outage Management

Develop an outage management program for generation, transmission and distribution assets.

The developed program should include processes and systems built with the objective to better align supply availability and demand according to system operations expectations and planning coordination.

- *Impact*: Operations

- *Timeline*: Immediate

5.1.4. Water Supply Management

Develop an operational water supply management for existing hydropower assets with the objective of tracking expected water availability for and regulation of hydropower generation, in coordination with outage management program mentioned earlier. Such a program should target operational short term (up to a week) scheduling and mid-term (up to 1 month) planning.

- *Impact*: Operations
- *Timeline*: Medium Term

5.1.5. Thermal Fuel Supply Management

Develop a coordinated thermal fuel supply management system dynamically reflecting the expected use of thermal generation, and in coordination with outage and water supply management programs.

- *Impact*: Operations
- *Timeline*: Medium Term

5.1.6. Demand Forecast

Demand forecast models are critical to generation, transmission and distribution planning. With the need to revisit the planning process in Cameroon, it is important for stakeholders to invest in expertise in demand forecasting and acquire the necessary infrastructure to perform such activity (beyond the current 2024-2027 indication of incremental industrial demand). A similar need might arise for system operations needs within the integrated network. We believe this approach in infrastructure assessment coupled with capacity building (see recommendation 5.1.19) carries more benefits than the outsourcing of demand forecast studies.

- *Impact*: Institutional
- *Timeline*: Medium Term

5.1.7. SCADA, AGC Infrastructure Expansion and Energy Management System

Generation, transmission and distribution assets monitoring infrastructure for better real-time health assessment is required for optimal control of grid-connected networks. That optimal control using SCADA architecture also requires investment in AGC and Energy Management System infrastructures. Such technology allows for a timely control of an integrated network and helps achieve significant operational costs over other control architectures. An investment roadmap based on a target control architecture for the integrated Cameroon's network should direct how priorities for their implementation are defined, in addition to the PRSEC's proposed transmission and distribution SCADA deployment in 2024 and 2027 respectively for a combined investment estimate of 8.2 Billion FCFA.

- *Impact*: Institutional
- *Timeline*: Immediate

5.1.8. Transmission Line Monitoring System

In a transmission grid architecture in Cameroon knows little redundancy and is characterized by critical line paths for electricity delivery. A line failure along the critical path could create long power outages in the affected regions which could be further prolonged because of low replacement equipment inventory. A proactive intelligent line monitoring system in contrast to the current manual monitoring protocol could reduce the frequency and duration of unplanned outages especially in areas with difficult access, thus increasing transmission network availability.

- *Impact*: Operations
- *Timeline*: Immediate

5.1.9. Energy Balance Report and Sector Performance Data

The need for Energy Balancing report is critical for the understanding of the historical energy production and consumption in the context of a country's economic environment, as well as an indicator for possible future trends. It also provides decision-making with an overview for possible energy conversion towards electricity. Its availability when adequately data fed informs on what sector development opportunities are in addition to lessons learned. This is also evidenced by our review of Ghana and Brazil's power sector planning approach showing that Energy Balance plays an important role in the process. The GoC should invest in the design and development of the program and infrastructure needed to produce a coherent Energy Balance report. At the minimum, the report should have should be produced annually and be designed for data exchange flexibility amongst stakeholders, acknowledging that some of its information holds cross-sectors benefits.

Likewise, the sector regulator should require actors to provide performance and operational cost information regularly throughout the year for sector activity monitoring. Recognizing that some of the data needed here could also be used for Energy Balance reporting, the information gathering platform should be designed with pertinence in mind.

- *Impact*: Institutional
- *Timeline*: Medium Term

5.1.10. National Water Reservoirs Management

As a country that intends to have more than 80% of its electricity generation through hydropower sources, it is necessary for Cameroon to initiate and develop an Integrated Water Resource Management (IWRM) program, that systematically for each main river/basin, looks into how water resources should be allocated competitively and economically for the households, commercial and industrial needs which include hydropower electricity from a planning perspective. A well designed IWRM program should include a Water Resource Planning component for hydropower generation activity vector and must preserve an optimal hydro morphology of the water courses in the impacted basins. Further, coherent IWRM program in a country like Cameroon must take into account the inter-regional climate pattern evolution the country experiencing.

- *Impact*: Institutional
- *Timeline*: Long Term

5.1.11. Grid Code Improvement

In addition to the recently developed Grid code components, a Planning Code and an Operations Code must be created to provide guidance in the development of sector planning in general and transmission network planning and reliability criteria in particular.

- *Impact*: Institutional
- *Timeline*: Medium Term

5.1.12. Transmission & Distribution Assets Reinforcements

Based on the recent [2024-2027] industrial demand forecast, needs for T&D reinforcement have been identified by the transmission System Operator and Distribution Utility. T&D needs over the same period on residential and commercial demand forecast must be performed and prioritized as well. The proposed reinforcements must also target the smooth absorbing of the upcoming Natchigal production. As such, it is critical that the proposed T&D reinforcements be executed timely: the execution requires completing the T&D technical assessments to meet the said demand and finding the necessary financing. Additionally, an assessment and corrective action plans on the reasons as to why reinforcement projects such as with the PRETERRS project are not executed timely must be performed.

Going forward such T&D assessment must also performed in the context of strict planning process analysis. Within that context, the circuits' protection assessment part must be coordinated between the transmission and distribution functions as well. The overall assessment must also take into account mid-term and long-term needs, and projects development likelihood such as Kikot's generation project development.

- *Impact*: Operations

- *Timeline*: Immediate

5.1.12.i. RIE and RIS Interconnection Reinforcement

A robust integrated network requires strong interconnections. The RIE-RIS interconnection is critical to the development of the mining and industrial potential located in the eastern part of the country. The 225 KV transmission line between Yaoundé (southern region) and Abong-Mbang (eastern region) must be better stabilized, while intra-connections within the eastern region such as the Bertoua - Abong-Mbang corridor must be reinforced adequately to improve network reliability.

- *Impact*: Operations
- *Timeline*: Immediate

5.1.12.ii. RIS-RIN Interconnection and PIRECT

With the recent launch of the Cameroon-Chad interconnection project, the first phase has been identified as the interconnection of the RIS and RIN networks within Cameroon while the second phase will link the northern region of Cameroon to Chad. An adequate assessment of communities' electrification benefits as well as commitment to the project implementation timeline in a socially and environmentally responsible manner should be the guiding principles of that project's execution. Technically, this requires the identification and installation of the personnel needed for the project execution and adherence to the projects implementation principles defined by the beneficiaries and project's financial sponsors, the World Bank and the African Development Bank. Because of the critical nature of project, implementation delays must be minimized in order not to penalize the economy of Chad expecting to receive competitive energy generation from Cameroon, or that of Cameroon expecting to replace expensive generation in the northern region of the country with cheaper generation from the southern region of the country. This project will also help accelerate regional integration within the context of the Central African Power Pool (CAPP).

- *Impact*: Operations
- *Timeline*: Immediate

5.1.13. Off-Grid and Rural Electrification: Harmonization and Communities Economic Development

Off-Grid and rural electrification solutions should be developed with the acknowledgement that most of their customers are economically fragile. As such, both private and government sponsored electrification programs or projects targeting these populations must provide them with incentives to encourage electricity access, and make it affordable. These incentives could be in the form of subsidies programs and linked with local economic development initiatives for the targeted communities and identified by them. They could also foster further investment initiatives in line with the already identified PRSEC's package of 8 Billion CFCA for small solar and hydropower plants. In that context, the additional recommendations are provided:

- Developing a Renewable Energy Master Plan as a byproduct of broader integrated system planning framework through co-optimization of on-grid and off-grid expansion options , thus considering off-grid and rural electrification objectives, guidelines and criteria within a comprehensive planning assessment (see recommendation 5.1.18)
- Encouraging policy and regulatory framework for an agile promotion and development of renewable energy projects
- Working towards the tariff structure harmonization for energy access affordability in economically disadvantaged areas
- Working towards the development of technical standards to apply in the development of rural and off-grid projects, for harmonization of possible future network anchoring or DER services standardization
- Investing in local human capital, research and development on the topic of renewable energy and related activities
- Reinforcing the AER deployment and rural electrification planning coordinator missions more efficiently, namely with technical assistance in its partnership with CTDs in the identification of communities rural electrification projects plan development with economic value on one hand, and adequate and dedicated funding on another
- Establish a collaborative framework between the AER and other entities involved in the rural electrification development on the basis of identified responsibilities in the context of an integrated planning framework.

- *Impact*: Institutional
- *Timeline*: immediate for tariff harmonization, Medium Term otherwise

5.1.14. Infrastructure Security

It has been reported that about 62% of the 630,000 installed smart meters in 2022 have been tampered with. This security breach should be addressed not only for the deployed equipment but also preventively for upcoming deployment phases as well. When also considering the recent billing platform hacking of the distribution utility, it becomes imperative that any infrastructure modernization initiative be conducted in partnership with the GoC to design end users platforms with adequate physical and cyber-security standards for the infrastructure to deploy. This design and implementation imperative must be extended to assets in the generation, transmission segments as their modernization also requires cyber-enabled equipment. The other aspect of security which concerns the physical integrity of the infrastructure must be analyzed as well, in the form of an assessment and remedial plan for the vulnerabilities of the deployed assets, especially of those deemed critical to systems operations.

- *Impact*: Institutional
- *Timeline*: Immediate

5.1.15. Revenue Collection Improvement, Public Consumption Management and Smart Distribution Digitization

With an imperative to curb fraud which in 2020 was estimated to be twice as high as its annual investment budget, the distribution utility must accelerate the modernization of the electricity consumption management and billing infrastructure, to improve monitoring and revenue collection. In that context the expected 2024-2025 deployment of 1.65 Million smart meters must be respected, while addressing all security issues observed in previously deployments and which have caused billing inaccuracy and utility revenue losses. Similarly, the GoC must invest in public energy consumption management infrastructure such as smart public lightning systems to reduce non-optimal energy usage.

These types of initiatives which involve digitization of the energy infrastructure should be seen as components of a broader smart distribution program for which decarbonization, energy consumption optimization and comfort level should be drivers to the identification and steps to the implementation of the processes and technology equipment selection beyond just smart meters deployments and public lightning monitoring concerns. A more targeted approach on the basis of a comprehensive analysis of what the objectives are and technological advances permit must be conducted for a more efficient technology deployment.

- *Impact*: Institutional
- *Timeline*: immediate

5.1.16. Sector Financial Stability

A critical aspect of sector’s sustainability requires for distribution utilities to collect enough revenue to invest in grid reinforcements and densification initiatives. In Cameroon, the distribution utility annual reports have shown that this becomes difficult due to unrecovered debt owed by public sector end users such as government companies, forcing the utility to borrow unfavorably on the short-term market to carry on with its investment mandates as short term solution, but creating a sector’s sustainability risk in the long term. Besides the financial restructuring need for the government companies to clear their existing debts, solutions such as allocation accounts for electricity spending must be implemented with enforcement triggers. On the other hand, knowing that collected revenues are continuing to be lower than actors incurred investment and operational costs, the inevitable cycle for make-whole related disbursement must be shortened.

Observed since 2017, the electricity sector financial imbalance persists in Cameroon and the risk of sector collapse has increased, with collected revenues continuing to be lower than actors' incurred investment and operational costs. One proposed solution from the GoC is to integrate additional demand within the grid. While relevant for grid expansion purposes, satisfying increasing demand as a way to reduce that imbalance must happen in way that the required infrastructure to meet that demand is implemented from a least-cost paradigm. Further it is important for the administered tariff not to be too far from the cost of service so as to reduce tariff compensation which drains additional financial resources from the government, and invest aggressively in network efficiency improvements and reduce the billing-to-payment cycle. A complementary aspect is the investment in smart demand programs, whereby end users control when best to consume electricity such as with time-of-use tariff articulations which can encourage load shifting towards off-peak periods and have a positive impact in infrastructure investments savings.

- *Impact*: Institutional
- *Timeline*: immediate

5.1.17. Hydropower-Solar Hybridization

The upcoming interconnection between the RIS and RIN offers natural supply complementarity availability for the integrated network. Exploring how that complementarity could be used for the southern region hydropower hybridization and fast energy supply capacity deployment in the northern region could be beneficial to a system with resource adequacy imbalance such as Cameroon's. An alternative in the form solar-hydro colocation at utility-scale could also be an option, even though the solar potential in the southern region is not as high. For off-grid considerations, hydropower-solar hybridization should be considered as economically relevant for the targeted communities.

- *Impact*: Institutional
- *Timeline*: Long term

5.1.18. Power Sector Planning Through an Integrated and Coordinated Framework

We have concluded as a result of our assessment that the power planning approach in Cameroon would benefit from an integrated framework.

This articulation can be justified first by the cross-sector use of the natural resources on which the government's 2035 vision to implement an electricity grid architecture consisting of hydropower utility-scale generation (85%), gas-fired generation (10%) and other renewable options (5%) relies. Adding to it the goal to achieve universal electricity access requires a structural approach to power sector planning. Next, such an approach should build on the cross-dependencies that exists amongst the concerned stakeholders entities but also amongst the resources cross-sector dependability. This evidence leads to the recognition that beyond that adequate integrated system planning must reflect the co-optimization of cross-sector energy resources for both on-grid and off-grid needs wherever justified.

A proposed Integrated Power Sector Planning (IPSP) framework capturing all aspects of our discussion and recommendations outlined in this chapter is presented in Figure 26. This comprehensive framework can serve as a guideline to system planners in Cameroon and be adapted to the country's power sector evolving environment.

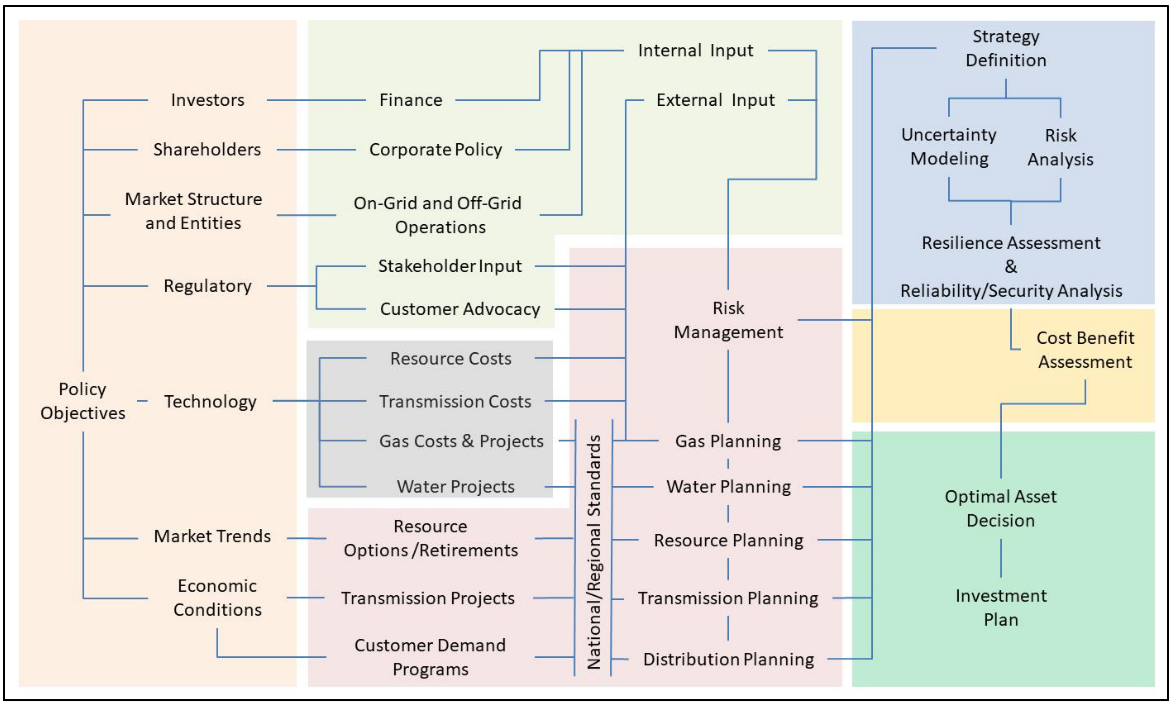


Figure 26: Proposed Integrated Power Sector Planning Framework (*adapted from EnergyExemplar*)

For the framework implementation to be successful, the following must be satisfied:

- First, all key stakeholders' entities involved the power sector and impacting the operational and planning framework must be identified,
- Then leveraging on the institutional structure of the identified entities, a planning coordinating entity with their members should be created, with roles allocated according to their mandates and expertise. The planning coordinating entity must be structured to handle managerial and technical oversight of all the activities associated with the planning process activities. This step should be the opportunity to identify the capacity building (see recommendation 5.1.19), tools and processes needs for each activity and role in the planning process, as well as reinforcing them as appropriate. With Cameroon eyeing electricity network interconnection with other countries, a planning coordinator should also help assess and integrate the medium and long-term reliability and security impacts to other interconnected systems. In practice, sector planning coordination and development under the proposed framework could be structured in various forms such as through:

- an entity under the leadership of the sector supervisory ministry as is the case in Ghana and South Africa,
- a specialized entity in charge of sector planning policies roadmap development as seen in Brazil with the interaction between CNPE (The National Council for Energy Policy) and EPE (The Energy Research Company), and in the United States with the Northwest Power and Conservation Council (**NPCC**) in charge of power system planning for Pacific Northwest region of the country.

- Next, the identification of needed information, the procedures to collect it and the data architecting framework (including data sharing protocols and procedures) required to perform the associated planning process activities must be put in place
- Next using the foundational paradigm of least-cost planning, electricity value chain planning analysis can be derived as a first step, ideally from a co-optimization or near co-optimization standpoint. In the case of Cameroon, it is important to include water and gas planning as components to the planning analysis framework besides the segments of production, transmission and distribution,
- Next, a risk assessment taking into consideration aspects of resilience (including climate change) and decision making under growing uncertainty must be performed and,
- Finally, a cost-benefit assessment of the retained investment portfolios candidates is executed in search of the best performing one, which should be the one of least-regret.

Once derived, a selected infrastructure investment plan must subject to periodic reviews and as agreed by the stakeholders. The review frequency must be determined in acknowledgement of the country's context within which the process is established. Experience from Ghana suggests a 2-3 year revision process while the 10-Year PDE plan in Brazil is produced yearly.

A National Master Plan requires regular updating, and the proposed IPSP framework can serve as a guideline towards a more adequate plan development, though the adoption of key aspects in the short to medium term.. In the long term, a full implementation of the IPSP will provide system planners and decision makers with a comprehensive approach to power sector planning

- *Impact*: Institutional
- *Timeline*: Medium Term

5.1.19. Power Sector Planning: a Need for Capacity Building

Recent experience in Ghana has shown that adequate power sector planning requires the involvement of all stakeholders and ownership throughout the process. A parallel can be drawn in Cameroon where expertise in all aspects of the planning framework is needed. Leveraging best practices and technical mentorship, the GoC must invest in human talent in every aspect of the planning process and help its institutions have full ownership of the process design and implementation. Expertise will be needed in several areas including regulatory landscape, renewable energy, demand forecast, generation planning, transmission planning, water infrastructure optimization, distribution planning, power systems analysis, grid code and reliability standards, gas-to-power optimization, market and systems operations, smart grid technology, energy financial modeling and risk management.

A capacity building program articulating these needs must be developed to include gender skills access and the option for partnership with professional institutions, universities and/or energy companies locally or within the extended region if relevant. One element of talent growth sustainability is the development of Centers of Excellence, by which expertise for the country and the region could be harvested. These orientations should be considered as complements to the estimated 15.7 Billion FCFA PRSEC's medium term's horizon (2023-2027) initiative to boost capacity building in the sector.

- *Impact*: Institutional
- *Timeline*: Medium Term