Update of the ECOWAS revised master plan for the development of power generation and transmission of electrical energy

Final Report

Volume 1 : Executive Summary

December 2018

Financing

European Union
11th EDF Regional Indicative Programme
Financing agreement EDF/2017/ 039-384

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TECHNICAL DOCUMENT

Our ref.: **WAPP-MP/4NT/0626321/000/09**
TS:
Imputation: P.011966/0004

INTERNAL

Client:

Project: **ECOWAS MASTER PLAN FOR THE DEVELOPMENT OF REGIONAL POWER GENERATION AND TRANSMISSION INFRASTRUCTURE 2019-2033**

Subject: VOLUME 1: Executive Summary

Comments:

REV.	YY/MM/DD	STAT.	WRITTEN	VERIFIED	APPROVED	VALIDATED
09	2019 01 17	FIN	*L. Bouzat *L. Charlier	*J. Dubois		*L. Charlier
08	2019 01 03	FIN	*L. Bouzat	*J. Dubois		*L. Charlier
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*This document is fully completely signed on 2019.01.17

TABLE OF CONTENTS

TABLE OF FIGURES

Final version

TABLE OF TABLES

Final version

ACRONYMS

ADB	*Asian Development Bank*
AFD	*Agence française de développement*
BIO	*Biomass Plant*
CAPEX	*Capital Expenditure*
CAPP	*Central Africa Power Pool*
CC	*Combined Cycle*
CEB	*Communauté Electrique du Bénin*
CEET	*Compagnie Energie Electrique du Togo*
CFB	*Circulating Fluidized Bed*
CIE	*Compagnie Ivoirienne d'Electricité*
CI-ENERGIES	*Côte d'Ivoire Energies*
CLSG	*Côte d'Ivoire – Liberia – Sierra Leone – Guinea loop*
COAL	*Coal*
COD	*Commercial operation Date*
CSP	*Concentrated Solar Plant*
CUE	*Cost of Unserved Energy*
DAM	*with Dam*
(D)DO	*Ordinary Diesel*
DFI	*Development finance institutions*
DI	*Diesel group*
DNI	*Direct Normal Irradiation*
DSO	*Société de distribution d'électricité (Distribution System Operator)*
EAGB	*Electricidade e Aguas da Guine-Bissau*
ECOWAS	*Economic Community of West African States*
EDG	*Electricité de Guinée*
EDM	*Electricité du Mali*
EDSA	*Electricity Distribution Supply Authority*
(E)ENS	*(Expected) Energy Not Served*
EGTC	*Electricity Generation and Transmission Company*
EIB	*European Investment Bank*
ERERA	*Ecowas Regional Electricity Regulatory Authority*
EU	*European Union*
EUR (or €)	*Euro*
FCFA	*Francs CFA*
FSRU	*Floating Storage and Regasification Unit*
GDP	*Gross Domestic Product*
GENCO	*GENenration COrporation*
GHI	*Global Horizontal Irradiation*
GO	*Gasoil*
GRIDCo	*Electricity Transmission Company of Ghana*

Final version

GT	*Gas Turbine*
GWh	*Giga Watt heure*
HFO	*Heavy fuel oil*
HRSG	*Heat Recovery Steam Generator*
HYD	*Hydroelectric plant*
ICC	*Information and Coordination Center*
IEA	*International Energy Agency*
IFI	*International Funding Institution*
IMF	*International Monetary Fund*
IPP	*Independent Power Producer*
IPT	*Independant Power Transporter*
IRENA	*International Renewable Energy Agency*
JET	*Jet A1*
LCO	*Light Crude Oil*
LCOE	*Levelized Cost of Electricity*
LEC	*Liberia Electricity Corporation*
LFO	*Light Fuel Oil*
LHV	*Low Heating Value*
LNG	*Liquefied Natural Gas*
LOLE	*Loss of Load Expectation*
LOLP	*Loss of Load Probability*
MMBTU	*Million British Thermal Unit*
MMCFD	*Million Cubic Feet per Day*
MRU	*Union de la Rivière Mano (Mano river Union)*
N/A	*Not Available*
NAWEC	*National Water and Electricity Company*
NBA	*Niger Basin Authority*
NDC	*National Determined Contribution*
NG	*Natural Gas*
NIGELEC	*Société nigérienne d'électricité*
NTP	*Notice to proceed*
O&M	*Operation & Maintenance*
OC	*Open Cycle*
OECD	*Organisation for Economic Co-operation and Development*
OLTC	*On Load Tap Changer*
OMVG	*Organisation de Mise en Valeur du fleuve Gambie*
OMVS	*Organisation de Mise en Valeur du fleuve Sénégal*
ONEE	*Office National de l'Electricité et l'Eau Potable (Morocco)*
OPEX	*Operating Expenditure*
PC	*Pulverized Coal*
PPA	*Power Purchase Agreement*
PPP	*Private Public Partnership*
PSS	*Power System Stabilizer*
pu	*per unit*

Final version

PV	*Photovoltaic plant*
RES	*Renewable Energy Sources*
ROR	*Run of river*
SAIDI	*System Average Interruption Duration Index : Indicateur de la durée moyenne de coupures sur le système*
SAIFI	*System Average Interruption Frequency Index : Indicateur de la fréquence moyenne de coupures sur le système*
SBEE	*Société Béninoise d'Energie Electrique*
SENELEC	*Société nationale d'électricité du Sénégal*
SOGEM	*Société de Gestion de l'Energie de Manantali*
SONABEL	*Société nationale d'électricité du Burkina*
ST	*Steam Turbine*
SV (or VS)	*Standard Value*
SVC	*Static Var Compensation*
TCN	*Transmission Company of Nigeria*
TSO	*Transmission System Operator*
USD (or US$ or $)	*US Dollar*
VRA	*Volta River Authority*
WAGP(A)	*Western Africa Gas Pipeline (Association)*
WAPP	*West Africa Power Pool*
WT	*Wind Farm*

1. INTRODUCTION

1.1. Context

The Economic Community of West African States (ECOWAS) is a regional community with a surface of 5.1 million of square km which represents about 17% of the African continent. With a population of more than 300 million inhabitants in 2017, ECOWAS Member States are home to about one-third of the population of sub-Saharan Africa.

ECOWAS has been created with a mandate of promoting economic integration in all fields of activity of the constituting countries. The fifteen-member countries making up ECOWAS are Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone, Senegal and Togo. The ECOWAS treaty (also known as treaty of Lagos) established the Community during its signature in Lagos (Nigeria) on May 28th, 1975.

One of the most important steps of economic integration in the field of energy was the creation, in 2006 of the Western African Power Pool (WAPP). The WAPP promotes the integration of the national power systems of the fourteen inland countries into a unified regional electricity market with the ultimate goal of providing, in the medium and long-term, a regular and reliable energy at competitive cost to the citizenry of the ECOWAS region

However, the region, which is characterized by a great diversity in terms of culture, language, demography and resources, faces enormous challenges in providing access to sustainable energy for its population. But the 15 ECOWAS Member States are driven by a common desire to offer "affordable, reliable, sustainable and modern energy for all", as per the three main goals of the Sustainable Energy for All (SE4All) initiative, launched by the United Nations Secretary-General.

West-African countries have a great opportunity to reach their objectives thanks to the vast untapped potential in renewable energy (including solar, wind, bioenergy and hydro-power). The Energy Transformation will happen both on-grid and off-grid. It involves the development of mini-grids with hybrid power generation, centralized and decentralized renewable projects potentially coupled with a more flexible demand side, enabled by storage and smart-metering technologies.

Several initiatives like the *African Renewable Energy Initiative* and the *ECOWAS policy on Renewable Energy* support this transformation. However, such a revolution requires financing, leadership and international cooperation. In this context the West African Power Pool is playing a significant role by supporting the development of major energy projects in the region.

Final version

1.2. Objectives of the project

The West African Power Pool promotes cooperation and supports the development of regional projects. In 2012, the Authority of the ECOWAS Heads of State and Government approved, through Supplementary Act A/SA.12/02/12, a list of 59 Priority Projects for the subregion that emanated from the update of the ECOWAS Revised Master Plan for the Generation and Transmission of Electrical Energy prepared by Tractebel.

Considering the evolution of

- the energy landscape,
- the socio-economic context of West Africa over the last 5 years and
- the difficulty in mobilizing public and concessional financing in the sub-region,
- the development of the power system in West Africa deviated from what was foreseen in 2011. A lot of challenges affect the utilities efficiency on several aspects including financial, regulatory, technical and organizational points of view.

Another key parameter which should affect the energy development roadmap of WAPP region is the expected increase penetration of Renewable Energy Sources (RES). Thanks to the significant decrease of costs and increased willingness for the transition to sustainable energy, many WAPP countries have revised their RES targets and launched RES projects.

Consequently, while some flagship generation and transmission projects were developed in the region, some of them are still under development or were strongly delayed while, in parallel new non-anticipated projects emerged.

In this context, the study presents four different main objectives:

- Assessing the **implementation status** of the priority projects identified in 2011, understanding the main challenges and barriers to the development of these projects and identifying the lessons learned that will be taken into account when updating the Master Plan;
- Identifying the **main challenges and critical factors** affecting the performance of utilities in their activities as a public service and proposing a new action plan and mitigation measures to address these constraints in a long-term perspective;
- Assessing the opportunities and constraints for the deployment of **Renewable Energy Sources** in the sub-regional power system (potential, economics, grid constraints…);
- Presenting a clear, comprehensive and coherent view of the future development of power generation and transmission facilities with a list of **priority projects** for West Africa that takes into account the new drivers of electricity generation and consumption, while integrating the current development of the power system at national and regional level and while providing recommendations for facilitating the implementation of the projects.

This will lead to an **update of the ECOWAS Master Plan for Generation and Transmission of Electrical Energy**, a comprehensive study providing a rational basis for decision making and implementation in the power sector.

1.3. Organisation of the report for the update of the ECOWAS revised master plan for the development of power generation and transmission of electrical energy

The report is divided into five main volumes corresponding to the five main deliverables of the study.

VOLUME 1: Executive Summary

Volume 1 is the synthesis of the Final Report of the update of the revised ECOWAS Master Plan. It contains the main recommendations of the study concerning the future development of the electricity generation and transmission infrastructures as well as a list of priority projects and the implementation strategy of these projects.

VOLUME 2: State of play of the current situation of the electricity system and perspectives

Volume 2 consists of a synthesis of data collected and assumptions used in the context of this project, and in particular for the update of the generation and transmission master plan.

VOLUME 3: Challenges and Action Plans for electricity Companies

Volume 3 aims at presenting the main challenges and critical factors affecting the performance and the sustainability of utilities members of WAPP and at recommending a new action plan and mitigation measures to address these critical factors from a transversal perspective...

VOLUME 4: Generation and Transmission Master Plan

Volume 4 is devoted to the results of the generation and transmission master plan: It presents a robust and economically optimal development plan while taking into account the current state of the energy sector in West Africa and opportunities for developing renewable energy sources in the region while ensuring the technical stability of the interconnected system

VOLUME 5: Priority Investment Program and Implementation Strategy

Volume 5 focuses first on carrying out a review of the implementation of the ECOWAS 2012-2025 Master Plan and assessing the causes of the gaps between what was initially planned and what was concretely achieved, allowing some effects to be taken into consideration for the development of the 2018-2033 updated master plan. Then, a new list of priority investment projects is drawn up on the basis of the generation-transmission master plan and a strategy is recommended for the progressive implementation of these projects.

2. OVERVIEW: ECONOMY AND ELECTRICITY SECTOR IN WEST AFRICA

2.1. Macroeconomic indicators

An important imbalance exists in the region between the different member countries of the WAPP. The electricity sector is a striking example of this imbalance. For example, in 2015, out of the 50,000 GWh of electricity consumed around 42,500 GWh were consumed only by Nigeria, Ghana and Côte d'Ivoire. Nigeria alone was responsible for 57% of the region's total consumption of nearly 28,500 GWh.

The following are some macroeconomic indicators to put the study in context.

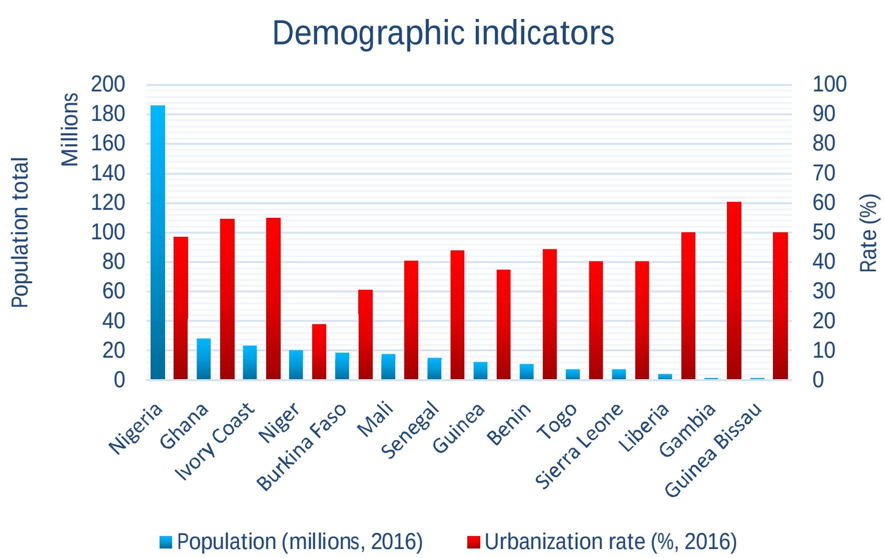

Figure 1: Demographic Indicators of ECOWAS Member Countries
World Bank data for the year 2016 (World Development Indicators, 2018)

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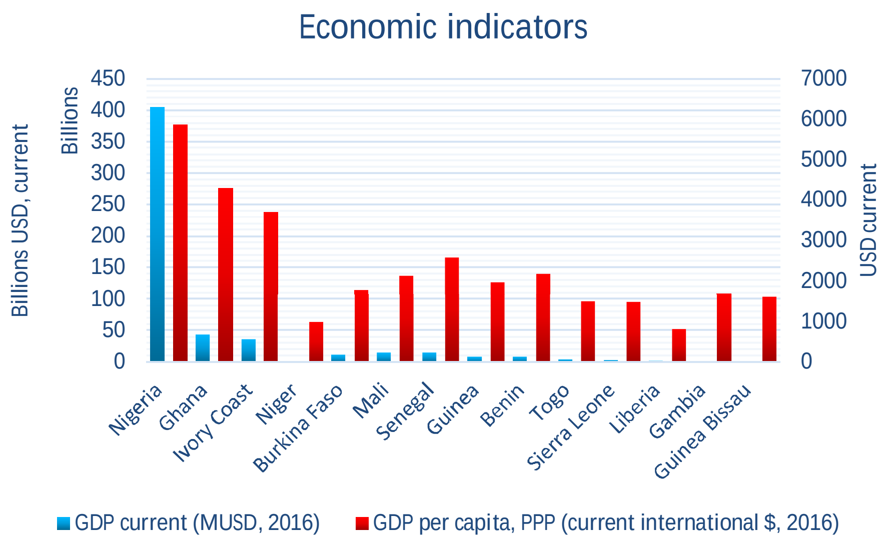

Figure 2: Indications on the economy of ECOWAS member countries
World Bank data for the year 2016 (World Development Indicators, 2018)

2.2. Governance and Institutional Framework

The different organizational patterns of the electricity sector value chain in the WAPP area are summarized below.

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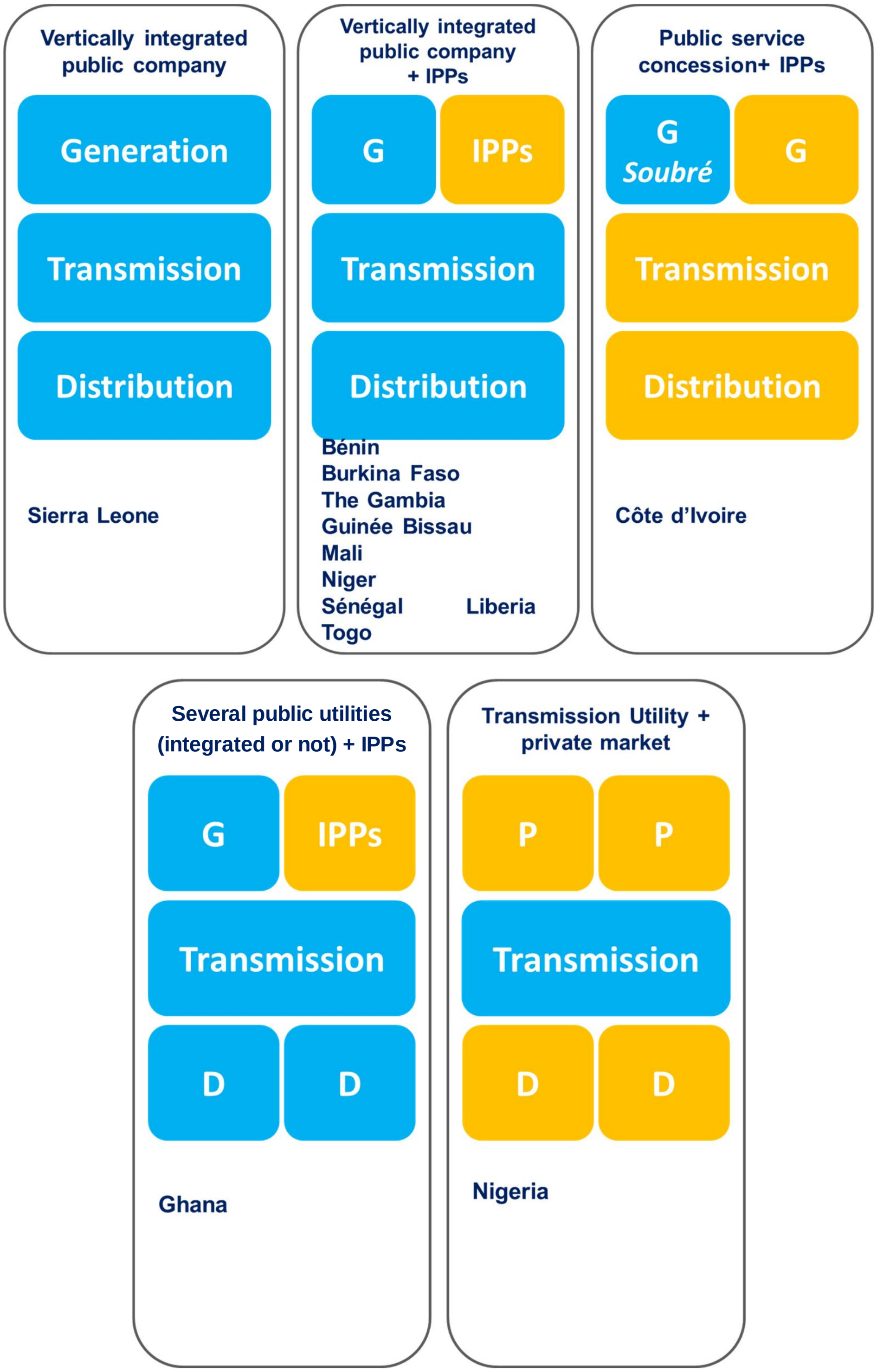

Figure 3: Organization plans of the electricity sector of the countries of the WAPP area

Final version

- Blue category means companies are public
- Yellow category means that companies are private
- The presence of IPPs in the production component means that the organization of the sector allows IPPs to intervene (without necessarily being the case.

A detailed description of the allocation of the sovereign and operational functions between the different actors of the electricity sector is presented for each country in the "country annexes" related to this report.

2.3. Technical efficiency

Technical efficiency refers to the technical performance of companies in the areas of generation, transmission and distribution.

2.3.1. Generation

Efficiency of generation refers to the ratio between installed capacity and available capacity; but also to the balance of the energy mix.

The two figures below show the relationship between installed capacity and available capacity:

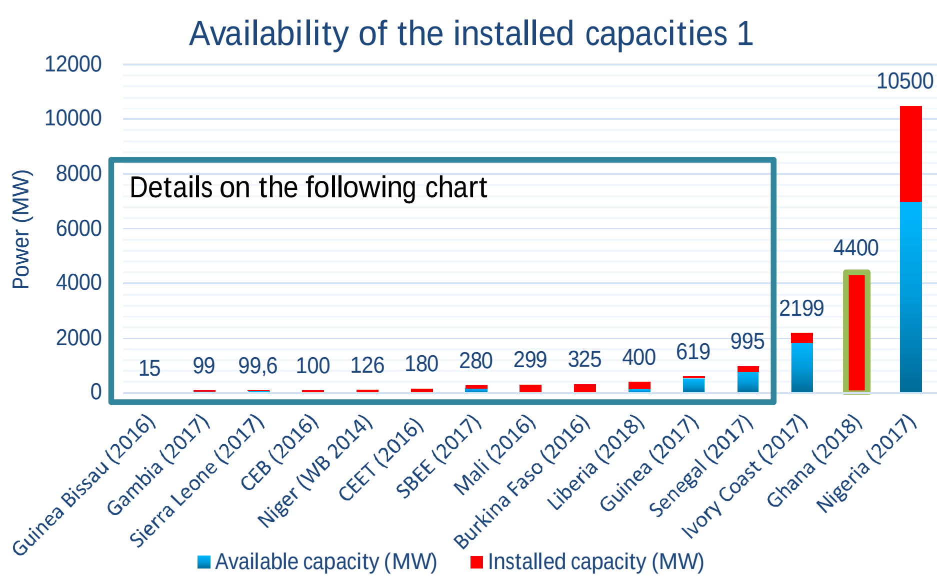

Figure 4: Availability of installed capacity 1

Ivory Coast, Ghana and Nigeria together account for approximately 80% of the installed capacity of the WAPP area. To facilitate the reading of this diagram, another scheme is proposed below, disregarding these three countries.

Final version

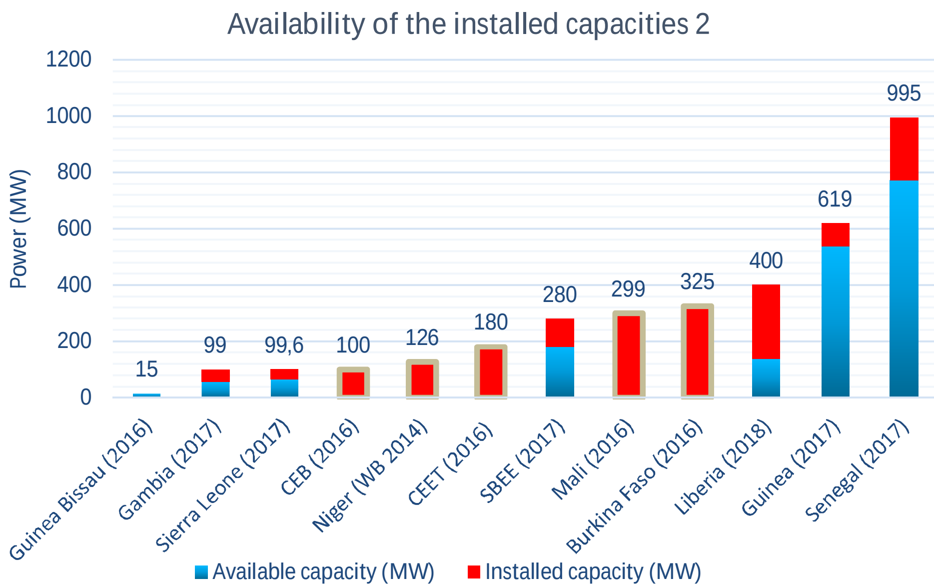

Figure 5: Availability of installed capacity 2

Concerning the CEB, Niger, CEET, Mali, Burkina Faso, Liberia and Ghana, data on the availability of production capacities were not known. Only the installed capacity for these countries is represented.

The energy mix in **installed capacity** adopted by the different countries in the zone is shown in the figure below:

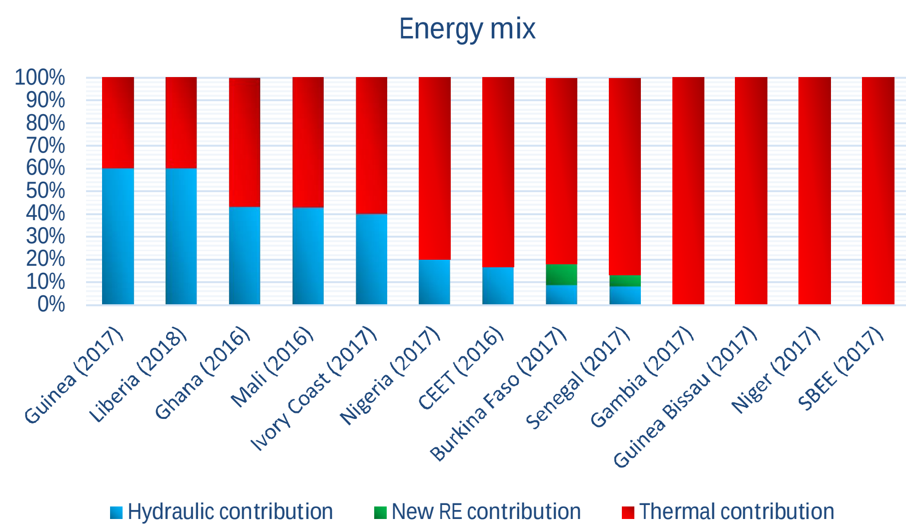

Figure 6: Energy mix of WAPP member countries

This figure shows that the energy mix is mainly dominated by thermal generation assets (gas, diesel, HFO, LFO). The rest of the mix concerns hydropower assets with the recent emergence of new renewables (solar PV).

Final version

2.3.2. Transmission

The efficiency of the transmission corresponds here to the interruptions and load-shedding on the public network. These interruptions are evaluated according to two axes: their numbers and their durations (respectively SAIFI and SAIDI).

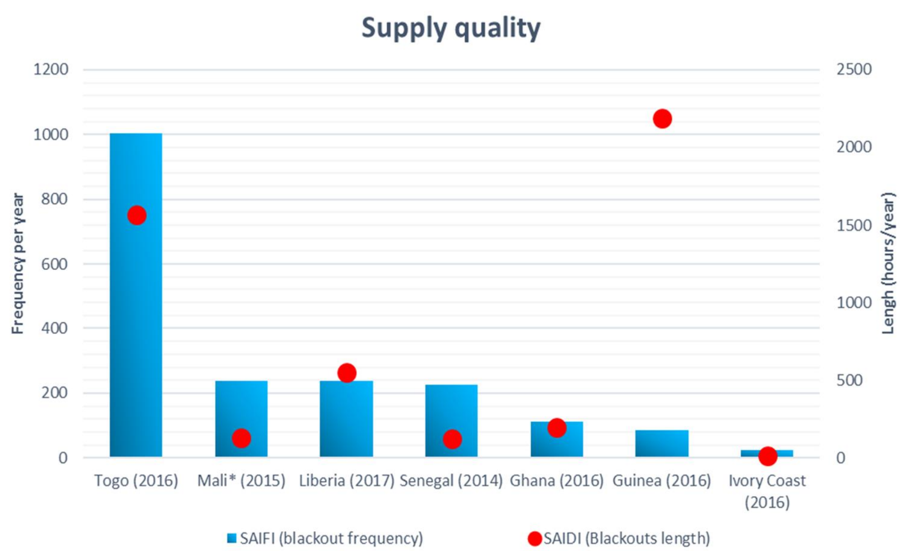

Figure 7: Supply quality – SAIFI and SAIDI

SAIFI and SAISI data were not available for all the countries studied.

** For Mali the results concern only the 150 and 225 kV network.*

Among the countries whose information was available:

- Togo has numerous interruptions lasting a long period of time;
- Mali, Liberia and Senegal show common constraints;
- Guinea has significantly reduced its interruptions frequencies, but they remain relatively long;
- Côte d'Ivoire has a very good supply quality.

2.3.3. Distribution

Efficiency of distribution is looked at through two aspects:

- Access rate of the population to electricity and,
- losses on transmission and distribution networks.

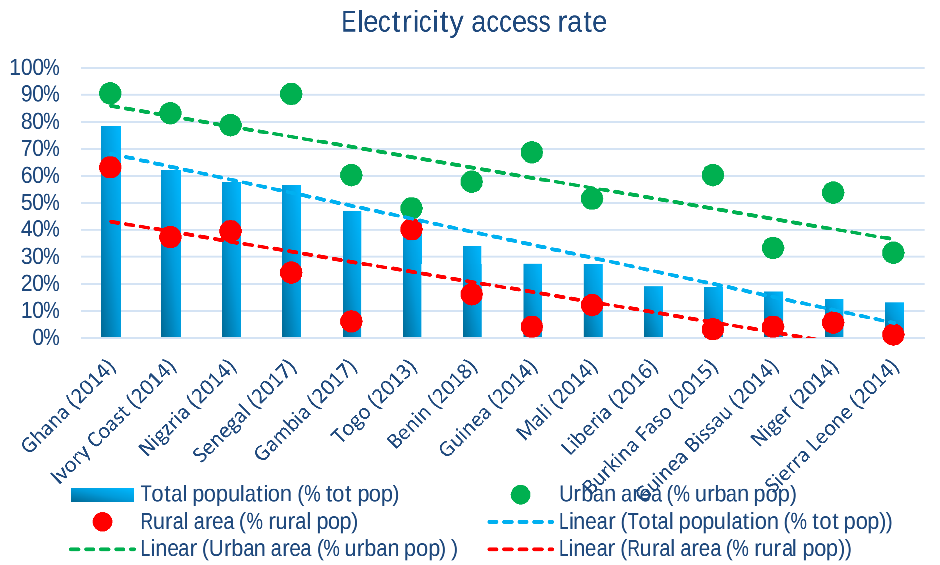

Figure 8: Rate of access to electricity of the population
World Bank data for the year 2016 (World Development Indicators, 2018)

The access rate of electricity to the population is relatively variable according to the countries considered. It ranges from almost 80% for Ghana to less than 10% for Liberia. While the rate of access to electricity in urban areas follows the same trend as access for the total population, the rate of access to rural areas diverges more than one country to another.

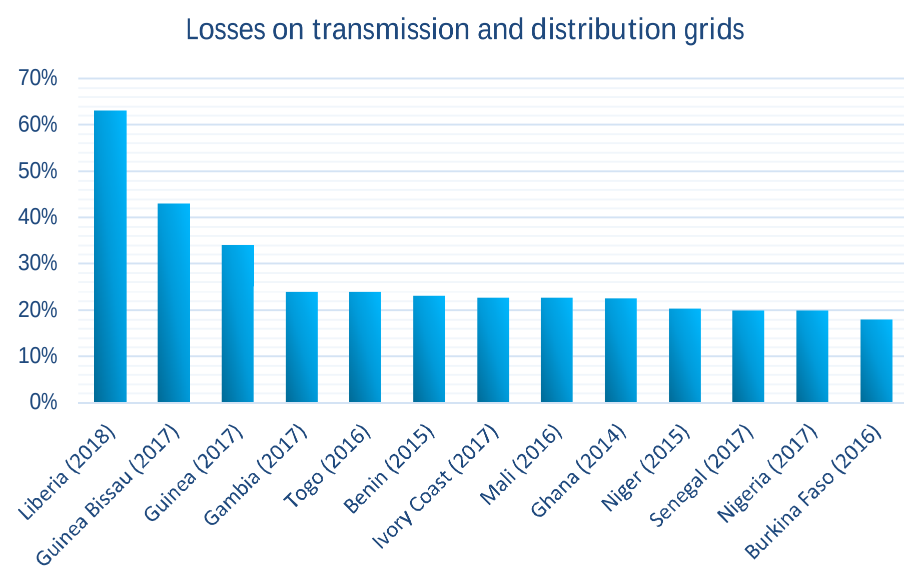

Figure 9: Rates of technical and non-technical losses on transmission and distribution networks

The loss rate on the transmission and distribution networks ranges from 18% for Burkina Faso to 43% for Guinea Bissau. However, most countries are in a narrow range between 20% and 26% of losses.

Final version

This rate considers both technical and non-technical losses. The details of these two variables are more fully discussed later in the report as they are critical factors in the performance of utility services. Finally, note that in addition to transmission and distribution losses, it is also worthwhile to consider generation losses (auxiliary consumption), typically amounting to 1 - 1.5% of gross output.

2.4. Financial efficiency

Financial efficiency refers here on the one hand to the tripartite relationship of cost, tariff and billing and, on the other hand, to the financial health of the sector.

2.4.1. Costs, tariffs and billing

The following information is included here:

- the cost of the electricity service,
- the average rates charged to end consumers and
- bill collection rate.

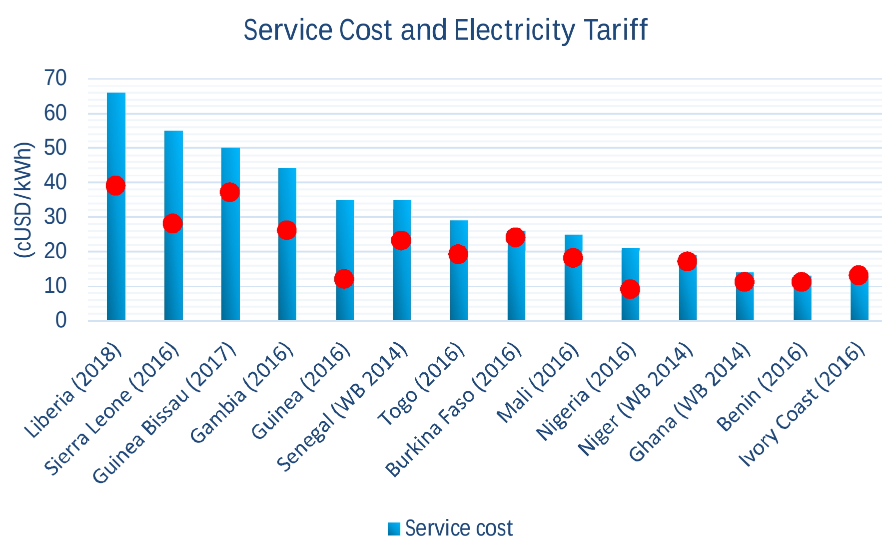

Figure 10: Costs of service and tariffs

The realization of this chart required to carry out conversions of currencies whose rates are given at the beginning of the report.

When data were not available as a result of data collection for this project, they were identified by "WB" attached to the country and were taken from the World Bank document: Financial Viability of Electricity Sectors in Sub -Saharan Africa - Quasi-Fiscal Deficits and Hidden Costs, World Bank Group, 2016.

The figure clearly indicates that tariffs applied in different countries do not cover the costs of electricity service. Some countries like Burkina Faso, Niger or Côte d'Ivoire are approaching it however.

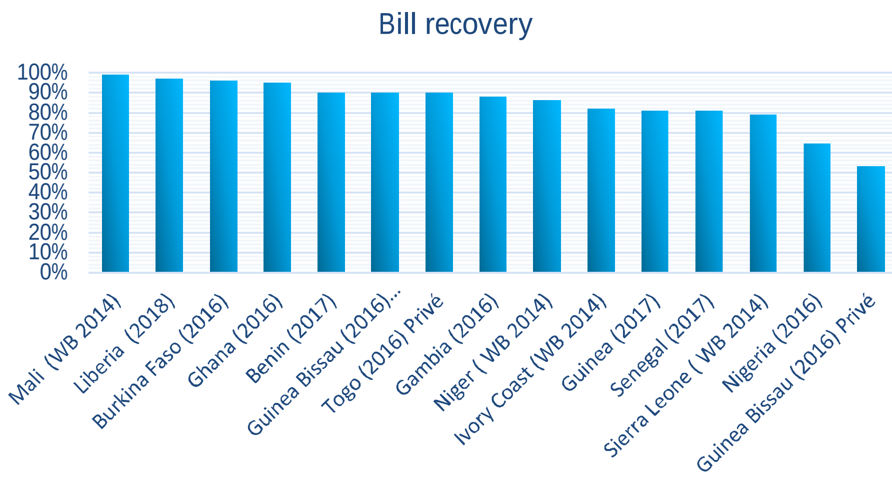

Figure 11: Bill collection rate

The bill collection rate contributes to the financial balance of the sector. The majority of countries find their collection rate at a relatively good level between 80% and 96%.

2.4.2. Financial health

The presentation of the financial health of the sector focuses on accounting and financial indicators such as: turnover and net income. They testify to the financial strength of society and the sector more generally.

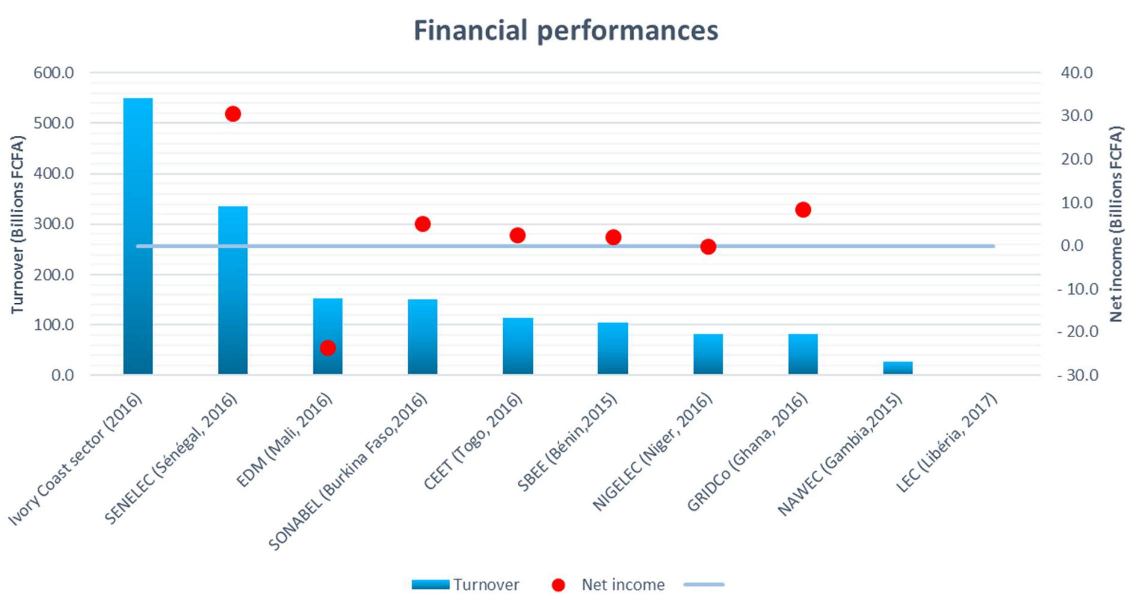

Figure 12: Financial results of Utilities

Final version

The turnover of the electricity sector shows significant differences from one country to another ranging from a few billion CFAF for Liberia to more than 500 billion CFAF for Côte d'Ivoire.

On the other hand, the net result indicates in some cases the difficulties encountered by the Utilities. This seems to be the case for EDM in Mali and, to a lesser extent, NIGELEC in Niger. SENELEC in Senegal, on the other hand, is showing significant profits.

3. STATE OF PLAY OF THE CURRENT SITUATION OF THE ELECTRICAL SYSTEM AND PROSPECTS

The West African energy sector is currently drastically evolving. This mutation creates many challenges for the planning and operation of the system, but the region has many resources that represent many opportunities for an energy transition in West Africa.

3.1. A high growth of electrical demand

With an average annual forecasted growth rate of more than 8% for the next 15 years according to the load forecast prepared within the framework of this study, the ECOWAS region ranks high among regions with high growth around the world.

In the subregion, the main vectors of demand growth are

- The **growth of the economy** (industry development and increased Gross Domestic Product) and
- The **residential consumption growth** (demographic growth, increase in quality of service, electrification, growth in household consumption...).

Countries currently facing a significant deficit in electrical infrastructure (generation units, transmission axes and distribution lines) have the greatest potential for growth at short-and medium-term.

The table below summarizes the peak-of-charge forecast for each country. It should be noted that this table presents the current potential demand, i.e. it includes the unserved demand and the self-generation.

Peak load (MW)	2018	2020	2022	2025	2030	2033	Average growth
BENIN	276	314	359	432	587	704	6,4%
BURKINA FASO	318	385	471	613	858	1043	8,3%
IVORY COAST	1420	1767	2013	2434	3316	3981	7,1%
GAMBIA	106	122	140	173	243	297	7,0%
GHANA	2225	2849	3217	3597	4380	4957	5,6%
GUINEE	421	482	551	666	914	1104	7,5%
GUINEA BISSAU	78	91	105	129	179	215	7,1%
LIBERIA	111	137	166	218	328	411	9,2%
MALI	568	621	680	778	976	1118	6,4%
NIGER	304	361	430	554	836	1063	9,1%
NIGERIA	8250	9740	11 500	15 000	23 750	32 500	9,5%

Final version

Peak load (MW)	2018	2020	2022	2025	2030	2033	Average growth
SENEGAL	656	773	944	1356	1760	2065	7,7%
SIERRA LEONE	362	393	428	487	607	696	9,1%
TOGO	253	288	328	397	540	646	6,5%
TOTAL	15348	18323	21332	26834	39274	50800	8.3%

Table 1: Load demand forecast by country

3.2. An insufficient generation fleet compared to demand, despite a significant potential

Many countries in the sub-region are now facing a deficit of means of production. Consequently emergency measures have regularly led to the signing of contracts for the rental of thermal groups that have been extended year after year. These solutions, although necessary, represent an important financial burden for countries and are insufficient given the potential demand.

Thus, and due to the lack of generation capacity in many WAPPP countries, reserve requirements are not strictly met and operational problems as well as load shedding and possible collapses of the entire system are observed throughout the year. This current challenge in the operation of the high-voltage network is accentuated by the fact that the transmission system does not currently meet the N-1 criteria.

Two furthers considerations are directly linked to this phenomenon:

- There is a strong need in the region to strengthen the interconnection axes in order to be able to share abundant resources in different regions of West Africa, including hydropower in Guinea and gas in Nigeria;
- It is essential to take advantage of the exceptional renewable resources (in particular solar resources) in landlocked countries in order to ensure a certain energy independence for these countries, as well as a substantial reduction in cost of electrical energy.

From the point of view of fossil resources, The Natural Gas historically represented a large part of the energy mix on the axis Nigeria, Benin, Togo, Ghana, Côte d'ivoire. In addition to Nigeria, which has a huge gas potential, Ghana and Côte d'ivoire are also two countries producing Natural Gas. In the coastal countries, the operation of the national gas fields and the importation of Nigerian gas through the Western Africa Gas Pipeline (WAGP) allowed the development of several gas-fired power plants. However, the region is currently facing a deficit of gas that, in some cases, induces the use of liquid fuels or a load shedding. In Nigeria, the first exporting country in Gas of the sub-region, the supply is frequently interrupted by the sabotage of transmission infrastructures (gas pipelines). The recent discovery of a huge gas field at Senegal and Mauritania coast (Grand Tortue – Estimated potential of 450 billion cubic meters) could nevertheless change the paradigm.

Final version

From a hydraulic point of view, Western Africa has 28 transboundary river basins. The most important are Niger (shared between 11 countries if the non-active part of the basin is taken into account), Senegal (4 countries), Volta (6 countries), Lake Chad and Comoe (4 countries). With the exception of Cape Verde, each ECOWAS country shares at least one watercourse with one of its neighbours. Fourteen cross-border basins are listed in Guinea, where a large number of rivers originate. There are eight in Côte d'ivoire, seven in Liberia, five in Nigeria and Sierra Leone. In total, cross-border basins cover 71% of the total area of the region (source: OECD). In recent years, many projects have been launched to develop the hydroelectric potential of the sub-region. This is the case in Guinea (Kaléta then Souapiti and Amaria), Côte d'ivoire (Soubré followed by other projects on Sassandra) and Nigeria (Zungeru and Mambilla are under construction). However, there is still a large untapped potential.

3.3. A very gradual integration of renewable energies

In addition to the large-scale thermal and hydroelectric projects under development, the subregion is tending to develop its solar potential, particularly in the countries of northern West Africa. Senegal, a pioneering country in the integration of renewables, reached, beginning 2018, 120MW of installed capacity, representing almost a quarter of the national generation capacity. Burkina Faso, Mali and the Gambia also have several projects underway, as well as Ghana, Côte d’Ivoire and Nigeria.

In order to offer " *Affordable, reliable, durable and modern energy for all* Thanks to the vast untapped potential of renewable energies (solar, wind and water), the ECOWAS Renewable energy policy has set the following objectives for renewable energies connected to the network:

1. Increase the share of renewable energy penetration in the electricity mix including the large hydropower at 35% on the 2020 horizon and 48% on the 2030 horizon;
2. Increase the share of renewable energy penetration while excluding large hydropower to 10% at the 2020 horizon and 19% by 2030. This will contribute to the commissioning of a generation capacity of 2424 MW of renewable energy from wind, solar, bioenergy and small hydro at 2020 horizon and 7606 MW on the 2030 horizon.

The objectives are attainable in particular in view of the solar potential of the subregion, in particular beyond the latitude 10 ° N, as expressed in the figure below.

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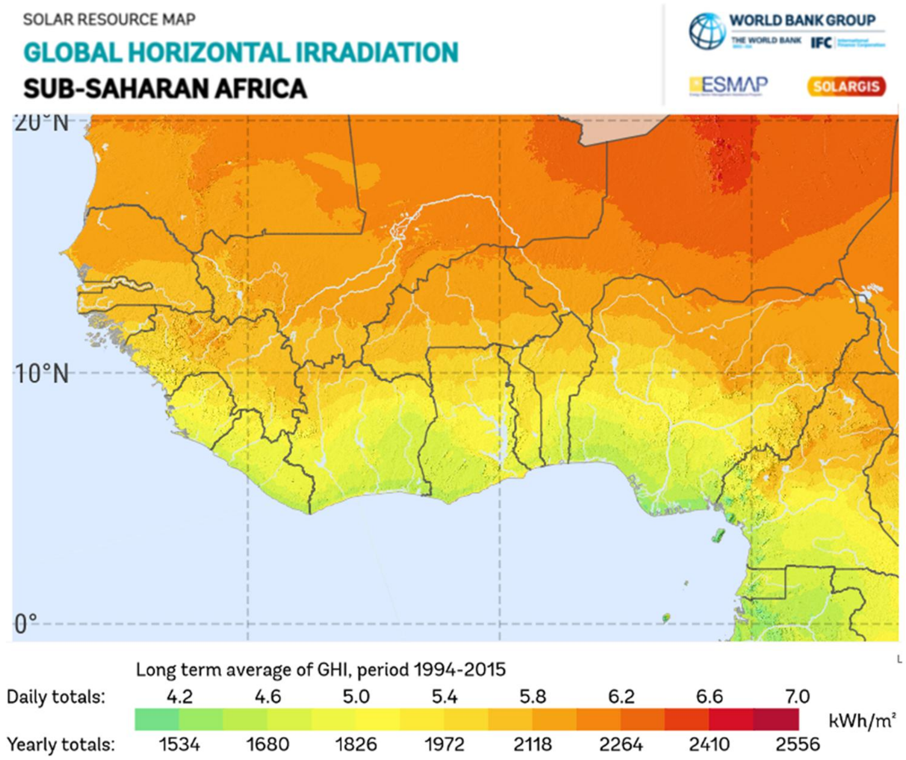

Figure 13: GHI Africa of The West 1994-2015 (© 2017 The World Bank, Solar resource data: Solargis)

Note, however, that integration of renewable energy in Senegal proves causing operational problems in maintaining the frequency and voltage criteria. Frequency differences are observed due to the lack of reserves in the system and the increasing penetration of wind and solar generation in Senegal and Mauritania. The main reasons for these challenges are:

- Limited capacity in the reactive power of the Senegalese network
- The reserves, which were previously provided by Felou and Manantali, must now be provided by the generation capacity in Senegal.

These difficulties now faced by Senegal could extend to the whole region because of the high penetration rate of renewable energies planned on the horizon of the study and the limited capabilities of the region to manage the intermittent and unpredictability of these sources. Concrete measures and planning rules will be required to deal with the change in renewable generation and to ensure that the available classic generation capacity (hydro, thermal...) will be sufficient. This aspect is of great importance to satisfy the evening peak when renewable generation decreases, and demand increases. In addition, special attention should be dedicated to the specificities of the renewable technology to be implemented and to the possibilities of voltage control of these technologies in order to meet the operational limits at any time of the day.

Integrating electricity storage should also allow facilitate the integration of renewable energy. A study is carried out in parallel and in coordination with the update of the master plan which will complement the list of Priority Projects through storage projects mechanisms for a better RES penetration.

3.4. A weak interconnected power system

While the power system of most of the 14 mainland countries of ECOWAS[1] were still isolated 15 years ago, the last decade has been marked by the commissioning of many interconnections and others are still under construction. The commissioning within the next 2 years of the CLSG line and the OMVG loop will lead to the interconnection of the 14 mainland countries of the subregion.

The interconnected network of the WAPP offers a multitude of opportunities for the exchange of electricity. However, the operation of such a network creates new challenges for the network operators. The stable functioning of the entire interconnected system remains a major issue for years to come.The interconnected network of the WAPP offers a multitude of current and future opportunities for the exchange of electrical energy. However, the operation of such a network creates new challenges for operators.

As such, the CEB network (Togo-Benin) is currently operated in two pockets, one connected to Nigeria and the other to Ghana. This split is necessary because the connection of these two regions causes critical frequency oscillations in the regional network. More specifically, the control of the frequency in Nigeria is problematic and the operating limits are not met. The challenge is partly related to the large size of the Nigerian network compared to neighbouring countries. The frequency variations in Nigeria therefore have a significant impact on the frequency of the system and the operational limits are no longer fulfilled. However, a synchronisation study was carried out and the implementation of the recommendations of this study should allow the coupling of the two systems.

In the same way, the transmission network of Mali is also operated in two pockets for stability issues, the 150kV network of the country has not been sized to ensure the junction between the 2 major interconnected networks. Thus, the Bamako-Ségou 150kV line is open, with part of the network connected to Côte d'Ivoire and the other part connected to the Manantali network.

The stable functioning of the entire interconnected system remains a major challenge for years to come. The list of priority projects to be developed in the next 3-4 years must incorporate this operational challenge. The stability study carried out highlights these priorities.

Final version

3.5. The need to operationalize a subregional electricity market

In the context of an interconnected power system, the operationalization of the Electricity Market launched in June 2018 will become all the more important as countries shall be ready to exchange energy with available transmission and generation capacity (in particular renewable but also hydropower and thermal).

[1] *ECOWAS has fifteen (15#) Member States that are Benin, Burkina, Cape Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo.*

The forthcoming commissioning of the interconnection Bolgatanga (Ghana)-Ouagadougou (Burkina Faso) will close the first loop in the interconnected network, substantially changing the flows in Côte d'ivoire and Ghana and the way to manage trade.

Indeed, up to now, contracts for the exchange of electricity between States are subject to bilateral agreements with a fixed rate for a long period and are monitored by a meter on the interconnection line. These contracts that proved their value in a radial market could be ineffective or sub-optimal in a large interconnected network in which all generation, options should be able to compete.

Like what exists in the world, different wholesale markets, set up on different time horizons will have to be put in place, from long-term agreements similar to those already signed, to day-ahead market to adjust the load-supply balance and finally to intraday market that will allow actors to adjust their purchase/sale orders for electricity according to changes in demand on the one hand and solar and wind resources on the other hand.

In parallel, the operationalization of the WAPP Information and Coordination Centre (ICC) which shall play the role of market operator, shall ensure among others, transparency and market neutrality due to the sharing of data and information, the maintenance of an up-to-date model of the interconnected power system, the enforcement of common operating rules, the harmonization of protection schemes, and the calculation of Net Transfer Capacity among the involved countries.

3.6. Diagnosis of the implementation of the previous master plan

In 2012, the Authority of the ECOWAS Heads of State and Government approved, through Supplementary Act A/SA.12/02/12, a list of 59 Priority Projects for the subregion that emanated from the update of the ECOWAS Revised Master Plan for the Generation and Transmission of Electrical Energy prepared by Tractebel.

Overall, the development of electricity projects in the region is broadly in line with the road map established in 2012. As such, among the electricity generation and transmission projects selected in the priority investment plan in 2011, 4 generation projects and 4 transmission project are or will be commissioned over the period 2012-2018. For the same period, only 3 generation projects on 17 and 1 transmission project on 11 are currently showing a real delay in their development since the search for funding has not been initiated.

Nevertheless, the analysis of the way this master plan was planned and the associated projects were implemented has led to lessons learned which should be taken into account to, in the future, reduce the delays in the implementation of the Master plan.

First, from the point of view of how the master plan was ***Planned*** In 2011, a number of limits were observed and in particular the marginal consideration of intermittent renewable resources in the sub-region, an approach exclusively based on economic aspects (least cost approach) without taking into account the notion of risk, too little consideration of operational constraints, an over-optimistic implementation schedule, a too generic implementation strategy and a coordination between regional planning and national planning that remains to be improved. Also, the 2018-2025 Master plan takes into account these lessons learned to propose an ambitious but realistic roadmap.

Secondly, from the point of view of how the projects were ***Implemented***, and ignoring exogenous parameters to the electrical sector, both success factors and constraints were observed.

Let's first note the Positive contribution from ECOWAS and its specialized agencies through their involvement and institutional support in the development of regional projects, particularly from the point of view of the preparation and signing of agreements between countries, the mobilization of funds and the sharing of knowledge.

The critical factors identified relate to the **project funding** (insufficient funding sources, low financial health of utilities and weakly effective collaboration with funding institutions), the inappropriate **regulatory and institutional framework** for the efficient mobilization of the private sector, the **contracting** (need to build capacity in drafting, negotiation and follow-up of specific contracts for the electricity sector) and the difficult procedures for the **social and environmental aspects** and **land security**.

Finally, it should be noted that uncertainties in the availability of gas resources and the constraints associated to the operation of the interconnected network also constitute a limitation to the development of regional projects

4. CRITICAL FACTORS AFFECTING THE PERFORMANCE OF UTILITIES AND CORRECTIVE ACTIONS

Beyond the techno-economic model developed as part of this Masterplan update, focus is put on identifying the challenges and critical factors affecting the WAPP Member Utilities. This approach first involves identifying and prioritizing difficulties and then proposing corrective measures to deal with them.

These corrective measures stand as concrete actions that are as effective as possible in order to best address the critical factors to help the implementation of the Master Plan.

4.1. Main challenges and critical factors identified in WAPP member countries

The exchanges and feedback gathered from the players in the electricity sub-sector allowed the identification of cross-cutting critical factors that are affecting the performance of WAPP member utilities.

On this basis, the different challenges and critical factors identified were analyzed in order to confront them. These challenges and critical factors are characterized in this study according to three axes:

Impacting

The impact of the critical factor corresponds to the impact of the critical factor considered on the efficiency, performance and sustainability of the services of the utilities. It is assessed here to what extent the critical factor is detrimental to utility in its proper functioning.

Transversal

Even though some of these challenges and critical factors appear to be country-specific with respect to the historical, cultural, political or economic context, others are repeated from one country to another in the sub-region. These critical factors will then be considered transversal.

Addressable

A critical factor will be considered as addressable from the point where measures and actions can be envisaged and carried out by the companies considered in this study. In addition, for the critical factor to be considered addressable, it is understood that the actions or actions can be conducted in a reasonable time and manner.

Hereafter are the main challenges and critical factors identified across WAPP member countries with their caracterization according to the 3 axes (Impacting, Transversal, Addressable). The description for each critical factor is in Volume 3.

Final version

Topics	Critical factors			
Governance	1. Sectoral governance often problematic	•		
	2. Areas of responsibilities sometimes unclear	•		
Planning	3. Supply-demand deficit compensated with expensive emergency solutions	•	•	•
	4. Transmission lines under development	•	•	•
	5. Distribution networks undermaintained and relatively limited	•	•	•
	6. Energy mix little diversified		•	•
Development of large projects	7. Regulatory and institutional framework inadequate for the efficient participation of the private sector	•		
	8. Few sources of funding and small fiscal space	•	•	
	9. Weak financial health of utilities	•	•	•
	10. Award of contracts by direct agreement, fast but expensive	•	•	•
	11. Capacity for contract arrangement and contract management to build	•	•	•
	12. Difficult access to land		•	•
Operational efficiency	13. Network management to strengthen		•	•
	14. Suboptimal maintenance of assets	•	•	•
	15. Technical constraints to the integration of new renewable energy		•	•
Revenue collection	16. Knowledge of costs to improve			•
	17. Tariffs not reflecting the real costs of the sector	•	•	
	18. Consumption of end customers poorly apprehended	•	•	•
	19. Chain of revenue collection to improve	•	•	•
Electricity as a commercial commodity	20. Commercial basis of cross-border exchanges of electricity to be strengthened	•	•	•
	21. Absence of customer service			•

Figure 14: Main critical factors identified

Final version

4.2. Measures and actions addressing the critical factors

By capitalizing on feedbacks, a series of measures and actions has been established. This series of actions comes from two different sources:

- Strategies already underway or planned by WAPP member utilities;
- An international benchmark of best practices.

Achieving an international benchmark permits to identify actions and measures adopted in different contexts favoring the performance of the electrical sector at national and regional levels. After analysis, some of these measures appeared to be transposable to the West African context.

Once the series of measures and actions have been established their analysis has been carried out. The actions were analyzed according to two axes:

- Their ability to effectively deal with the critical factor,
- Their ability to act on a panel of critical factors rather than just one.

A prioritization of the corrective actions was carried out on the basis of the critical factors that can be treated by them. This hierarchy allowed actions to be ranked according to a certain degree of importance. Transversal actions to priority critical factors were considered important.

The figures below show this hierarchy as well as a list of measures and actions to address identified critical factors.

Final version

Topics	Remedial actions
Governance	• 1. Appropriate use of management contracts • 2. Reinforcement of the regulator's role and its prerogatives on electricity tariff mechanisms • 3. Reorganization of utilities' structures to better match the market
Planning	• 4. Capitalization of the ICC and improve dispatching procedures • 5. Harmonization of master plans, strategic plans and roadmaps • 6. Extension and strengthening of networks and interconnections as a determinant of the system's performance
Development of large projects	• 7. Diversification of project implementation schemes and definition of a portfolio of sovereign guarantees • 8. Enhancement of clearness in procurement procedures • 9. Ensure efforts to secure project budgets and anticipate preconditions
Operational efficiency	• 10. Development of a grid code facilitating the optimization of the energy system
Financial health	• 11. Financial restructuring of utilities • 12. Activity-based costing and an annual financial statements audits to improve transparency
Commercial efficiency	• 13. Standardization of import / export contractual clauses to facilitate trades • 14. Implementation of customer management software and call centers • 15. Implementation of prepaid meters and decentralization of invoice and bill collection activities
Skills development	• 16. Technical and legal support to be strengthened by DFIs • 17. Technical and contractual capacities to be strengthened through the regional university network

Figure 15: Synthesis of the main measures and corrective actions

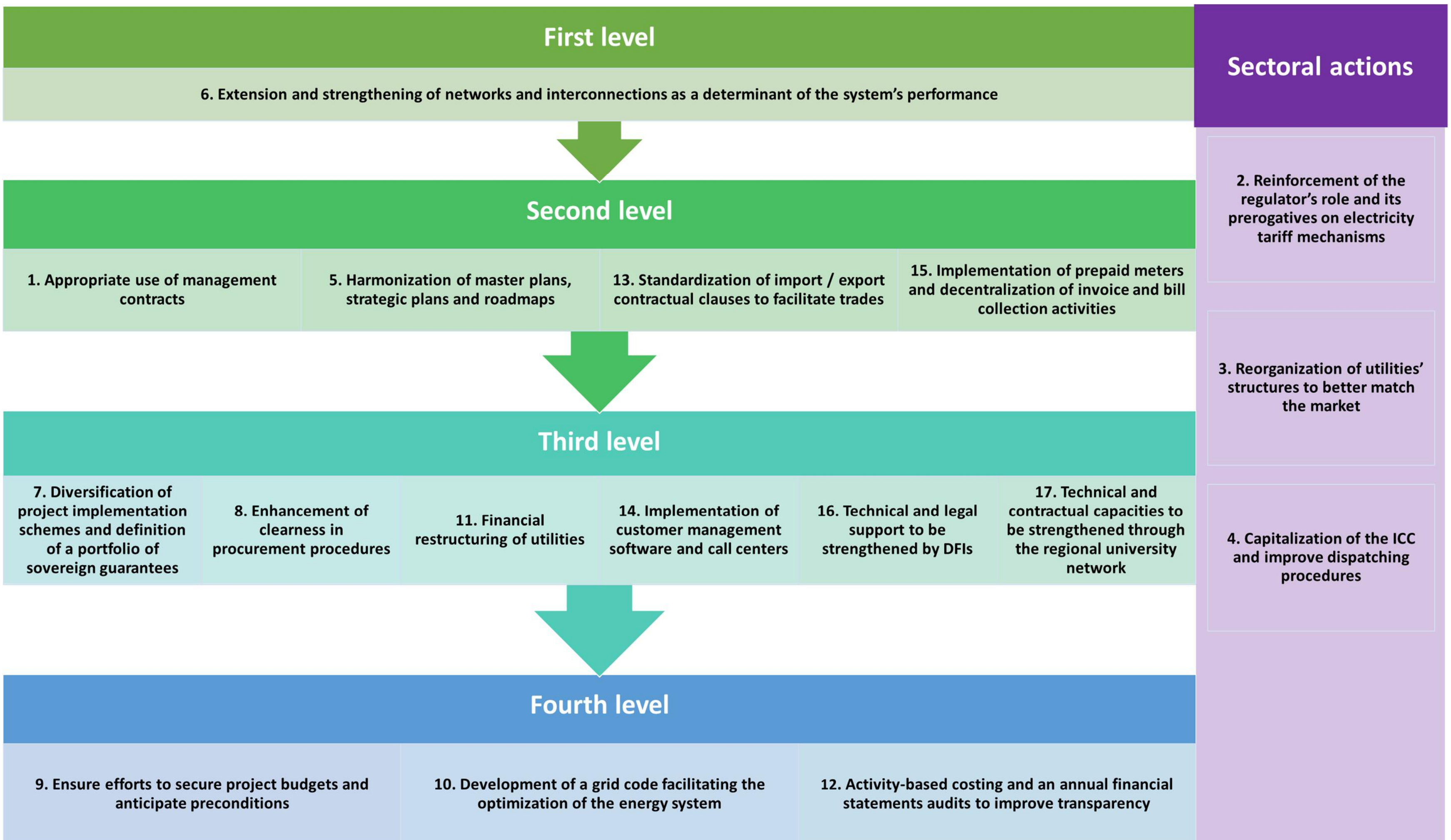

Figure 16: Prioritization of actions relating to priority 1 critical factors addressed

4.3. Activities carryable by the WAPP

The WAPP, through its regional influence, can carry out certain activities facilitating the implementation of transverse corrective actions. These activities are grouped by typology:

- Information share and communication activities
- Coordination activities
- Consulting activities
- Proactive steps

Information share and communication on best practices activities

Information share and communication on transposable best practices activities can be carried out by the WAPP through:

- Gathering and centralizing feedbacks from previous management contracts in Guinea and Liberia. The WAPP's comparative audit could highlight areas of vigilance and best practice for future experiments.

- A valorization of the ICC by a communication campaign in the different member countries.

- A market study and an ex post analysis on the prepaid meters adoption in Burkina Faso, Senegal and Togo. Such analysis might help to better understand how their implementation could be conduct in other countries of the region.

Coordination activities

Coordination activities can be carried out by the WAPP through:

- Coordination between the Ecowas Regional Electricity Regulatory Authority (ERERA) and the administrative authorities of the different member countries in the framework of the establishment or strengthening of the prerogative of the national regulator.

- Multi-country coordination for the development of electricity transmission networks and interconnections through its regional vision of the electricity sector.

- Coordination with DFIs on various topics related to project development and improvement of sectoral organization, namely:
  - The creation of a legislative and institutional framework for project development and the opportunity to transpose it to different countries;
  - Planning of upstream project development approaches concerning the environmental and social impact studies and measures, particularly on regional priority projects;
  - The transfer of technical and legal expertise from DFIs to administrations and electricity utilities.

Final version

Consulting activities

Consulting activities can be carried out by the WAPP through:

- Standardization of procedures and technical requirements in the development of national Grid Codes.

- Recommendations during the development of national master plans through a participation or consultation during this elaboration in order to ensure their harmonization with the regional master plan.

- Standardization of certain contractual clauses of electricity import / export agreements in order to facilitate multinational exchanges with a view to fluidizing the market. [Mainly to be strengthened as this activity has already been conducted by the WAPP.]

Proactive steps

Proactive steps can be carried out by the WAPP through the release of a funding line for training utilities employees to improve new sectoral skills. This would be accompanied by the formalization of partnerships between the WAPP and the region's universities specialized in technical, financial, economic and legal matters.

5. GENERATION AND TRANSMISSION MASTER PLAN

Given the current situation in the power sector and the issues identified for its future development, the Generation-Transmission Master plan has been developed to meet three main objectives:

- **The optimum integration of renewable energies** in the West African power system, taking into account economic, environmental and technical constraints;
- The need to **guaranteeing security of supply** at short, medium and long-term, taking into account the *Needs* in terms of electrical energy and *Constraints* related to the generation (especially renewable) and the transmission (sometimes over long distances) of electricity;
- **The development of infrastructure** (transmission and generation) necessary to establish an electricity market in West Africa, taking into account the identified operational constraints;

The resulting Generation-Transmission Master plan was thus compiled. Given the different issues faced by the sector in the short, medium and long term, the master plan has been divided into these three temporal horizons.

Finally, in addition to the optimal development of the West African system, a preliminary analysis of the opportunities for exchange beyond the WAPP area was also conducted, considering, on the one hand, the possibilities of exchange with North Africa, and on the other hand, with the Central African Power Pool (CAPP)

5.1. Integration of renewable energies

The generation master plan suggests a transition to the development of renewable projects (hydropower on the one hand but also solar and wind energy on the other) in all the countries of the subregion. This development plan, although governed by economic considerations, takes into account the financial and technical aspects associated with the deployment of renewable energies.

As such, if no constraint were considered, the least cost option to meet the demand on the horizon of the study would be selected. In this context, there would be a cost threshold below which the PV solar option would become marginally more interesting than the thermal options in West Africa. The existence of this level would have two effects:

- On the one hand, before the crossing of this threshold, investments in PV solar projects in the subregion would remain marginal if one refers to economic criteria only
- On the other hand, at the pivotal year (year when the investment threshold is crossed), the investment volumes would be considerable (several tens of GW invested in a single year)

Taking the risk into account in the master plan allows us to deviate from this scenario, which, although economically optimal, is difficult to implement in practice. In order to take into account the limited financial capacities of the Member States of the WAPP, particularly due to the fact that renewable projects have a high capital intensity and the technical limits linked to the integration of RES into the still young network of the WAPP, it was decided to set a limit on the annual investment by country. As such, the maximum capacity that can be invested each year for each technology (wind and solar PV) has been defined at 10% of national peak demand. This limit has several effects:

- It has been defined in such a way as to reach, at the study horizon, a volume of renewable investment close to the one observed in the optimal case from the economic point of view;
- It allows a better distribution of investments in the time, before and after the pivotal year ;
- It allows for a better geographical distribution of investments, as the countries of the North of the region are no longer solely responsible for all renewable projects.

In addition, dynamic studies carried out for the years 2022 and 2025 considered an instantaneous integration rate at the solar peak of respectively 17% in 2022 and 28% in 2025. For this rate, the studies demonstrated the technical feasibility of the integration of intermittent renewable energy while optimizing the operation of the system. Thus, the techno-economic feasibility integrating intermittent renewable energy has been demonstrated for a total of 3.3 GW by 2022, 7.0 GW by 2025, 9.6 GW by 2029 and 12.1 GW by 2033.

The total economic potential of the sub-region is 37.5 GW at the 2033 horizon (i.e. 25.4 GW in addition to the previously reported 12.1 GW). This economic potential, in order to be able to be developed, must nevertheless be the subject of extensive studies, especially from the technical point of view.

5.2. Security of supply

Security of supply is one of the key issues in this master plan. Two major issues were identified :

- The need for sufficient installed capacity to reliably meet the electricity demand;
- The need for primary resources to feed power plants (and in particular thermal power plants).

5.2.1. Installed Capacity Requirement

The present master plan is designed to bring the Loss of Load Expectation (LOLE) to 24 hours a year in the whole region at the end of the study in 2033, while considering an interconnected system where mutual support is possible to compensate for the lack of generation in a given country.

The LOLE is a probabilistic criterion that indicates the expected number of hours in a year in which the demand exceeds the available generation capacity, resulting in the inability to provide the full load without mitigation measures.

However, as noted above, the master plan suggests the massive development of intermittent renewable energies in the subregion. These renewable projects will allow to reduce the energy costs as well as the environmental footprint of the electricity sector but, given their intermittent nature, they cannot actively participate in the security of supply of the system.

For this reason, it is essential to maintain in the system an installed hydroelectric and/or thermal capacity that will ensure the security of supply at any time. Thus, in the long term, it has been demonstrated the need to maintain investments in gas turbines in the various countries, particularly in Nigeria for 3500 MW, in Ghana for 300 MW and in Côte d'ivoire for 300 MW but also in other countries.

It should also be noted that the massive development of renewable projects in the sub-region will require the deployment of flexible means of production to quickly compensate for the intermittency of solar and renewable resources.

Lastly, it is important to mention that battery storage will have to play a major role in improving flexibility and increasing the security of supply in the subregion, not only in the long-term, but also in the mid- and short-terms. Considering the expected evolution in the cost of storage technologies, batteries could complement some of the investments in gas turbines during the study period, support frequency and voltage control in the network, and facilitate the further deployment of variable renewable energy projects.

5.2.2. Securing Fuel supply

Despite the development of hydroelectric and intermittent renewable potential in the subregion, the dependence of countries on fossil resources will remain significant in the next 15 years. The commissioning of thermal capacity will be necessary to secure the electrical supply. However, feeding these plants is a crucial issue for the sub-region.

Natural gas in particular will play a major role in the electrical supply of the sub-region.

Given this fact, the impact of the unavailability of this resource on the results of the master plan and the variability in the cost of gas was investigated.

With regard to the **availability of the resource**, the dependence of the subregion on a single source of supply creates a major risk for countries.

The majority of these needs are obviously concentrated in Nigeria, accounting for 77% of the region's gas consumption on average on the study horizon.

In addition to Nigeria accounting for 77% of the region's gas consumption on average on the study horizon, the countries for which gas availability is also crucial are Ghana, Côte d'Ivoire and Senegal. Ghana and Côte d'ivoire are characterised by indigenous reserves that are decreasing over time. These countries will therefore have to guarantee the security of supply via other gas sources, whether LNG units or WAGP. The exploitation of gas resources in Senegal is planned to start in 2025 and gas requirements are expected to grow up to 183 Mmscfd on the horizon 2033.

In Benin, the development of combined-cycle gas power plant projects, including the 450 MW regional WAPP project, also calls for the development of gas supply infrastructures. The proposal made in this master plan is to enhance the reliability of the WAGP, providing for gas supply opportunities not only from Nigeria but also from Ghana. Togo could also benefit from such a development of the gas network.

In conclusion, it is advisable to diversify the sources of supply: indigenous sources in Nigeria, Ghana, Côte d'ivoire and, in the medium term, in Senegal, to which are added gas sources imported via LNG terminals recommended in Côte d'Ivoire and Ghana, or via the WAGP.

Finally, from the point of view of the **cost of gas**, the analyses conducted showed that a variation of this factor did not significantly alter the optimal investment plan on the horizon of the study. A slight slippage of renewable projects (hydro and solar PV) is nevertheless observed during the period. However, given that the cost of natural gas accounts for approximately 45% of the total cost (investment + operation) of the master plan over the study period, any change in the cost of the resource will affect the total cost of operations in a significant way.

5.3. Development of transmission infrastructure

The development of transmission infrastructure in West Africa essentially meets two objectives:

- To enable the safe operation of the power system taking into account, on the one hand, the challenges linked to the interconnection of the 14 countries of the subregion, and on the other hand the integration of renewable energies (technical considerations);
- To enable the sharing of the means of generation in an optimum way (economic objective)

5.3.1. Safe operation of the transmission system

5.3.1.1. OPERATION OF THE INTERCONNECTED NETWORK

From 2020, the 14 countries of the subregion will be interconnected. Beyond the issue associated to the implementation schedule for the commissioning of planned transmission projects at short-term, there is an operational challenge to ensure the stable and coordinated operation of the entire WAPP interconnected system. Two sections appear to be critical

- The connection of Niger-Nigeria with the rest of WAPP;
- The connection between Western ECOWAS Member States (Senegal, Mali, Guinea, Guinea-Bissau, The Gambia, Sierra Leone and Liberia) with the rest of WAPP.

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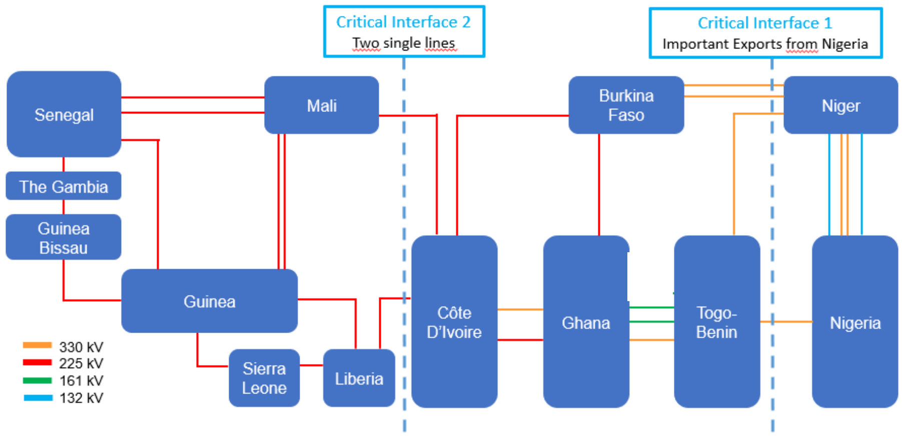

Figure 17: Presentation of critical interfaces

The investment plan must therefore ensure that these two Interfaces include a minimum of 3 interconnection lines in order to guarantee the stability of the system. It is worthy to note that:

- For the critical interface 1, the implementation of the 330 kV North Core, the Median Backbone (in the mid-term) and the strengthening of the 330 kV Nigeria-Benin axis thus appears as a priority.
- For the critical interface 2, the implementation of the 2nd circuit of the 225 kV CLSG interconnection project and the acceleration of the 330 kV Ghana-Burkina-Mali interconnection project, in particular the Bobo-Sikasso segment, are essential.

It is also necessary to expand the measures defined in the WAPP Synchronization Study by strengthening the capacities of the Static Var Compensators (SVCs) in Niger and Burkina and by setting the Power System Stabilizer (PSS) of key generation units located at the endpoints of the system to stabilize an interzonal oscillation mode (frequency 0.27 Hz) in the system.

Finally, it is recommended to develop special protection schemes (SPS) to ensure the safety of the system in the event of an incident. In broad terms, an update of the WAPP Operations Manual and a harmonization of the protection schemes (UFLS, interconnection protections,...) is reommended.

Final version

5.3.1.2. INTEGRATION OF RENEWABLE ENERGIES

With the new capacity of renewable power generation which is planned to connect to the grid in the 2033 horizon, new operational limits can be reached.

Operating a power system with high instantaneous penetration of renewables poses numerous operational challenges which must be addressed to ensure a high system reliability. These operational challenges can be classified depending on the timescale of interest. A short non-exhaustive overview is given below. These different aspects should be studied in a dedicated study to define the operational constraints and measures to be taken to allow the important share of renewable. These studies should comprise of a review of the grid code, such as the WAPP Operational Handbook, as well as a renewable integration study which will study the points mentioned in the following paragraphs.

- Within the timescale of minutes to hours, both the variability and especially the limited predictability of renewables (PV and wind power) may have a direct impact on the required operating reserves guaranteeing the balance between generation and demand.
  - First, the variability of such units adds to the overall power imbalance that drives the amount and flexibility of the reserves. Forecast errors on the other hand create an uncertainty and require real-time relatively higher load following or ramping reserves.
  - Secondly, especially with a very high penetration, such units will replace traditional power plants, which normally guarantee the provision of the required reserves and ancillary services. Additional measures have therefore to be taken to guarantee the balance between generation and demand at all times.
- Operational impacts at faster timescales (seconds to minutes) are mainly related to the way these units are interfaced with the network. The strong coupling of a traditional synchronous generator to the grid ensures a high short-circuit power as well as an inertial response. On the contrary, converters typically transform direct current (DC) electricity to AC power by controlling semiconductor devices at a high switching frequency. Due to this intermediate DC link which decouples the generator from the grid, no inertial response is provided, and the converter interface also inherently weakens or eliminates the response to grid faults.

  Instead of the physical characteristics of the synchronous machine, the control strategy of the converter predominately determines the electrical dynamic interaction with the system. However, both the high short-circuit power as well as the inertial response are essential for the operation of current transmission grids. A high and sustained short-circuit current during grid faults, will limit the impact area of voltage dips and triggering fault detection by protection relays. The inertial response on the other hand will limit the rate of change of frequency (ROCOF) after a power imbalance in the system and as such inherently provides time for the governors and turbines to react in order to stabilize the system frequency. Less inertia immediately leads to higher ROCOF values and lower minimum frequencies for the same considered incident. Without taking additional measures, this will lead to large scale load shedding or tripping of protection relays.

The dynamic studies carried out for the years 2022 and 2025 considered an instantaneous integration rate at the solar peak of respectively 17% in 2022 and 28% in 2025. For this rate, the studies demonstrated the technical feasibility of the integration of intermittent renewable energy while optimizing the operation of the system. Nevertheless, the development of the intermittent renewable potential as suggested by the economic analyzes (ie 37.5 GW by 2033, which could lead to an instantaneous integration rate of 60%) will have to be demonstrated by detailed dynamic analyzes conducted at the national level.

5.3.2. Sharing the generation

One of the challenges of the mid-term, long-term horizon is to develop a strong interconnected network to ensure synergy between hydroelectric resources, gas and solar. For example, hydroelectricity is predominantly used during the evening peak as well as during the night, when solar energy is unavailable, even if the hydraulic producible is maintained at a technical minimum during the day, especially for irrigation issues.

Thus, when analyzing the system from the point of view of marginal costs, it can be observed that the massive investments in renewable energy over the medium term as well as the development of the interconnected network will draw downwards the marginal costs of the whole region. These costs will vary from 80.6 USD/MWh in 2022 to 49 USD/MWh in 2029. In addition to this reduction of marginal costs in the region, it can also be noted that the latter vary strongly depending on the time of day considered.

If we analyze the situation during the day (12 am), we observe the marginal costs as shown in the figure below. These are naturally weaker in the North of the region (where the bulk of electricity is produced by solar photovoltaic technology) as well as in Guinea and Sierra Leone where many hydropower plants are now active.

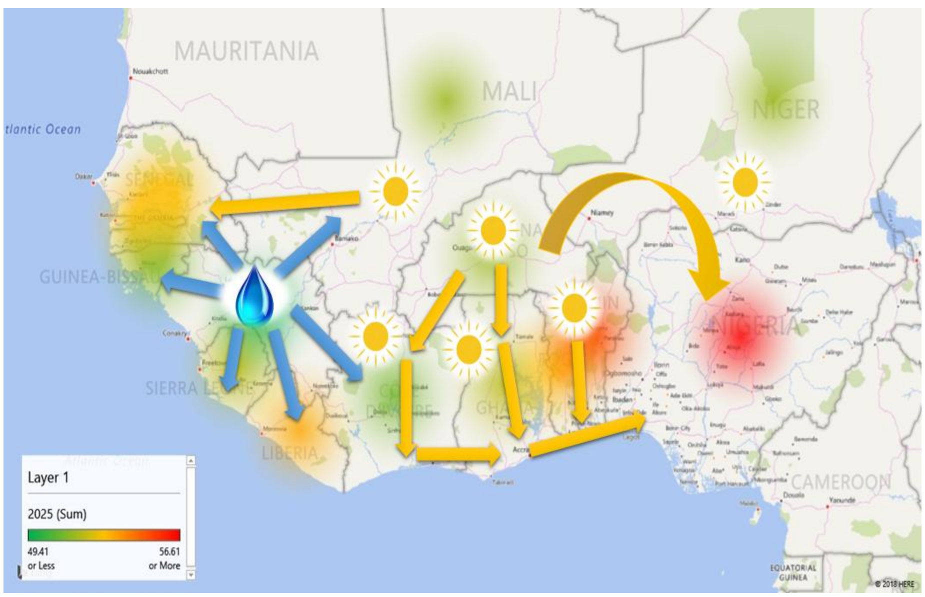

Figure 18: Distribution of average marginal costs in the region at 12 am in 2025

During the evening peak at 9pm, the situation is different. The countries of the North, such as Mali, Burkina Faso and Niger, must now import electricity, given the unavailability of solar energy. They are therefore facing the highest marginal costs at that moment. These imports come mainly from the countries using gas resources that run their combined-cycle power plants at full power (mainly Nigeria, Ghana, Côte d'Ivoire and Senegal). In the figure below, we can see that the flows observed at 12am are reversed in the evening.

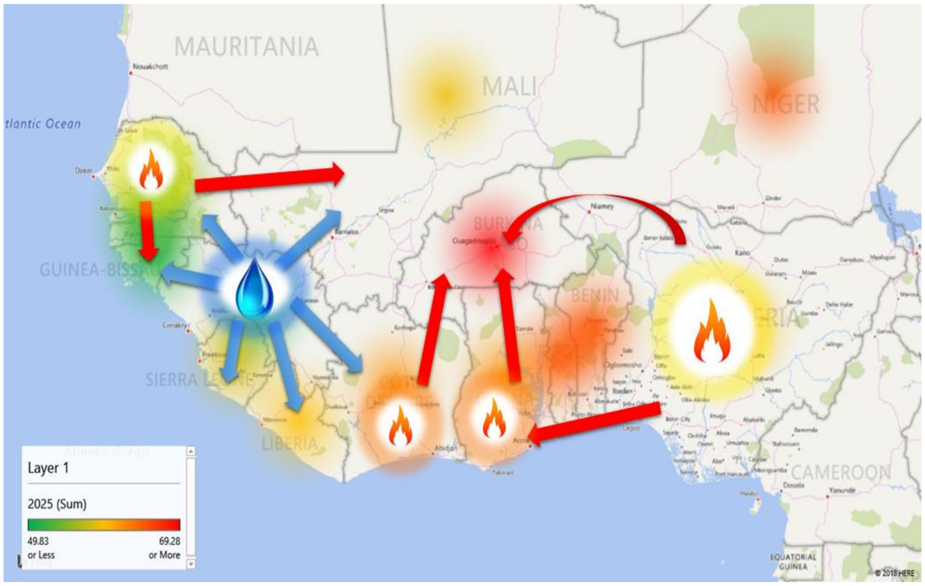

Figure 19: Distribution of average marginal costs in the region at 9 pm in 2025

These massive flows justify the development and/or strengthening of major transmission axes throughout the subregion.

5.4. Electricity Master Plan

5.4.1. Short-term Master Plan (2018 – 2022)

The electric demand for ECOWAS of 15.3 GW in 2018 should evolve towards 21.3 GW in 2022. Such growth requires the massive development of generation and transmission infrastructure and the list of decided generation and transmission projects is important for the years to come. These investments are major in ensuring the region's supply security with affordable energy.

From the point of view of generation, the short-term horizon is thus characterized by the commissioning of many hydroelectric units totaling 2 103 MW. In addition, 46% of the new power installed by 2022 should concern renewable energy technologies. In order to succeed in this transition the development of solar projects in all the countries of the sub-region will have to be supported by a regulatory framework and appropriate financial measures.

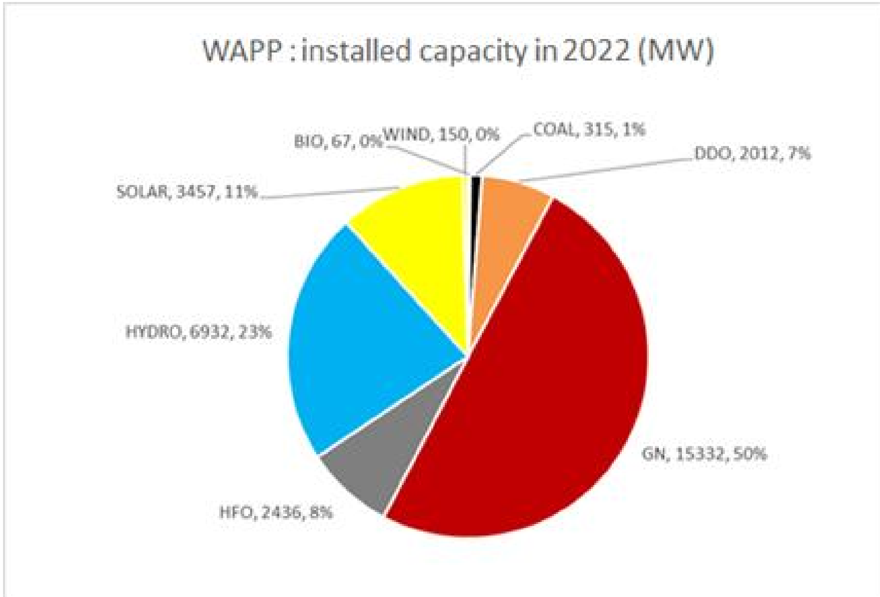

Figure 20: Total Installed Capacity in WAPP region, by technology, at 2022 horizon (MW)

In the short term, in addition to the commissioning of the decided interconnection projects, the priority will be to ensure the operational security of the interconnected network thanks to the rapid commissioning:

- of the second circuit of CLSG interconnection to ensure the security of supply in Liberia, Sierra Leone and Guinea Bissau but also to ensure the N-1 operation in this zone;
- of the 330kV Bolgatanga-Bobo-Sikasso line, and in particular the Bobo, Sikasso section to allow the stable functioning of the WAPP interconnected network.

5.4.2. Medium-term Master Plan (2023 – 2029)

At mid-term, the load demand should continue growing, evolving from 21.3 GW in 2022, to 26.8 GW in 2025 and 36.4 GW in 2029.

Based on the results of the generation master plan, the medium-term horizon will significantly increase the share of renewable energy in the region's energy mix. An economic potential of 19 285 MW has been identified by 2029.

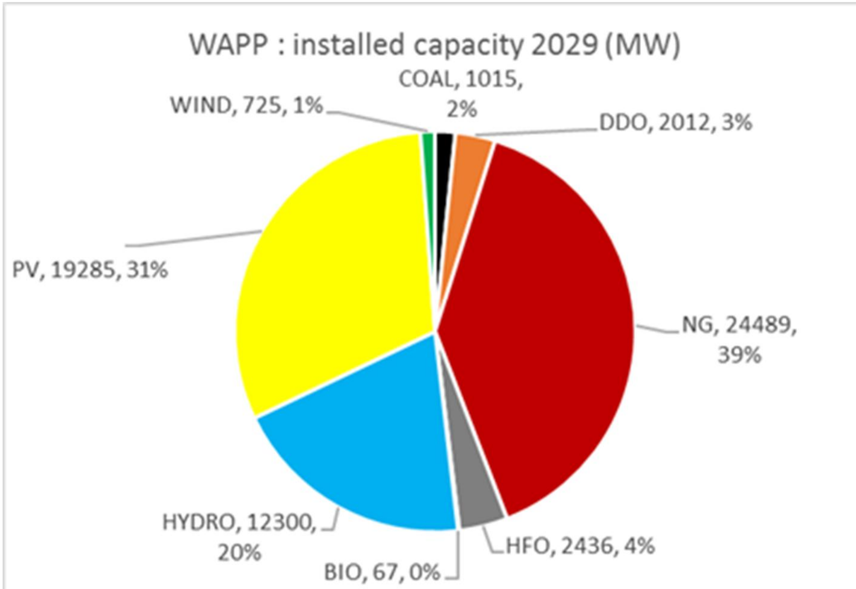

Figure 21: Total Installed Capacity in WAPP region, by technology, at 2029 horizon (MW) , including the potential solar projects identified

Therefore, in 2029, 38% of the electricity produced throughout the West African region will come from renewable energy technologies, including 24% hydropower, 13% solar photovoltaic and 1% wind power.

From the point of view of power system, the main needs in terms of reinforcing interconnections are:

- Reinforcement of Import-Export capabilities of Nigeria by the construction of the 330kV median backbone between Nigeria (Kainji) and Côte d'Ivoire (Ferke) with intermediate substations in Ghana, Togo and Benin (see Figure below). This line is of crucial importance for the integration of renewable energies in the long term;
- Second line of Guinea-Mali interconnection for the exchange of renewable energy (hydro and solar). The construction must coincide with the commissioning of Koukoutamba. This new double-circuit interconnection will connect to the existing 225 KV substation Linsan (Guinea) on one side and to the 225 KV Manantali substation (Mali), on the other hand;
- The new 225kV interconnection line between the Conakry (Fomi) and Côte d'Ivoire (Boundiali) to also connect the site of the Morisanako (100MW Hydro + 100MW PV);
- Liberia-Côte d'Ivoire interconnection (Buchanan – San Pedro) to be development in the same time as the hydroelectric site of Tiboto (shared between Liberia and Côte d'Ivoire).

5.4.3. Long-term Master Plan (2030 and beyond)

The long-term period considered in this study covers the years 2030 to 2033. Over this long-term interval, demand continues to grow exponentially in the region, as the synchronous peak demand of the region is foreseen to evolve from 36.4 GW in 2029 to 50.8 GW in 2033.

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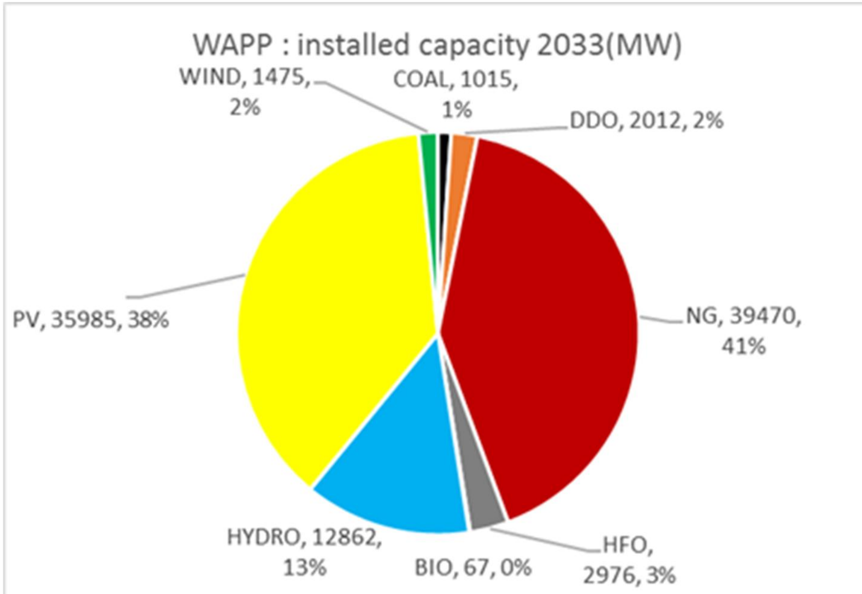

Figure 22: Total Installed Capacity in WAPP region, by technology, at 2033 horizon (MW) , including the potential solar projects identified

Compared to the medium-term period, it can be seen that investments in hydroelectric units are proportionally very small. Indeed, the most economically interesting projects have been taken into account in the mid-term and the remaining candidate projects do not appear as an economically viable options for the power supply of the sub-region at the 2033 horizon.

On this horizon, and given the integration rate of renewable energy, one of the main issues lies in the satisfaction of the reliability criteria and the contribution to the flexibility of the system. As a result, additional investments must be made in thermal units mainly from 2030. This explains in particular why investments in gas plants are proportionately more important on the long-term horizon compared to other horizons.

From the point of view of the transmission network, in the long-term, the recommended interconnections are:

- A 330kV axis between Senegal, Guinea, Mali, Burkina Faso and Côte d'ivoire which will connect to the median backbone at Ferkessedougou.
  - The total distance from the Tobène To Linsan and until Sikasso is about 1600 km. Because of the long distances between these potential substations, additional substations should be created to increase the transmission capacity of the line and allow for easier operation of the system;
  - Between Sikasso and Bobo, the 330kV section of the Bolgatanga-Bobo-Sikasso line to be developed in the short-term will connect Burkina Faso to this axis;
  - Between Bobo and Ferke, a new 330kV axis will close the east-west axis.
- A new 330kV axis between Nigeria and Niger. This new double-circuit line will connect Salkadamna (Niger) to a new 330kV substation in Maban (Niger), to Gazoua (Niger) and to Katsina (Nigeria);

Final version

- A second 330kV North-South axis in Ghana between Bolgatanga, Juale and Dawa near of the border with Togo;
- The doubling of the OMVG axis (coastal side) allowing to strengthen transfer capacity and to ensure N-1

5.4.4. Synthesis of the Master Plan

The electric demand for ECOWAS of 15.3 GW in 2018 should evolve towards 21.3 GW in 2022, 26.8 GW in 2025, 36.4 GW in 2029 and 50.8 GW in 2033.

The map presented in Appendix illustrates the expected development of the West African power system by 2033 to meet this growing demand.

As a result of the generation-transmission master plan, the total installed capacity of ECOWAS of 18.1 GW in 2018 should reach 30.6 GW in 2022, 44.2 GW in 2025, 51.9 GW in 2029 and 70.3 GW in 2033, in order to meet the demand.

- In 2022, thermal power plants will have to reach 20.1 GW, hydro power plants, 6.9 GW, and RES excluding hydro 3.6 GW.
- In 2025, thermal power plants will have to reach 25.6 GW, the hydro power plants, 11.6 GW, and RES excluding hydro 7.0 GW.
- In 2029, thermal power plants will have to reach 30.0 GW, hydro power plants, 12.3 GW, and RES excluding hydro 9.6 GW.
- In 2033, thermal power plants will have to reach 45.4 GW, hydro power plants, 12.8 GW, and RES excluding hydro 12.1 GW.

In addition, in order to reduce the energy costs as well as the environmental footprint of the electricity sector, additional solar energy projects could be developed. An additional economic potential of 25 GW has been identified and could be developed by the countries, which would eventually bring the intermittent renewable installed capacity to 37.5 GW.

On this basis, from the point of view of the energy mix, the intermittent renewable projects would represent 18% of the energy produced on the horizon of the study. Natural gas will nevertheless continue to dominate the energy mix, with a share of up to 60% as shown in the figure below. Natural gas will replace the HFO and the DDO on the horizon of the study. Finally, it can be seen that the share of hydropower in the energy mix, after increasing in the medium term, finally decreases at the end of the study, given that all the economically interesting projects will have been implemented.

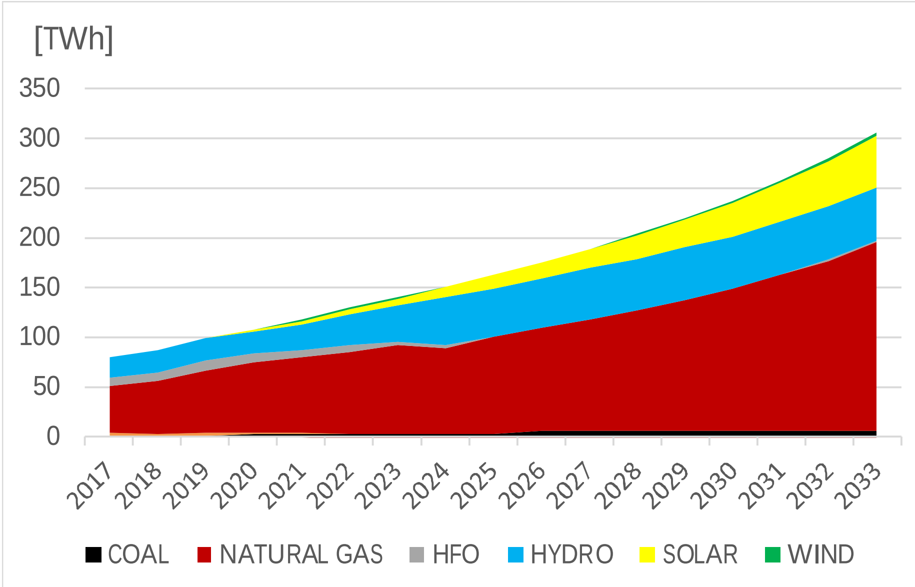

Figure 23: Evolution of Energy Mix (TWh)

From the average cost of generation, the following evolution has been observed:

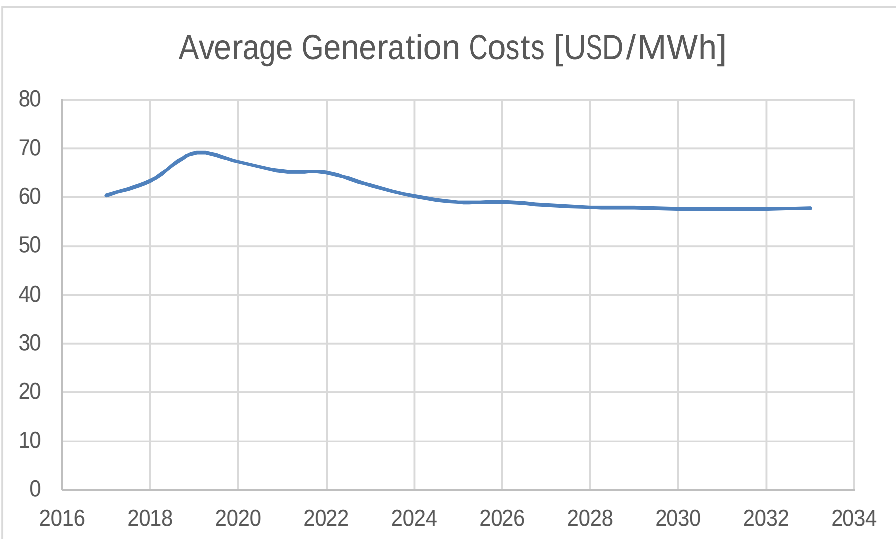

Figure 24: Evolution of the average cost of generation [USD/MWh]

One can see a growing trend of average generation cost at short-term, associated with a growth in demand to be fueled by heavy fuels. From 2020 on, the positive effect of new interconnections can be noted. In the long term, the average cost is stabilizing below 60 USD/MWh. The structure of the cost changes however strongly in the course of the time. At the beginning of the study horizon, the variable costs (including fuel cost) account for more than 75% of the generation costs, while in the long term they represent only 55% of the total cost of generation thanks to the emergence of renewable projects. Such a situation will reduce the exposure to the volatility of the cost of fossil fuels but demonstrates the need for capital that will be faced by countries in the next 20 years.

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6. PRIORITY REGIONAL INVESTMENT PROGRAM

6.1. Priority Regional Projects

In addition to the decided projects, the priority list of regional generation and transmission projects have been recommended on the basis of the following criteria:

- A minimum size of 150 MW;
- A major role in the sustainable development of the sub-region
- A regional vocation (location, sharing of energy between border countries, importance at regional level)

On this basis, the proposed list of regional priority projects under the ECOWAS Master Plan for the Development of Regional Power Generation and Transmission Infrastructure 2019 – 2033 shall be characterized by the following:

- **75 (#) regional projects**, deemed priority, with an estimated total investment cost of US$36.39 billion, of these,
  - **28 (#) Transmission line** projects of approximately 22,932 km of high-voltage transmission lines at an estimated cost of US$10.48 billion;
  - **47 (#) generation projects** with a total capacity of approximately 15.49 GW at an estimated cost of US$25.91 billion;
- Given that the WAPP, in the short term, shall achieve the power system integration of the 14 mainland ECOWAS Member States, the priority list also contains transmission line projects that shall enable WAPP interconnect beyond its current area of coverage in order to among others, further economically diversify its energy mix. These include the northern part of Africa through Morocco and the Central African Power Pool to Inga.
- The generation projects comprise:
  - 31.1% thermal projects operating mainly with natural gas and
  - 68.9% renewable energy projects (10.67 GW) of which 29.5% involve Variable Renewable Energy (VRE) projects (3.15 GW solar, wind);
- VRE projects constitute 20.33 % of the total generation in the priority list.

All of these projects contribute in one way or the other towards the sustainable development of the ECOWAS sub-region, the further development of the regional electricity market and/or the improvement of security of supply in West Africa. There are therefore of paramount importance for the sub-region and their implementation, even though a challenge, shall allow for the optimal development of the WAPP interconnected system. The list of regional priority projects is as indicated in Annex and the map also in Annex illustrates their approximate localisation

With regards to the realization of these priority projects, it should be noted that historically, the public sector were entirely responsible for the development of capital-intensive and strategic power generation and transmission projects. Nevertheless, the current budgetary constraints of ECOWAS Member States coupled with the high investment requirements for the development of energy projects have given rise to alternate modes of structuring projects involving the private sector. Depending on the solution chosen, the latter can bear a greater or lesser responsibility for the realization of the projects. This mode of project development is called "Public Private Partnership (PPP)".

International experience of this type of project developement shows that private sector participation generally brings benefits in relation to the implementation of projects with public interest. The private partner brings proven experience in the design, development and construction of major projects in the electricity sector. The partner shall also have more experience and incentives for EPC contracts to be signed and implemented effectively, thereby maximizing project interest. All these lead to potentially obtaining the best price for projects as well as possibly achieveing commissioning dates according to planned schedules. In addition, private sector participation, with the experience, organization and financial discipline that it brings, generally ensures adequate project operation and maintenance and therefore ensures sustainability

The implementation strategy for each of the recommended priority projects shall have to take into account among others, the intrinsic characteristics of these projects, the technologies concerned and the number of partners (or Member States) concerned.

Solar and wind renewable energy projects represent particularly interesting opportunities to favor the participation of the private sector. The development of these types of projects by the private sector could be systematically done through Auctions that could involve different development schemes such as the "plug-and-play" scheme. Such schemes generally tend to reduce the risks for private investors with regards to construction and power evacuation.

Large thermal generation projects represent also opportunities to attract private partners to take charge of the project development, following the example of the regional Maria Gleta project. Key success factors of this approach reside in securing the fuel supply, whose responsibility can be transferred to the private partner, and in obtaining electricity purchase commitments from the relevant States, for which a strong regional coordination is required.

Where the public sector has to continue to be involved in the implementation of projects, such as cross-border interconnection projects, it is strongly recommended an institutional framework reflecting the joint implementation of projects continue to be pursued. The WAPP has already employed variations of this strategy in some of its existing projects such as the 225 kV CLSG Project, the 330 kV Northcore Project as well as the 225 kV Ghana – Burkina Interconnection Project.

6.2. Exchange opportunities beyond the WAPP area

Given that the WAPP, in the short term, shall achieve the power system integration of the 14 mainland ECOWAS Member States, it makes sense that the WAPP takes steps during the period covered by the study to further economically diversify its energy mix. A plausible course of action in this regard is to interconnect beyond its current area of coverage.

6.2.1. Interconnection with the Northern part of Africa

In order to link the WAPP system to the Northern Africa and European power systems through Morocco, different interconnection options have been analyzed and compared from a techno-economic point of view. On the basis of preliminary analyses, the option of a HVDC–VSC with line route from Tobene (Senegal) to Dakhla (Morocco) is recommended.

The preliminary economic analysis has determined that there is an economic interest in interconnecting WAPP and North Africa. The WAPP system will benefit from a reduction in installed capacity requirements and operational costs due to imports from Morocco and probably from North Africa as well as Europe.

From a technical point of view, given the weak connection points, additional measures must be taken to apply the HVDC CCS or AC technology for a nominal value of 1 GVA. The HVDC VSC option in a bipolar configuration is therefore a priori the most appropriate solution for the system, especially when network support is required or future system extensions are provided.

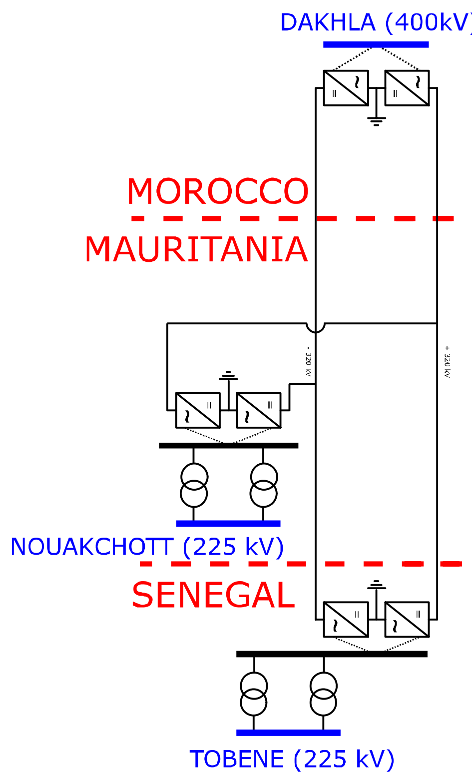

Figure 25: Optimal Configuration for the North Africa – West Africa Interconnection

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6.2.2. Interconnection with the Central African Power Pool

From an economic point of view, there is an interest in interconnecting the WAPP network with the Central African Power Pool (CAPP) to not only access the abundant and low-cost power from Inga but also from other hydropower sites in the CAPP region. Also, beyond the cost savings to be realized in terms of operational costs, the interconnection shall also result in economies in terms of investment costs, since this interconnection shall displace the need for additional thermal units, which would have been needed in the reference case for reliability.

6.2.3. Connection Opportunities with Cape Verde

The interconnection of Cape Verde with WAPP is technically feasible through an HVDC cable to connect Praia (Cape Verde) and Dakar (Senegal), a distance of about 650 km. This interconnection could benefit the sub-region in ways that include the sharing of the solar and wind resources of the archipelago as well as the improvement of the security of supply for Cape Verde. Given the level of demand currently on the archipelago (less than 100 MW) and in light of the exchanges that could take place, the implementation of HVDC cables seems prohibitive. A precondition for the interconnection with the mainland, is the linking of the islands that shall not only improve the security of supply but shall also deploy more optimally the numerous renewable energy projects and reduce cost.

6.3. Priority Action Plan for WAPP

In addition to the development of the 75 Priority projects, the major actions to be undertaken by the WAPP for an efficient implementation of the Master plan as well as an optimal operation of the interconnected system include:

Support to the development of renewable energy projects

In addition to the optimum leveraging of hydropower resources through the development of priority projects, the economic analyses carried out conclude that by 2033, the development of the proposed variable renewable energy projects (solar PV and to a lesser extent wind turbine) shall constitute 18% of energy produced on the basis of renewable resources (excluding hydro) within the sub-region.

In particular, the dynamic studies carried out for the years 2022 and 2025 considered an instantaneous integration rate at the solar peak of respectively 17% in 2022 and 28% in 2025. For this rate, the studies demonstrated the technical feasibility of the integration of intermittent renewable energy while optimizing the operation of the system. Thus, the techno-economic feasibility integrating intermittent renewable energy has been demonstrated for a total of 3.3 GW by 2022, 7.0 GW by 2025, 9.6 GW by 2029 and 12.1 GW by 2033.

Of these intermittent renewable projects, 15 solar, wind and hybrid projects were included in the list of priority projects for a total of 3.15 GW

In addition, an economic potential for a total of 37.5 GW by 2033 (ie 24.9 GW in addition to the 12.1 GW previously presented) has been identified. This economic potential, in order to be developed, will nevertheless have to be the subject of in-depth studies, particularly from a technical point of view.

As such, the WAPP shall have to play an important role as a driving force by accompanying the countries in their energy transition through among others the shared experience for the contract arrangement of generation agreements, the support to the development of in-depth network studies in the different Member States, and the securing of adequate funding sources for the preparation and implementation of the projects.

The availability of the necessary skills should also be ensured by supporting a capacity building program in areas that include operations and planning management.

In addition, it is recommended that the WAPP pursue other opportunities related to renewable energy deployment such as the hybridization of hydropower and thermal power plants, the development of floating photovoltaic technologies and the deployment of storage technologies (including battery), and to subsequently implement the related projects for which the economic viability have been demonstrated.

Monitoring the development of projects carried out by other regional entities

By their mandate, a number of sub-regional entities (such as OMVS, OMVG, CEB, NBA, MRU) have the responsibility to develop generation and interconnection infrastructure that shall benefit their respective Member States. Sometimes it is a multi-purpose infrastructure but for which the generation or transmission of electricity play an important role. Given their regional impact, these generation (especially renewable and hydropower) and transmission projects should be closely monitored by the WAPP independent of their size.

Support to the optimal operation of the interconnected network

In order to ensure the optimal and coordinated operation of the interconnected network and thus successfully synchronize the electrical networks of the 14 mainland ECOWAS Member States, the WAPP and its Member Utilities shall have to undertake actions that include:

Recommendation	Approximative cost of the measure
Tune PSS of some large units at the extremities of the WAPP system to improve the damping of a critical 0.27 Hz interarea mode between eastern WAPP and the rest of WAPP	500kUSD[2]
Update the WAPP Operations Manual	300 kUSD
Set up a Special Proctection Scheme (SPS) to increase trade between Nigeria and the rest of the WAPP	2 MUSD
Improve dynamic voltage compensation by adding one SVC at Ouagadougou (Burkina) and one at Salkadamna (Niger)	30 MUSD
Operationalize the WAPP Information and Coordination Centre (CIC)	

It is strongly urged that the 330 kV Ghana – Burkina – Mali Interconnection Project (approximately US$234 million) as well as the 2nd Circuit of the CLSG Project (approximately US$131 million) be implemented soonest as they shall both contribute towards the optimal operation of the interconnected system.

Implementation of action plans to improve the performance of WAPP member utilities

Based on the best practices observed in the WAPP member utilities as well as in other regions of the world facing with similar issues, a list of actions has been proposed that aim at improving the performance, the efficiency and the sustainability of WAPP member utilities.

Depending on the context of each country and each utility, the sequence in which the actions are implemented may vary. Nevertheless, in view of the cross-cutting nature of the critical factors affecting the performance of utilities within the region, the following priority actions can be proposed:

[2] Source : synchronisation study

Theme	Main priority actions to implement at utility level
Governance	Adequate use of plan contracts, performance contracts and management contracts taking advantage of the lessons learned from utilities having experienced them.
Planning	Pursuit of the consistency between national masterplans and the ambitions reflected in the regional masterplan.
	Extension and reinforcement of national networks and interconnections as a key factor for system performance.
Development of large projects	Diversification of development modes and increased involvement of the private sector.
Commercial efficiency	Support to cross-border electricity exchanges by standardizing contractual clauses of electricity import and export, with the support of ERERA.
	Implementation of clientele management systems and of call centers.
	Implementation of pre-paid metering systems and decentralization of invoicing and payment collection activities.
Capacity development	Reinforcement of human resources in technical, legal, financing, commercial and procurement areas in collaboration with Development Finance Institutions, strengthening of WAPP Centers of Excellence and creation of partnerships with universities in the sub-region.

Action Plan to promote the diligent implementation of projects

A diagnosis of the implementation of the priority projects from the 2012 – 2025 regional masterplan has been conducted through the collection of lessons learned by the actors involved in these projects. This approach highlighted recurrent delaying factors for the development of projects and for the compliance to the schedule established in the previous masterplan.

Based on this diagnosis, an implementation strategy has been established for the updated regional masterplan with the objective of reducing the duration of project development. The proposed actions are the following:

Actions to promote the diligent implementation of projects

Further deployment of institutional frameworks that reflect the common implementation of regional projects such as the creation of Special Purpose Companies (e.g. Transco CLSG) or Joint Project Management Units (e.g. Northcore, OMVG Loop).

Identification of new sources of financing for the implementation of environmental and social mitigation measures from Development Finance Institutions and possibly, pre-financing by the private sector.

Reinforcement of the WAPP to ensure a coordination between national planning and the ambitions of the regional masterplan, in particular through the development of a reference planning software for the region.

Scaling-up of private sector participation in the development of regional variable renewable energy projects. This could include, among others, the development of large renewable energy (solar and wind) priority projects through Auctions involving « plug-and-play » scheme.

Reinforcement of the WAPP to extend its coordination and information sharing activities beyond the Member utilities and the WAPP Technical and Financial Partners to reach other Actors within the sub-sector such as National Regulators, Manufacturing and Industry, other high-level government entities involved in the electricity sub-sector, and other financing institutions (national export-import banks, investment funds, etc).

Advocating increased coordination among the Development Finance Institutions (DFIs) supporting regional projects, in particular regarding the harmonization of procurement guidelines for reginal projects, the harmonization of disbursement conditions where various DFIs are involved in the same project and the coordination with export-import banks active in the projects' countries.

Enhancing funding for project pre-investment studies including the rapid operationalization of the FODETE to fund project preparation activities.

Granting of land with free-zone status at appropriate target locations by countries that have been identified to host the regional solar and/or wind power parks

Diversification of financing resources for the realization of the priority projects that could include Green Climate Fund and enhanced private sector participation

Setting-up of rewarding and strategic partnerships that are fully aligned with the priorities of the Region and shall, among others, facilitate the implementation of the Master Plan

APPENDIX

Priority Generation Projects

	Name of the Project	Installed Capacity MW	Cost Estimated MUSD	Date of commissioning
ShortTerm	*Gouina Hydropower plant (OMVS)	140	462	2020
	*Souapiti Hydropower plant In Guinea	450	1350	2020
	*Gribo-Popoli Hydropower plant in Côte d'Ivoire	112	345	2021
	*Sambangalou Hydropower plant (OMVG)	128	454	2022
	*Zungeru Hydropower plant in Nigeria	700	1200	2022
	*Fomi Hydropower plant in Guinea	90	620	2022
	*Wind Farm in Senegal	150	230	2019-2021
	*Azito IV Thermal Power Plant CC in Côte d'Ivoire	253	302	2020
	*Ciprel V Thermal Power Plant CC in Côte d'Ivoire	412	505	2021
	*Early POWER Thermal Power Plant CC in Ghana	300	390	2019
	*GPGC Thermal Power Plant CC in Ghana	170	221	2019
	*Amandi Thermal Power Plant CC in Ghana	240	312	2019
	*Rotan Thermal Power Plant CC in Ghana	330	429	2022
	*KADUNA Thermal Power Plant in Nigeria	215	280	2019
	*OKPAI Thermal Power Plant in Nigeria	450	585	2020
	*SALKADAMNA Thermal (Coal) Power Plant in Niger	200	573	2021
	Maria Gleta Thermal Power Plant in Benin	450	585	2022 recommended for the first GT
	Boutoubre Hydropower plant in Côte d'Ivoire	150	343	2022 recommended (1st group)
TOTAL SHORT-TERM		4940 MW	9185 MUSD	

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	Name of the Project	Installed Capacity MW	Cost Estimated MUSD	Date of commissioning
Mid-term	*Amaria Hydropower plant in Guinea	300	600	2023
	*Bumbuna II Hydropower plant in Sierra Leone	143	358	2023
	*Louga Hydropower plant in Côte d'Ivoire	246	647	2023
	*Koukoutamba Hydropower plant (OMVS)	294	689	2024
	*Mambilla Hydropower plant in Nigeria	3050	5800	2024
	*Adjaralla Hydropower plant (Togo-Benin)	147	333	2026
	*Tiboto Hydropower plant (Côte d'Ivoire-Liberia)	225	599	2028
	*Alaoji II Thermal Power Plant in Nigeria	285	371	2025
	*San Pedro Thermal (coal) Power Plant in Côte d'Ivoire	700	1900	2026-2029
	Solar Farm PV in Burkina Faso	150	139	2022-2024 Recommended
	Solar Farm PV in Mali	150	139	2022-2024 Recommended
	Solar Farm PV in Côte d'Ivoire	150	143	2022-2024 Recommended
	Solar Farm PV in The Gambia	150	130	2023-2025 Recommended
	Solar Farm PV in Benin	150	120	2024-2026 Recommended
	Solar Farm PV in Nigeria	1000	695	2025-2029 Recommended
	Solar Farm PV in Ghana	150	108	2026-2027 Recommended
	Grand Kinkon Hydropower plant in Guinea	291	350	2023 Recommended
	Morisananko in Guinea (Hybrid PV – Hydro)	200	353	2025 Recommended
	Bonkon Diara Hydropower plant in Guinea	174	211	2025 Recommended
	Boureya Hydropower plant (OMVS)	114	448	2029 Recommended
	Aboadze II Thermal Power Plant in in Ghana	450	585	2029 Recommended
TOTAL MID-TERM		8699 MW	14808 MUSD	

Final version

	Name of the Project	Installed Capacity MW	Cost Estimated MUSD	Date of commissioning
Long-term	Solar Farm PV in Niger	150	90	2030 Recommended
	Solar Farm PV in Burkina (Phase II)	150	84	2031 Recommended
	Solar Farm PV in Mali (Phase II)	150	77	2032 Recommended
	Wind Farm in Nigeria	300	190	2030 Recommended
	Mano Hydropower plant (MRU)	180	487	2030 Recommended
	Songon Thermal power plant in Côte d'Ivoire	369	480	2031 Recommended
	Saint Paul Reservoir In Liberia	1st phase: Via Reservoir 2nd phase : New project 360 MW to 585MW	511 (for the first phase)	1st phase: 2025 Recommended 2nd phase : 2030
TOTAL LONG-TERM		1883 MW	1919 MUSD	
GRAND TOTAL		**13592 MW**	**24594 MUSD**	

** Decided Project*

Final version

Priority Transmission Projects

	Line	Level Voltage KV	Length [km]	Estimated cost [MUSD]	Date of commissioning
Short-term	*Coastal backbone project: interconnection Volta (Ghana) - Lomé (Togo) - Sakété (Benin)	330	340	122	2019
	*Laboa-Boundiali-Ferkessedougou (Côte d'Ivoire)	225	310	115	2019
	*Line Kayes (Mali)-Tambacounda (Senegal) (part of the Manantali II project of OMVS)	225	288	94	2020
	*Interconnection CLSG (Interconnection Côte d'ivoire-Liberia-Sierra Leone-Guinea)	225	1303	517	2020
	*OMVG Loop (Senegal-The Gambia-Guinea Bissau-Guinea)	225	1677	722	2020
	*Manantali-Bamako line in Mali (part of the Manantali II project of the OMVS)	225	317	85	2021
	*Inteconnexion Guinea - Mali	225	1074	436	2021
	*Project North Core (interconnection Nigeria- Niger -Benin/Togo-Burkina)	330	832	541	2022
	*Kayes Line (Mali)-Kiffa (Mauritania) (part of the Manantali II project of the OMVS)	225	420	184	2022
	Second circuit of the CLSG interconnection to be commissioned in the same time as the first circuit	225	1303	131	2020
	Line Bolgatanga (Ghana)-Bobo (Burkina Faso)-Sikasso (Mali)	330	555	341	2022 Recommended
TOTAL SHORT-TERM			8419 km	3288 MUSD	
Mid-term	*Line Manantali (Mali)-Boureya (Guinea)-Koukoutamba(Guinea)-Linsan (Guinea) (part of the Manantali II project of the OMVS)	225	462	166	2024
	*Line Buchanan (Liberia)-San Pedro (Côte d'Ivoire)	225	520	129	2028
	*Strengthening interconnection Côte d'ivoire-Ghana	330	387	156	2029
	*Line Boundiali (Côte d'Ivoire)-Tenrgela (Côte d'Ivoire)- Syama (Mali) - Bougouni (Mali)	225	330	96	2029

Final version

	Line	Level Voltage KV	Length [km]	Estimated cost [MUSD]	Date of commissioning
	Line Fomi (Guinea)-Boundiali (Côte d'ivoire)	225	380	96	2025 Recommended
	Median Backbone (Nigeria-Benin-Togo-Ghana-Côte d'Ivoire)	330	1350	813	2025 Recommended
	Strengthening the coastal Backbone First Phase Nigeria-Benin 2nd Phase Benin-Togo-Ghana	330	400	281	First Phase: 2025 recommended Second Phase: 2028 recommended
	Line Labé- Koukoutamba In Guinea	225	115	50	2024 recommended
	Connection Segou Bamako	225	290	105	2025 recommended
TOTAL MID-TERM			4234 km	1892 MUSD	
Long-term	Western Backbone (Senegal-The Gambia-Guinea Bissau-Guinea-Mali) to reach Ghana-Burkina-Mali	330	1600	912	2033 Recommended
Long-term	Link Bobo (Burkina Faso)-Ferke (Côte d'Ivoire) to connect the Western Backbone to the Median	330	213	126	2033 Recommended
Long-term	Reinforcement of the Western section of the OMVG loop	225	800	301	2030 recommended
Long-term	Strengthening Niger-Nigeria Interconnection	330	510	332	2033 Recommended
Long-term	Second North-south axis in Ghana	330	750	426	2030 recommended
Long-term	Eastern Backbone in Nigeria	330	1856	966	2033
Long-term	Interconnection WAPP (Senegal/OMVS) - Northern Africa through Morocco		1250	*615*	2033
Long-term	Interconnection WAPP (Nigeria) - CAPP (Inga)		3300	*1622*	2033
TOTAL LONG-TERM			10279 km	5300 MUSD	
GRAND TOTAL			**22932 km**	**10480 MUSD**	

** Decided Project*

Final version

Transversal Actions

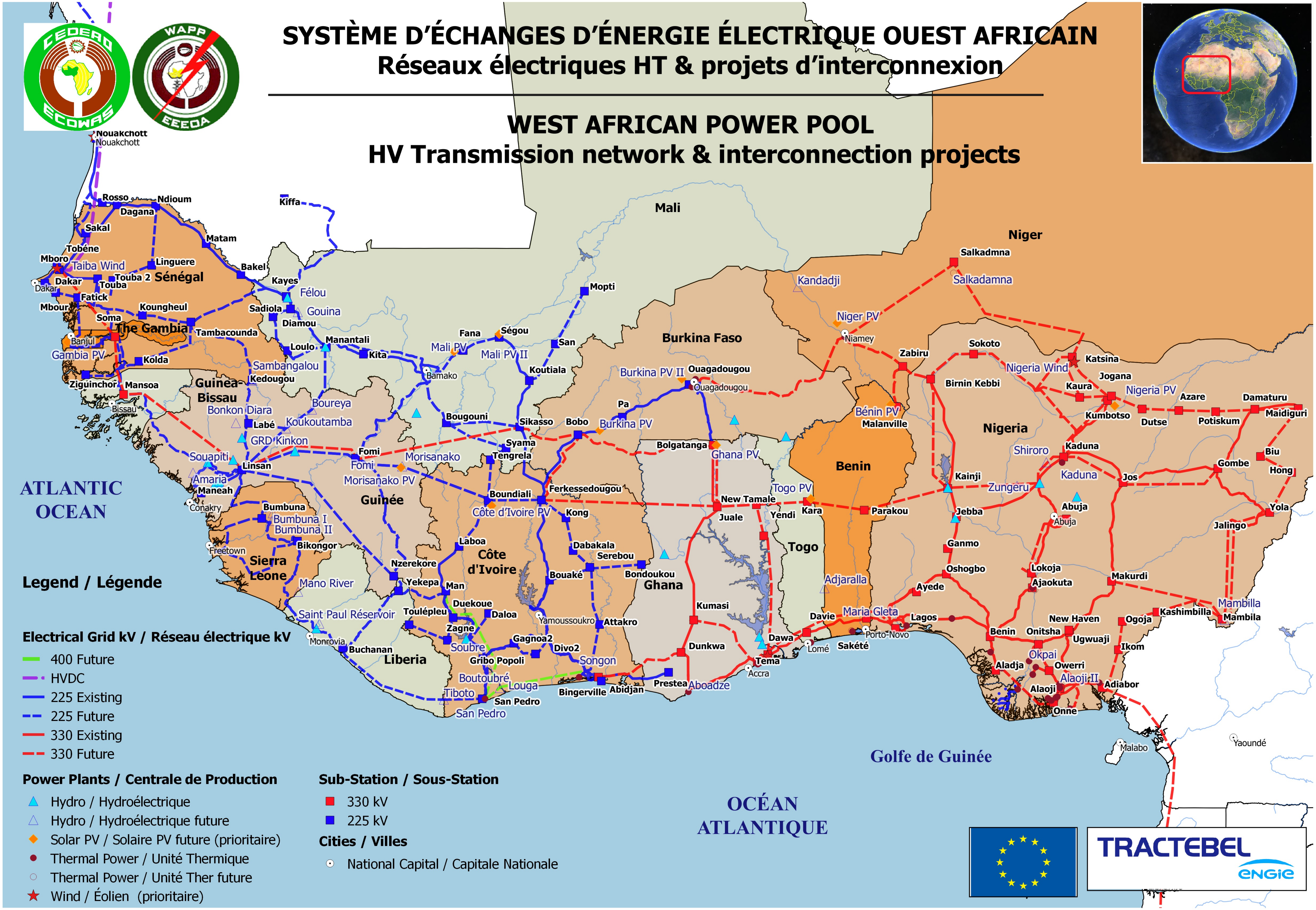
Transversal Actions	Support to the development of variable renewable energy projects at national level in ECOWAS Member States
	Monitor the development of projects being developed by other sub-regional entities (OMVG, OMVS, NBA, CEB, MRU)
	Pursue opportunities related to renewable energy deployment eg hybridization of hydropower and thermal power plants, floating photovoltaic technologies, deployment of storage technologies (including battery), and implement related projects should they be proven beneficial
	Deploy supplementary measures aimed at further consolidating the synchronism of the WAPP interconnected system
	Support WAPP Member Utilities prepare and implement Action Plans aimed at improving their efficiency and performance
	Develop a regional approach to address some of the challenges faced by the Distribution Utilities of the WAPP
	Continue the capacity building/reinforcement of WAPP Member Utilities and accelerate the development of the WAPP Centers of Excellence

Map of the Transmission Network

Final version

SYSTÈME D'ÉCHANGES D'ÉNERGIE ÉLECTRIQUE OUEST AFRICAIN
Réseaux électriques HT & projets d'interconnexion

WEST AFRICAN POWER POOL
HV Transmission network & interconnection projects



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