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# Assessing the needs, gaps and capacity development requirements for open source tools for energy planning and investment for climate action in Africa

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# Declaration

I, Axel Nguedia Nguedoung, hereby affirm that the master thesis at hand is my own written work and that I have used no other source and aids others than that indicated. Only the cited sources have been used; direct quoting and paraphrase quoting have been identified as such.

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Signature

# Dedication

"To my beloved mother and to the loving memory of my father."

# Acknowledgement

I would like to express my deep gratitude to the initiators of this programme, the African Union Commission, the Government of Algeria and their German partners DAAD, GIZ and KFW for enabling this programme.

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# Abstract

Africa is highly endowed with all forms of energy resources – both fossil and renewables. Yet, the continent is the only region in the world with the lowest access rate to electricity and clean energy for cooking. Accelerated efforts are needed if the huge energy deficit in the continent is to be closed towards meeting the development goals set in Agenda 2063 and the UN 2030 Agenda for sustainable development. Although, not a highly emitting region, The Paris Agreement on climate change provides the framework and opportunity for Africa to meet its increasing energy needs in a low carbon and climate resilient way. As such, all African countries have included renewable energy in their Intended Nationally Determined Contributions (INDCs) to climate action under the framework of the Paris Agreement. To better optimize Africa's energy supply and meet the ambitious set in the INDCs for increased shares of renewable energies, there is a need to strengthen the institutional and individual capacity on the continent for optimum energy and investment planning of the available resources; taking into account all the different opportunities available in the continent.

This study analyses the requirements of energy and investment planning. It assesses the gaps in energy planning of selected countries across the continent with focus on the enabling environment for renewable energies deployment and energy efficiency promotion. It also assesses the capacity development needs in energy planning across the continent with specific attention given on the use of energy planning tools - especially open source tools. The study has been done adopting reviewing method regarding the different energy planning tools available and their characteristics, and conducting a survey with different organizations across the continent using a questionnaire.

The study reveals that the enabling environment in northern part of the continent is the one with less gaps regarding renewable deployment and energy efficiency promotion. The study reveals that as far as the enabling environment for renewable energy deployment is concerned, there is a wide gap regarding access of renewable energy based generation to the grid across the continent, however, the Northern African region is the region which

records less gap. The institutional and legal framework is the area with less gap recorded in all regions excepted in Central Africa. Regarding energy efficiency, there is no general trend regarding the gaps that varies from one region to another. However, the Northern region is the one with less gaps.

Across the continent, more than 35% of institutions surveyed require capacity building in the areas of resource assessment, institutional design, policy design, investment and project finance and in energy planning. More than 65% are requiring capacity building in the three last areas (policy design, investment and project finance and in energy planning). More specifically, regarding energy planning, 64% of surveyed institutions do not use energy planning tools to support the sector's development policies and in the case these tools are used, 62% of institutions required skilled human resource.

The study also shows that, open source energy planning tools, while having more or less same characteristics as traditional licensed tools, offer more flexibility in term of capability of integrating non-priced and price induced policies or addition of new technologies. It also demonstrates the application of open source tool in optimizing the electricity mix of the Central African region by 2030 in different scenarios. This showed that increasing power trade in electricity development plan of the region can generate up to 5% total cost savings and can enable countries with small electricity demand such as Equatorial Guinea to become net exporter with more than 50% of its electricity generated being exported.

**Key words: INDCs, enabling environment, optimization, trade.**

# Résumé

L'Afrique regorge un énorme potentiel en ressource énergétiques tant d'origine fossile que d'origine renouvelable. Cependant, le continent est la seule région du globe enregistrant le plus faible taux d'accès à l'électricité et aux énergies de cuisson propres. D'importants efforts sont nécessaires pour combler l'énorme déficit énergétique sur le continent en vue de l'atteinte des objectives de développement fixes dans l'Agenda 2063 et l'Agenda des Nation Unies pour le Développement Durable. Etant l'une des régions les moins polluantes du globe, les Accords de Paris sur les changements climatiques définissent le carde et l'opportunité pour l'Afrique de répondre a ses besoins sans cesse croissants en énergie en utilisant des moyens bas carbone et résilients au climat. Ainsi, les pays Africains ont incorporé les énergies renouvelables dans leurs Contributions Prévues Déterminées au niveau National (CPDN) dans le cadre des Accords de Paris. Dans le but d'optimiser l'approvisionnement en énergie en Afrique et d'atteindre les ambitions d'augmentation des proportions des énergies renouvelables inscrites dans les CPDNs, il est important de renforcer les capacités institutionnelle et individuelles sur le continent pour une planification optimale des ressources en prenant en compte toutes les différentes opportunités dont le continent regorge.

Cette étude analyse les prérequis en matière de planification des investissements dans le secteur de l'énergie ; évaluant les manquements dans la planification énergétique dans un ensemble de pays à travers le continent plus précisément par rapport à l'état des lieux de l'environnement pour le déploiement des énergies renouvelables et la promotion de l'efficacité énergétique. Elle évalue aussi les besoins en terme de développement des capacités dans la planification énergétique à travers le continent avec une attention particulière portée sur l'utilisation des outils de planification énergétiques. L'étude a été conduite suivant la méthode de revue en ce qui concerne les différents outils de planification énergétique disponible et leurs caractéristiques ; suivie d'une enquête auprès de différentes organisations à travers le continent au moyen d'un questionnaire.

Au terme de cette étude il en ressort que la partie nord du continent est celle avec un environnement plus propice au déploiement des énergies renouvelables et la promotion de l'efficacité énergétique. Concernant les énergies renouvelables, il est observable des grands manquements en ce qui concerne l'accès de l'électricité de source renouvelable au réseau électrique; La région du Nord étant celle avec le moins de manquements enregistres. Le cadre institutionnel et légal est celui avec le moins de manquements enregistrés dans toutes les régions à l'exception de l'Afrique centrale. Pour ce qui est de la promotion de l'efficacité énergétique, il n'existe pas de tendance générale à travers le continent, cependant la région du Nord reste celle avec le moins de manquements.

A travers, le continent, plus de 35% des institutions ayant participées à l'enquête nécessitent le développement des capacités dans les domaines de l'évaluation des ressources, la conception institutionnelle, l'investissement et le financement des projets et la planification énergétique. Plus de 65% nécessitent dans les trois derniers domaines suscités. Par rapport à la planification énergétique, l'étude révèle que 64% des institutions enquêtées n'ont pas recours aux outils de planification pour appuyer le développement des différentes politiques, et quand bien même ils sont utilisés, il existe un manque de personnel qualifié pour leur utilisation.

L'étude révèle aussi que, les outils de planification énergétiques de type 'Open Source' bien qu'ayant plus ou moins les mêmes caractéristiques que ceux de type 'Licensed' offrent plus de flexibilité en terme de capacité d'intégration des politiques de prix induits, les politiques a effets intangibles aussi bien de ce qui est de l'intégration de nouvelles technologies. Elle démontre aussi une application d'un de ces outils notamment OseMOSYS dans l'optimisation du mix énergétique de la région Afrique Centrale à l'horizon 2030 suivant différents scenarios. Il en ressort que l'intégration du commerce de l'électricité dans les politiques de planification énergétiques est capital, produisant d'importants avantages. En effet, l'augmentation du commerce électrique au sein de la région Afrique Centrale pourrait générer jusqu'à 5% de réduction du cout total tout en permettant à des pays à faible demande électrique de devenir net exportateur d'électricité,

à l'exemple de la Guinée Equatorial qui verrait près de la moitié de sa production électrique exportée générant ainsi des revenus additionnels.

**Mots clés : CPDN, environnement propice, optimisation, commerce d'électricité**

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## Acronyms and Abbreviations

| | |
|---|---|
| AIM | Asian-Pacific integrated model |
| CAPP | Central Africa Power Pool |
| CAR | Central African Republic |
| CFL | Central fluorescent lamps |
| CHP | Combined heat and power |
| COMELEC | Communaute Maghrebine d'Electricite |
| DRC | Congo Democratic Republic |
| CSP | Concentrated Solar Power |
| DICE | The Dynamic Integrate model of Climate and Economy |
| EAC | Eastern African Community |
| E. Guinea | Equatorial Guinea |
| EAPP | Eastern Africa Power Pool |
| EJ | Exajoule |
| EMPS | EFI's Multi-Area Power market Simulator |
| ENPEP-BALANCE | Energy and Power Evaluation Programme |
| ERIS | Energy Research and Investment Strategies |
| ETSA | Energy Technology System Analysis |
| FIT | Feed-in-Tariff |
| GW | Gigawattt |
| IEA | International Energy Agency |
| IRENA | International Renewable Energy Agency |
| kWh | kilowatt-hour |
| LCEDN | The Low Carbon Energy Development Network |
| LCOE | Levelized Cost of Electricity |
| LEAP | Long-range Energy Alternatives Planning |
| MESAP | Modular Energy System Analysis and Planning |
| MESSAGE | Model for Energy Supply Strategies Alternatives and their General Environmental Impacts |
| Mtoe | Megatone oil equivalent |

| | |
|---|---|
| MW | Megawatt |
| NDC | Nationally Determined Contribution |
| OECD | Organization for Economic Cooperation and Development |
| OseMOSYS | The Open Source Energy Model System |
| PIDA | Programme for Industrial Development of Africa |
| PJ | petajoules |
| POLES | Prospective Outlook on Long-Term Energy System |
| PV | Photovoltaic |
| RE | Renewable energy |
| SAGE | System for analysis of global energy markets |
| SAPP | Southern Africa Power Pool |
| SDG | Sustainable Development Goal |
| TEMBA | The Electricity model based for Africa |
| TFEC | Total final energy consumption |
| TIMES | The Integrate Markal-Efom System |
| TPES | Total primary energy supply |
| TRNSYS | Transient system |
| TWh | Terawatt-hour |
| UNECA | United Nation Economic Commission for Africa |
| UNFCCC | United Nation Framework Convention on Climate Change |
| USD | US Dollar |
| WAPP | Western Africa Power Pool |
| WASP | Wien Automatic System Planning |
| WEM | World Energy Model |

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# 1. Introduction

## 1.1 Background

Appropriate and affordable energy supply is key for socio-economic development and transition to modern industrial and service-oriented societies. Energy is a central factor which affects society's living standard and improves people well-being and welfare. It is a pillar for of economic development. Nowadays, its importance is becoming more and more important, especially in regard to the sustainable development of communities including social and economic aspects. More specifically, access to electricity is a strong causal determinant of economic development; affecting the labor market outcomes with increase in employment and revenues in connected areas (Jacopo G. et al., 2014). However, accessibility to energy around the world is not evenly distributed, with a big contrast among different regions of the globe (developed countries and developing countries) and even within regions (Africa, Asia).

Access to modern energy which encompasses with two main aspects; access to electricity, and access to clean and modern cooking facilities has been defined by the United Nations as a Sustainable Development Goal (SDG 7) as part of the objectives defined in his Agenda 2030 for sustainable development aiming at shifting the world onto sustainable and resilient paths[1]. Though, there has been significant increase in the number of people with access to modern energy this last decade, the rapid increase of the global population has eclipsed this state of art.

To date, the African continent as well as other parts of the globe is facing a chronic situation of scarcity in access to modern energy. According to the International Energy Agency, 1.2 billions of people around the globe do not have access to electricity and more than 2.4 billion rely on traditional use of biomass for cooking (IEA, Modern energy for all, 2016). Africa accounts for 28% of world's population relying on traditional use of biomass

[1] The United Nations, 2015. *Transforming our world: the 2030 Agenda for sustainable Development*

with 68% share of population within the continent and concerning electricity access, Africa accounts for 53% of the world population without access to electricity, with a continent electrification rate of 43% (urban 68% and rural 26%) (IEA, 2015).

Aiming at tackling this chronic lack of access to electricity, Africa in his new conductive environment for advancing socio-economic development and integration defined in the Agenda 2063, through long term planning, set a target of ensuring access to modern, efficient, reliable, cost effective, renewable and environmentally friendly to all while harnessing all its energy resources[2]. However, African as well as other parts of the world is experiencing the severe consequences and harms of climate change such as global warming, droughts, increase of sea level, etc. due to the global situation of the current energy supply and use based on limited resources of fossil fuels, committed themselves in a global shift in development patterns namely global transition in other to reduce the harms their different activities are doing on the environment. This transition implies a shift from the use of traditional reliance of fossil fuel resources to cleaner energy resources. The role the renewable energies could play especially in mitigating the global Greenhouse Gases emissions were defined and highlighted in the framework of The Paris Agreement in his article 6 (UNFCCC, 2015).

In this framework, Africa set an Agenda for addressing the power deficit the continent is subjected to, using clean energy paths for development, especially regarding the achievement of the sustainable development goals more specifically regarding the achievement of the sustainable development goal seven with the achievement of universal access to energy by 2030 (LCEDN, 2016). Therefore, there is a need for Africa to tap into the energy resource potentials it is endowed of in other to address this issue. Indeed, the continent is endowed of non-negligible potential regarding renewable energy resources, with almost all the renewable energy resources are available in every part of the continent.

[2] AUC, 2014. *Agenda 2063:The world we want*

As well traditional energy potential is huge in the continent with major producers being Nigeria, Algeria for gas and oil, Angola for oil and South Africa for coal (Birol, 2016).

The implementation of this Agenda to be a success will need in upstream to think, plan energy projects and programs in that regard and be able to overcome prospective challenges that may appear. LCEDN (2016) highlighted that, local authority capacities in the continent, lack of capacity, lack of resources and lack of capabilities are among others, the major challenges to overcome in other to successfully implement cleaner development patterns in Africa. This would be done, through capacity development paradigm that United Nations Development Programme (2008b) defined as an endogenous process where the ability of individuals, organizations, society and communities to make choices, perform functions, solve problems and set and achieve objectives are obtained, strengthened, adapted, maintained or changed over time. It is the core concept in addressing sustainability issues including in the energy sector, it helps defining policy solutions and helps in avoiding projects to not meet the expected outcomes, or in the worst case scenario to collapse.

Therefore, there will be a need to make proper planning relatively to the various energy resources to be exploited, especially since it requires major investments for infrastructures development as well as policy framework establishments. A good understanding of the energy planning framework in energy sector, a good review of the required needs as well as a proper assessment of these needs have to be done in conception phase of each project in other insure the achievement the expected energy outcomes. Especially based on the fact that, nowadays, sustainable solutions to energy problems do no longer consist of exclusive optimal allocation of traditional resources but should address the human-environmental system as a whole while taking into account the three dimension of sustainability which are social, economic and environmental[3].

[3] UNDP, Energy for sustainable development: A policy agenda, 2002

## 1.2 Problem Statement

Africa is resolutely determined to achieve its development goals as set its Agenda 2063 in one hand, and in another to achieve the sustainable development goals as defined in the UN 2030 Agenda for Sustainable development. The role energy should play in the achievement of these goals is crucial especially regarding access to affordable and reliable electricity supply. Despite the tremendous potential the continent is endowed of, electricity access is still very low. Governments across the continent have set ambitious targets towards increasing electricity access using cleaner pathways. Therefore for this to happen, there is a need for proper investment planning while taking into account the different opportunities available.

The present study aims at investigating the needs and gaps relatively to capacity development of energy in the context whereby Africa is looking forward to address the chronic lack of energy access of its population. The increasing competitiveness of renewable energies technologies in the world nowadays, as well as the related markets are opportunities which could be taken by Africa. Especially having in mind that most of African population lacking access to energy are located in remote area.

In that regard, enhancing competitiveness of renewable energy technology markets could substantially improve its development. Also, the role that renewable energies could play in that regard is not the unique option which can be considered. The use of conventional energy technologies as well should be considered. Though, a specific attention should be pay regarding its utilization in a more environmental friendly way. Therefore, energy efficiency capacity can help also in achieving the above mentioned goal of increasing energy access to African population.

In this study, the research question can be defined as follows:

*What are the critical energy capacity development gaps that Africa needs to address in order meet its development Agenda 2063 and the UN 2030 Agenda for Sustainable Development?*

To answer this question, some sub questions will be formulated as well. They are the following:

1) What are the needs and gaps in energy capacity development in Africa today?
2) What are the needs in energy capacity development especially regarding energy planning in other to properly plan the future investments in Africa?
3) What are the different energy modelling and planning tools that are used for proper energy investments planning?
4) Which could be among these different energy modelling and planning tools the most appropriate ones in African context?

**1.3 Objectives**

In a context where, Africans countries are looking forward to reduce the increasing number of their populations who lack access to energy, and with the paramount aim of achieving the goal of universal access to energy by 2030 in the world and in Africa in particular, this study aims at these specific objectives:

1) Review the energy capacity needs for of the African continent regarding in energy planning with regard to renewable energies as well as energy efficiency capacities development;
2) Assess the existing energy capacity especially regarding the power sector;
3) Assess the gaps regarding energy planning with specific attention given to renewable energies as well as energy efficiency;
4) Review the various open source energy modeling and planning tools available which can help addressing the above mentioned energy planning needs;
5) Evaluate these open source energy modeling and planning tools analyzed.

In other to achieve the above mentioned objectives, the analysis of the present study is organized as follows:

**Chapter 2** discusses the methodology applied in this study. **Chapter 3** reviews the concept of energy planning, its requirements, importance and challenges especially in African context; it reviews also the some of the various energy modelling and planning tools both open source and licensed ones. **Chapter 4** reviews the current status of the power sector on the continent including the resource potentials, access to electricity and the existing generation capacity. **Chapter 5** summarizes the planned capacities and future projections regarding electricity demand. **Chapter 6** assesses the gaps and the needs in energy planning with focus on the enabling environment and the utilization of energy planning tools. **Chapter 7** provides some strategic approaches in other to overcome the above needs. **Chapter 8** concludes in summarizing the findings of this study relatively to the different objectives.

# 2. Methodology

In other to conduct this study, we define an approach based on objectives defined for our study. These are: - the review of the needs and gaps for energy capacity development, and – the assessment of the different open source energy modeling and planning tools in addressing these needs and gaps, in the Africa, as well capacity development requirements. To ensure that all relevant dimension of the question are include in the study, expertise from academia and experts will be frequently done throughout the study.

The study will be conducted in two mains parts:

## 2.1 Part one

Here we will focus on energy planning in Africa with the following entry points:

1) The review of energy planning while highlighting its importance in African context will be highlighted: its requirements and the challenges of implementing it in Africa

2) A review of different energy modelling and planning tools which can address the above needs and gaps in energy planning. It will consist of the identification and compilation of the various energy modelling and planning tools available will be made including both open source and non-open source one; with stress on the limitations and advantages of each tool vis a vis the energy planning challenges in Africa.

Subhes et al. (2010) highlighted a set of specificities which have to be taken into account when evaluating energy systems models in developing countries and thus in Africa. In addition to that, other features will be looked at such as the model's accessibility in term of disaggregation level of the data required, the capability to analyze non-price and price induced policies, the level of skill required, the capability of addition of new technologies to not be exhaustive.

## 2.2 Part two

### 2.2.1 The gaps assessment

The gap analysis is made following different aspects of the capacities in other to meet the planned energy demand. Therefore we will be looking at:

- The availability of data relative to the projection of the demand;
- The adequacy of the planned capacities with regard to the available resource potentials of the country (ies).

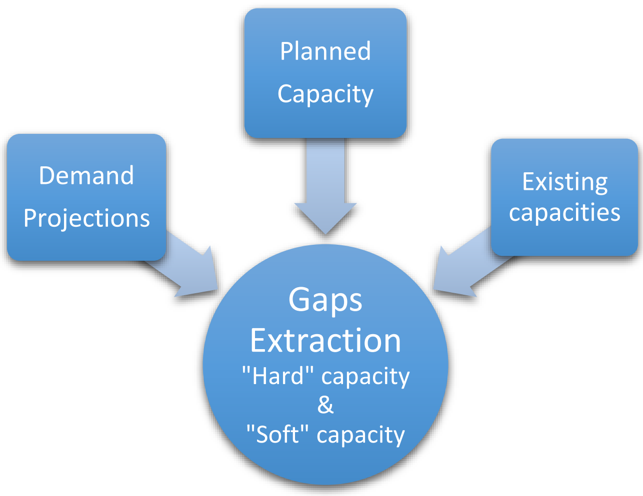


*Figure 2. 1: Gap assessment process*

- The aspects related to the enabling environment with regard to the development of renewable energies and the promotion of energy efficiency in order to effectively achieve the planned capacities. Thus, with regard to the above mentioned items the availability of different criteria are checked, and are described as follows:
    - Regarding renewable energy:
        - Established institutional and legal framework, with the presence of dedicated authority aiming at promoting renewable energies, a defined target, and the existence of legal framework;
        - The regulatory framework with the existence of different instruments (fiscal, regulatory), public finance;

        - Grid code existence and priority access to the grid from electricity generated from renewable energy sources;
        - The public availability of detailed renewable energy atlas.
    - Regarding energy efficiency:
        - Established institutional and legal framework including the presence of dedicated authority aiming at promoting renewable energies, a defined target, and the existence of legal framework in force in the country;
        - Electricity pricing for residential, public and large scale consumers;
        - Incentive in place for the energy efficiency projects development;
        - Mandatory energy audits in all sector of the economy;
        - Defined labeling system and minimum performance standards regarding electric appliances;

Each of the above criteria is composed of sub-criteria, each having equal weight and will be assigned unit value when available and zero otherwise. Each of the criteria will then have aggregate scores of his sub-criteria and will be normalized to range between 0 and 1 using a “distance to frontier” approach with 1 representing the frontier (World Bank, 2016). A high score indicating less gap with regard to the criteria.

2.2.2 The capacity development needs

The capacity development needs regarding energy planning will be done as described below:

1) The identification of the different stakeholders of the selected region playing key roles in the electricity sub-sector, from the decision making sphere to the implementation and realization area is made. Therefore the following institutions or organizations constitute a priority for our study:

    a) The regional economic communities (REC)

b) The central agencies in charge of the energy sector mainly the ministries in charge of energy

c) The authorities in charge of the management of the rivers especially in the case of trans-boundaries rivers namely River basin Authorities

d) Some stakeholders in the private sector including financial institutions dealing with energy projects and private companies operating in the sector.

2) The questionnaire design:

The questionnaire highlights the different aspects of capacity including required capacity as well as existing one. It emphasizes on the ability of different stakeholders in using energy planning tools.

3) Stakeholders survey and data gathering

The data collection part of this work was done through an online survey in other to reach the different stakeholders spread across the continent. In other to capture relevant information from stakeholders, were surveyed responsible in the department of energy of different organization involved in the energy planning processes in their respective organizations.

The main goal is to survey the whole 53 countries' ministry in charge of energy, the different regional economic communities, the different river basin authorities and additionally some actors in the private sector in other to have a most comprehensive picture of the needs in energy planning on the continent.

### 2.2.3 Proposition of an optimized energy plan for the case study region

The proposed optimized energy capacity plan will be done using the Open Source energy Modelling System (OSeMOSYS). OSeMOSYS is a dynamic, bottom-up model using linear optimization techniques. It determines the optimal investment strategy and production mix of technologies and fuel required to meet an exogenous defined energy demand. It assumes like others optimization models a perfect market implying perfect competition and foresight.[4]

The model structure consists of electricity demand projection and a database of power supply technologies characterized by economic, technical and environmental parameters as well as information relative to capital stock and remaining lifespan. Data relative to energy resources are provided by the model user. The model is restricted by constraints which reflect among other, the operational requirements, governmental policies, etc. every parameter entered in the model is time dependent and can be adjust to reflect a given scenario (Constantinos Taliotis, 2016).

The model divided the country level value into three components: - Heavy industry connected to the generation points with high voltage. They have less transmission and no distribution losses; - Urban including (residential, commercial, small industries) connected to generation points with more extensive transmission and distribution systems, therefore account for more losses; and – Rural residential with more transmission and distribution losses.

The Figure 2.2 shows the schematic of the program with all the technologies and the different interconnections between them; from the resource to the end uses.

[4] (Howells, et al., 2011)

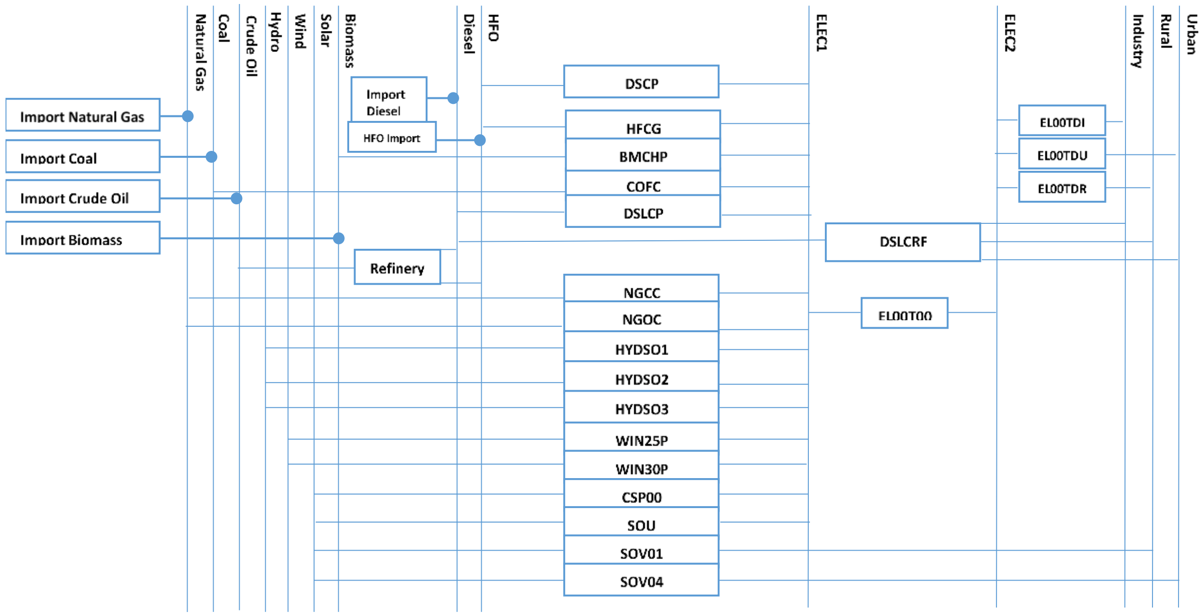


*Figure 2.2: TEMBA model for the different countries of the region*

<u>Scenarios definition</u>

a) Central Africa 2030 Trade Stagnation

*General description*

The scenario refers to the projections in 2030 based on the policies which are already in place. The scenario provides an alternative electricity generation mix path for the central African region based on the renewable energy potential while optimizing the cost to be involved for its achievement. It assumes that no further investments in cross-border transmission lines are made within the model time horizon.

All the assumptions used to fill the missing data points for the central African region are as follows:

Key assumptions:

Some of the parameters are kept constants throughout the analysis. They are:

- The discount rate: 5%
- The horizon of the study that spans from 2015 to 2030

- Each year is split in 4 time slices. The time slice distribution depending on the season and the type of day is assumed equal to a single value : 0.25 as shown in the Table 2.1 below; where each season accounts for the raining and drying period of the year and two different day types: “Day” and “Night”

*Table 2.1: Time slice distribution per season and type of day*

| | | Rainy | | Dry | |
|---|---|---|---|---|---|
| | | Day | Night | Day | Night |
| | | 0.5 | 0.5 | 0.5 | 0.5 |
| Rainy | 0.5 | 0.25 | 0.25 | | |
| Dry | 0.5 | | | 0.25 | 0.25 |

- Transmission and distribution losses are based on country’s historical data
- Efficiency of technologies are assumed to be constant during the model horizon
- The generation technologies are based on the existing generation technologies and their associated learning curve (IRENA, 2013). These technologies are:

*Table 2.2: Technologies assumed in the model*

| **Technology** | **Type** | **Connected to** |
|---|---|---|
| Fossil fuel based | | |
| Diesel internal combustion engines | Distributed | -Industry and rural networks |
| Centralized diesel engines | Centralized | Transmission network |
| Heavy fuel-oil fired power plants | | |
| Open cycle gas turbine | | |
| Combine cycle gas turbine | | |
| Hydropower | | |
| - Dam | Centralized | Transmission network |
| - Run-of-river | | |

| | | |
|---|---|---|
| - Small and medium hydro | Distributed | Rural network |
| Onshore wind farms | Centralized | Transmission network |
| Biomass fired (CHP) plants | | |
| Solar PV utility scale | | |
| Solar PV rooftop | | |
| - without storage | Distributed | Urban network |
| - with 1 kWh battery storage | | |
| - with 2 kWh battery storage | | |
| - without storage | | Rural network |
| - with 1 kWh battery storage | | |
| - with 2 kWh battery storage | | |
| Solar thermal | | |
| - without storage | Centralized | Transmission network |
| - with thermal storage | | |
| - with gas co-firing | | |

The generation technology costs including capital and fixed operation and maintenance costs are assumed based on (Olson, Schlag, Patel, & Kwok, 2014);

*The demand:*

The demand growth pattern relative to annual demand are provided in Figure 5.1 and the specific demand profiles are assumed based on the data provided in the table below.

*Table 2. 3: Specified demand profile*

| | | Rainy | | Dry | |
|---|---|---|---|---|---|
| | | Day | Night | Day | Night |
| | | 0.529 | 0.478 | 0.520 | 0.479 |
| Rainy | 0.51 | 0.266 | 0.244 | | |
| Dry | 0.49 | | | 0.255 | 0.235 |

Source: Constantinos Taliotis (2016).

*The trade:*

The existing interconnection between countries of the region are assumed with an attention to the Congo – Congo DR existing interconnection of 60 MW[5].

The renewable energy targets are based on the planned targets from countries NDCs with a contribution in the mix of at least 10 to 15% of renewable energy excluding large hydro in the electricity mix by 2030.

b) Scenario 2: Central Africa Trade expansion 2030

This scenario assumes the above mentioned assumptions, however, it takes into account all the planned and committed cross-border transmission lines within the region as defined and planned in the priority projects of the CAPP[6].

[5] (Sparrow & Bowen, 2005)
[6] (The Infrastructure Consortium for Africa, 2011)

# 3. Energy Planning

## 3.1 Introduction

Meeting energy demand and its dynamic character has always been a challenge, especially since this should be done within boundaries compelled to a set of limitations in different dimensions: technological, political and environmental to not be exhaustive. It has been necessary to come up with planning methodologies in other to overcome this issue. These methodologies have been often used by decision maker in the past and nowadays are of great importance for future planning strategies at all level (local, regional and national).

There is no universal definition of energy planning since its application is not unique but depends on the conditions. However, Kahen (1995) provided a general definition: “a matter of assessing the supply and demand for energy and attempting to balance them now and in the future” (Kahen, 1998). Furthermore, Van beeck (2003) defined it as “a decision-making process of selecting the energy infrastructure to invest in”. Thus defined as a process, there is a set of steps which has to be fulfilled. These different steps are summarized in the table below:

*Table 3. 1: Energy planning steps*

| Step | Focus area |
|---|---|
| **Introduction** | Problem identification<br>Objectives statement |
| **Possible solution definitions** | Alternative policies or actions in relation to the problem and objectives |
| **Possible solutions analysis** | Alternative policies consequences |
| | Alternative policies consequences evaluation |
| | Action plan development<br>Results and action plan dissemination for implementation |

*Source: Foell (1985);*

This table suggests that energy planning is a process in which alternative options, more specifically, their impacts, are evaluated and only the most appropriate one among the various options is chosen at the end of the process.

Though, there is no universal measure in the comparison process of the different options. Therefore there are some issues which are involved in the process: Determining future amounts and forms of energy demand, identification of supply option that can meet future energy demand at all times, finding ways of identifying and express impacts of options, finding ways of mutually compare impacts of options, appraising options and selection of final energy infrastructure (Rad, 2011).

There is a set of methods and models in use in the planning process. Cormio et al. (2003) provided a scheme for classification of energy planning methods according to the planning level and the required time scale. It defines three main methods:

- Planning by model, where planning is based on the use of mathematical or statistical method based models including econometric, optimization;
- Planning by analogy, which consists of making plan based on the structure of successful existing one;
- Planning by inquiry, which is based on statistical answers of a set of selected experts.

To date several energy models have been developed as decision support tools for supporting the energy planning. From their first aim of providing energy forecast, they have now wide focus area including environmental impacts of energy use. Van beeck (2003) summarized the general energy model characteristic that are shown in the table below:

*Table 3.2: Energy model characteristics*

| Characteristic | Description |
|---|---|
| **Perspective on the future** | Predicting/forecasting, exploring, backcasting |
| **Specific purposes** | Energy demand, energy supply, impact assessment, appraisal, integrated approach |
| **Model structure: Internal and External assumptions** | Internal assumptions: Degree of indigenization, non-energy sector components description, energy end-uses description, energy supply technologies description, External assumptions: population growth, economic growth, energy demand and supply, price and income elasticity of energy demand, |
| **Analytical approach** | Top-down, Bottom-up |
| **Underlying methodology** | Econometric, macro-economic, economic equilibrium, optimization, simulation, spreadsheet, backcasting, multi-criteria methodologies |
| **Mathematical approach** | Linear programming, Mixed-integer programming, Dynamic programming |
| **Geographical coverage** | Local, regional, national, global, project |
| **Sectorial coverage** | Energy sector or overall economy |
| **Time horizon** | Short term, medium term, long term |
| **Data requirements** | Aggregate, disaggregate, monetary, ordinal, qualitative. |

*Source: Van Beeck (2003)*

Although, these models are tools used to support policy making decision in providing frame for appropriate policy direction, they just try to describe the reality, providing insight to different policy options to decision makers. Indeed, due to the complexity of energy system regarding their technical and non-technical aspects, models' impacts in energy planning is not always obtained. Recalling that "*a model can be a technical success but still fail to make any impact on the planning process*", Wene & Bo highlighted the procedural aspects of the energy planning process which cannot yet be model since they are not quantitative data which are regularly the one modeled (Wene &

Bo, 1988). Furthermore, Biswas (1990) argues that models can only be applicable for what is able to be modeled, highlighting also that, there are some qualitative aspects such as behavioral ones which cannot be accounted.

Therefore, there is a need to take into account the others aspects of energy systems, different from technical and economical which models are yet able to models. These aspects include the systemic aspects both internally and externally (relative to the relation between the system and its environment), the social aspects of the system as well. Rad (2011) argued that energy systems are open systems which consist of three main components which need to be taken into account in planning: technical systems, energy management and system relations.

Thus, energy planning should be a process that has a sustainable character. It should be able to meet future energy needs while taking into account all the energy-related aspects into the energy planning process at the same time. Allowing flexibility to unpredictable change due to market fluctuation, political system or changes in technologies or economy. Also all the various stakeholders involved in the process should be taken into account.

Moreover, a good planning process should consider to share information among stakeholders and propose best solutions which satisfy all participant interests (Webler & Tuler, 2006).

D. Rad (2011) provides the characteristics of a sustainable energy planning process which can be stated as follows: Long-term energy planning perspectives, flexibility against unexpected changes, integration of sustainable dimensions in energy planning, robust institutional guidelines, and sufficient public private participation.

The implementation of the energy planning needs in other to produce the expected outcomes some requirements to be met.

## 3.2 Energy Planning Requirements

3.2.1 Statistics and data availability

Energy data availability and statistic are of vital importance as far as energy planning is concerned. They should help in identifying and assessing the energy-use areas, identifying their trends as well. This encompasses with:

*3.2.1.1 Energy services and energy demand information*

- Data relative to the future amount and form of energy demand by the end-users in the different sectors including households, industry and commerce, and transport. Therefore there is a need to know the purpose of the energy demand called energy services among which we can mention electricity, heat or fuels such as Liquid Petroleum Gas, etc.

- Energy demand projections relatively to current growth rates in energy consumption for the different sectors.

*3.2.1.2 Energy supply information:*

Information relative to energy supply are basically of two types

- Data regarding the energy resources available both renewables and non-renewables which could be used in energy conversion units/energy infrastructures. This includes climate data (solar, wind, etc), hydrological data, biomass data, existing proven reserve regarding fossil fuels, etc.

- Data regarding the technologies which can be used to convert energy resources into proper energy forms demanded including technology efficiency, capacity factor. The availability of local technical know-how for construction, operation and maintenance of the energy system, as well as the availability of the spare parts for maintenance as well, are of importance regarding their related costs concerning fixed and variable in the case of existing plants, to which should be added capital costs for new plants.

– Data on existing infrastructures including their installed capacities, their actual generation capacity and life time in other to have a good quantitative baseline for any scenario projection.

### 3.2.2 Ownership of the planning skill

If it is true that Africa needs to improve its access to energy for purposes ranging from the basic commodity of access to electricity/energy to the main aim of supporting the economy growth, it is to stress as well that this cannot happen without developing in a sustainable way local human resource to be involved in the planning phase of the energy projects. It is of great importance that the planning skills are owned by the beneficiaries or the prescribers of the projects. Acknowledging the sustainability character of energy projects, regarding their implementation and even their development, the ownership of the projects and the skills encompassed in the project development / implantation is very important; thus, as part of the skills required the planning skills need to be fully owned as well. Indeed, owning these skills will help the planners to be able to make adjustments or any other modifications on any given project, freely and independently at all time. Furthermore, it allows the planners to be free to innovate and/or customize, if needed, the projects (models) according to the specificities of the locality, the policy to be implemented, etc. Also, this state will help reducing the dependence on foreign expertise in the planning stage of energy projects in the continent.

## 3.3 Importance of energy planning

Energy planning is of great importance as it is the driving force of the energy sector development of any locality, region or country. The strong correlation between energy sector and the whole economy development put energy planning at the center of any development policy. Energy planning is of great importance in matching demand and supply sides within an economy. In that regard, it looks forward to providing, after investigating various options, the least cost possible for providing the needed energy services to end users. Some of the other aspects highlighting the importance of energy planning are as follows:

### 3.3.1 Define paths for long-term sector development

Energy planning defines the road map of the energy sector development at short, medium and long term. Indeed, by setting the policies and providing the guidelines for meeting the future needs of the national objectives, energy planning allows the definition of a clear vision of how the sector will be in the future. It defines how the future energy needs are intended to be meet using the best possible options in term of resources to harvest, technologies to be used, for affordable and reliable energy services delivery. Thus, it is the foundation of the different strategies and policies definition and establishment which will frame and give orientation for the sector development: - For instance, the energy security planning scheme would aim at providing sufficient and reliable energy supplies at any time and at reasonable prices, while reducing the dependence on other countries in terms of fuel importations in the case of countries which do not have fossil fuel reserves; looking at how available energy resources can be harvest in other to fulfill the intended needs. This could be done prioritizing the development of one form of energy or another depending on the availability and will contribute to master energy prices and therefore, insulate the economy from their volatility. In the case of countries with fossil fuel reserves, energy planning can help as well in defining whether the country is planning to fully exploit this fossil resources or advocate for limitation in its use because of a decision of mitigating environmental harms or even keeping those resources for future generations.

### 3.3.2 Enabling platform for subsector coordination

Energy planning is at the baseline of the subsector coordination. Indeed, it induces the establishment of the institutional framework framing the plan. This framework defines the missions and attributes of all stakeholders involved in the planning process, from the central agencies at the top decision making area to the decentralized one, and in different areas of concern such as rural electrification, off grid electrification, etc. Good planning will avoid overlaps in attributes and missions of stakeholders and will allow clarity and dialogue/collaboration among stakeholders for the subsector coordination.

### 3.3.3 Create stability in future policy direction and increase investor's confidence

Energy planning provides good indicator for investors' involvement. Indeed, energy plans define the energy targets including both renewable and non-renewable energies for a given time horizon; it allows the development of an effective institutional framework of the power sector in term of; clear definition of regulatory as well as legal frameworks. It provides therefore, guidelines to enable the energy plan implementation. It enables the establishment and development of an energy market since there would be well-defined and established rules and regulations for and within the market. Investors, can then have a clear picture of the future perspectives, regarding the targeted market and within the timeframe provided by the planning. Thus, energy planning helps creating favorable conditions in other to attract private sector investments and participation for the sector development. Also, by defining and developing human resource capacities through the value chain for a given future, energy planning gives a clear indicator to the private sector on the availability of human local resource for the ease of business' settlement and development.

## 3.4 Challenges of doing energy planning in Africa

### 3.4.1 Data availability

Lack of data. One of the most important barrier in doing energy planning in Africa is the documentation regarding the availability of data required in the upstream of the planning process. The lack of historical data regarding the energy consumption and demand patterns, which could help having a better appreciation of the trends in energy consumption at the end users side and in the different sectors is a serious concern. For instance, Swaziland renewable energies readiness assessment revealed that an overall domestic energy consumption is suffering from a chronic lack of comprehensive data required for good planning regarding the country's energy sector (IRNEA, 2014a).

Data consistency: another concern when doing energy planning in Africa, is in the case of data availability, the lack of consistency in the data when dealing with demand forecasting. As an example after assessing the Southern African Power Pool demand forecast for the period 2006-2013 was lower than the actual demand growth (IRENA, 2015c). This situation lower the accuracy of the planning which leads to unbalanced demand and supply schemes.

### 3.4.2 Coordination and cooperation

Coordination cooperation among the different stakeholders involved in the planning process, is a very crucial challenge which needs to be overcome in the continent. It is a concern that happens at two different levels. At national level (within the institutions/stakeholders involved in the sector) and at regional (among stakeholders involved in regional planning). Indeed, there is a need to harmonize, coordinate policies, legal frameworks, targets and goals of National Energy Plans with regard to integrating energy projects defined at a broader scale in Regional Energy Plan.

Cooperation is very important at regional scale, especially when it comes to full and optimum exploitation of the resources available in a country within a region or even resources available in a region. Therefore, a need of interconnection between regional power pools should have a specific attention enabling exchange from providers (producers); in that regard regional strategies should be based on dominant systems within the region which have the capabilities to play a major role in that exchange especially in their capacity of becoming net importers.

### 3.4.3 Access to Finance

Access to finance is at the hearth of the planning process in Africa and especially in energy projects. Implementation of planned energy projects that Africa aims at put in place in other to improve energy access within the context of climate change require huge amount of money. Central Africa needs for instance for implementing its energy projects in the framework of the action for climate change about 30 billion USD of which most should be raised by the private sector with a fairly low contribution of countries' government (UNECA, 2016). Therefore, there is a need to establish good and innovative actions in this regard to enable the private sector contribution through both foreign funding from international institutions, bilateral cooperation, or even private foreign investors; and domestic funding via local entrepreneurs and local private investors.

### 3.5 Energy Models

Africa today in his goal to increase in a sustainable way energy access through proper planning, it is important to know how effectively, the available tools can be helpful in that regard. Therefore, a descriptive analysis of some of the models tools is addressed here.

In the area of energy planning, a wide range of models and planning tools are used to fulfill the desire goal of coping with the constant changes in addressing the energy services needs of the end users. Among these tools we can distinguish between open source models and non-open source models. Open source models as their name suggests are models which allow access to the source code. DeCariolis et al. (2012) defined them as models which source code (the set of equations which translate the world characteristics (energy system) as well as the various assumptions of the models are based on) access is freely allowed from a public web portal and without any preliminary conditions towards the modelling team. In contrast, non-open (close) models are models which source code access when allowed is submit under preliminary conditions from the modelling team.

3.5.1 Close source models

EnergyPLAN

EnergyPLAN is a bottom-up model using simulation type methodology which has been developed and expand on is since 1999 at Aalborg University, in Denmark (Lund & Munster, 2003). It is a deterministic input/output model with general input being demands, renewable energy sources, plant capacities and regulatory strategic option regarding import/export.

ENPEP-BALANCE

The Energy and Power Evaluation Program (ENPEP-BALANCE) is a non-linear top-down type model which balance demand and available resources and technologies. It was developed by the Center for Energy, Environmental, and Economic System Analysis (CEEESA) (US) which allows the evaluation of the whole energy system, including both demand and supply sides as well as the environmental effects of various energy policies. It finds an equilibrium (balance) between the supply and demand curves for all the components include within the energy network, using an iterative method (US DOE Office of Sciences, 2016).

EMPS

EMPS (EFI's Multi-Area Power market Simulator) is an optimization type tool that has been developed and continually refined since 1975 by SINTEF (Stiftelsen for Industriell og Teknisk Forskning) Energy Research (previously EFI) in Norway. It is a tool for forecasting and planning in electricity markets. It has been developed for optimization and simulation of hydrothermal power systems with a considerable share of hydro power (SINTEF, n.d.).

LEAP

Long-range energy alternatives planning is a bottom–up type model, which uses accounting approach to generate coherent inside of energy demand and supply sides, using the physical description of the entire energy system. It investigates the various implications of market shares' alternatives on the demand in the demand forecasting, and uses the accounting and simulation approaches to answer to the possible alternative scenario development (Subhes, Bhattacharyya, Govinda, & Timilsina, 2010)

MESAP

Modular Energy System Analysis and Planning, is a bottom-up optimization model that was developed in the Institute of Energy Economy and Rational Use of Energy at the University of Stuttgart. It aims at providing insights on energy supply and demand sides relatively to the cost as well as environmental impact of a given energy system. Based on technology oriented approach, it analyses different technology option in energy service supply including generation, storage and transport technologies.

MESSAGE

MESSAGE (Model for Energy Supply Strategies Alternatives and their General Environmental Impact) is a dynamic linear programing model designed for optimization of energy supply and utilization. It is a system engineering optimization model type used in short to long-term energy system, conceived by the International Institute for Applied System Analysis (IIASA) in Austria.

NEMS

The National Energy Modeling System is a hybrid computer based energy modeling tool of partial equilibrium type, developed by the Energy Information Administration (EIA) of the US Department of Energy. It allows the development of forecasts of the energy, economic, environmental and security impact of various energy policies and assumptions about the energy market. It is composed of six main family modules: supply, demand, conversion, energy/economy simulation, international oil market simulation and general market equilibrium integration (eia, 2003).

POLES

Prospective Outlook on Long-Term Energy System, is a hybrid type model, using accounting approach that has been used by the E.U. to analyze and simulate long term energy policies analysis. It uses a disaggregated end-use approach to analyze the demand though, differentiating between intensive and non-intensive uses. Based on the learning curve and the niche market concepts, the model simulate the impacts/role of renewable and new technologies (Subhes, Bhattacharyya, Govinda, & Timilsina, 2010).

RETScreen

The ‘Clean Energy Management Software’ is bottom-up type model developed by the Natural Resources Canada in 1996 (Canada, 2016). It is a project based model tool with cost optimization approach rather than operational optimization which uses a set of economic indicators including Internal Rate of Return and Net Present Value. It generates scenarios of worldwide energy system production and savings, emission reductions of renewable energy based technologies comparatively to a base case scenario of fossil fuel based technology. It covers the electricity and the heat sectors within a maximum time horizon of 50 years with a one month time-step.

TIMES

It is a partial equilibrium energy tools developed in a joint effort under the IEA's Energy Technology System Analysis Program (ETSAP) since 1978. It combines two different complementary approaches namely economic (top-bottom) and technical engineering (top-bottom). It uses linear programing for least cost optimization of energy systems. It optimizes the cost by minimizing the cost of the whole system or a specific sector considering the investments and operation decisions.

TRNSYS

Transient system simulation is a bottom-up type model developed by the Thermal Energy System Specialists and the University of Visconsin-Solar Energy Laboratory in the US. It simulates the behavior of transient energy systems with specific focus on electric and thermal energy systems. It optimizes the energy system cost as well as its operational condition, using a second time-step over a time horizon which can go for several years (Thermal Energy System Specialists LLC, 2016)

WASP

Wien Automatic System Planning, developed by the IAEA, it is designed to give an optimal economic answer to generation expansion policies for electric utility systems by minimizing the discounted cost of electricity generation. It is based on linear programming technique to determining optimal policy dispatch satisfying constraints defined by the user, by evaluating all power plant candidates to be added for expansion in the planning horizon still under the defined constraints. The model covers national geographical area and the electricity system as well as the environment (Subhes, Bhattacharyya, Govinda, & Timilsina, 2010).

WEM

World Energy Model is a hybrid type model, using accounting approach that has been used to generate World Energy Outlooks of the EIA. It is based on four main components which are: the final demand module which uses the disaggregated end-use approach for forecasting and other variables as drivers of energy demand; the power generation module that takes into account the electricity demand and the possible energy technology alternatives; fossil fuel supply module and emissions trading. Its geographical coverage range from country to global and address the whole energy sector.

3.5.2 Open source models

AIM

Asian-Pacific integrated model, is a top-bottom type model that aims at investigating the emission and absorption of greenhouse gases in the Asian-Pacific region as well as the socio-economic impacts on the natural environment. It consists of three different models each targeting specifically on of the following: the emissions, the greenhouse concentration in the atmosphere and the influence of climate change on the natural environment (Kainumaa, Matsuokab, & Morit, 2003).

BALMOREL

The BALMOREL energy model is a bottom-up, partial equilibrium model which supports modelling and analysis of the energy sector with emphasis on electricity and the combined heat and power sectors in an international perspective. It optimizes energy problem based on the principle of maximizing the sum producers' and consumers' surplus establishing therefore a balance between demand and supply (Joomlashack, n.d.).

DICE:

The Dynamic Integrate model of Climate and Economy is an analytical and empirical model used to represent climate change in economic, political and scientific aspects. It is an aggregate model that divides the world into 12 different regions and is designed as policy optimization that optimizes the economic objective function associate to a given consumption path. (Nordhaus & Sztorc, 2013).

ERIS

Energy Research and Investment Strategies is a multi-regional bottom-up technology explicit energy optimization model that integrates technology learning curves. It was developed jointly by the Environmentally Compatible Energy Strategies (ECS) and project at the International Institute for Applied System Analysis (IIASA) and the Economic group of the Paul Scherrer Institute (PSI). Here, exogenous demand is supplied from the competing generation (production) technologies regarding electric (non-electric) sector under user specified constraints (Turton & Barreto, 2004).

OSeMOSYS

OSeMOSYS is a full-fledged system optimization model for long term energy planning. It is linear programing model which has as objective to estimate the lowest cost (Net Present Value) of an energy system to meet a given demand of energy and energy services. This estimation is done following a number of constraints and guidelines which include the storage, the capacity adequacy, the energy balance, constraints relatively to reserve margin, activity and capacity, and emissions (Howells, et al., 2011).

SAGE

System for analysis of global energy markets, is a hybrid, technology explicit type model using partial equilibrium approach with elastic demand, developed by the US department of Energy to assess the global energy situation. It generates a supply-demand equilibrium that maximizes the net total surplus while minimizing the total cost of the entire energy system. The model encompasses with 15 regions among which Africa and operates on a 5 years' time step for a maximum time horizon of eleven 5 years (US DOE, 2003).

### 3.5.3 Energy planning models tools summary

The table below summarizes the details of the different models above mentioned, with regard to their activity and geographical coverage, their specific data requirements, their underlying approach, their advantages and limitations with regard to their ability to cope with priced-induced policies, non-priced policies and with the integration or addition of new technologies, and the level of skills required.

*Table 3.3: Energy planning tools evaluation*

| ***Criteria*** | *BALMOREL* | *EnergyPLAN* | *ENEP-BALANCE* | *ERIS* | *EMPS* |
|---|---|---|---|---|---|
| **Approach** | Optimization | Optimization | Equilibrium | Optimization | Optimization |
| **Geographical coverage** | Regional | Regional / national | National / international | Global | Local to regional |
| **Activity coverage** | Electricity, heat | Electricity, heat, transport | Electricity, heat, transport | Electricity, heat, transport | Electricity (hydro) |
| **Level of disaggregation** | High | Low | Low | High | Low |
| **Data needed** | Extensive | Extensive | Limited | Extensive | Extensive but can be limited |
| **Skill requirements** | Limited | High | Limited | High | high |
| **Capability of analyzing priced-induced policies** | High | Good | High | High | High |
| **Capability of analyzing non-price policies** | Possible | Good | Very good | Good | Good |
| **New technology addition** | Possible | Possible | Difficult | Possible | Unknown |

| *LEAP* | *MESAP* | *MESSAGE* | *NEMS* | *OSeMOSYS* | *POLES* | *TIMES* |
|---|---|---|---|---|---|---|
| Accounting | Optimization | Optimization | Optimization | Optimization | Accounting | Optimization |
| Local to national | National | National to regional | Local to national | Local to regional | Global | National to regional |
| Electricity, heat, transport | Electricity, heat, transport | Electricity, heat, transport | Electricity, heat, transport | Electricity, heat, transport | Electricity, heat, transport | Electricity, heat, transport |
| Low | High | High | High | High | Predefined | High |
| Extensive but can be limited | Extensive | Extensive | Extensive | Extensive | Extensive | Extensive |
| Limited | Very high | High | Very high | High | Very high | Very high |
| Do not exist | Possible | Good | Good | Very good | Good | Good |
| Very good | Good | Good | Good | Good | Good | Good |
| Possible | Possible | Possible | Difficult | Possible | Difficult | Possible |

| *WASP* | *WEM* |
|---|---|
| Optimization | Accounting |
| National | Global |
| Electricity, environment | Electricity, heat, transport |
| Low | Low |
| Extensive | Extensive |
| High | Very high |
| Good | Good |
| Good | Good |
| Possible | Difficult |

# 4. Current Energy Access Status in Africa

## 4.1 Africa energy landscape

### 4.1.1 Primary energy supply mix

Africa primary energy need are covered by diverse landscape of energy resources both conventional and renewable. It is largely dependent on biomass resources and fossil fuels. In 2013, the total primary energy supply (TPES) in the continent was estimated at 746 Mtoe[7] from which, 48% is are from solid biofuels (fuel wood) and oil, gas and coal account for half of the total share (IEA, World Energy Trends: Energy balances of non-OECD countries, 2015). The renewable energies (modern) contribution is still negligible. The Pie chart below summarizes the contribution of different fuels to the TPES in the continent.

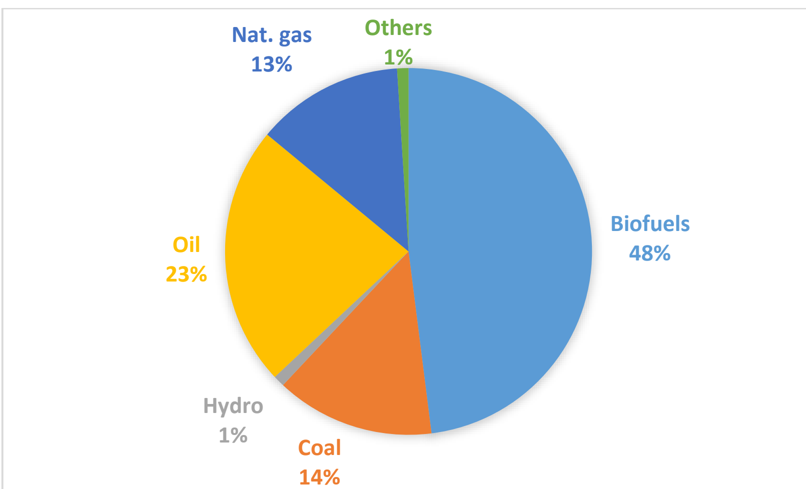


*Figure 4. 1: Total Primary Energy Supply*

Source IEA (2015)

### 4.1.2 Energy consumption by sector – total energy consumption

Africa total final energy consumption (TFEC) is basically from both fossil fuels and renewables. There is more or less a balance in the share between those two sources of energy in TFEC. IRENA (2015) shows that over 23 EJ of total final energy consumption

[7] This value does not take into account electricity trade

in the continent in 2013, 13 EJ accounts for renewable energies from which only 1.1 EJ is from modern types of renewables an equivalent of 5% of the TFEC. 50% of this accounts for firewood used in efficient cookstoves, followed by hydropower 28% and industrial residues with 10%.

The contribution of renewable energies in TFEC regarding the different sectors of activity namely, building, industry and power generation do not follow a uniform path. There is a high dependence on renewable energies in the building sector with about 80% of the need covered mainly for heating purpose; about 30% in the industry sector accounting as well for heating and less than 20% for power generation. The figure bellow shows the contribution of renewable energies by sector in 2013.

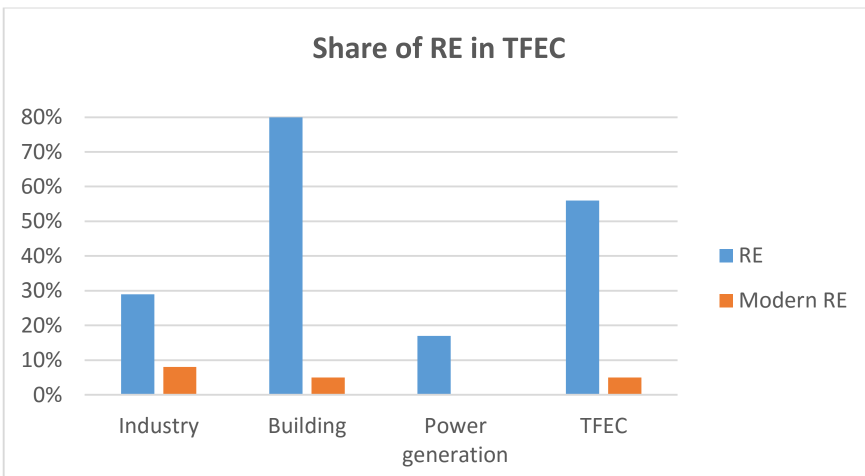


*Figure 4. 2: Share of Renewable Energies in TFEC*

Source: compiled from (IRENA, 2015a)

The building sector is highly dependent on RE to cover its needs, however still in a traditional and not efficient way. The use of firewood and charcoal in traditional cookstoves is still very common. In the case of the industrial sector, the high dependence on firewood for heat generation in boilers is also common.

## 4.2 Africa resource potentials and access to energy

### 4.2.1 The renewable energies resource potential

Africa is endowed of abundant resources as far as renewable energies resources are considered. This encompasses with solar, hydropower resource, wind, geothermal and biomass resources.

#### *4.2.1.1 Hydro*

Africa has abundant hydropower potential and is ranked as the region with the most untapped potential. This potential is located in four main hydroelectric hubs and involves several river basins: the Niger and Senegal rivers in West Africa, the Congo river in Central Africa, the Nile river basin in East Africa and the Limpopo, Orange and Zambezi rivers in Southern Africa.

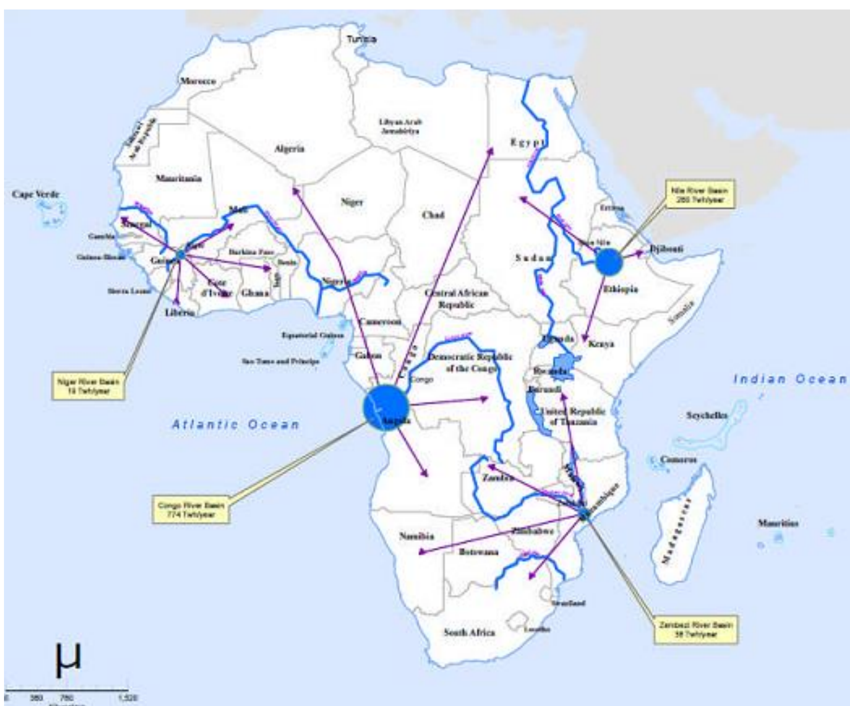


*Figure 4.3: The main hydropower potential in Africa*

Source: PIDA (2011)

It was estimated in 2013, that 92 % of the technical feasible potential has not been yet developed (IRENA - ETSA, 2015). This resource is more or less available in all the continent. However, it is more concentrated in the wet region of central, eastern and southern Africa; where more than 85% of the potential is located. The figure bellows shows the hydro potential of the continent.

*4.2.1.2 Solar energy*

The solar resource on the continent is one of the most widespread resource across the continent. It covers almost all the area of the continent with about 74% of the continent receiving more than 1900 kWh/m2/year. This allows the resource to be suitable for power application and the figure below generated by SolarGis shows the global horizontal radiation on the continent, with an almost uniform distribution of the resource across the continent.

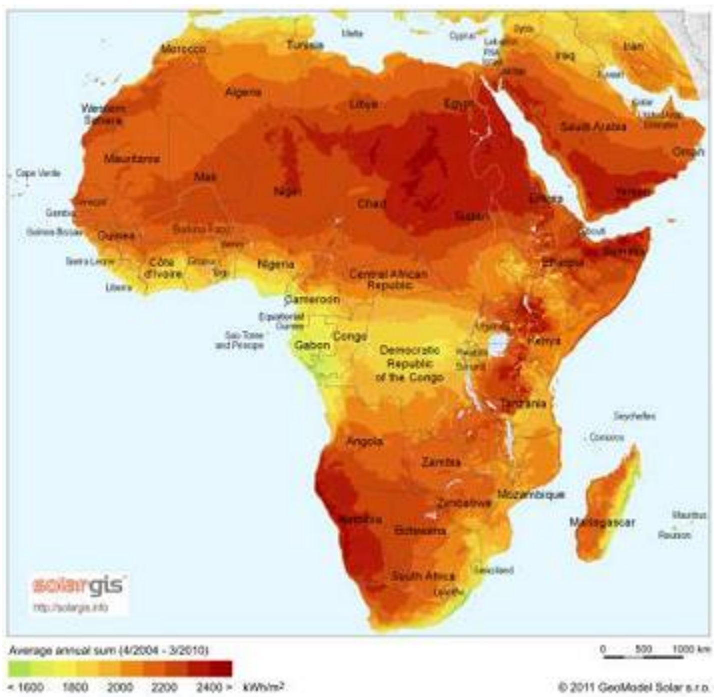


*Figure 4.4: Africa global horizontal irradiation.*

Source: SolarGis (2011)

The technical theoretical potential of solar PV and concentrated solar power on the continent are estimated at 100 GW and about half of it respectively (IRENA, 2015b). The figure below summarizes this potential relatively to each region of the continent.

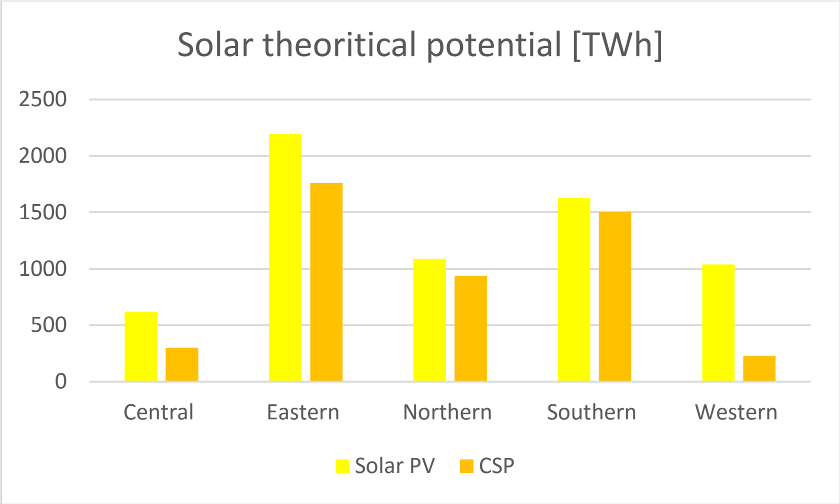


*Figure 4.5: Solar energy theoretical potential*

Source: IRENA (2012b)

*4.2.1.3 Wind energy*

Wind energy resource on the continent represents about 20% of the global wind energy. It is more concentrated in the northern and southern parts of the continent, as well as in the horn of the continent in the eastern part. Its theoretical potential is largely greater than the demand and it is estimated that over 15% of this potential is considered as high quality resource (IRENA, 2015a). Its theoretical potential in the continent is shown in the figure below assuming 30% - 40% capacity factor.

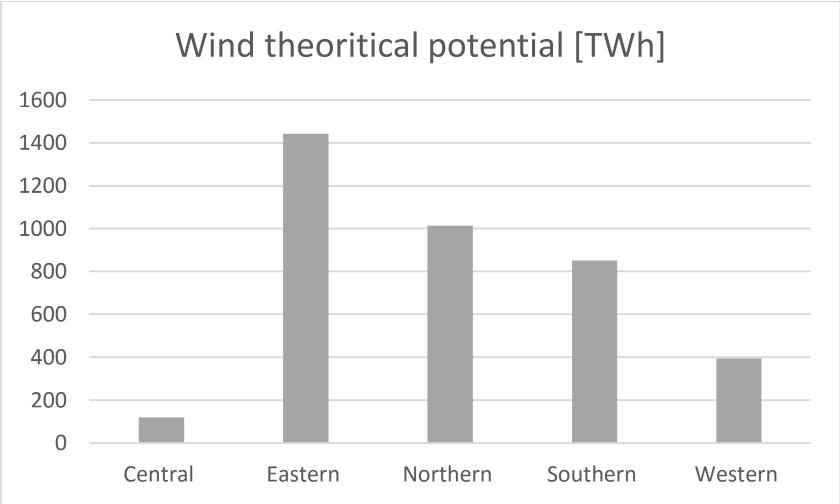


*Figure 4.6: Wind theoretical potential in Africa*

Source: IRENA (2012b)

*4.2.1.4 Biomass energy*

Biomass energy is not equitably distribute across the continent as shown in the figure below; the Central region of the continent being the most important area where the resource is concentrated. Biomass energy potential for power generation is mainly based on woody biomass and sugar canes. Its potential is estimated at 400 to 800 petajoules (PJ) for woody biomass and 400 to 500 PJ for sugar canes representing a generation capacity potential of 12 to 20 GW (IRENA, 2015b).

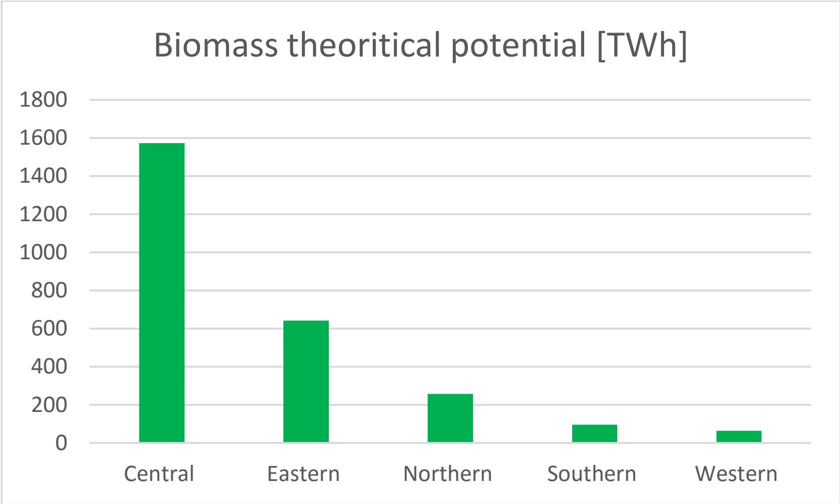


*Figure 4.7: Biomass theoretical potential in Africa*

Source: IRENA (2012b)

*4.2.1.5 Geothermal energy*

The geothermal energy resource potential on the continent is confined to the eastern and southern parts of the continent. Its potential is estimated to be about 15 GW located all along the Rift Valley (Geothermal Energy Association, 2016). Kenya and Ethiopia are the countries with the largest potentials of the geothermal resource.

4.2.2 Energy access

*4.2.2.1 Electricity*

Access to electricity on the continent is very low. Indeed, about 635 millions of African do not have access to electricity. That results in a continent electrification rate of 43% with very low access regarding the populations of rural areas compare to urban ones

(68% and 26% respectively) (IEA, 2015). However, there is no uniform distribution regarding this indicator when looking at the different regions of the continent. The Northern[8] region of the country records a very high electrification rate compare to the others at both urban and rural levels. The Eastern region record the lowest electrification rate (22%) with only 8% of rural electrification rate. The figure bellow summarize the electrification rate of the different region of the continent.

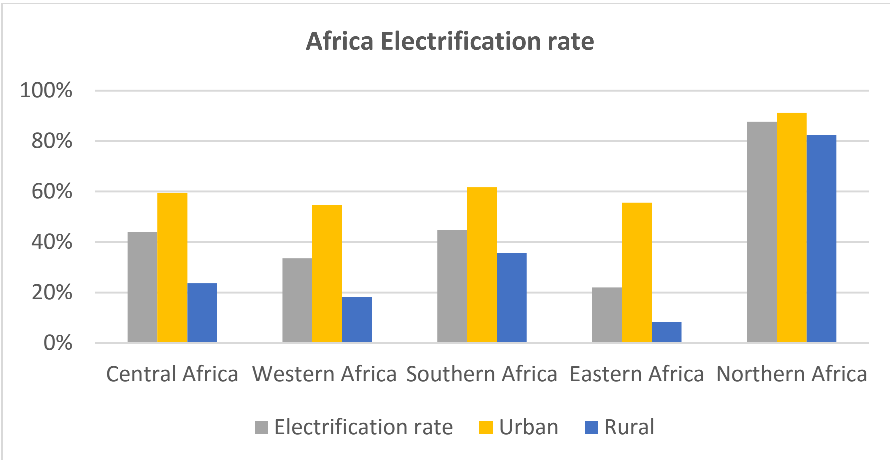


*Figure 4.8: Africa Electrification rate*

Source: compiled from IEA (2013)

*4.2.2.2 Access to clean and modern cooking facilities*

In Africa around 754 million people (68% of the continent population) (IEA, 2013) are estimated to rely on the traditional use of solid biomass for cooking, most of the time using inefficient stoves. Western and eastern regions record the highest share of population relying on the use of traditional biomass for cooking, with countries such as Uganda, Guinea, Mali etc. were almost the whole of the population is dependent on it. Northern Africa record the lowest share of population with in contrast almost all the population using efficient and modern means for cooking[9]. Apart from the Northern region, a minimum of half of the people are using solid biomass in a traditional way for cooking purpose as shown in the figure below.

[8] Northern region including Algeria, Egypt, Libya, Morocco, Tunisia, Mauritania.
[9] Excepted Mauritania in the Northern region less than 1% of the population rely on the use of traditional biomass for cooking

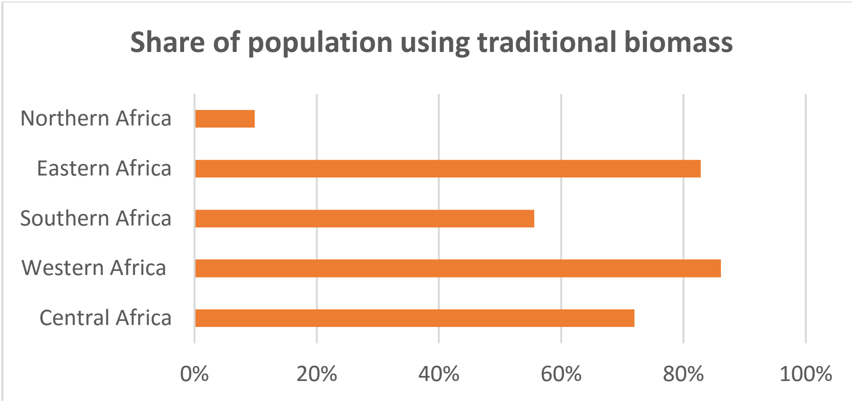


*Figure 4.9: Share of African population using traditional biomass for cooking,*
Source: compiled from IEA (2013)

## 4.3 Power generation

### 4.3.1 Africa

#### *4.3.1.1 Electricity generation*

At the end of the year 2014, Africa's electricity generation is about 739 TWh with more than 85% coming from fossil fuels generation in thermal power plants. Coal-fired and gas-fired power plants account for two third of the continent total generation. The renewable energies contribute to a fifth of the total generation with hydropower representing more than 75%.

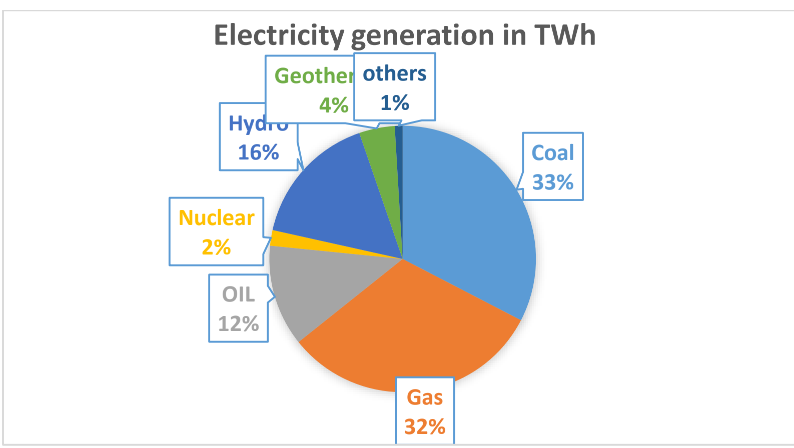


*Figure 4.10: Electricity generation in Africa.*
Source: The Total Shift Project (2016)

### *4.3.1.2 Installed capacity*

Africa power installed capacity at the end of the year 2014, is 146 GW of which, 78% come from thermal power plants mainly using coal and gas as fuels. Less than a fifth (17%) are from hydro; the others renewable energies accounting for just four percent of the total generation capacity.

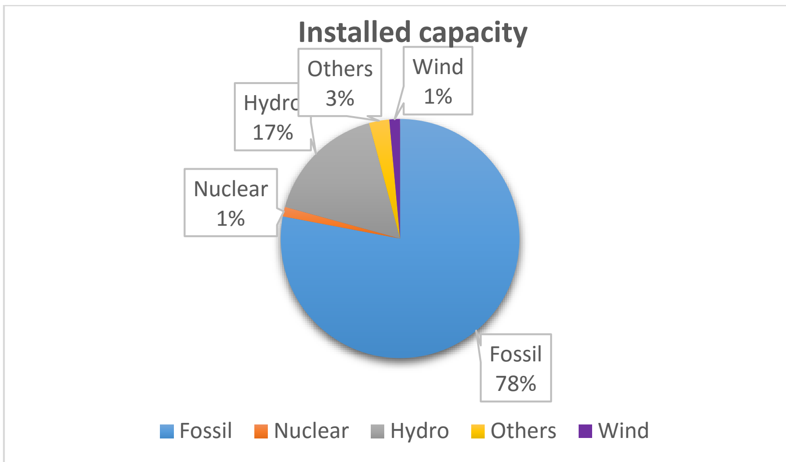


*Figure 4.11: Share of Africa installed capacity by resources*

Source: The Total Shift Project (2016)

## 4.3.2 Central Africa

### *4.3.2.1 Electricity generation*

Central Africa electricity generation is estimated at 20.8 TWh, with a large dependence on hydropower generation which accounts for 78% of the region generation. Thermal plants generation account respectively for 18% and 8% for oil and gas based fuels. Cameroon and Democratic republic of Congo are the principal contributors to the sector with both contributing about 17 TWh representing more than 80% of the total generation of the region.

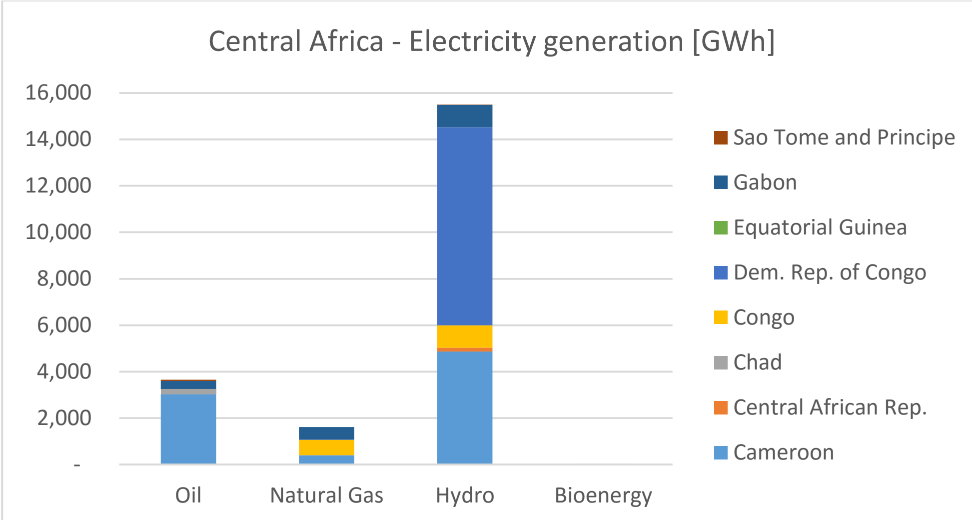


*Figure 4.12: Central Africa- Electricity generation.*

Source: The Total Shift Project (2016)

### *4.3.2.2 Installed capacity*

The region grid-connected installed capacity is 4.6 GW with hydropower capacity being the only renewable energy contributing to the mix with a share of 80% of which 67% is from Congo DR whose capacity depends almost exclusively on hydro; followed by Cameroon with 20% of hydro capacity. The fossil fuels based capacity account for the remaining (20%), Cameroon and Gabon being the principal contributors: 65% and 19% respectively.

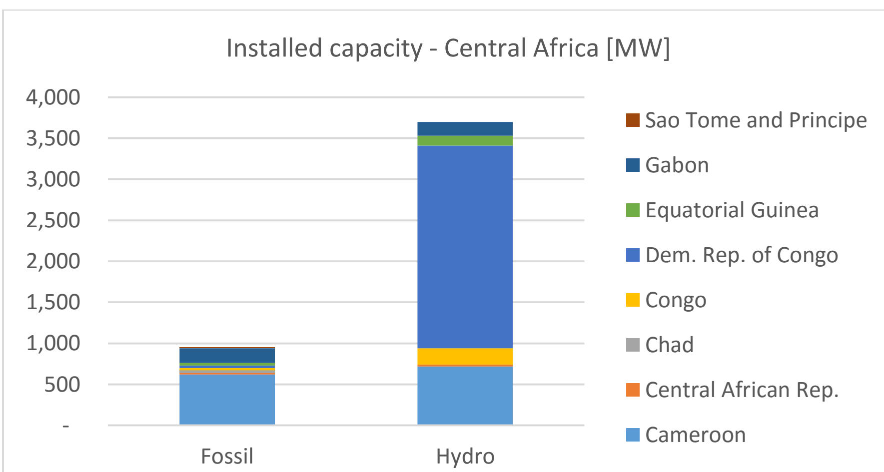


*Figure 4.13: Central Africa installed capacity*

Source: The Total Shift Project (2016)

## 4.3.3 Eastern Africa

### *4.3.3.1 Electricity generation*

Eastern Africa electricity generation is estimated at 40.6 TWh, with a large dependence on hydropower generation which accounts for 60% of the region generation. Thermal plants generation account for 37% almost exclusively depending on oil with 30%, gas and coal only 7%. Ethiopia, Kenya, Soudan and Tanzania are the principal contributors to the sector with a total share of about 30 TWh representing 73% of the total generation of the region.

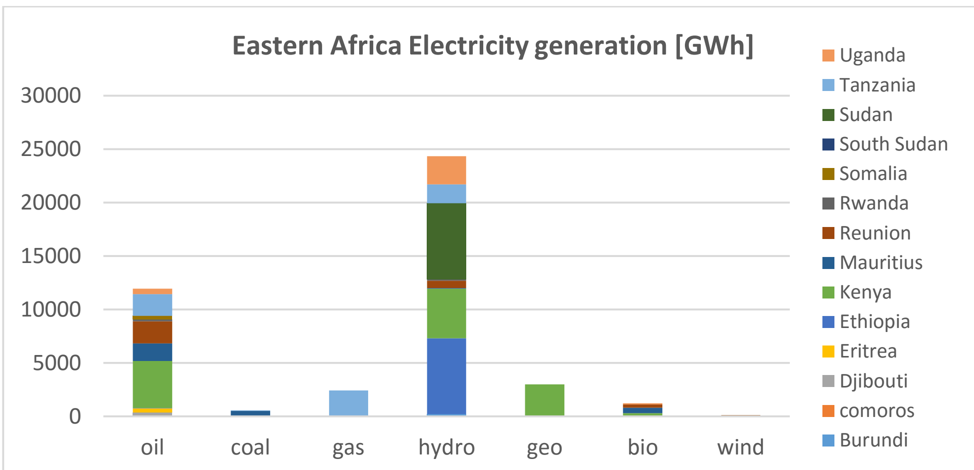


*Figure 4.14: Eastern Africa Electricity generation*

Source: The Total Shift Project (2016)

### *4.3.3.2 Installed capacity*

The region grid-connected installed capacity is 9.4 GW with hydropower and fossil based capacity having the big share 48% and 42% respectively. Geothermal accounts for 6% and the remaining renewable only 4%.

Ethiopia and Kenya own a high share of these capacities with 23% and 33% of the capacity of the region respectively.

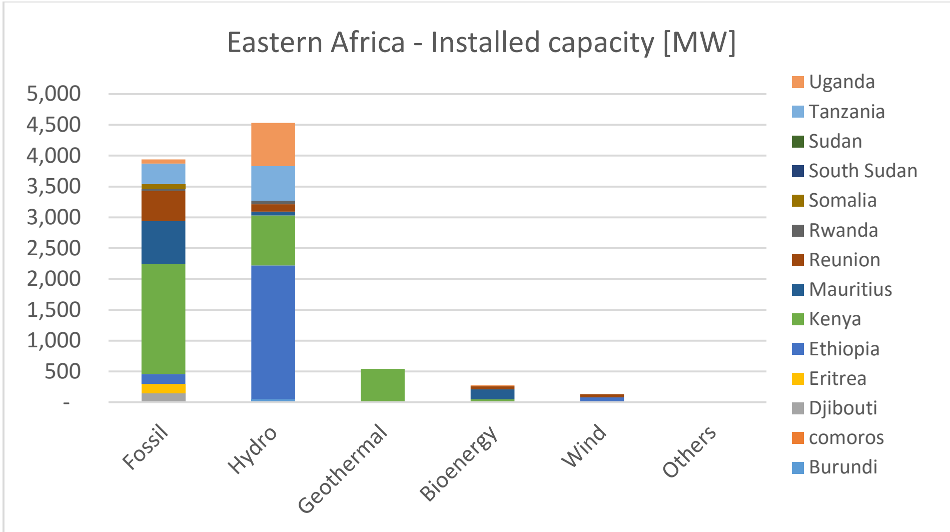


*Figure 4.15: Eastern Africa - Installed capacity*

Source: The Total Shift Project (2016)

## 4.3.4 Southern Africa

### *4.3.4.1 Electricity generation*

Southern Africa electricity generation is estimated at 322 TWh, with a large dependence on thermal plants generation. Coal-fired power plants generation account for more than 70% of the region generation, oil, gas and nuclear contributing only 6%. Renewable energies based generation account for about 24% of which hydro and geothermal represent 14% and 9% respectively. More than 75% of the region electricity generation is from South Africa, followed by Zimbabwe 11%.

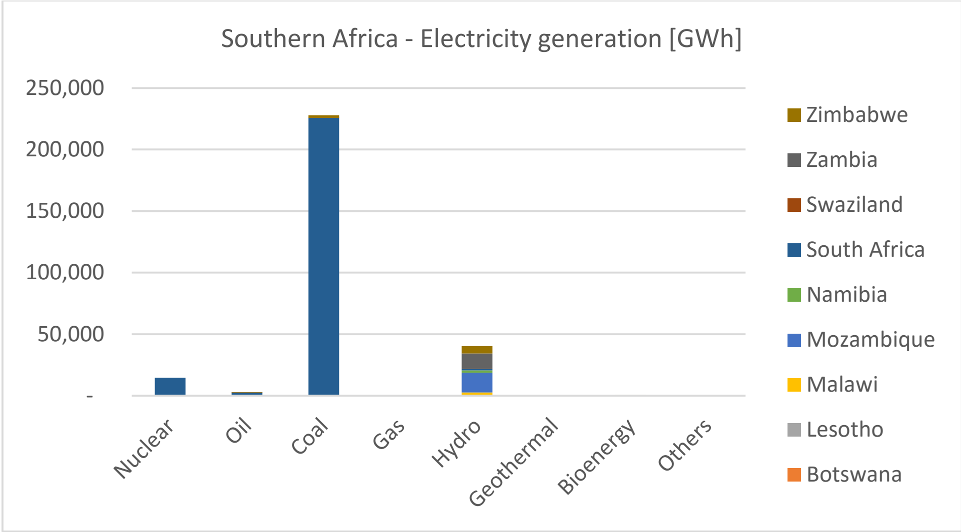


*Figure 4.16: Southern Africa - Electricity generation.*

Source: The Total Shift Project (2016)

### *4.3.4.2 Installed capacity*

The region total installed capacity is 55 GW with 78% of it from fossil fuels, mainly coal. Hydropower capacities contribute to a share of 12% and nuclear 3%. The others renewable energies capacity account for only 7%. More than 80% of the capacities of the region are located in South Africa, followed by Mozambique with nearly 5%.

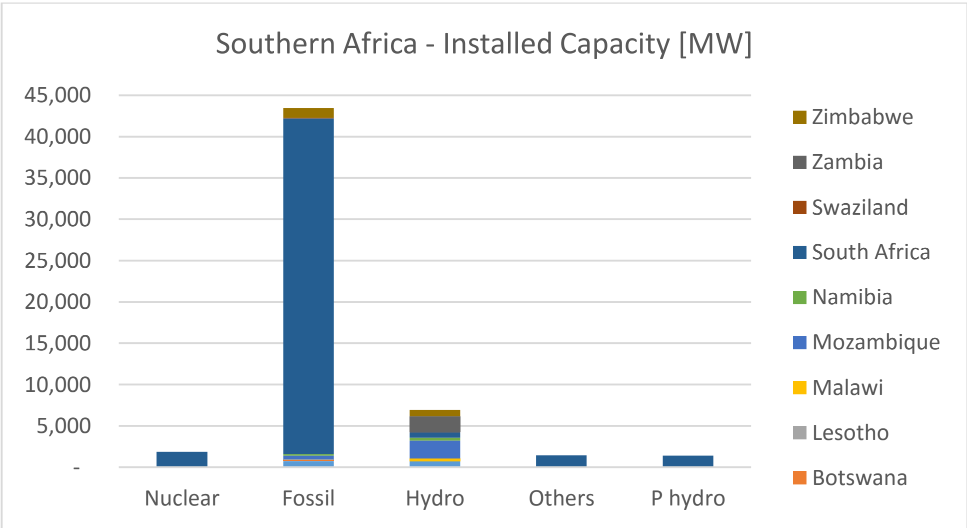


*Figure 4.17: Southern Africa - Installed capacity*

Source: The Total Shift Project (2016)

## 4.3.5 Northern Africa

### *4.3.5.1 Electricity generation*

Southern Africa electricity generation is estimated at 291 TWh, with a large dependence on thermal plants generation. Oil-fired and gas power plants generation account for more than 74% of the region generation. Renewable energies based generation account for about 7% of which hydro and wind represent 5% and 1% respectively. More than half of the region electricity generation is from Egypt, followed by Algeria 19%.

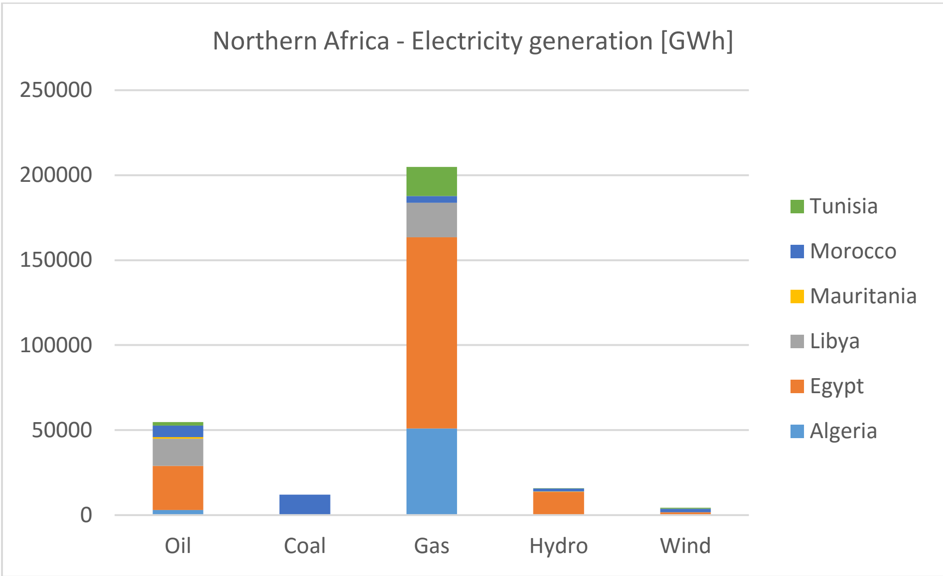


*Figure 4.18: Northern Africa - Electricity generation.*

Source: The Total Shift Project (2016)

### *4.3.5.2 Installed capacity*

The region total installed capacity is 63 GW with 90% of it from fossil fuels, mainly oil and gas. Hydropower capacities contribute to a share of 7%, wind 2% and the remaining renewables 1%. Algeria and Egypt account for more than 66% of the capacities of the region. Morocco and Tunisia representing 19% of the capacities of the region.

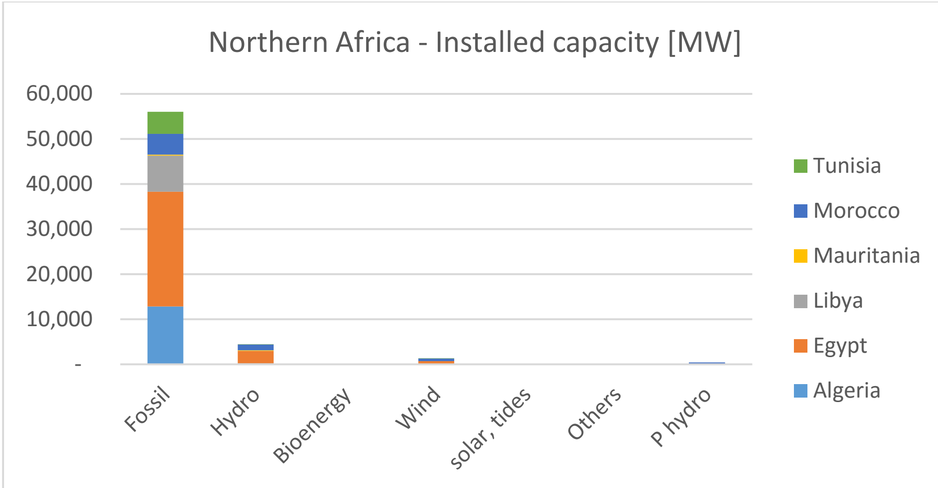


*Figure 4.19: Northern Africa - Installed capacity.*
Source: The Total Shift Project (2016)

## 4.3.6 Western Africa

### *4.3.6.1 Electricity generation*

West Africa electricity generation is estimated at 59 TWh, with no predominance of a given resources. Natural gas based power plants generation have the biggest share with 42% , followed by oil based thermal plants generation 20% and hydro with 33% is the renewable energy resources with significant contribution. Nigeria and Ghana are the main contributors to the region electricity generation with 50% and 14% share respectively.

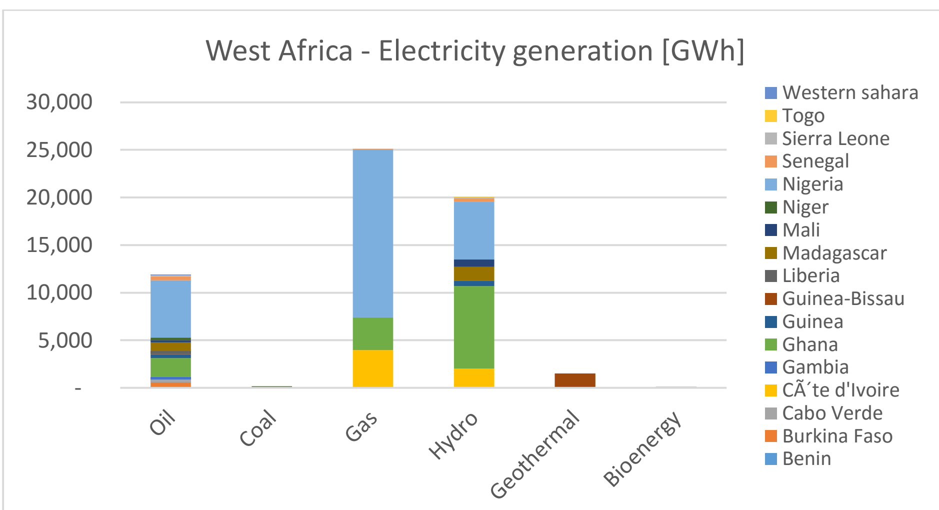


*Figure 4.20: West Africa - Electricity generation.*
Source: The Total Shift Project (2016)

### *4.3.6.2 Installed capacity*

The region total installed capacity is 13.7 GW with 67% of it from fossil fuels, mainly oil and gas of which Nigeria accounts for 47% and Ghana 16%. Hydropower capacities contribute to a share of 32% mainly from Nigeria and Ghana as well which shares are 46% and 27% respectively. Wind and bioenergy constitute the remaining 1%. Cote d'Ivoire, Nigeria and Ghana account for about 75% of the total installed capacity of the region.

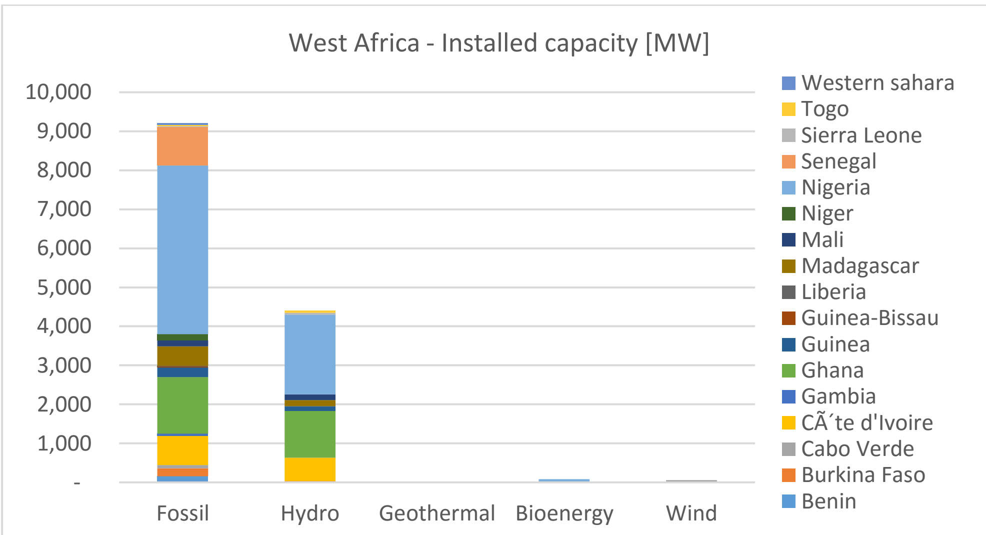


*Figure 4.21: West Africa - Installed capacity.*

Source: The Total Shift Project (2016)

## 4.4 Renewable energy technologies costs and trends

### 4.4.1 Renewable energy generation costs

Nowadays, the cost of renewable energy technologies is becoming more and more competitive. The renewable energy technology have been experiencing these recent years, substantial improvements regarding technology performance, especially regarding the cost of generation of solar PV and CSP which are based on the solar resource which the continent is endowed of. The other renewable energies technologies: biomass for power, geothermal power and hydropower with a character of mature technologies can provide lowest generation cost where economic resource is available. The figure below shows the power generation cost evolution of the recent years (IRENA, 2014c).

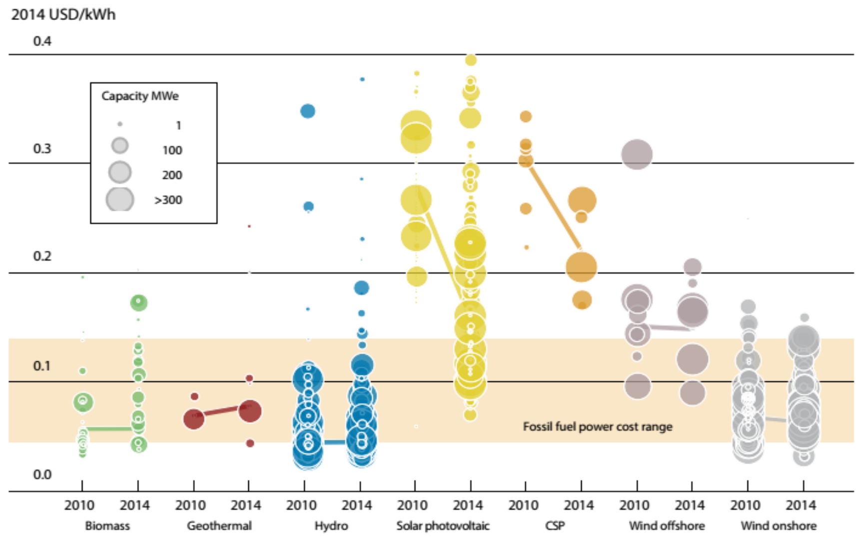


*Figure 4.22: Renewable energy power generation costs.*

Source: IRENA, 2014c.

The renewable energy generation costs for the case of solar energy based generation have seen their LCOE decrease of nearly 50% and 30% from 2010 to 2014 to reach 0.15 USD per kilowatt hour and 0.2 USD per kilowatt hour for solar PV and CSP respectively.

In Africa, as part of the rest of the world, excluding OECD countries, China and India, the generation costs of renewable energy power generation is in average less than 0.1 USD / kWh regarding biomass for power, geothermal for power, hydropower and wind onshore. Solar energy based power generation costs are in average around 0.2 USD / kWh.

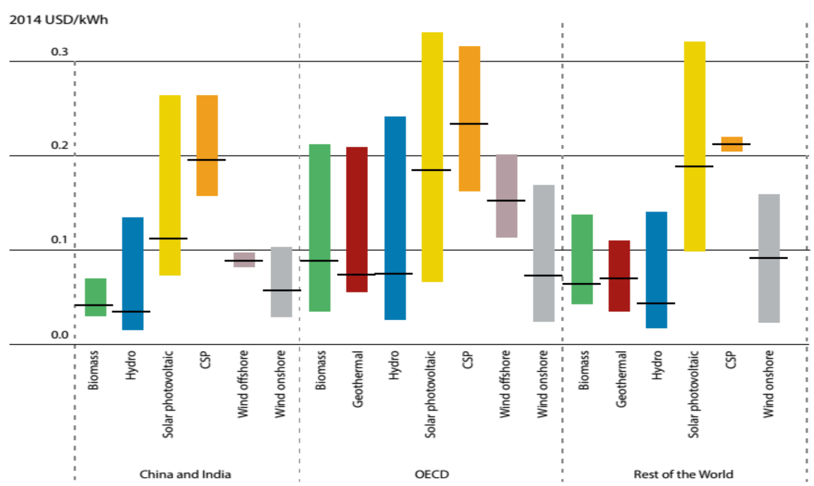


*Figure 4.23: Renewable energy power generation costs in Africa*

Source: IRENA, 2014c.

### 4.4.2 Trends of renewable energy power generation technologies

The cost of renewable energy technologies have recorded in the last decades significant decrease especially with the notably increase in production of equipment. IRENA made a study on the future trends of renewable energy technology investment cost for the next years. The trends of renewable investment costs summarized in the graph below, shows potential decrease in solar energy based power technologies of nearly 50% for CSP and more than 50% regarding solar PV and biomass (wood combustion) by 2050. Wind power and geothermal more mature are expected to see a small decrease especially for the case of wind power (IRENA, 2015b).

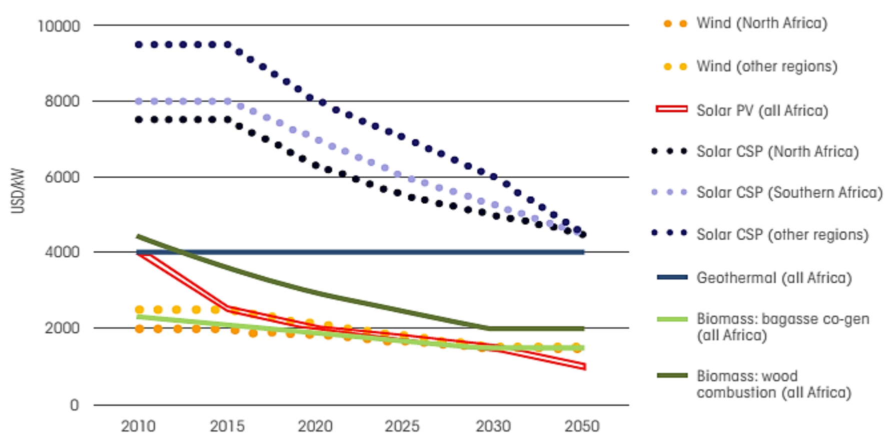


*Figure 4.24: Renewable energy technologies investment cost trends*

Source IRENA (2015)

## 4.5 Policy landscape

Achieving goals and objectives set by government in other to achieve universal access to electricity by 2030 will need strong commitment from governments, policy-makers in establishing regulatory and policy framework to enable and attract private investment for the development of renewable energies on the continent. This will happen only with well-defined national energy plans, with clear approaches and strategies towards increasing generation capacity, improvement in energy access and poverty alleviation, including others policy mechanisms.

Mallon (2006) insisted on the existence of well-established experience especially in the European Union regarding policy mechanism in increasing renewable energies supply. Four main classes of mechanism used by states or governments to increase renewable energy generation capacity and supply are: feed-in tariff laws, quotas, competitive tendering; and financial incentives.

In Africa to date, it is important to highlight that, there are a number of measure which have been taken. A minimum of 35 countries of the continent have defined renewable energy targets, 16 countries found with policies on energy efficiency while 24 countries record at least one regulatory instrument and 38 countries have at least one economic instrument in force regarding the development of renewable energies (ren21, 2016).

Though, they need further advancement. Countries such a Kenya, Ghana and South Africa are leading in the area with a set of regulatory policies and financial incentives and public financing mechanisms adopted (IRENA, 2015a).

### 4.5.1 Central Africa

In central Africa region, even if none of the countries has established policies on energy efficiency, of the total of eight countries only five do have renewable energy targets namely: Cameroon, Gabon, Chad, Congo and Democratic republic of Congo. Regarding economic instruments, only two countries: Cameroon and Congo Democratic recorded in forced instruments: fiscal incentive regarding tax reduction in the case of Cameroon and both fiscal incentives and public finance in the case of Congo Democratic Republic (ren21, 2016), (IEA, 2016).

### 4.5.2 Eastern Africa

In the region, of the total number of member states, six recorded in force renewable energy targets whereas four have implemented energy efficiency policies, with Ethiopia, Kenya and Mauritius having in place both policies.

Regarding economic instruments, fiscal incentives are the most used instruments especially capital subsidies and tax reductions (five and six countries respectively) have put in place these instruments, while public investments are the most common instrument regarding public finance. The figure below summarizes the different instruments in force in the region.

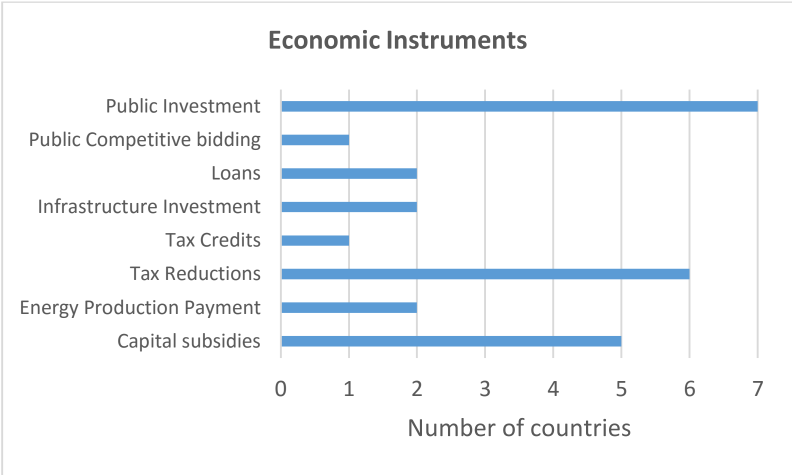


*Figure 4.25 Economic instruments in place in Eastern Africa.*
Source: compiled from (IEA, 2016), (ren21, 2016)

Regulatory instruments in place in the region are principally feed-in-tariff, codes and standards heat obligation / mandate and tendering; with Kenya being the leading country with all of these instruments in place.

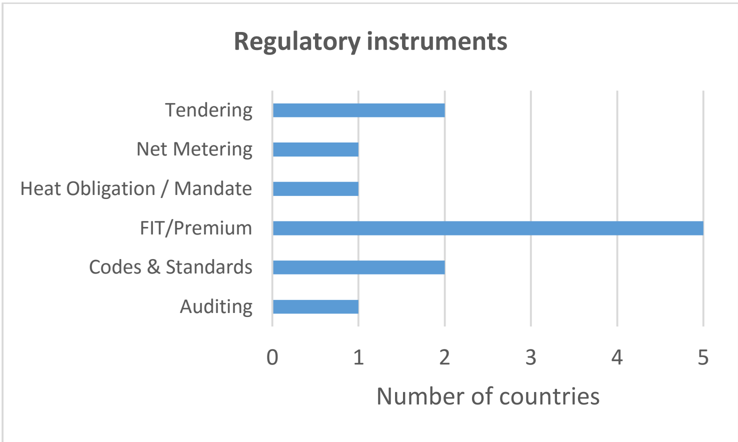


*Figure 4.26: Eastern Africa regulatory instruments*
Source: compiled from (IEA, 2016), (ren21, 2016)

### 4.5.3 Northern Africa

Apart from Mauritania, the countries in the region have policies regarding renewable energy targets and energy efficiency. The economic instruments in the region are mainly of two type: fiscal incentive (mainly tax reductions) and public finance measures. As a whole, the region records about 20 economic instruments with Algeria, Egypt, Morocco and Tunisia leading with at least three instruments in place.

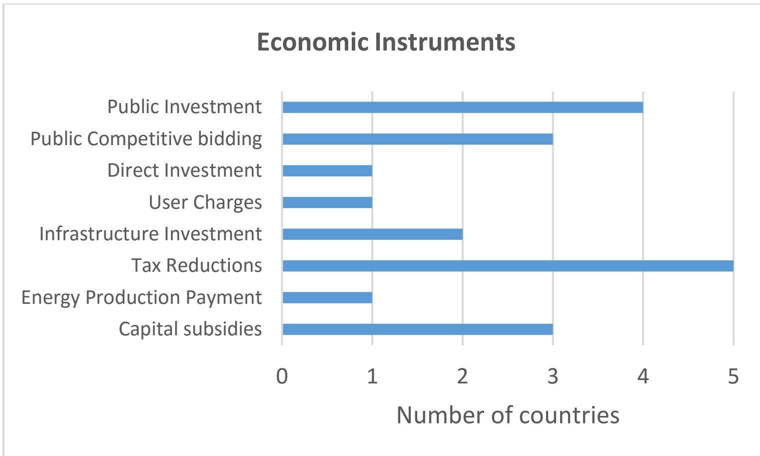


*Figure 4.27: Northern Africa economic instruments*

Source: compiled from (IEA, 2016), (ren21, 2016)

The regulatory instruments in place in the region are mainly codes and standards, feed-in-tariff, net metering as well as tendering. Algeria, Egypt and morocco record at least three of the above instruments in place. The chart below summarized the regulatory instruments in place in the region.

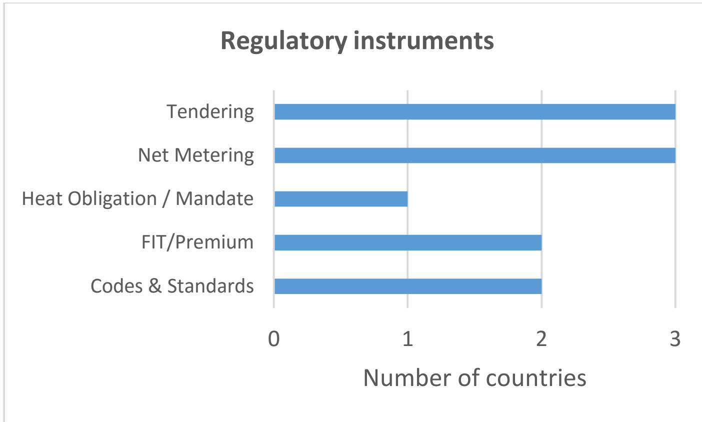


*Figure 4.28: Northern Africa regulatory instruments*

Source: compiled from (IEA, 2016), (ren21, 2016)

### 4.5.4 Southern Africa

Renewable energy policies in the region are receiving a specific attention. To date, almost all the countries of the region have in place renewable energy targets[10], while policies regarding energy efficiency are still at their early stage of development in about two countries of the region.

The economic instruments in the region are mainly focusing on fiscal incentives withal the countries of the region having in place at least of the different incentives measures. As well, public finance measures are in place in all the countries of the region.

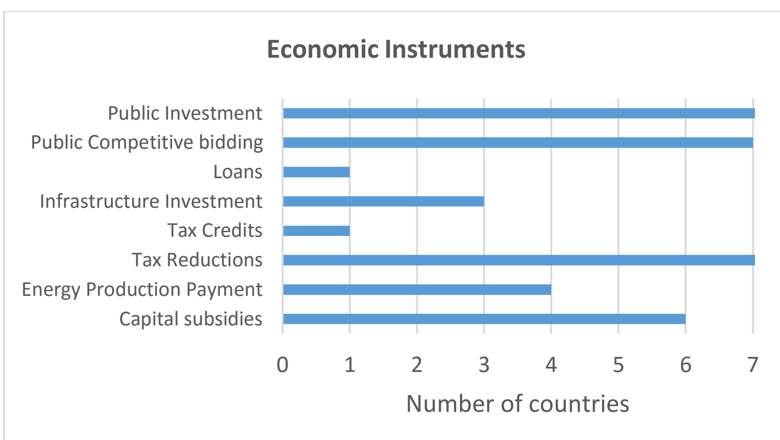


*Figure 4.29: Southern Africa countries with economic instruments.*

Source: compiled from (IEA, 2016), (ren21, 2016)

[10] Apart from Swaziland

As far as regulatory instruments are concerned in the region, it was found that up 23 measures have been put in place in the region, with the most used being tendering, codes and standards, feed-in-tariffs and net metering. South Africa and Namibia record a minimum of four of these instruments in place.

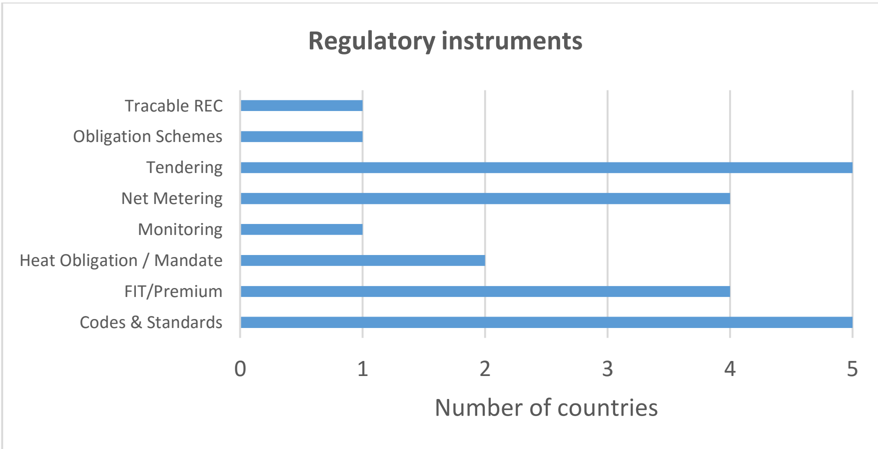


*Figure 4. 30: Southern Africa countries with regulatory instruments.*

Source: compiled from (IEA, 2016), (ren21, 2016)

### 4.5.5 Western Africa

In the region, more than half of the countries have put in place renewable energy policies, while about half of them have in place policies regarding energy efficiency. However, some countries such as Cote d'Ivoire and Nigeria have put in place policies regarding both renewable energy targets and energy efficiency.

In the region as a whole, about 35 instrument have been put in place principally fiscal incentives (tax reduction) accounting for half of these measures and public finance measures (public investment) accounting for about twenty percent. Mali, Ghana and Nigeria are the countries in the region with at least five economic instruments in place.

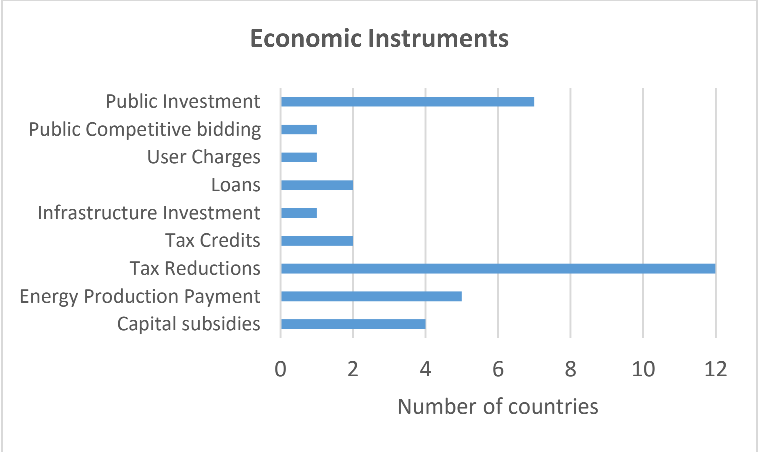


*Figure 4.31: Western African countries with economic instruments.*

Source: compiled from (IEA, 2016), (ren21, 2016)

As regard to regulatory instruments, only seven countries were found with at least instrument in place and only two countries: Ghana and Senegal with more than four regulatory instruments in place. Nevertheless, feed-in-tariffs instruments remain the most used instrument in the region.

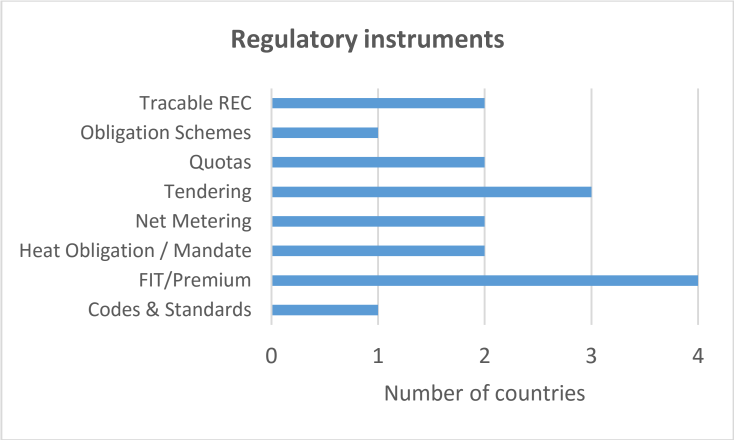


*Figure 4.32: Western African countries with regulatory instruments*

Source: compiled from (IEA, 2016), (ren21, 2016)

## 4.6 Trade

The continent consist of small isolated economies. The integration of power infrastructure is needed to promote regional integration and enable economies of scale. In that regard, regional power pools have been set up in order to allow and enable regional trade among countries. This would allow to take the advantage of substituting thermal power plant to cleaner one especially large hydro in one hand and reduce substantially operation costs of power generation in another hand.

Regional power trade could imply many potential benefits in establishing mutual cross-border trade of electricity. One of the most important benefit, being the ability to raise capital investments.

To date, power trade in the continent is still limited. In 2013, the continent recorded 40 TWh imports and 29 TWh exports regarding trade. Most of it occurred within the SAPP, between South Africa and Mozambique and in the COMELEC between Algeria, Morocco, Tunisia and Egypt and Libya.

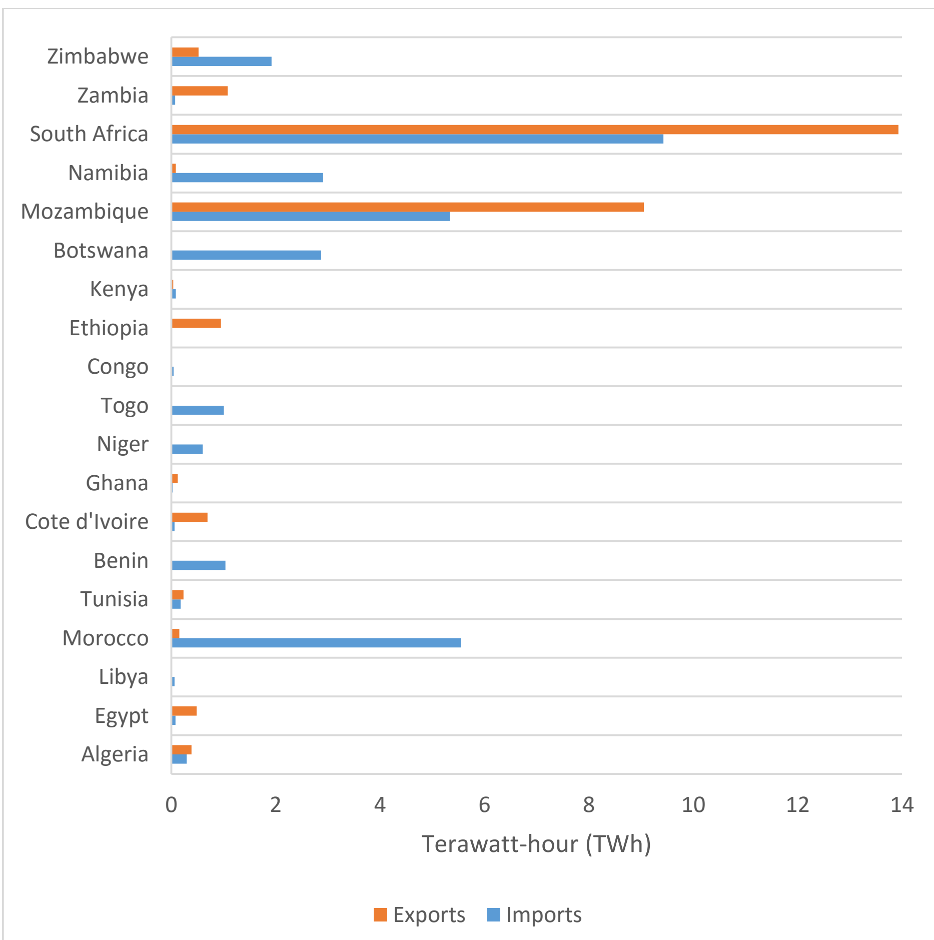


*Figure 4.33: Africa electricity trade.*

Source IEA (2013)

In the Northern Africa, the countries are interconnected through the Mediterranean Energy Ring. Morocco being the largest exporter due to the vast renewable energy programme he developed that enables him to export electricity to Spain. In the SAPP, Namibia, Botswana depend on imports from South Africa while Zimbabwe depend on both South Africa and Zambia[11]. In the WAPP, Benin and Togo depend on imports from Cote d'Ivoire and Ghana, and Niger depends from imports from Nigeria. The CAPP trade is still developing, however it is to acknowledge that there are small cross-border trades happening in the region especially between Congo and Congo D.R., and between Cameroon and Chad.

Though, the different power pools made progress in developing standards and agreements in order to allow the sector growth especially foe the case of SAPP, COMELEC and WAPP, the overall traded volume in the continent remains very small. It represents only 11% of the total electricity consumption of the continent.

The continent total cross-border transmission lines has a maximum capacity of 10,167 MW[12]. However, several cross-borders projects are being developed in order to increase trade within and across regions. In that regard, the EAPP is developing an ambitious cross-border expansion. It aims at developing Ethiopian hydropower sector with the Gibe III and Grand Renaissance projects and the development of geothermal power in Kenya. The construction of a cross-border transmission line of a capacity in either way of 2,000 MW is ongoing between Ethiopia and Kenya in that regard. Integration of others countries of the region are planned (AEEP, 2014).

In the case of the WAPP, there are several projects; ongoing and planned aiming at reinforcing the power trade in the region. Several high voltage cross-border transmission lines are being constructed and are expected to be commissioned latest by 2020. By 2020, all the countries of the region would be interconnected into five different sub-programs

[11] Southern African Power Pool Annual Report (2011)
[12] Including Morocco-Spain cross-border transmission line of 1,400 MW

namely Northcore, Inter Zonal, CLSG, OMVG-OMVS and Coastal Backbone (WAPP, 2016).

In the ECCAS region, several interconnections projects are ongoing or planned in other to increase the trade within the region. Some of the priority projects include the Equatorial Guinea – Cameroon, Gabon - Equatorial Guinea, Congo – Gabon interconnections each with a capacity of 600 MW, and Cameroon – Chad interconnection of 125MW capacity (The Infrastructure Consortium for Africa, 2011).

Regarding inter-regional trade, several projects are in pipeline for connecting the different power pools of the continent. Under its Priority Action Plan, the PIDA aims at establishing four different transmission corridors across the continent: the West African Power Transmission Corridor, the Central Africa Transmission Corridor, the North Africa central corridor and the North South transmission corridor. They aim in a short term (2020) to interconnect the countries of the region among themselves and in the long term (2040) to interconnect all the four corridors in other to enable a complete power trade within the continent (Moulot, 2015).

# 5. Future Projections and Trends

## 5.1 Africa electricity demand

Electricity demand in the continent is recording a steady growth; it is expected to be driven by the economy growth, the development of the industrial sector as well as the rate of urbanization.

African rural population represent up to 40% of the total population, however, they only represent 10% of the total electricity demand on the continent. This share is not expected to change until 2030 because of the increase in electricity access that would occur in urban areas. However, in absolute value the rural demand is expected to increase from 68 to 180 TWh per year between 2013 and 2030 (IRENA, 2015a).

### 5.1.1 Central Africa

Electricity demand in the region is expected to see an increase of almost three fold from 2014 to 30 to 25 TWh to 90TWh respectively. The urban demand in the region will account for 57%, while industry and rural demand will account for 39% and 4% respectively (IRENA, 2015b). The figure below shows the demand growth path of the region.

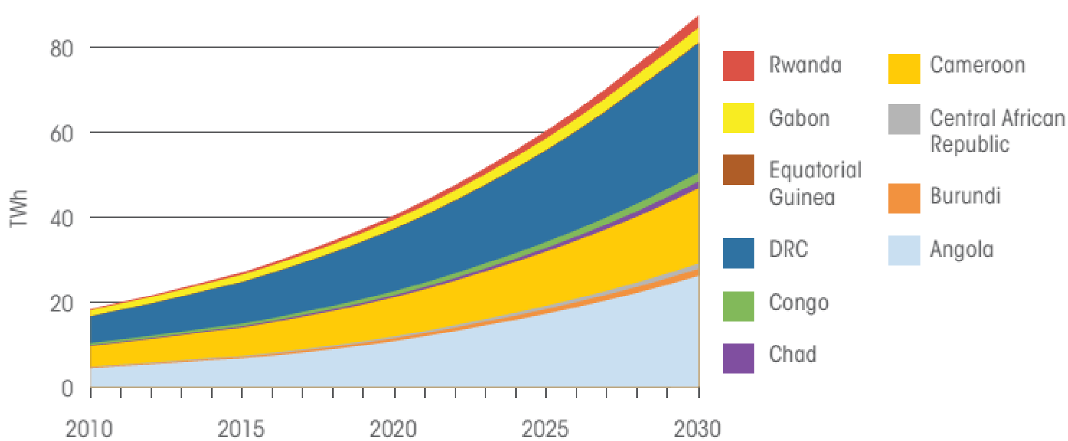


*Figure 5.1: Central Africa electricity demand projection.*

Source IRENA (2015b)

### 5.1.2 Eastern Africa

Based on Eastern Africa Power Pool/EAC the demand projection is expected to see an increase with of a factor of 2.5 from 200 TWh in 2015 to 500 TWh in 2030. Industry should account for 44% of the demand in 2030, while residential both urban and rural account for 39% and 17% respectively (IRENA, 2015b). In the figure below are shown the path for demand growth of the region.

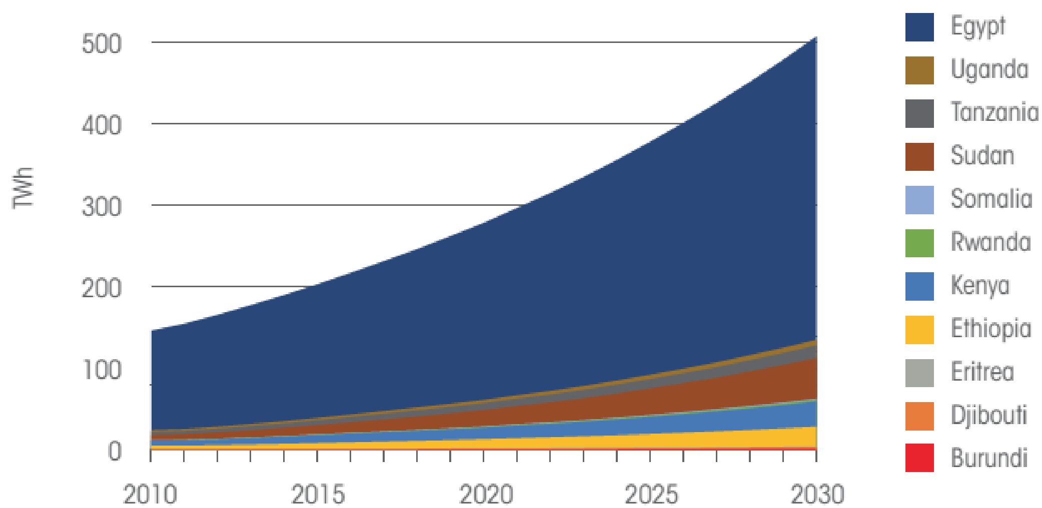


*Figure 5.2: Eastern Africa electricity demand projection.*

Source IRENA (2015b)

### 5.1.3 Northern Africa

Electricity demand in the region is expected to grow with a factor of 3.3 from 2014 to 2030, with an increase in demand from 300 TWh to 1000 TWh. The share of urban, rural and industrial demand observed today (42%, 11% and 45% respectively) is not expected to change in large proportion. However, a slight increase in the share of urban demand is expected due to urbanization (IRENA, 2015b). The figure below shows the path for demand growth of the region.

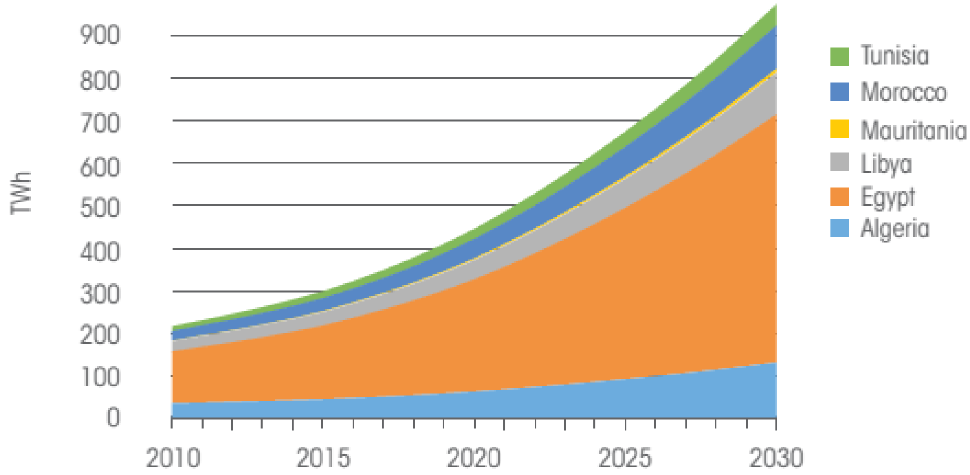


*Figure 5.3: Northern Africa electricity demand projection.*

Source IRENA (2015b)

Algeria peak power demand was 12,400 MW in 2015 with an annual percentage increase of 8% per annum[13]. The peak power demand projection is expected therefore to reach 39,300 MW by 2030. Morocco in his electricity development plan is expected to see the peak power demand to reach 20,000 MW by 2030 with an electricity demand of about 133 TWh[14] whereas Tunisia electricity demand is expected to grow throughout the years and reach a value of 26.7 TWh under a scenario based on implementation of energy efficient measures in consumption by 2030[15].

### 5.1.4 Southern Africa

Southern Africa region electricity demand projection is expected to grow with a relatively low rate: from about 320 TWh to 580 TWh. This, driven by the achieve maturity of South Africa and the industrial development process of the remaining countries of the region (IRENA, 2015b). The path of the demand growth are as follows:

[13] eia, Country analysis Brief: Algeria (2016)
[14] Morocco ministry of energy, mining, water and environment; National energy strategy: Timeline 2030
[15] New version of the Tunisian Solar Plan (2012)

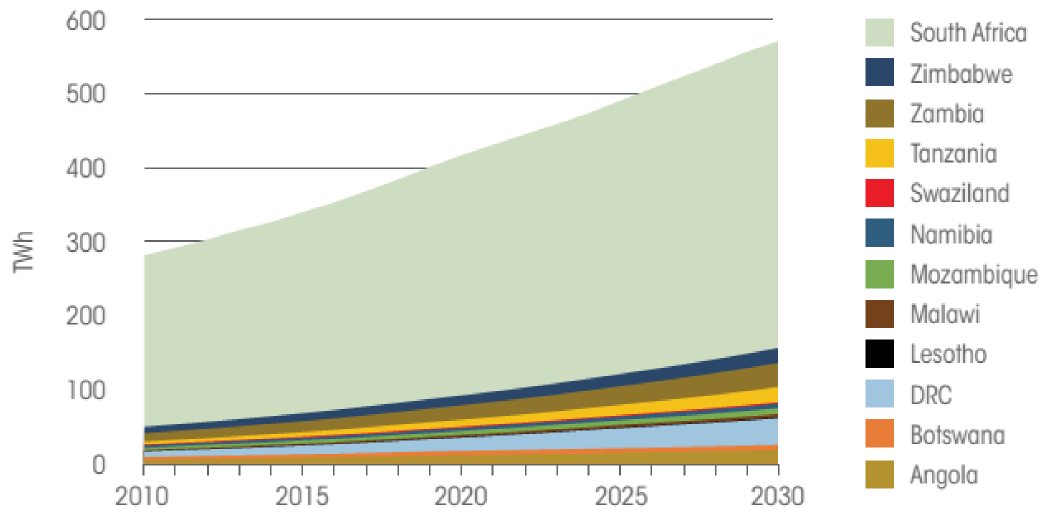


*Figure 5.4: Southern Africa electricity demand projection*

Source IRENA (2015b)

Regarding generation capacity, Angola's electricity power demand is expected to grow at a strong pace, with a percentage increase of 12.5% between 2017 and 2025. The peak power demand would reach 8,800 MW in 2025 with establishment of extractive industries (SE4All, 2015).

Lesotho power demand has been increasing over the past years, and is expected to increase to 275 MW by 2025[16], while Malawi power demand projection is expected to increase by a percentage of 7% per annum to reach 857 MW and 1597MW in 2020 and 2030 respectively[17].

### 5.1.5 Western Africa

The demand of electricity in the region is expected to grow substantially. An increase of about three fold is predicted to happen between 2014 and 2030, from about 75 TWh to about 225 TWh; the urban demand is expected to see a drop from 87% to 48%, industrial and rural demand will rise till 45% and 7% respectively (IRENA, 2015b). The figure below the path of the expected demand.

[16] Lesotho Electricity Authority (2013)
[17] Ministry of energy Malawi (2014)

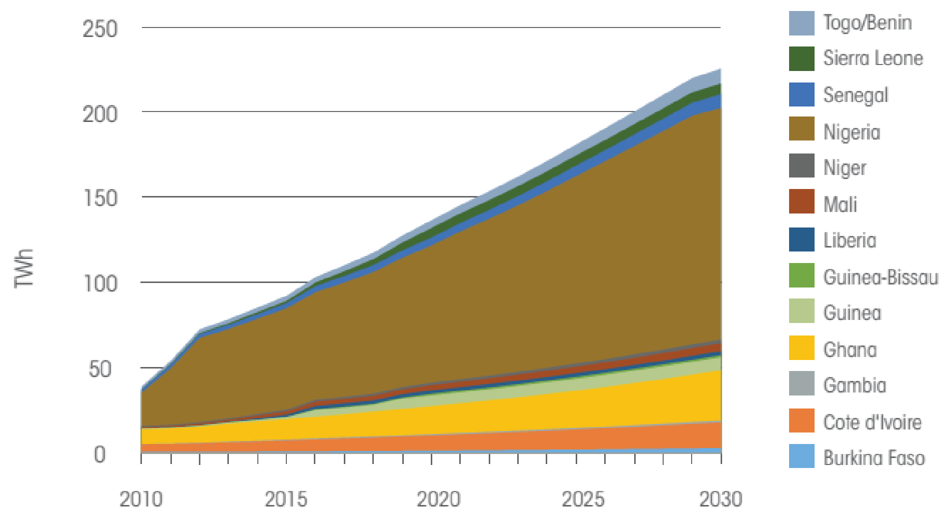


*Figure 5.5: Western Africa electricity demand by 2030.*

Source IRENA (2015b)

## 5.2 The Nationally Determined Contributions (NDCs)

African countries in their will to reduce the scarcity and the lack of access to modern energy (electricity) set different targets and objectives in order to scale up their respective generation capacity. The following summarizes the contributions of the renewable energies within the NDCs.

### 5.2.1 Hydro power

Hydropower is the major renewable energy resources harvested across the five regions of the continent as shown in the figure below[18]. Indeed, in the Central African region, hydropower planned capacities are expected to reach about 55 GW by 2030 to 2035 with large share of it coming from the development of the Inga river potential in Congo DR to reach up to 44.8 GW. The remaining capacity accounting for the other countries of the region including Cameroon, Congo and Gabon, the latter with planned capacity of 1,900 MW and 700 MW respectively[19]. The Northern region though having a restricted potential is planning a capacity slightly higher than 6 GW with Egypt and Morocco

[18] Hydropower potential data were assumed with 60% capacity factor and 98% availability factor and are subjected to +/- 50% uncertainty excluding data for Central and Southern African regions.

[19] UNECA (2016) Central African Region - Energy component.

accounting for almost all of it; both planning half of the totality of these capacities[20]. As regard to the Eastern African region hydro power development accounts for more than half of the total region's planned capacity with nearly 16 GW. This development is planned in mainly Ethiopia, Tanzania and Kenya with planned capacity of 11 GW, 3.3 GW and 1.2 GW respectively[21]. As well, hydropower recorded an important share in the Southern part of the continent. It accounts for 42% (16 GW) of the renewable energy planned capacities with Angola being the country with the largest planned capacity (6.7 GW) and followed by countries such as Zambia, South Africa and Zimbabwe whose planned capacity are respectively 2.9 GW, 2.65 GW and 2.6 GW. In the last region of the continent, namely the Western region, hydropower development is expected to reach 20 GW[22]. Nigeria accounts for more than half in the share followed by Guinea and Cote d'Ivoire with 12% and 9 % respectively[23].

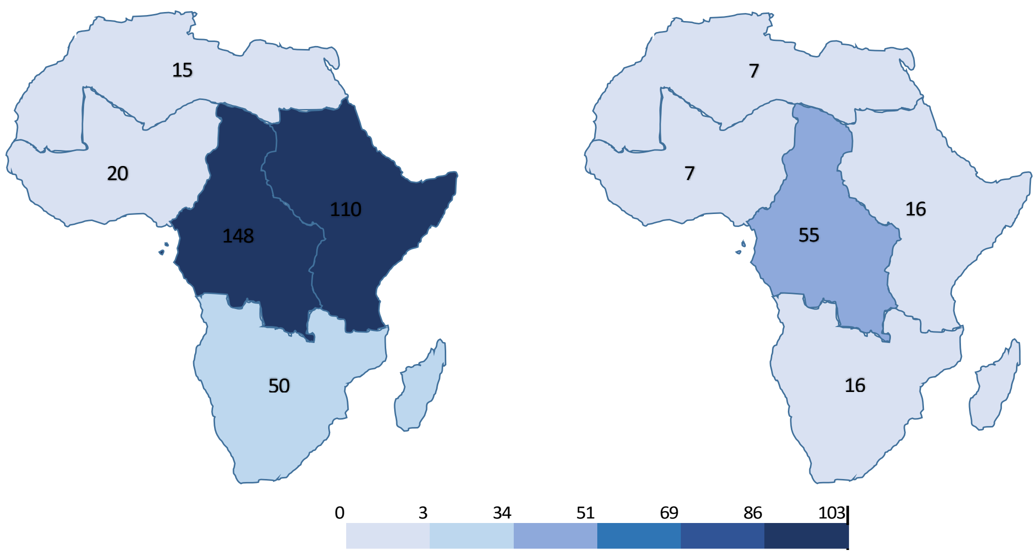


*Figure 5.6: Hydropower theoretical technical potential (left) and planned capacity (right) in GW.*

Source: compiled from countries' NDCs, electricity Master plans & IRENA (2012b)

[20] Egypt (2015): Energy Policy Laws and Regulations Handbook Volume 1 *Strategic Information and Basic Laws* MENA factsheet: Morocco (2016)
[21] Data do not include Uganda hydropower development
[22] Excluding hydropower planned capacity from The Gambia and Cabo Verde
[23] Data compiled from countries' NDCs and the ECOWAS portal: ecowrex.org

### 5.2.2 Solar PV

Solar photovoltaic development planned in the countries' NDCs on the continent revealed a total planned capacity of about 52 GW. Its distribution across the region of the continent is not uniform. Indeed, the Northern and Southern regions account for 63% of the total planned capacities. This planned development are more specifically due to ambitious solar plan of Algeria, Morocco and Egypt in the Northern region, South Africa in the Southern region and Nigeria in the Western region. However, as shown in the following figure, the solar PV development is still very low as compare to the potential of

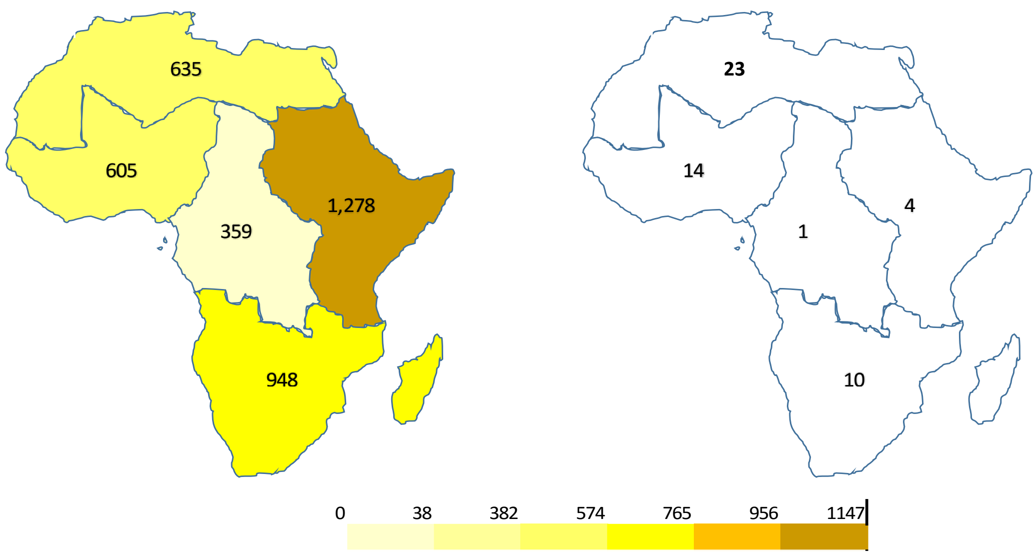


*Figure 5.7: Solar PV theoretical technical potential (left) and planned capacity (right) in GW.*

the continent[24].

Source: compiled from countries' NDCs, electricity Master plans & IRENA (2012b)

### 5.2.3 Concentrated Solar Power

The development of solar energy through concentrated solar power in the continent is expected to reach in the respective timeline of NDCs, a cumulative capacity of 6 GW.

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[24] Solar PV potential data were assumed with 20% capacity factor and 98% availability factor and are subjected to +/- 50% uncertainty

The northern region accounts for 71% of this planned development across the countries of the region with Algeria, Libya, Egypt and Tunisia respective capacity of 2 GW, 1200 GW, 700 GW and 460 MW. The Southern African region accounts for 1.3 GW mainly from South Africa planned capacity and Botswana with respectively 1.2 GW and 0.1 GW, while in Eastern Africa Sudan is the country foresee the development of CSP with a planned 0.1

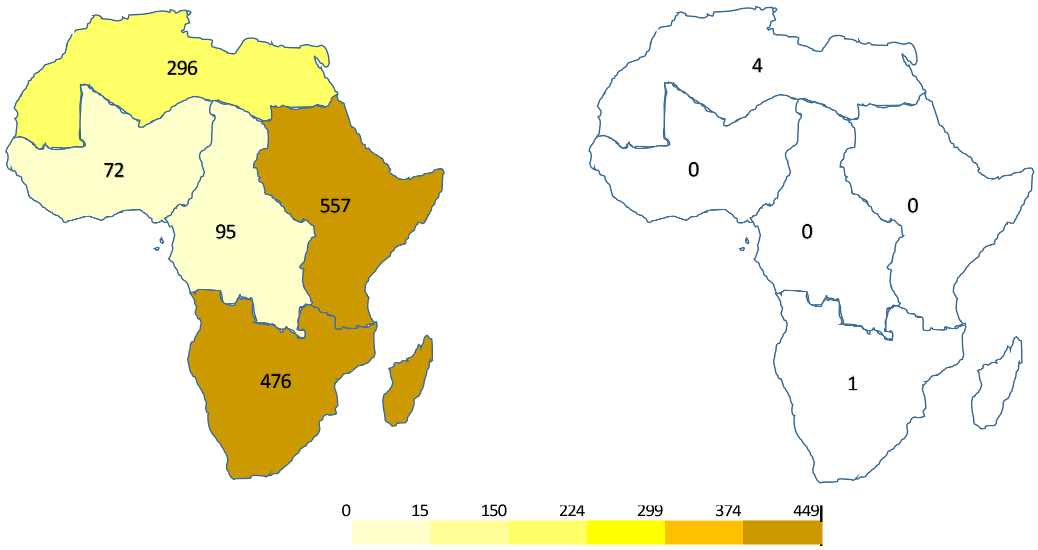



*Figure 5.8: CSP theoretical technical potential (left) and planned capacity (right) in GW.*

GW capacity. The figure below summarizes the planned capacity in the continent while comparing them to the existing potential[25].

Source: compiled from countries' NDCs, electricity Master plans & IRENA (2012b)

### 5.2.4 Wind

The different countries of the continent planned the development of wind energy resource, though, not always being in accordance with the potential they are having. Over an estimate of 38 GW planned capacity on the continent, the Northern accounts for 54%, followed by the Southern part 26%, the Western part 10% and the Eastern part 9%. In the northern part, wind planned capacity is a major component of countries' electricity sector development. Indeed, Egypt, Algeria and Morocco are planning a development of the

[25] CSP potential data were assumed with 40% capacity factor and 100% availability factor and are subjected to +/- 50% uncertainty

resource of at least 5 GW each with Egypt capacity to reach 7.2 GW. The remaining countries of the region are planning less capacity though, still important with Libya, Tunisia and Mauritania capacities being 2 GW, 1.8GW and 0.1 GW respectively.

In the southern region, the resource development is mainly planned in South Africa and Angola with capacity of 9 GW and 0.68 GW respectively. The Western African wind development is mainly planned in Nigeria and Mali with respective capacity to reach 3.2 GW and 0.225 GW.

The Eastern African region wind power development is planned in several countries: Ethiopia, Soudan, Kenya, Tanzania and Djibouti. Soudan and Ethiopia being countries with planned capacities of 1 GW and 1.5 GW respectively while Kenya capacity are to reach nearly 0.9 GW.

The central African region planned development of wind resource is still fairly low. However, some Cameroon and Chad are planning a contribution of the resource in the mix of about 0.4 GW. The following figure summarizes the wind resource based planned capacity in the continent with regard to the available potential[26].

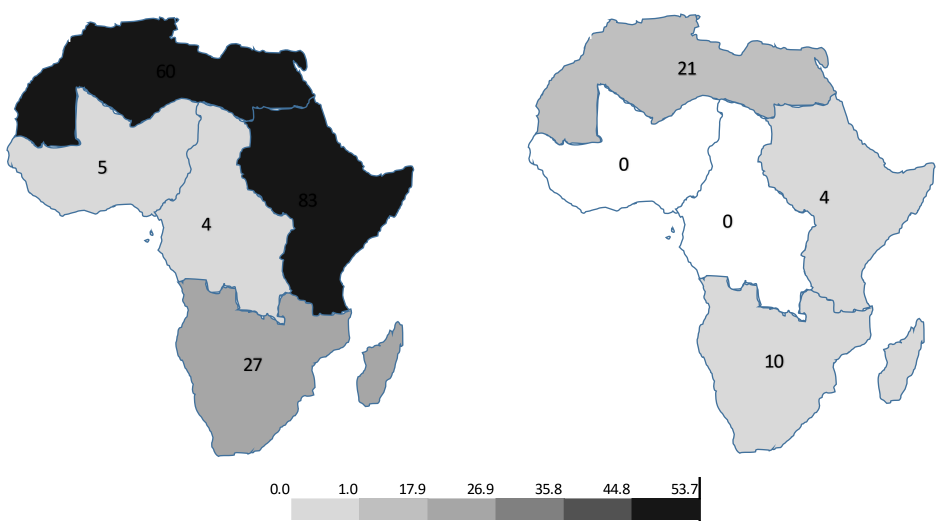



*Figure 5.9: Wind theoretical technical potential (left) and planned capacity (right) in GW. )*

Source: compiled from countries' NDCs, electricity Master plans & IRENA (2012b)

[26] Wind potential data were assumed with 40% capacity factor and 95% availability factor and are subjected to +/- 50% uncertainty

### 5.2.5 Biomass

The development of biomass resource for electricity generation in NDCs revealed a fairly low contribution of biomass in the future electricity mix of the continent as shown in the figure below. A total planned capacity of about 5 GW is expected on the continent with 59% planned in the Northern region mostly from Egypt and Algeria with planned capacity of 1.5 GW and 1GW respectively; Eastern and Southern Africa with 14% each with Angola accounting for most of it in Southern Africa while Kenya and Sudan in Eastern Africa account for 80% of the planned capacity. In the Western African region, Nigeria accounts for the majority of planned capacity (68%). In the central African countries, apart from Cameroon including biomass in the mix (even if very low), the remaining countries did not consider biomass development in their respective electricity mix as shown in the figure below[27].

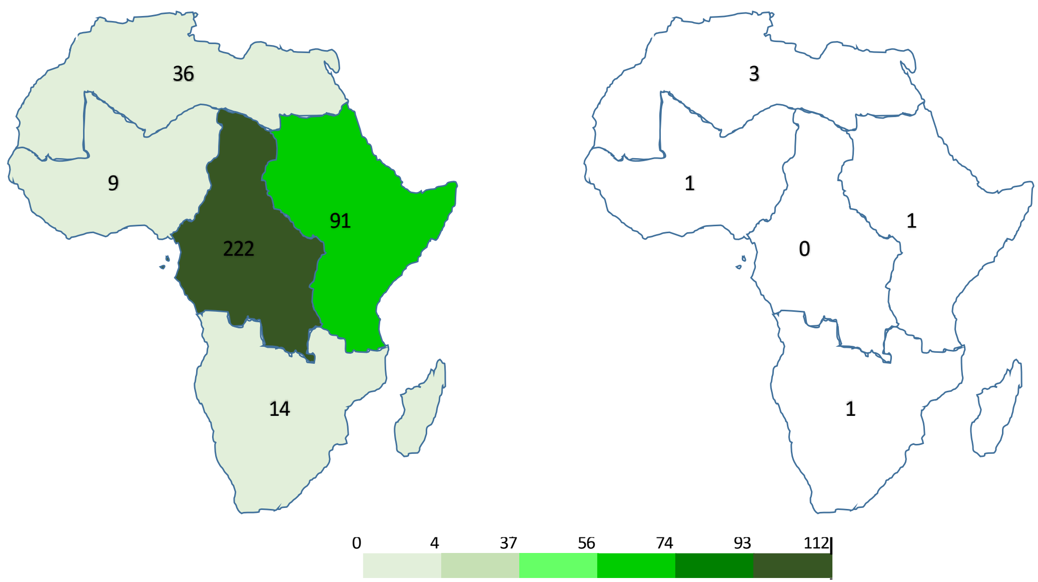



*Figure 5.10: Biomass theoretical technical potential (left) and planned capacity (right) in GW.*

Source: compiled from countries' NDCs, electricity Master plans & IRENA (2012b)

[27] Biomass potential data were assumed with 85% capacity factor and 95% availability factor and are subjected to +/-50% uncertainty

### 5.2.6 Geothermal

Geothermal development in the continent is mainly located in the Eastern region due to the geographical restriction of the resource on the continent. It is planned up to 5 GW capacity of geothermal in the region. The main contributors being Kenya, Ethiopia and Djibouti with respective planned capacity of 2.2 GW, 1.2 GW for the latter. Other region of the continent developed as well their resource when available, including in the Northern part with small development in Algeria for instance.

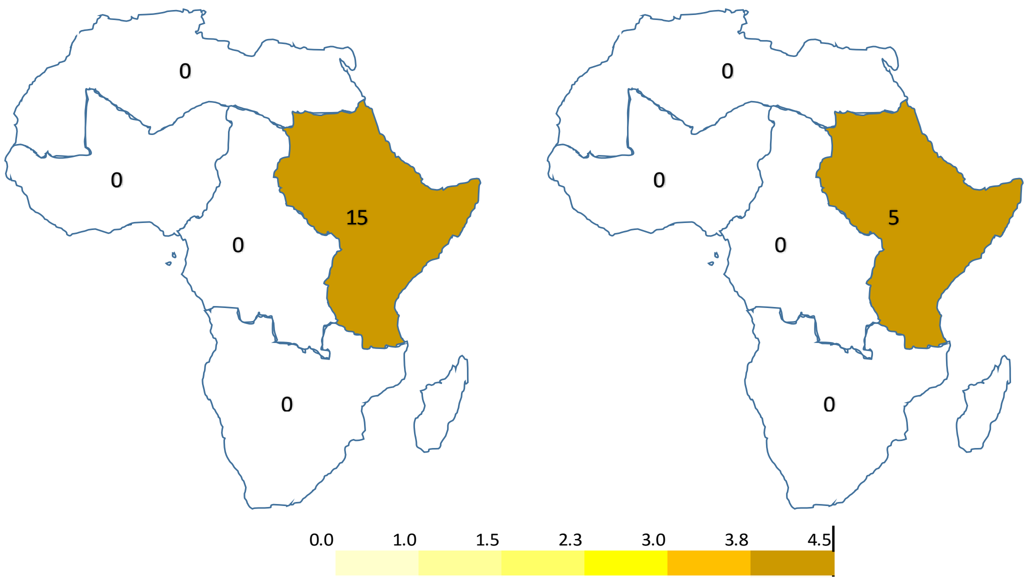



*Figure 5.11: Geothermal theoretical technical potential (left) and planned capacity (right) in GW.*

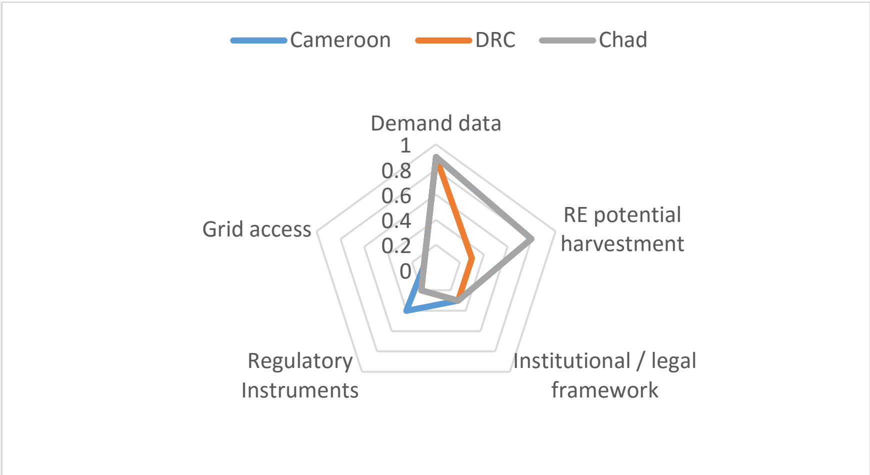
Source: compiled from countries' NDCs & electricity Master plans

# 6. Energy Planning Gaps and Needs

## 6.1 Energy planning gaps

### 6.1.1 Central Africa

There is a set of gaps that have been highlighted in the selected countries of the region regarding renewable energies and energy efficiency. These gaps are displayed in the figures below.



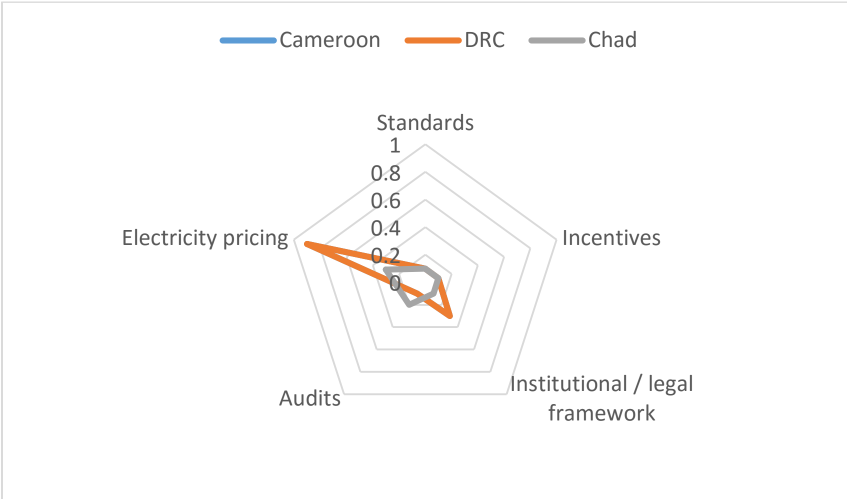




*Figure 6.1: Renewable energy gaps (top) and Energy efficiency gaps (bottom) in selected countries of Central Africa*

*5.1.1.1 Cameroon*

**Renewable energies**

The renewable energy contribution in the planned generation mix excluding large hydro is not very low as regard to the renewable energy potential the country is endowed of (biomass, solar PV and wind) with for instance only 1% electricity generation from biomass power.

*Institutional / legal framework*

As regard to renewable energy development in the country, a little has been done with in term of institutional and legal framework. Indeed, in the country, there is no dedicated authority in place aiming at promoting renewable energies; also, the legal framework of renewable energies is still absent. However, these institution and legal framework are in development.

*Regulation framework*

There is no regulatory economic instruments yet established with regard to the development of renewable energies in the country.

*Grid access and renewable energy atlas availability*

So far, no grid code or priority access to the grid for renewable energy based electricity generation have been made.

Apart from hydroelectric atlas, there is no details atlas regarding the remaining renewable energy resources.

**Energy efficiency**

The potential of energy efficiency is very important in the energy sector particularly in the electricity sub-sector.

*Policy / legal framework*

The country despite the energy efficiency target planned, does not have defined policy for the promotion of energy efficiency. As well, there is no legal framework and no dedicated authority in place to promote energy efficiency and conservation.

*Plans/strategies*

There are no clear incentives to consumers to adopt energy efficient consumption patterns and to develop energy efficient projects.

There is no mandatory energy audits for public entities, utility supplier or large scale consumers.

No minimum performance standards have been set regarding common electric appliances, as well, there is no labelling standard in place.

*6.1.1.2 Congo Democratic Republic*

**Renewable energies**

The renewable energies in the sector development of the country is exclusively focusing on hydropower resource despite the severe variability this resource is subjected to, as part of the effects of climate change. Indeed, the country is endowed of non-negligible renewable energy resources excluding hydro (solar, wind and biomass) which could play a role in the future generation mix of the country.

*Institutional / legal framework*

The legal framework in the electricity sector, defined in the ‘electricity code’, do not clarify on a specific basis the legal framework regarding renewable energies.

*Regulatory framework*

The regulatory framework do not define regulatory instruments for the deployment of the renewable energies such as Feed in tariffs, auctions, or net metering. However, there is an economic instrument in force especially fiscal incentives which are framed in ‘The Investment Code’.

*Grid access and renewable energy atlas availability*

So far, no grid code or priority access to the grid for renewable energy based electricity generation have been made.

**Energy efficiency**

*Policy / legal framework*

The country has no policy regarding the promotion of energy efficiency. Therefore, there is no national target in this regard nor specific legal framework.

*Plans/strategies*

The country has not put in place incentives for consumers and energy efficiency projects developers.

There is no energy audits for utility supplier, public entities or large scale consumers.

No minimum performance standards have been set regarding common electric appliances, as well, there is no labelling standard in place.

*6.1.1.3 Chad*

**Renewable energies**

There is a clear will of diversifying renewable energy sources in the mix especially acknowledging the scarcity of hydro power in the country. However, in the projected mix, there is a lack of consideration of biomass resources which the country is endowed of.

*Institutional / legal framework*

There is an established institutional and legal framework framing the electricity sector through the ministry, however, there is no dedicated authority yet established for the promotion of renewable energies nor specific legal framework for renewable energies.

*Regulatory framework*

The regulatory framework do not specifically define clear instruments for the deployment of renewable energies. Indeed, there is no established regulatory instruments, neither economic instruments, neither regulatory instruments in force.

*Grid access and renewable energy atlas availability*

There is no grid code in place in the country as well as no priority access to the grid for renewable energy electricity generation.

The country does not published detailed renewable energy atlas.

**Energy efficiency**

*Policy / legal framework*

Despite the potential in the subsector, the country has not yet established policy or legal framework on energy efficiency.

*Plans/strategies*

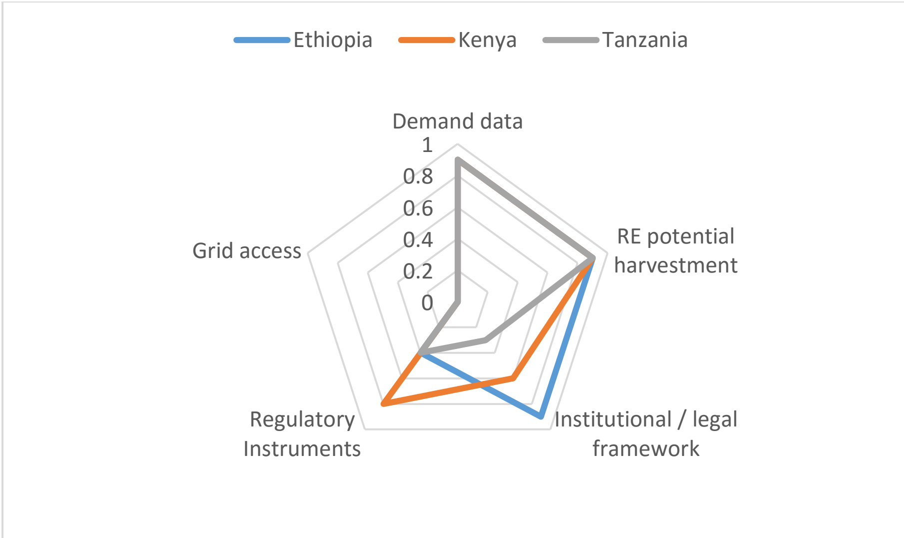
There is no incentive relative to the promotion of energy efficiency. As well, no energy audits for utility supplier, public entities or large scale consumers have been put in place.

No minimum performance standards have been set regarding common electric appliances, as well, there is no labelling standard in place.

Despite the fact that electricity tariffs are high in the country, it is to acknowledge the fact that they are subsidized.

### 6.1.2 Eastern Africa

There is a set of gaps that have been highlighted in the selected countries of the region regarding renewable energies and energy efficiency. These gaps are displayed in the figures below.



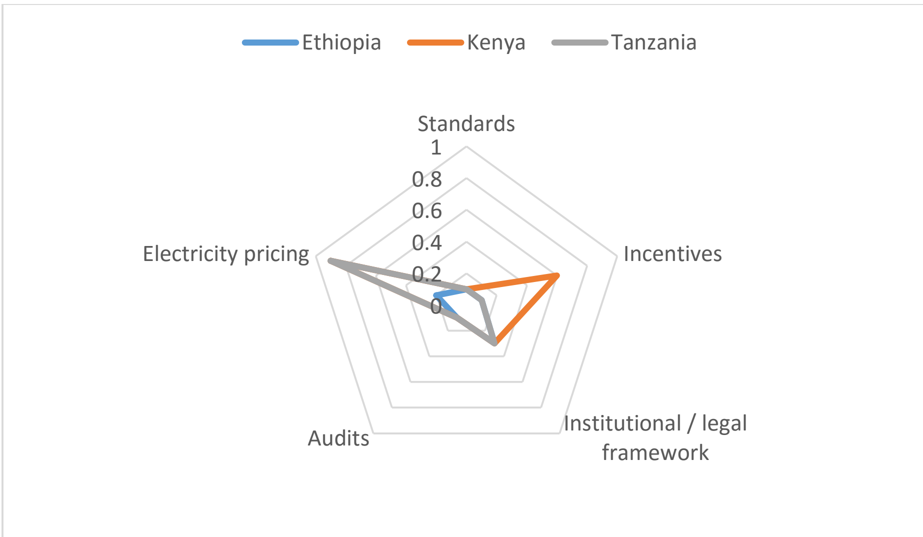




*Figure 6.2: Renewable energy gaps (top) and Energy efficiency gaps (bottom) in selected countries of Eastern Africa*

**Renewable energies**

*Policy/regulation*

*Grid code and access*

There is a gap in the planned renewable energy capacity and the lack of regulation regarding the prioritization of renewable energy electricity generation access to the grid.

Also there is no specific operational rules for managing renewable energies especially regarding grid code.

Regarding Carbon Pricing Mechanism, the country has not yet set legally binding greenhouse gas emission reduction target.

*Available detailed renewable energy atlas*

There is no detailed renewable energy atlas of the country published.

**Energy efficiency**

*Policy/legal framework*

The country has not yet established energy efficiency target at national level, and do not have energy efficiency legal framework.

*Strategy*

There is no incentive mechanisms in place especially for energy supply utilities toward investments in energy efficiency.

There is no schemes regarding energy efficiency labelling or building energy codes yet adopted. As well no minimum performance standards regarding electric appliances are in place.

*6.1.2.2 Ethiopia*

**Renewable energies**

The energy plan of the country even though, focuses on a mix on renewable energy resources available (hydro, geothermal, solar and wind), is strongly relying on hydropower for the years to come notwithstanding the water level variability for the next years due to climate change; as well the small interest in solar PV is also to acknowledge.

*Institutional / legal framework*

There is a lack of legal framework regarding the development of renewable energies.

*Regulatory/policy*

The country regulatory framework regarding the deployment of renewable energies, is mainly based economic instruments (capital investment, tax reduction, public investment). The regulatory instruments are not yet established (FIT, or Auctions, etc).

There is no bidding or auctions to promote renewable energies.

There is no incentives regarding the development of distributed generation or net metering regulatory policy.

*Grid access and renewable energy atlas availability*

There is a gap in the planned renewable energy capacity and the lack of regulation regarding the prioritization of renewable energy electricity generation access to the grid.

Also there is no specific operational rules for managing renewable energies especially regarding grid code.

There is no detailed renewable energy atlas of the country published.

**Energy efficiency**

*Policy / legal framework*

There is no target at national level regarding energy efficiency despite the policy in place.

*Plans/strategies*

The sub-sector of energy efficiency, though having in place policy in place, does not harvest the huge potential it has. Despite the promotion of energy efficiency through the promotion of CFLs, in the country, there is no regulation yet in place to extend it the appliances with highest potential through energy labelling systems, and to the building sector through energy building code and audits.

There is no incentives or mandate in place for energy supply utility, public entities and large consumer to invest in energy efficiency.

*6.1.2.3 Sudan*

**Renewable energies**

*Regulatory/policy framework*

Even though the country has established dedicated authority for the regulation of the electricity sector, the country has so far not established or not detailed regulatory mechanisms in force in other to frame the deployment of renewable energies he is planning.

**Energy efficiency**

*Policy*

There is a gap between the projected ambitious plan and the actual state. The country has not yet established policy measures regarding energy efficiency.

*6.1.2.3 Tanzania*

**Renewable energies**

*Regulatory / policy framework*

The country has not yet defined renewable energy target; however, there is a planned share of renewable energies in total capacity.

The country, apart from FiT in place, do not have any other established regulatory instruments in place. Economic (fiscal) instruments are also part of the regulatory instruments landscape.

*Grid access and renewable energy atlas availability*

There is a gap in the planned renewable energy capacity and the lack of regulation regarding the prioritization of renewable energy electricity generation access to the grid.

Also there is no specific operational rules for managing renewable energies especially regarding grid code.

There is no detailed renewable energy atlas of the country published.

**Energy efficiency**

*Policy / legal framework*

There is no policy in place regarding the promotion of energy efficiency in the country resulting in a lack of national target and legal framework.

*Plans/strategies*

There is no incentive measure toward the increase /promotion of energy efficiency at both suppliers and end users levels.

There is no minimum performance standards in place for common electric appliances. Also, energy labelling standards systems and mandatory energy audits for public entities, utility and large scale consumers are not in place.

There is no incentives or mandate in place for energy supply utility, public entities and large consumer to invest in energy efficiency.

6.1.3 Northern Africa:

There is a set of gaps that have been highlighted in the selected countries of the region regarding renewable energies and energy efficiency. These gaps are displayed in the figures below.


*Figure 6.3: Renewable energy gaps (top) and Energy efficiency gaps (bottom) in selected countries of Northern Africa*

### *6.3.1.1 Algeria*

**Renewable energies**

*Regulatory framework*

There is gap in renewable energies regarding the lack of net metering schemes as regulatory instruments in order to promote distributed generation.

**Energy efficiency**

*Plans/strategies*

Regarding electricity pricing, it is still obvious the subsidized character of electricity tariffs from natural gas generation. There is also no special tariff in place for households to promote rational use of electricity.

There is also a lack of energy audits in the residential and the tertiary sectors.

*6.3.1.2 Tunisia*

**Renewable energies**

Regulatory framework

There is to date no competitive bidding (auctions) in place to promote the development of renewable energies.

*Grid code and access*

Though there is a grid code already developed in the country, there is still no priority access to the grid for electricity generated from renewable energy.

*Available detailed renewable energy atlas*

There is no detailed solar atlas of the country published in the country.

*6.3.1.3 Mauritania*

**Renewable energies**

*Policy / legal framework*

There is no dedicated legal framework for renewable energy development, however the sector is framed under the general electricity code.

*Regulatory framework*

There is no regulatory instruments in place in the country to further improve the development of renewable energies.

*Grid code and access*

There is no grid code in place regarding renewable energy and no priority access to the grid for renewable energy electricity generation.

*Available detailed renewable energy atlas*

There is no available detailed renewable energy atlas for both solar and wind published.

**Energy efficiency**

*Policy / legal framework*

The country has not defined target regarding energy efficiency and do not have existing legal framework on energy efficiency.

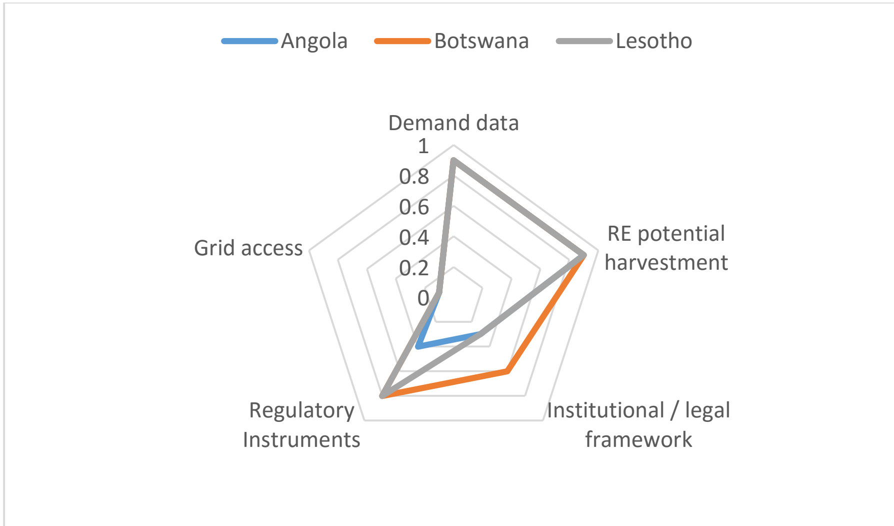
*Plans/strategies*

Electricity tariffs in place in the country do not reflect the generation costs with subsidies applied. Also, there is no incentives in place for the adoption of efficient consumption pattern from the consumers.

No mandatory energy audits are in place for the building sector and public entities.

### 6.1.4 Southern Africa

There is a set of gaps that have been highlighted in the selected countries of the region regarding renewable energies and energy efficiency. These gaps are displayed in the figures below.



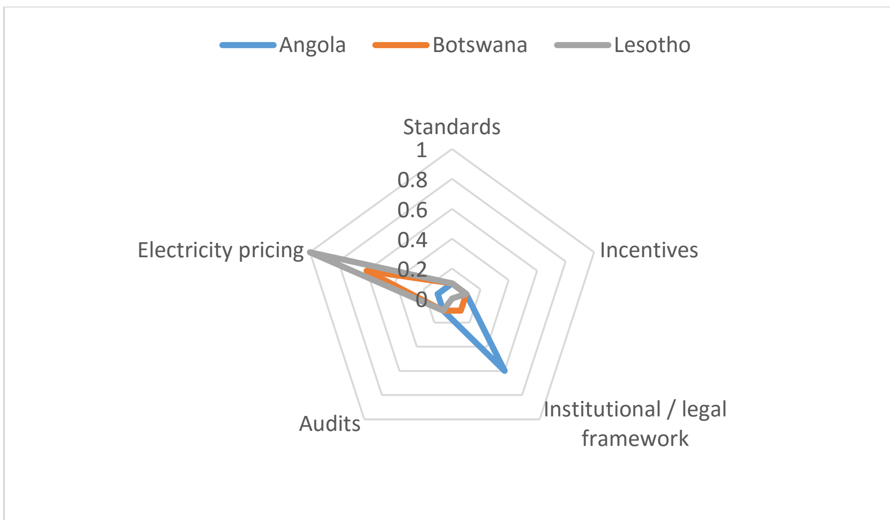




*Figure 6.4: Renewable energy gaps (top) and Energy efficiency gaps (bottom) in selected countries of Southern Africa*

### *6.1.4.1 Angola*

**Renewable energies**

The planned generation capacity scheme of the country reveals an over reliance on hydro power resource in the electricity mix as far as renewable energy are concerned. It is important to acknowledge the high potential of solar energy, wind energy and biomass in the country, contrasting with their planned capacity contribution in the mix of only 3%.

*Institutional / legal framework*

There is no established authority in place dedicated to the promotion and the deployment of renewable energies, and the legal framework is still undeveloped.

*Regulatory and policy framework*

The regulatory framework landscape is based on fiscal incentives mainly tax reduction, while enabling regulatory instrument such as FIT could of great importance especially in the country context where the electricity tariffs applied are subsidized. Also there is no auctions nor net metering in place to promote renewable energies.

*Grid access and renewable energy atlas availability*

There is a gap in the planned renewable energy capacity and the lack of regulation regarding the prioritization of renewable energy electricity generation access to the grid.

Also there is no specific operational rules for managing renewable energies especially regarding grid code.

**Energy efficiency**

*Policy / legal framework*

The country has not yet established policy regarding the promotion of energy efficiency. Despite, a legal framework in place, there is no established authority yet in place.

*Plans/strategies*

There is no incentive relative to the promotion of energy efficiency. As well, no energy audits for utility supplier, public entities or large scale consumers have been put in place.

No minimum performance standards have been set regarding common electric appliances, as well, there is no labelling standard in place.

Electricity tariffs applied in the country are subsidized, especially electricity generation from fossil fuel.

*6.1.4.2 Botswana*

**Renewable energies**

There is a gap between the expected renewable energy target the country is planning to achieve (25%) and the planned capacity scheme with a contribution of solar (the only renewable energy in consideration) plants capacity of only 100 MW (7%) of the total capacity despite the solar potential the country is endowed of.

*Institutional / legal framework*

Botswana does not have dedicated agency in place for promoting renewable energies. However, the authority has been created and is in the process of being established.

*Regulatory and policy framework*

The country records various regulatory instruments regarding renewable energy development (FiTs and auctions). However, there is no net metering in place to foster develop distributed generation especially for solar PV development.

*Grid access and renewable energy atlas availability*

There is a gap in the planned renewable energy capacity and the lack of regulation regarding the prioritization of renewable energy electricity generation access to the grid.

Also there is no specific operational rules for managing renewable energies especially regarding grid code.

There is no detailed renewable energy atlas of the country published yet, however they are under development.

**Energy efficiency**

*Policy / legal framework*

There is no defined policy regarding energy efficiency. Therefore, no legal framework and dedicated authority to promote energy efficiency.

*Plans/strategies*

There is no incentive relative to the promotion of energy efficiency. As well, no energy audits for utility supplier, public entities or large scale consumers have been put in place.

No minimum performance standards have been set regarding common electric appliances, as well, there is no labelling standard in place.

Electricity pricing in the domestic residential sector are subsidized.

*6.1.4.3 Lesotho*

Lesotho projected power demand and generation capacity are in adequacy even though there is a small surplus in generation capacity of about 5 MW compare to the projected demand.

**Renewable energies**

*Institutional / legal framework*

There is no established authority in place dedicated to the promotion and the deployment of renewable energies, and the legal framework is still undeveloped.

*Regulatory and policy framework*

The regulatory framework landscape is based on fiscal incentives mainly capital subsidies and tax reduction and regulatory instruments (auctions and net metering). There is no FiT in place in the country.

*Grid access and renewable energy atlas availability*

There is a gap in the planned renewable energy capacity and the lack of regulation regarding the prioritization of renewable energy electricity generation access to the grid.

Also there is no specific operational rules for managing renewable energies especially regarding grid code.

There is yet no renewable energy atlas in the country. However, the wind atlas is under development.

**Energy efficiency**

*Policy / legal framework*

There is no defined policy regarding energy efficiency. Therefore, no legal framework and dedicated authority to promote energy efficiency.

*Plans/strategies*

There is no incentive relative to the promotion of energy efficiency. As well, no energy audits for utility supplier, public entities or large scale consumers have been put in place.

No minimum performance standards have been set regarding common electric appliances, as well, there is no labelling standard in place.

### 6.1.5 Western Africa

There is a set of gaps that have been highlighted in the selected countries of the region regarding renewable energies and energy efficiency. These gaps are displayed in the figures below.

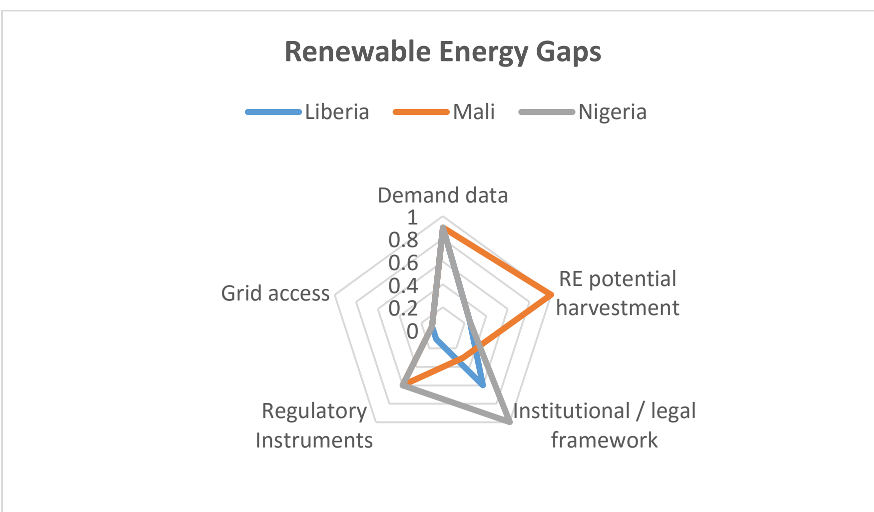



*Figure 6.5: Renewable energy gaps in selected countries of Western Africa*

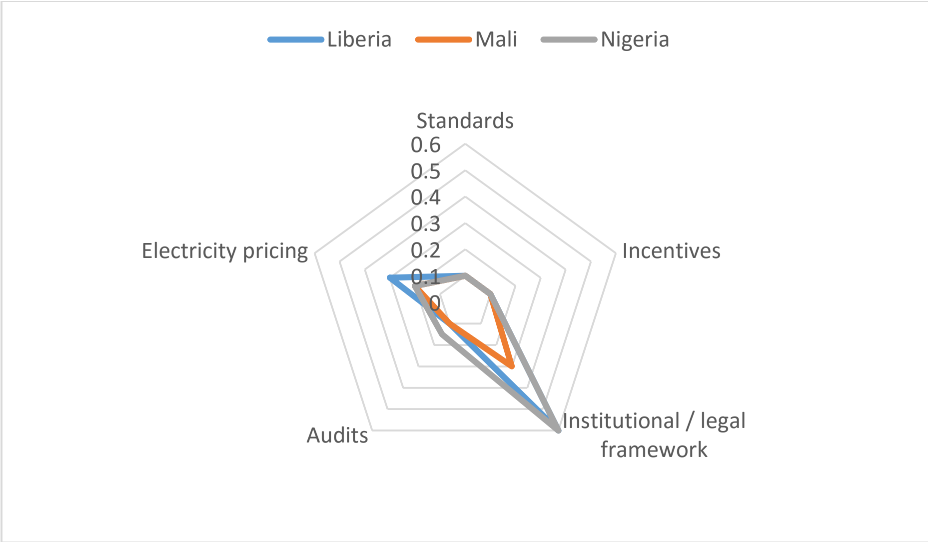



*Figure 6.6: Energy Efficiency gaps in selected countries of Western Africa*

#### *6.1.5.1 Nigeria*

**Renewable energies**

*Regulatory framework*

There is no competitive bidding or auctions in place in the country for renewable energy promotion.

*Grid access*

There is no grid code and standards in place for the integration of renewable energy based generation in the network.

*Available detailed renewable energy atlas*

There is no renewable energy atlas yet published by the government.

**Energy efficiency**

*Policy / legal framework*

There is no legal framework yet in force regarding the promotion of energy efficiency in the country, though it is in development.

*Plans/strategies*

There is no incentive relative to the promotion of energy efficiency. As well, no energy audits for utility supplier, public entities or large scale consumers have been put in place.

No minimum performance standards have been set regarding common electric appliances, as well, there is no labelling standard in place.

Electricity tariffs applied in the country are subsidized, especially electricity generation from fossil fuel. Electricity generation from fossil fuel are subsidized for all sectors of the society.

*5.1.5.2 Mali*

**Renewable energies**

There is a gap between the country ambition and the strategies regarding renewable energies. The country electricity expansion plan does not consider renewable energies as well as the current transmission expansion plan.

*Institutional / legal framework*

There is no specific legislation in place for renewable energy development despite the National Strategy for the Development of Renewable adopted in 2006.

*Regulatory framework*

There is no competitive bidding or auctions in place for the development of renewable energies, also, there is no FIT nor net metering schemes in place to support distributed generation.

*Grid access and Available detailed renewable energy atlas*

The country has not yet set proper grid code which integrates renewable energy generation expansion. There is no priority regarding access of electricity generation to the grid already defined.

**Energy efficiency**

*Policy / legal framework*

There is no defined policy and legal framework yet in force regarding the promotion of energy efficiency in the country, though it is in development.

*Plans/strategies*

There is no incentive mechanisms in place to invest in energy efficiency for energy supply utilities, public entities and large scale consumers.

There is no schemes regarding energy efficiency labelling or building energy codes yet adopted.

There is no established minimum standard (performance) regarding commonly used electric appliances.

Electricity generation from fossil fuel is subsidized for all types of consumers from domestic to industrial consumers.

*6.1.5.3 Liberia*

**Renewable energies**

Policy / legal framework

The policy and legal framework of the country has been partly established with a legal framework in force as well as a target definition. However, there is still a lack of an agency dedicated to promote the renewable energies, though, there is an agency in place for renewable energy promotion but with focus only on rural sector development.

*Regulatory framework*

Regarding the regulatory framework, there is a gap between the planned expansion of the electricity generation capacity mix and the place renewable energies should play and the regulatory instruments in force in the country. Indeed, the country has not yet established instruments aiming at promoting the renewable energies such as FiT, auctions or public finance mechanisms such as fiscal incentives or tax relief scheme.

*Grid access Available detailed renewable energy atlas*

The country has not yet developed specific grid code for renewable energy electricy based generation. Also, there is a lack of regulation regarding the prioritization of renewable energy electricity generation access to the grid.

In addition, there is no publicly available renewable energy atlas with attention to the available renewable energy resources in the country.

**Energy efficiency**

*Policy / legal framework*

The policy and legal framework of the country with regard to energy efficiency is lacking an established legal framework to promote the latter in a context where the country has set target and policy in the sector.

*Strategy*

As strategy, the country has not yet established any strategy aiming at promoting the sector. Indeed, there is no incentives in place for large scale energy users and public entities regarding the investment in energy efficiency.

There is no standards yet adopted regarding energy labelling systems, minimum performance of electric appliances and building energy codes.

## 6.2 Energy planning needs

The countries of the continent in their respective development plans established action plans and strategies with regard to the development of their economy. In the energy sector, plans have been developed, however there are a set of readjustments which would have to be done for the implementation of the desired or more update plans.

In this regard, there are some needs which African countries in the development and implementation of their different agendas would require in order to achieve their objectives.

### 6.2.1 Institutional and human capacity

In term of institutional and human capacity, it appears that at least 35% of the ministries in charge of energy on the continent require capacity development in the following areas: institutional design, resource assessment, investment and project finance, policy design and energy planning.

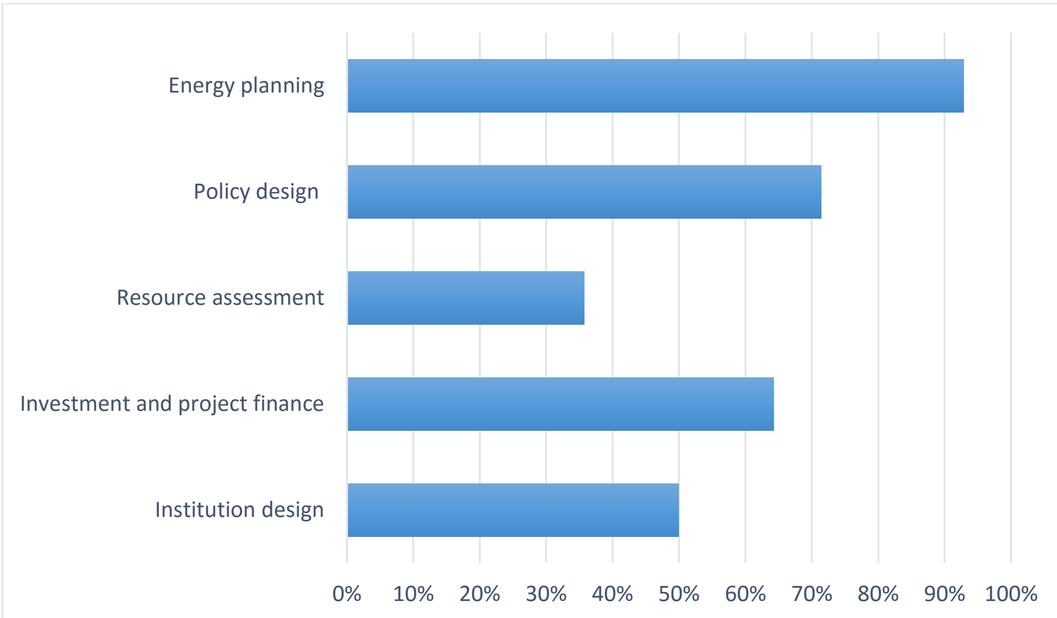



*Figure 6.7: Institutional & human capacity needs*

Furthermore, area such as policy design and energy planning revealed laager needs especially in the context that is the one of Africa today.

In the area of policy design, African countries, engaged in the development of their energy sector with a high contribution of renewable energies do not have well defined policies to frame the development expected. Indeed, of the country surveyed, 11.76% did not develop National Energy Plan toward the development of energy sector; regarding renewable energies, though being part of the development plan of these countries, 23.53% do not have renewable energy target. Moreover, acknowledging the role energy efficiency should play alongside with the development of renewable energies, the policies regarding energy efficiency are still in their early stage and to date, 76.47% of the countries do not have clear incentives for the promotion and the improvement of the energy efficiency.

### 6.2.2 Energy planning needs

Regarding specifically to energy planning, some areas have been scrutinized such as availability upstream of the planning process of demand projection, the use of energy planning tools to support the planning activities.

*Data on electricity demand projection*

On the availability of data relative to demand projection, it appears that about a quarter of the countries do not have available data reading electricity demand projection.

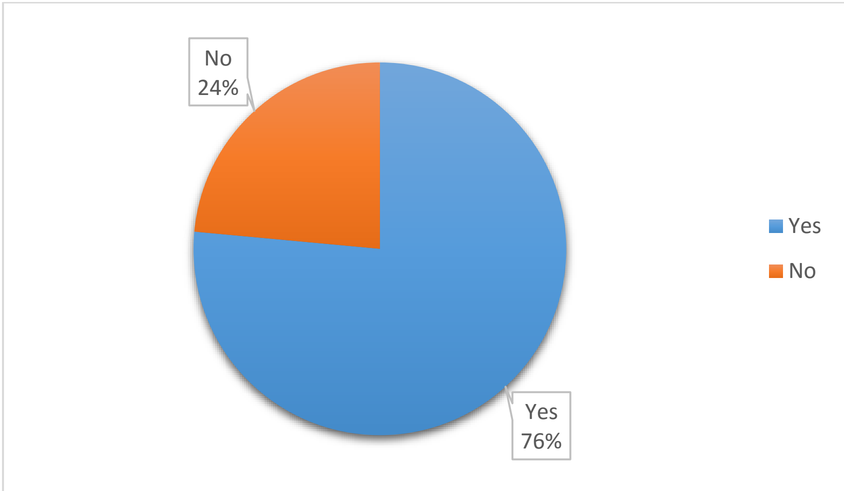



*Figure 6.8: Availability of electricity demand projection*

*Energy planning tools*

The need of energy planning tools is an emergency today more than ever. They are of great importance in supporting countries' energy policy and development. In fact, their use is very crucial for the incorporation of renewable energy power in generation and transmission plans and for the development and update of different energy plans at country and power pool levels respectively while including cost effective renewable technologies options.

In that regard, looking at the rate of use of these tools in content, it comes that the use of energy planning tools are not well established in the planning process. Indeed, around 64% of ministry of energy do not use energy planning tools in the design and planning process of future energy sector development. However, more than half of the respondents do use them with the most used being MAED (Model for Analysis of Energy Demand) developed by IAEA, MESSAGE and WASP.

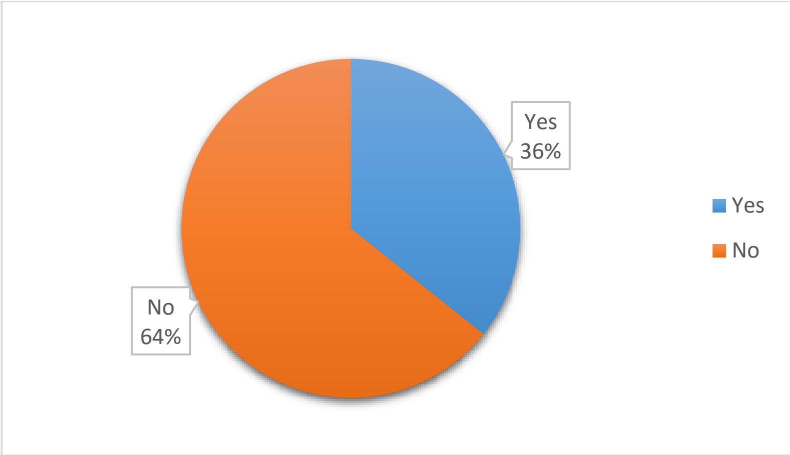



*Figure 6.9: Use of energy planning tools*

*Availability of sufficient skilled human resource for energy planning tools' use*

Regarding the effective use and application of the planning tools, more specifically the availability of skilled human resource for their used, slightly more than a third of the organizations do have enough human resource for their effective use.

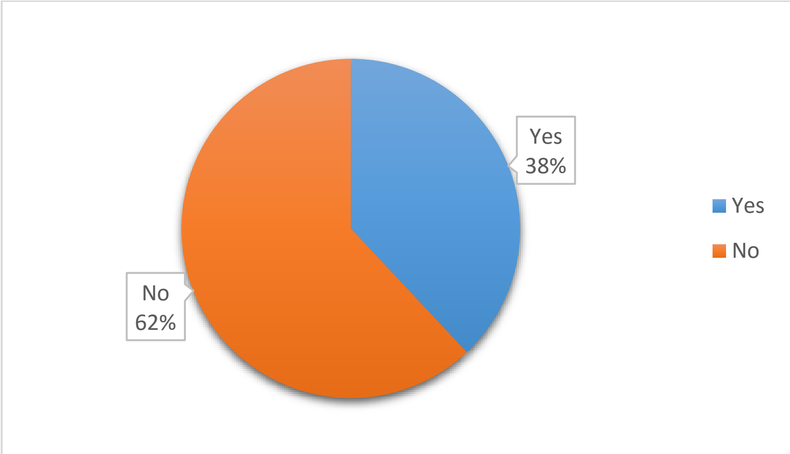



*Figure 6.10: Availability of skilled human resource for the use of planning tools*

### 6.2.3 Need for good enabling environment

The gaps identified in the gaps analysis shown above regarding the enabling environment suitable for the deployment of renewable energies in the continent showed the important need for African countries to develop and build an Enabling environment for renewable energy investments with:

- The creation of frameworks in order to open markets to the private sector, through Independent Power Producers,
- The reduction of cots of renewable energy power financing with establishing of policies to decrease their investments costs especially through domestic supply different components involved in energy systems,
- The facilitation of renewable energy power trade within regions (among countries) and among the different regions of the continent.

# 7. Strategic Approach

In the overall objective of achieving the overall targets countries assigned to themselves, there is a need to addressing the concerns and needs highlighted in the previous sections, especially regarding the use of energy planning tools to better design and planned their electricity mix in an optimal way.

## 7.1 The opportunity of open source energy modeling tools

There are a set of features which make the attractiveness of open source energy community as compare to traditional licensed models.

### *7.1.1 Repeatability*

Open source energy models offer the possibility to the energy community to repeat/check analysis (experiment) made using a model to insure that effectively the results have a scientific character. In the scientific world, results need to be checked once or many times in other to lead to a general consensus. We can recall this though of Henry (1997): "experiments like mathematics, are not self-evidently true. To be convince of their truth, you either have to know what you are doing, or accept them on faith." This reinforce the repeatability character of experiment which has to be done in other to obtain any scientific outcome. Thus, access to the source code of energy models enable analysts to know actually what is going on in the process of outcome generation; knowing what are the different equations which are computed in other to get the model outcomes and what are the different sequences the model follows in generating those results.

### *7.1.2 Model improvement and credibility*

Open source models as their structure suggest, allow analysts and developers from third party (external community) to access the source code. Therefore, they can get inside the thousand lines of code describing the model and scrutinize it to check whether they are mistakes or not in the source code elaboration, as it is defined, in other to produce the expected results. This additional expertise from external users sometimes lead to highlight some errors. Creating thereby a climate of confidence is more likely to be built as regard to the model, which will lead to its adhesion or even its adoption by the energy community and policy makers. Regarding this aspect projects developed with open source models are experiencing remarkable wealth (Wiese, 2015).

Openness of source code with the implied interactivity of the energy community analysts and experts will lead to highlight some of the lacks and gaps contained within the model code. It will help identifying hidden mistakes in the model mathematical formulation of the code; or even bugs inherent in it. Therefore, the dynamic participation of developers both internal and external will enable and imply model revision, development and improvement and ideally help the model to reach an error-free state.

### *7.1.3 Flexibility*

Models which follow the open source principles, allow public users and energy analysts can scrutinize the different parts of the code defining the models, modify the code and even distribute it. Therefore, there is a freedom after having understood and mastered how the models have been built, and run, to customize the models in such a way that they address specific needs. This aspect open source models offer, is of great importance since most of these models are designed for developed countries perspectives with their specificities and can allow the expansion of the models to other geographical area (developing world) and in Africa more specifically

Moreover, they can allow through their structure, the integration within larger traditional models which have been used for many years, and one which have been modelled number of projects. An example, is the case of the OSeMOSYS which can be integrated into more established energy models such as LEAP. In this regard, OSeMOSYS has been used to support national energy planning in South Africa (Bazilian, et al., 2012).

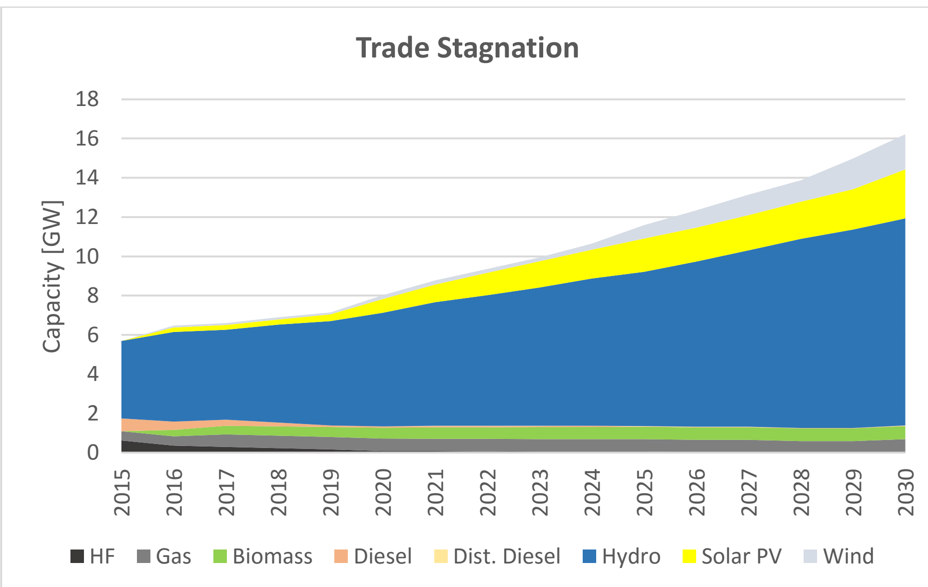
### *7.1.4 Low cost*

Not less important than the previous items discussed above, the cost parameter of open source energy models is a reason why open source are preferred to traditional proprietary energy models. Indeed, they are available in most of the cases[28] at cost free, on a web portal. Though, there could be some restrictions regarding the use of the code even when it is accessible. Some open source energy model require software such as solver which need to be purchased. But still it represents a greater advantage compare to traditional, proprietary energy models which are commercially available.

## 7.2 Case study: Central African electricity mix using OSeMOSYS

### 7.2.1 Generation capacity mix

In response to addressing the chronic lack of access to electricity in the region, major investments would be required in power generation capacity. As shown in the Figure 7.1 below, the power installed capacity will increase from its current value of 5.62 GW to 16.21 GW and 16.15 GW in 2030 in the Trade Stagnation and in the Trade Expansion scenarios respectively.




[28] There are tools which allow open source code access though under some conditions.

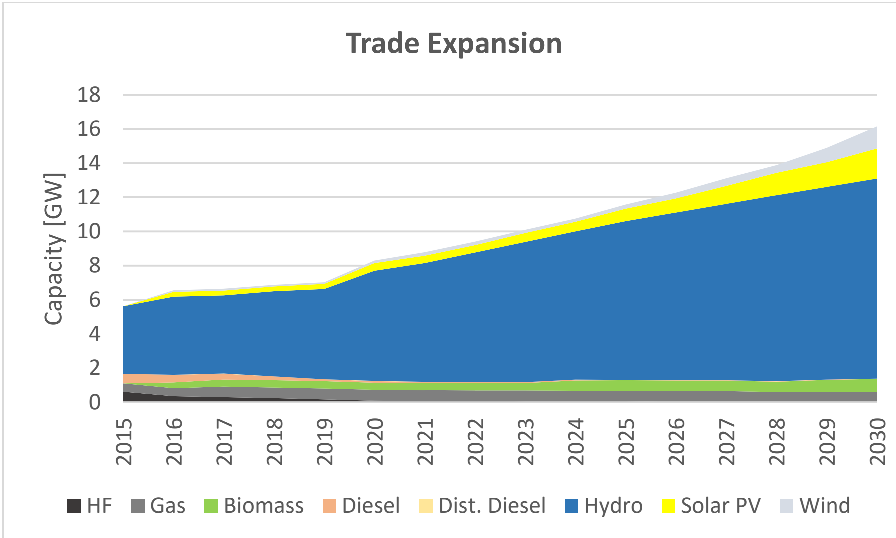



*Figure 7.1: Evolution of total installed capacity in the region in Trade Stagnation (top) and Trade Expansion (bottom)*

In both scenarios, significant generation capacity addition are made in renewable energies, with hydropower accounting for the largest share with an expansion from 4 GW in 2015 to 10.5 GW and 11.7 GW by 2030 respectively in the Stagnation and Expansion scenarios. The expansion of other renewable energy as well are remarkable, solar and wind expansion record the most remarkable expansion from a non-existing contribution in the generation capacity to 15% and 11% in the Stagnation scenario, and to 11% to 8% in the Expansion one by 2030 respectively. Regarding fossil fuels based generation capacity, no further investments are made with a limitation in the use of Heavy fuel based generation, as well as Diesel ones.

### 7.2.2 Electricity generation mix

In the Trade stagnation scenario, of the total of 65.5 TWh generated in the region, only 0.5 TWh contribute to trade between DRC and Congo. Hydro power generation will constitute the largest share in the mix about 80% while gas-fired generation will continuously decrease; being replaced by biomass and wind generation to reach a 5% share in the mix as shown in the Figure 7.2 below.

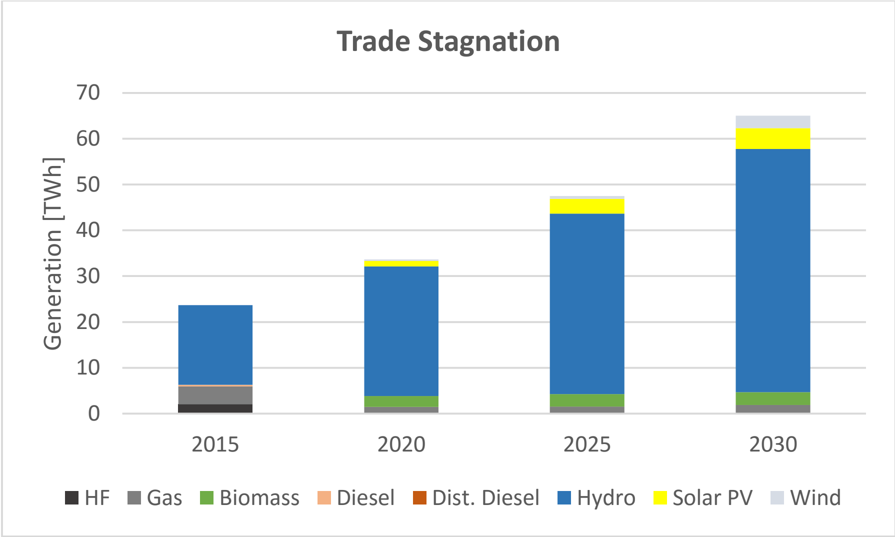



*Figure 7.2: Evolution of electricity generation in the region in Trade Stagnation scenario*

The Trade Expansion scenario will see significant increase in electricity generation and in the electricity trade volume. Of the 74 TWh generated, 9 TWh will contribute to trade within the region by 2030 based on further generation from hydropower. Contribution of gas-fired generation will gradually decrease to a negligible contribution in the mix replaced by renewable energy development including more specifically hydro as shown in Figure 7.3.

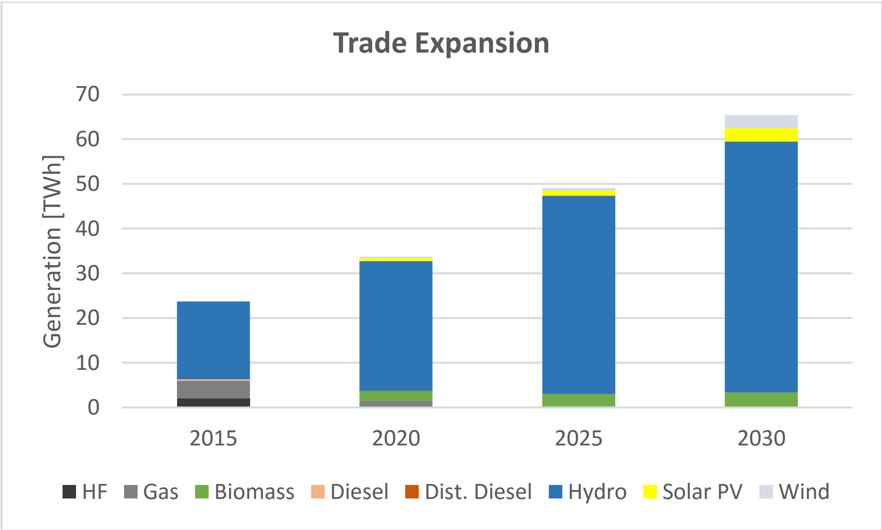
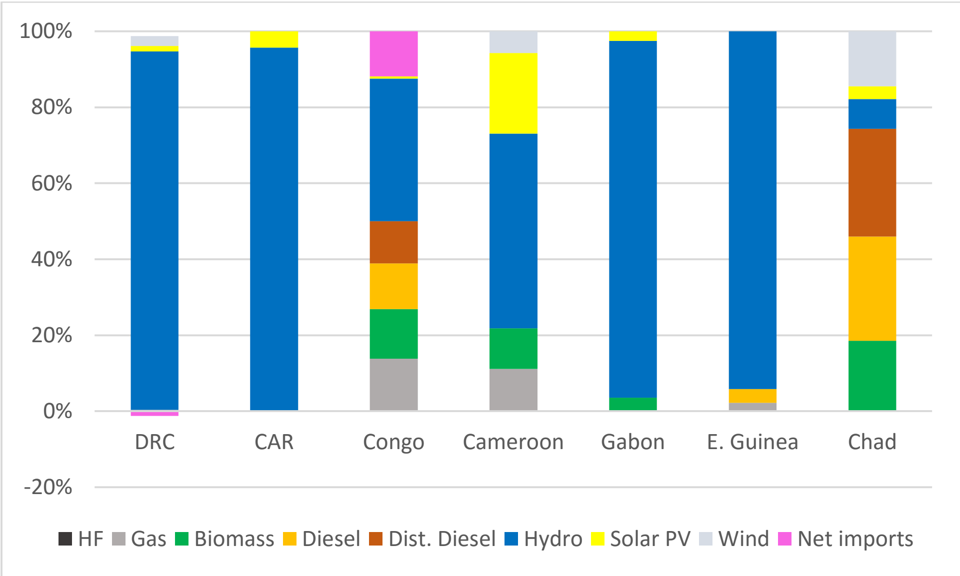



*Figure 7.3: Evolution of electricity generation in the region in Trade Expansion scenario*

As compare to the Stagnation scenario, where trade is limited among countries in the region, here, the availability of more inter-connexion among countries, will give the opportunity to countries with small electricity demand to become net exporters. Indeed, the Figure 7.4 below show that in 2030, Chad, Gabon and Congo become net exporters with exports reaching 9%, 13% and 57% of their electricity demand respectively. Therefore, this could help small countries in developing their infrastructures while taking at the same time advantage of the savings potential linked to trade.



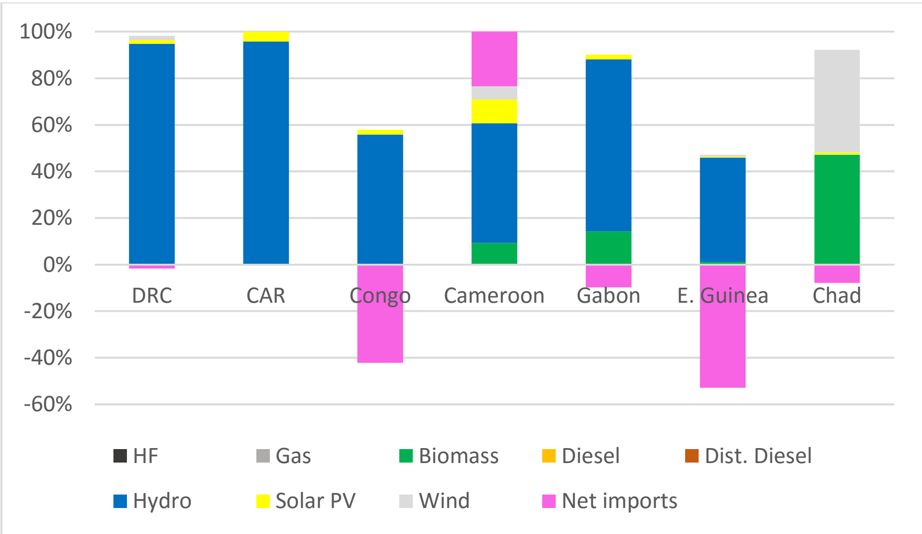




*Figure 7.4: Generation mix of countries in the region in 2030 in Trade Stagnation (top) and Trade Expansion (bottom)*

### 7.2.3 Financial requirements

In order to achieve more grid integration in the region, investments are required with operation and maintenance costs as well as fuel costs. The total costs of generation including the above mentioned parameters will slightly decrease in the Trade Expansion scenario compare to the Trade stagnation one. In the earlier years the total system costs in the Expansion scenario will be higher due to high amounts of investments required to build the new infrastructures. However, as from 2021, the total system costs will become lower in the Expansion scenario as a result of a decrease in expenditures related to fuel consumption. The total model period cost savings will be in the range of 600 million USD and the total system costs evolution throughout the model period is shown in the Figure 7.5 below.

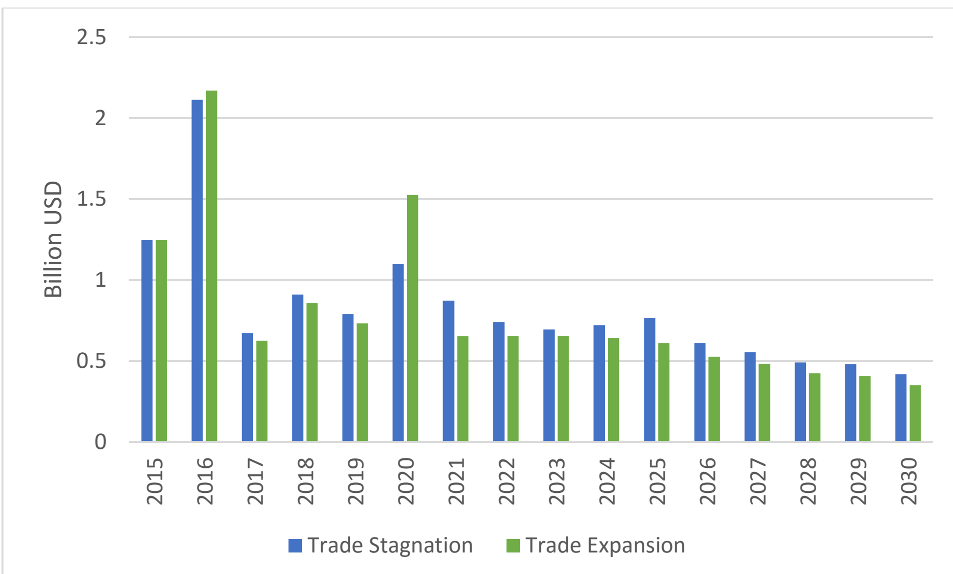



*Figure 7.5: Total system discounted costs of the model period in the region*

# 8. Conclusion and suggestions for further work

## 8.1 Conclusion

This study was based on basically review and survey of African countries' electricity development plans in order to evaluate the needs and gaps regarding investment planning. Different aspects were highlighted in this regard: the availability of data relative to demand projection, the adequacy of the planned capacity with regard to the available resources and the existence of a good enabling environment to frame the planned capacity expansion. Also it reviewed some of the different energy planning tools available to support the planning process, looking at traditional licensed tools as well as open source tools summarizing some of their characteristics.

The study shows that in their electricity sector development plans, Northern African countries though recording the largest capacity planned record less gaps both in term of data availability and planned capacity adequacy with regard to resource potential. Moreover their enabling environment for RE sector development is well established. In contrast, the Central African region regarding these same aspects still have a lot to do as far as planned capacity adequacy and resource potential is concerned and more importantly regarding the establishment of a good enabling environment.

As regard to the needs, it appears that at least half of the countries in the continent required capacity building in the areas of institution design, policy design and in energy planning. More specifically with regard to energy planning, about two third of the respondents do not use planning tools to support their sectorial development policies. In addition to that, there is a need to develop skilled human resource in order to be able to use these tools. Aside of this need of using tools there is the fundamental need of developing and establishing good enabling environment in the continent.

The study in reviewing some energy models shows that both traditional licensed and open source energy planning tools are more or less equivalent addressing the same areas, same geographical and both with ability to cope with specific policies including (non-priced and price-induced). Moreover open source tools can offer even more flexibility in adapting themselves to specific conditions while offering the advantage of being sometimes freeware. In addition to data, a demonstration of the capability of open source was made based on OSeMOSYS to develop an alternative electricity development plan for the Central African region based on the available resource potential. It shows that cost effective electricity development plan are possible and highlights the importance and the benefits of enabling power trade while designing and planning electricity sector development.

## 8.2 Suggestions for further work

This study is designed to assess the needs and gaps for energy capacity development and proposed alternative sector development pathway using open source energy planning models. Alternative sector development pathway which was for this study based on generic data due to the lack of ground based data regarding demand projection, fuel costs, technology costs, etc.

The work done in the study could be carried further in developing countries' electricity demand projections based on their different development objectives and targets, and developing optimized cost-effective electricity development path ways that take into account countries' specific realities and customized technology options.

# References

AECOM International Development. (2011). *Clean Energy Capacity Needs: Botswana, Mauritius and Namibia.* USAID/Southern Africa.

AEEP. (2014). *Status Report.*

Algeria. (2015). *Intended National Determined Contribution.*

ANME. (2012). *Nouvelle version du Plan Solaire Tunisien.*

Bazilian, M., Rice, A., Rotich, J., Howells, M., DeCarolis, J., Macmillan, S., . . . Liebreich, M. (2012). Open source software and crowdsourcing for energy analysis. *Energy Policy, 49*, 149-153.

Beuzekom, I., Gibescu, M., & Slootweg, J. (2015). A review of multi-energy system planning and optimization tools for sustainable urban development. *IEEE*.

Birol, F. (2016). *The role of energy access in meeting Africa's Sustainable Development Agenda.*

Blume, B. D., Ford, J. K., Baldwin, T. T., & Huang, J. L. (2010). Transfer of training: A meta-analytic review. Journal of Management. *36 (4)*(2010), 1040-1064.

Boris Schinke, J. K. (2016). *Project: Middle East North Africa Sustainable ELECtricity Trajectories (MENA-SELECT): Country fact sheet Morocco.*

Bouille, D. and McDade, S. (2002). *Capacity Development, in Energy for Sustainable: A policy Agenda.* New York: UNDP.

Canada, N. R. (2016, April 18). *RETScreen*. Retrieved April 18, 2016, from http://www.nrcan.gc.ca/energy/software-tools/7465

Connolly, D., Lund, H., Mathiesen, B., & Leahy, M. (2010). A review of computer tools for analysing the integration of renewable energy into various energy systems. *Applied Energy, 87*, 1059-1082.

Constantinos Taliotis, A. S. (2016). An indicative analysis of investment opportunities in the African electricity supply sector - Using TEMBA (The Electricity Model Base for Africa). *Energy for Sustainable Development*, 50-66.

Cormio, C., Dicorato, M., Minoia, A., & Trovato, M. ((2003). A regional energy planning methodology including renewable energy sources and environmental constraints. *Renewable and Sustainable Energy Reviews, 7*(2), 99-130.

Daniel, M., & Vania, M. (2016, July 7). Retrieved from www.usea.org: https://www.usea.org/sites/default/files/event-file/497/South_Africa_Country_Presentation.pdf

Department of Development and Planning, Aalborg University. (2016, April 23). *NEMS*. Retrieved April 10, 2016, from http://www.energyplan.eu/othertools/national/nems/

Dirk Aßmann, Ulrich Laumanns and Dieter Uh. (2006). *Renewable Energy: A global review of technologies, Policies and Markets.* London: EARTHSCAN.

ECREE. (2012). *A Study of Capacity Needs for Renewable Energy and Energy Efficiency in the ECOWAS Member States.* ECREE.

ECREEE. (2015). *Liberia presentation ECOWAS sustainable energy policy and investment high level forum.*

eia. (2003). *The National Energy Modeling System: An Overview 2003.* EIA. Retrieved from http://www.eia.doe.gov/oiaf/aeo/overview/index.html

Enemark, S., & Ahene, R. . (2002). Capacity building in land management – Implementing land policy reforms in Malawi. *Paper presented at the FIG XXII International Congress. Washington DC*.

Energypedia. (2016). *The role of Capacity Needs Assessments for the accelerated deployment of renewable energy.* Retrieved March 30, 2016, from https://energypedia.info/images/5/5e/II_Concept_Paper_Capacity_Needs_Assessment_WG.pdf

Foell, W. K. (1985). Energy planning in developing countries. *Energy policy*, *13*(4), 350-354.

Geothermal Energy Association. (2016). *US-East Africa Geothermal Partnership (EAGP)*. (Geothermal Energy Association) Retrieved March 22, 2016, from http://www.geo-energy.org/EastAfrica/eagp.aspx

GIZ. (2015). *The Nigerian Energy Sector: An Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification.*

GlobalData. (2015). *Power Generation Technologies Capacities, Generation and Markets.* London.

Howells, M., Rogner, H., Strachan, N., Heaps, C., Huntington, H., Kypreos, S., . . . Roehrl, A. (2011). OSeMOSYS: The Open Source Energy Modeling System An introduction to its ethos, structure and development. *Energy Policy*, *39*, 5850–5870.

IEA. (2015). *World Energy Outlook.* IEA.

IEA. (2015). *World Energy Trends: Energy balances of non-OECD countries.* IEA.

iea. (2016). *Country Analysis Brief: Algeria.*

IEA. (2016, June 28). *IEA/IRENA joint policiesand measures database*. Retrieved from International Energy Agency: http://www.iea.org/policiesandmeasures/renewableenergy/

IEA. (2016, April 22). *Modern energy for all*. (IEA) Retrieved February 20th, 2016, from http://www.worldenergyoutlook.org/resources/energydevelopment/

ILO. (2011). *Study of occupational and skills needs in renewable energy: final report.* Geneva: International Labour Office (ILO).

IRENA - ETSA. (2015). *Hydropower Technology Brief.* IRENA - ETSA.

IRENA. (2012b). *Prospects for the African power sector.* Abu Dhabi: IRENA.

IRENA. (2012c). *Capacity Development Needs Giagnostics for Renewable Energy - CADRE.* IRENA.

IRENA. (2013). *West African power pool: planning and prospects for renewable energy.* Abu Dahbi.

IRENA. (2014b). *Estimating the renewable energy potential in Africa: A GIS approach.* IRENA.

IRENA. (2014c). *Renewable Energies Power Costs.*

IRENA. (2015a). *Africa 2030: Roadmap for a rnenewable energy future.* IRENA.

IRENA. (2015b). *Africa power sector: Planning and prospects for renewable enrgy.*

IRENA. (2015c). *African Clean Energy Corridor: Analysis of Infrastructure for Renewable Power in Eastern and Southern Africa.* IRENA.

IRENA. (2015d, March). *Capacity Needs Assessments for Rural Electrification.* Retrieved March 21, 2015, from http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=30&CatID=79&SubcatID=260

IRENA. (2015e). *Renewable Energy Capacity Statistics.*

IRNEA. (2014a). *Swaziland Renewable Energy Readiness Assessment.* IRENA.

Jacopo G. et al. (2014). Access to modern energy: A review of impacts evaluations. *Energy: resources and market*, 18.

Joomlashack. (n.d.). *Balmorel energy system*. Retrieved March 14, 2016, from http://www.eabalmorel.dk

Kahen, G. (1998). (1998). Integrating energy planning and techno-economic development: A solid basis for the assessment and transfer of energy technology to developing countries. *Energy sources, 20*(4-5), 343-361.

Kainumaa, M., Matsuokab, Y., & Morit, T. (2003). Analysis of Post-Kyoto Scenarios : The AIM Model. Retrieved from http://www.oecd.org/dev/1923103.pdf

LCEDN. (2016, July 19). *The READ project*. Retrieved from The Low Carbon Energy Development Network: http://thereadproject.co.uk/?page_id=22

Lund, H., & Munster, E. (2003). Modelling of energy systems with a high percentage of CHP and wind power. *Renewable Energy, 14*, 2179-2193.

Morocco. (2015). *Intended National Determined contribution.*

Moulot, J. (2015). *Regional Energy Infrastructure and Resilience: Case of PIDA.* NEPAD.

Nordhaus, W., & Sztorc, P. (2013). *DICE 2013R: Introduction and User's Manual.*

Olson, A., Schlag, N., Patel, K., & Kwok, G. (2014). *Capital cost review of power generation technologies.* San Francisco: Energy Environment Economics Inc.

Pascual Sanz, Veenstra, Wehn de Montalvo, van Tulder, Alaerts. (2013). What counts as ‘‘results” in capacity development partnerships between water operators? A multi-path approach toward accountability, adaptation and learning. *Water Policy, 15*, 242-266. Retrieved from http://dx.doi.org/10.2166/wp.2013.022.

Rad, F. (2011). *On Sustainability in Local Energy Planning.* Lund University.

Rao, S., & Riahi, K. (2006, September). The role of Non-CO2 greenhouse gases in Climate Change Mitigation: Long term scenarios for the 21st century. *Energy Journal*, *27*(09/2006), 177-200. Retrieved from https://www.researchgate.net/publication/46523215_The_Role_of_Non-CO2_Greenhouse_Gases_in_Climate_Change_Mitigation_Long-term_Scenarios_for_the_21st_Century

ren21. (2016, June 28). *REN21 Interactive Map* . Retrieved from http://www.ren21.net/status-of-renewables/ren21-interactive-map/

Republic of Cameroon. (2006). *Assistance au Ministère de l'Energie et de l'Eau dans l'élaboration du Plan de Développement à long terme du Secteur de l'Électricité* Horizon *2030 (PDSE 2030).*

Sastre Merino & de los Rios Carmenado. (2012). Capacity building in developing countries. *Procedia – Social and Behavioral Sciences, 46*, 960-967. Retrieved from http://dx.doi.org/10.1016/j.sbspro.2012.05.231

SE4ALL. (2014). *Kingdom of Swaziland Country Action Plan.*

SE4All. (2015). *Rapid Assessment and Gap Analysis: Angola.*

SINTEF. (n.d.). *EMPS - multi area power-market simulator*. (SINTEF) Retrieved 03 14, 2916, from https://www.sintef.no/en/software/emps-multi-area-power-market-simulator/

Sonelgaz. (2016, July 7). *Programme des énergies renouvelables*. Retrieved from Sonelgaz: http://www.sonelgaz.dz/?page=article&id=34

South Africa National Planning Comission. (2012). *NATIONAL DEVELOPMENT PLAN 2030: Our futur - make it work.*

Sparrow, F., & Bowen, B. H. (2005). *The CAPP Demonstration Long-Term Planning Model.* USA: Purdue University.

Subhes, C., Bhattacharyya, Govinda, & Timilsina, R. (2010). A review of energy system models. *IJESM, 4*(03 August 2010), 494-518.

The Infrastructure Consortium for Africa. (2011). *Regional power status in African power pools.*

The Total Shift Project. (2016, July 25-28). *The Total Shift Project*. Retrieved from The shift project data portal: http://www.tsp-data-portal.org/Breakdown-of-Electricity-Capacity-by-Energy-Source#tspQvChart

Themistocleous, G., & Wearne, S. H. (2000). Project management topic coverage in journals. *International Journal of Project Management, 18*, 7-11.

Thermal Energy System Specialists LLC. (2016). *TRNSYS transient system energy tool*. (TRNSYS) Retrieved April 18, 2016, from http://www.trnsys.com/#1

Turton, H., & Barreto, L. (2004). *The Extended Energy-Systems ERIS Model: An Overview*. IIASA.

UNDP. (2000). *The World Energy Assessment.* New York: UNDP.

UNDP. (2002). *Energy for sustainable development: A policy agenda.* New York: UNDP.

UNDP Capacity Development group. (2009). *Overview of UNDP's approach to supporting capacity development.* . UNDP.

UNECA. (2016). *Central Africa-Energy.*

UNFCCC. (2015). *Adoption of The Paris Agreement.* Paris: UNFCCC.

US DOE. (2003). *System for the Analysis of Global Energy Markets.* Washington DC: US DOE.

US DOE Office of Sciences. (2016, April 23). Energy and Power Evaluation Program (ENPEP-BALANCE). Argonne National Laboratory.

Vallejo B., Wehn U. (2016). Capacity Development Evaluation: The Challenge of the Results Agenda and Measuring Return on Investment in the Global South. *79*, 1-13.

WAPP. (2016, July 29). *Status of priority projects /2015.* Retrieved from West Africa Power Pool: http://www.ecowapp.org/?page_id=168

Webler, T., & Tuler, S. (2006). Four perspectives on public participation process in environmental assessment and decision making: Combined results from 10 case studies. *Policy Studies Journal, 4*, 699-722.

Wehn, U. (2014). Effective knowledge and capacity development for enhancing the post-2015 development goals. *International Development Studies Lecture Series 2014-2015.* University of Amsterdam.

Wene, C.-O., & Bo, R. (1988). A comprehensive energy model in the municipal energy planning process. *European Journal of Operational Research, 33*, 212-222.

Wiese, F. (2015). *renpass Renewanle Energies Simulation Pathways-Open source an approach to meet challenges in energy modelling.* University of Flensburg.

Wing, I. S., Daenzer, K., Fisher-Vanden, K., & Calvin, K. (2011). *Phoenix Model Documentation.* JGCRI. Retrieved April 14, 2016, from http://www.globalchange.umd.edu/data/models/phx_documentation_august_2011.pdf

World Bank. (2016, July 28). *RISE scoring methodology.* Retrieved from World Bank : http://rise.worldbank.org/methodology/scoring-methodology

# Appendix

1. Please provide us with tour personal information *

| | |
|---|---|
| Country: | * |
| First Name: | * |
| Last Name: | * |
| Name of the organization: | * |
| Role: | * |
| Tel: | * |
| Fax: | * |
| Email: | * |

**2. Please select among the following organizations which one you belong to:** *

- Ministry in charge of Energy
- Regional Economic community
- River Basin Authority
- Private Sector

**3. Do you have established regional management strategy of the river?** *

- Yes
- No

**4. Are there available data regarding the variation of the level of the river for the coming years?**

- Yes
- No

Please specify the time line:

**5. What is the energy generation potential of the river?**

**6. Regarding climate change effects, are there edging options in meeting the planned power objectives with the use of others renewable energies?** *

- Yes
- No

If yes please specify:

**7. In term of institutional and human capacities, which of the following areas requires capacity building?** *

- Institution design
- Investment/project finance
- Resource assessment
- Energy planning
- Policy design
- Other (please specify):

**8. Are energy planning tools being used in the management of the river?** *

- Yes
- No

If Yes, please specify the tools used:

**9. If yes, is there sufficient skilled human resource for their use?**

- Yes
- No

Please specify how many they are:

**10. Is there available and reliable Internet access within your organization?**

- Yes
- No

**11. Are human resource familiar with ITC?**

- [ ] Yes
- [ ] No

If Yes, please specify how many hours they could be willing to spend online per day?

**12. Among the following activities, which one do you think are priority for capacity building on RE and EE in your country?**

- [ ] In-house training
- [ ] Vocational training
- [ ] Workshops and seminars
- [ ] Other (please specify):

**13. Which technology are you investing in?** *

- [ ] Hydro
- [ ] Solar PV
- [ ] Solar thermal
- [ ] Wind
- [ ] Biomass
- [ ] Geothermal
- [ ] Other (please specify):

**14. Is climate change a concern for your business?** *

- [ ] Yes
- [ ] No

**15. If yes, what are the edging options of your investments?**

Option 1:

Option 2:

Option 3:

**16. Are you using energy planning tools in your business models?** *

- Yes
- No

If Yes, please specify the tools used:

**17. If energy planning tools are used, is there sufficient skilled human resource for their use?**

- Yes
- No

Please specify how many they are:

**18. Is there available and reliable Internet access within your organization?**

- Yes
- No

**19. Are human resource familiar with ITC?** *

- Yes
- No

If Yes, please specify how many hours they could be willing to spend online per day?

**20. Among the following activities, which one do you think are priority for capacity building on RE and EE in your country?** *

- In-house training
- Vocational training
- Workshops and seminars
- Other (please specify):

**21. Is there Regional Energy Plan in place in the region?** *

- Yes
- No

**22. If yes, is there regional renewable energies target in the Regional Energy Plan ?** *

- Yes
- No

If Yes, please specify the target and time line:

**23. Is there legal framework established regarding the regional trade in the region?** *

- Yes
- No

If Yes, please specify:

**24. How is the Regional Master Plan defined within the region regarding the electricity imports and exports? (Ex: Cameroon - Importer - from - Congo - 100 MW)**

| | Name | Importer / Exporter | To / From | Name | Total Amount (MW) |
|---|---|---|---|---|---|
| Country1 | | | | | |
| Country2 | | | | | |
| Country3 | | | | | |
| Country4 | | | | | |
| Country5 | | | | | |
| Country6 | | | | | |

**25. In term of institutional and human capacities, which of the following areas requires capacity building?** *

- Institution design
- Investment/project finance
- Resource assessment
- Energy planning
- Policy design
- Other (please specify):

**26. Concerning energy planning,** *

| | Yes | No |
|---|---|---|
| Are energy planning tools being used? | | |

If Yes, please specify the tools used :

**27. If energy planning tools are used, is there sufficient skilled human resource for their use?**

- Yes
- No

If Yes, please specify how many they are:

**28. Is there available and reliable Internet access within your organization?** *

- Yes
- No

**29. Are human resource familiar with ITC?** *

- Yes
- No

If Yes, please specify how many hours they could be willing to spend online per day?

**30. Among the following activities, which one do you think are priority for capacity building on RE and EE in your country? ***

- In-house training
- Vocational training
- Workshops and seminars
- Other (please specify):

**31. Has your country developed National Energy Plan towards energy access improvement?**

- Yes
- No

**32. Has your country set renewable energies target in the Energy Plan ?** *

- Yes
- No

If Yes, please specify the target and time line:

**33. Has your country passed specific policies / legislations on:** *

| | Yes | No |
|---|---|---|
| Feed-in tariffs | | |
| Renewable Portofolio Standard | | |
| Direct subsidies on technology investment | | |
| Tax/duties exemptions/reductions | | |
| Auctions | | |

Other (please specify):

**34. Are there incentives for energy efficiency promotion and improvement?** *

Yes

No

If Yes, please specify:

**35. What are the electricity tariffs in place:** *

| | Tariff (UDS/kWh) | Subsidized (Yes / No) |
|---|---|---|
| Domestic: | | |
| Commercial: | | |
| Industrial low voltage: | | |
| Industrial medium voltage: | | |
| Industrial high voltage: | | |

**36. What is the country:**

| | Total | Biomass | Hydro | Geothermal | Solar PV | CSP | Wind |
|---|---|---|---|---|---|---|---|
| Actual installed capacity in MW ? | | | | | | | |
| Actual electricity generation in GWh ? | | | | | | | |
| Planned capacity in MW? | | | | | | | |
| By when? | | | | | | | |

**37. Are there data relative to electricity demand projection?** *

☐ Yes

☐ No

**38. If yes please specify the demand projection and the time line:**

| | Peak power demand in MW | Electricity demand in GWh | Time line |
|---|---|---|---|
| Projection: | | | |

**39. In term of institutional and human capacities, which of the following areas requires capacity building?** *

☐ Institution design

☐ Investment/project finance

☐ Resource assessment

Energy planning

Policy design

Other (please specify):

**40. Concerning energy planning,** *

| | Yes | No |
| --- | --- | --- |
| Are energy planning tools being used? | | |

If Yes, please specify the tools used :

**41. If energy planning tools are used, is there sufficient skilled human resource for their use?**

Yes

No

If Yes, please specify how many they are:

**42. Is there available and reliable Internet access within your organization?**

Yes

No

**43. Are human resource familiar with ITC?**

Yes

No

If Yes, please specify how many hours they could be willing to spend online per day?

**44. Among the following activities, which one do you think are priority for capacity building on RE and EE in your country?**

- In-house training
- Vocational training
- Workshops and seminars
- Other (please specify):