The EU Technical Assistance Facility (TAF)
for Sustainable Energy

THE AFRICAN UNION ELECTRICITY SECTOR OUTLOOK (AUESO)

In 2021, the African Union Commission requested the support of the European Union's Technical Assistance Facility (TAF) for sustainable energy, to analyse the different scenarios of Africa's energy future. This analysis would offer a better understanding of the current status and future evolution of the electricity sector in Africa and identify the key drivers. It would also serve as a basis to support the development of the "Strategic Planning, Action Plan and Guidelines for the African Single Electricity Market".

The resulting **African Union Electricity Sector Outlook (AUESO)** is a comparative analysis of the main studies conducted by different institutions for the African electricity sector. The AUESO is therefore not the result of a specific modelling application for the African electricity system per se, rather the consolidation of results from existing studies in the sector.

The different input assumptions of each study were identified clearly to understand their importance and their effect on the results. Indicators based on the outputs, provide insight on the possible trajectories of the African electricity sector and the associated advantages that could support strategic decisions for the sector. Existing scenarios are compared on a common basis using a robust methodology covering the lack of comparative studies in this domain. This analysis helps to limit the biases of each study and identify the common trends in the sector.

The main outcomes from the report is the evolution of Renewable Energy Sources penetration and power generation installed capacity, the evolution of cross-border electricity exchanges and interconnection capacities, and the importance of a common methodology to model the African electricity system.

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ABBREVIATIONS

ACEC	African Clean Energy Corridor
AfCFTA	African Continental Free Trade Area
AFREC	African Energy Commission
AfSEM	African Single Electricity Market
AUC	African Union Commission
AUC DIE	African Union Commission - Department of Infrastructure and Energy
AUESO	African Union Electricity Sector Outlook
CAPP	Central African Power Pool
C.A.R.	Central African Republic
CCS	Carbon Capture and Storage
CMP	Continental Masterplan
COMELEC	Comité Maghrébin de l’électricité (Maghreb Electricity Committee)
D.R.C.	The Democratic Republic of the Congo
EAPP	East African Power Pool
EE	Energy Efficiency
EU JRC	European Union Joint Research Centre
EU TAF	European Union Technical Assistance Facility for sustainable energy
EUC	European Union Commission
GDP	Gross Domestic Product
GWh	Giga watt-hours
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hours
O&M	Operation and Maintenance
RES	Renewable Energy Sources
SAPP	Southern African Power Pool
T&D	Transmission and Distribution
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VRE	Variable Renewable Energy
WAPP	West African Power Pool
WEO	World Energy Outlook

1. THE AFRICAN UNION ELECTRICITY SECTOR OUTLOOK (AUESO) – SUMMARY OF FINDINGS

In 2021, the African Union Commission requested the support of the European Union's Technical Assistance Facility (TAF) for sustainable energy, to analyse the different scenarios of Africa's energy future towards the 2040 horizon. The analysis would serve as a basis in the development of the newly launched African Single Electricity Market - AfSEM. The resulting **African Union Electricity Sector Outlook (AUESO)** aims to present, compare, and contrast the various 'energy scenarios' for the electricity sector in Africa, as developed internationally by a number of institutions.

The African Union Electricity Sector Outlook (AUESO) aims to present, compare, and contrast the various 'energy scenarios' for the electricity sector in Africa, as developed internationally by a number of institutions.

Though energy scenarios are not meant to be predictions of the future, they do provide an opportunity for comparison between alternative outcomes. Diving into the multiple 'alternative scenarios' developed internationally offers useful insights on the possible trajectories of the African electricity sector.

The AUESO comparative study of these 'alternative scenarios' reveals advantages and possible issues that could impact on policy and strategy decisions affecting Africa's electricity sector – especially within the ambitious ongoing work to connect all African regional electricity markets under the new **African Single Electricity market (AfSEM)**.

The African Single Electricity Market (AfSEM)

African Single Electricity Market

The African Union (AU), with the support of the European Union (AU), has launched the African Single Electricity Market - AfSEM, a continent-wide electricity market that will help provide greater energy security, sustainability and competitiveness. The goal is ambitious: the AfSEM will become one of the largest electricity markets in the world, consisting of the African Union's 55 Member States and its regional organisations and institutions, covering a population of more than 1.3 billion.

Ramping up sustainable electricity generation capacity by 2030 to keep pace with growing demand will require from 39 to 62 billion euro of annual financing. Coordinated inter-regional planning will help lower capital investments needs and provide more competitive pricing for homes, businesses and industries.

The new integrated African Single Electricity Market will provide a common energy governance system for the continent's interconnected electricity infrastructure, linking the five current regional Power Pools by way of a Continental Power Masterplan (CMP), a "blueprint" to enable seamless cross-border trade in electricity. Continental-level governance is an opportunity for the energy transition in Africa. The economies of scale brought by the AfSEM, coupled with Africa's enormous potential for renewable electricity, will help leverage innovative solutions.

The AfSEM exemplifies the African Union's vision for an integrated and prosperous continent, as outlined in its Agenda 2063 development blueprint. AfSEM is also one of the tools to equip the African Continental Free Trade Area (AfCFTA), which aspires to create a single market for goods and services to deepen economic integration, towards catalysing the socio-economic development of the continent.

2015	2017	2021	2023	2040
African Union Commission (AUC) and European Union (EU) partner to launch the Harmonisation of Africa's Regional Electricity Markets initiative	*The AUC - Harmonisation of Electricity Sector Strategy and Action Plan adopted by the AU Heads of State and Government*	*Official launch of the African Single Electricity Market (AfSEM) (June); Adoption of AfSEM Policy Paper, Roadmap and governance structure by the AU Heads of State and Government (February)*	*AfSEM will start to be progressively implemented*	*AfSEM is expected to be fully operational*

1.1. AUESO METHODOLOGY

The African Union Electricity Sector Outlook (AUESO) Comprehensive Study is the result of an exhaustive literature review, with a number of scenarios analysed for deeper investigation of common findings:

Table 1.1: Steps of the AUESO methodology

1.	Analysis of the current situation of the electricity sector on the African continent
2.	Alternative Scenarios: • Comparison of the source studies' assumptions, indicators, and findings • Comparison of the projections using quantitative indicators; identification of common trends and divergence among the scenarios
3.	AUESO study findings: • Common findings for policy decision-making • Challenges and recommendations for future studies
4.	Recommendations – Pathway to 2040: • Main conclusions in alignment with the African Single Electricity Market - AfSEM Policy and Roadmap[1] for the short, medium, and long-term horizon

1.1.1. The 'Alternative Scenarios' for the African Electricity Sector

The different studies analysed are based on different input assumptions. These were clearly identified, in order to then weigh their effects on the study results.

The 'alternative scenarios' for developing the AUESO, in support to the development of the African Single Electricity Market (AfSEM), were based on the following selection of sources:

- **The African Energy Outlook** of the International Energy Agency (IEA). IEA presents an in-depth view and analysis for the development of the African energy sector, capitalising from extensive experience in producing energy outlooks using a proven modelling framework.
- **The IRENA Planning and Prospect series** of the International Renewable Energy Agency (IRENA). IRENA presents a view focusing on the maximisation of renewable energy utilisation in regions of the African continent, using widely accepted modelling tools.
- **Energy projections for African Countries** study by the Joint Research Centre of the European Commission (EU JRC). JRC focuses more on the climate perspective of the energy system, presenting scenarios relevant to the Paris agreement. A least-cost optimisation tool is used, which could provide insights on the most climate-friendly pathways for the energy sector. The analysis is performed at the country level. The study also provides in-depth analysis and offers recommendations regarding the water-energy nexus for Africa's energy sector.
- **The Power Pool Masterplans,** as were analysed in the **Baseline Study of the Continental Masterplan (CMP) Phase 1**. The projections provided by the **Regional Power Pools** constitute a bottom-up view of the development of the power system, from the perspective of the entities directly connected with the operation of the system. Information and relevant data for the regional Masterplans is provided by the member countries for each power pool. In the CMP Phase 1 study existing plans where consulted and updated information from the Power Pools was incorporated in the analysis.

1.1.2. AUESO Indicators

The AUESO study of 'alternative scenarios' presents results in the form of indicators. The indicators selected in order to analyse the results of the studies were:

1. Electricity demand projection
2. Installed capacity and electricity generation
3. Exchanges of electricity

[1] link

1.2. COMMON FINDINGS FOR POLICY DECISION-MAKING

Despite the diversified scenarios, certain common trends stand out, upon which **conclusions for robust policy decisions for the development of the African power system** can be drawn.

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1.2.1. Electricity demand projection

Electricity demand projection is crucial for the analysis of the power system: demand level for the continent across the different scenarios is compared; largest consumers are identified, since they will be important for shaping the overall demand in the Power Pools; sharp increases in the projected demand (highest Compound Annual Growth Rate -CAGR) suggest potential emerging and driving markets.

- **Demand level**

  Better access to electricity is considered as one of the key factors in demand projections. All studies point to a significant increase in electricity consumption, with a Combined Annual Growth Rate (CAGR) ranging from 4% to 6% between 2020 and 2040 across the various studies reviewed (Figure 1.1).

  Increased access will require the development of distribution and transmission networks, and a reliable supply of affordable, environmental-friendly electricity.

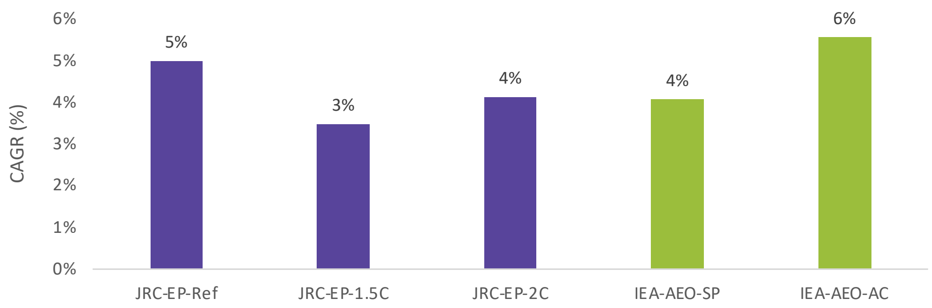

Figure 1.1: Compound Annual Growth Rate for Continental demand – 2020 to 2040

- **Large consumers and emerging/ driving markets**

  In the AUESO analysis, the largest electricity consumers are identified, since they will be important for shaping the overall demand in the power pools. Countries that show a large increase in the projected demand are identified as potential emerging and driving markets:

  Demand in the **West African Power Pool (WAPP)** is projected to double from 2020 to 2030, with the same trend from 2030 to 2040. Nigeria remains the largest consumer over the entire time horizon and is the main driver of this increase, with a demand expected to more than quadruple between 2020 and 2040. Ghana is also showing a noticeable increase in electricity demand. The Ivory Coast is projected to increase its demand considerably, and become the 3rd largest consumer in the Power Pool by 2040.

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  WAPP follows a trend similar to the other regions where the highest growth rates are exhibited by smaller consumers -for example: Guinea, Burkina Faso, and Liberia with a CAGR between 8% and 11% over 2020-2030.

  South Africa continues to dominate the demand in the **Southern African Power Pool (SAPP)** region, but its relative share falls by some 10% by 2030, and by another 5% -reaching less than 60% - in 2040. The increase of the demand in Zambia, Angola, Mozambique, Tanzania and DRC, is filling this void. South Africa is projected to remain the second largest consumer in the continent after Egypt in the horizon until 2040.

  The projections of electricity demand in the **East African Power Pool (EAPP)** show a continuation of the current situation: Egypt is the dominant consumer of electricity, and Libya is consistently coming in second. In all the projections, Ethiopia is emerging as the third largest consumer, with Tanzania, Kenya and Sudan following with similar levels of consumption by 2040.

Overall, Algeria is projected to remain the largest consumer in the **Comité Maghrébin de l'Électricité (COMELEC)/North African Power Pool (NAPP)** region, followed by Morocco, Libya and Tunisia.

The projections for the **Central African Power Pool (CAPP)** feature a high degree of variation between the different studies, mainly due to the differences in the demand projections of the three largest consumers in 2030 -namely Angola, Cameroon, and DRC.

1.2.2. Installed capacity and electricity generation

The rate of construction of renewable energy projects is increased in the medium and long terms, even in the rather conservative projections in the Power Pool Masterplans. Capacity additions of solar PV is expected to dominate renewable energy installations.

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The optimistic scenarios show an increase of the installation rate of PVs from about 5GW per year between 2020 and 2030 to almost 19GW per year in the period after 2030 as a sum over twenty countries of EAPP and SAPP. The additions of wind capacity become increasingly significant over this period, reaching 11GW per year in the EAPP and 6GW per year in SAPP.

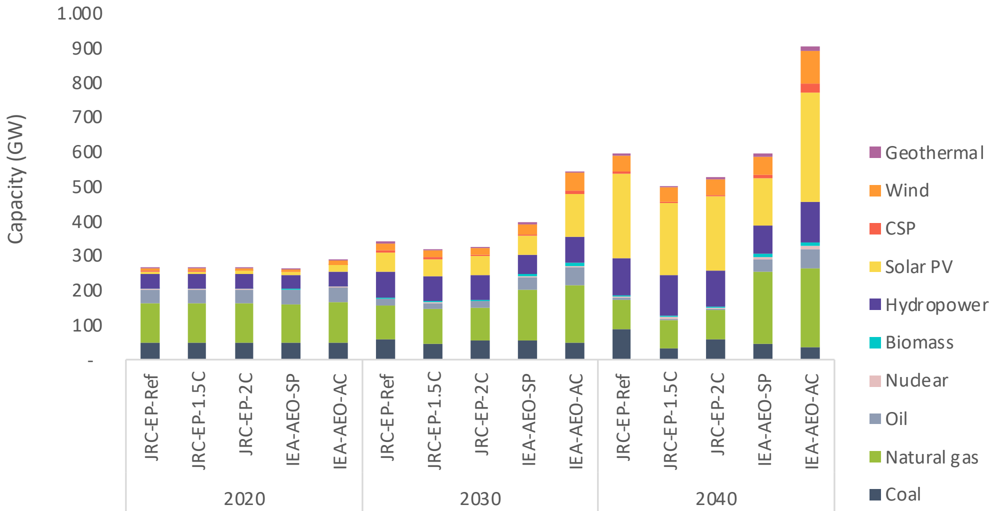
- **Key technologies in the future energy mix**

The generation capacity required to cover the projected demand is one of the main indicators driving the need for investments in the power sector. The evolution of the capacity of different technologies in the different scenarios is important in order to identify the key technologies in the future energy mix and also to identify how sensitive these choices will be depending on the different scenario narratives or dimensions.

Scenarios from other institutions show higher penetration of variable renewables (VRES) across all Power Pools, compared to the Power Pool Masterplans, which focus more on conventional generation and hydro plants. Worth noting is that current trends project particular reduction costs for PV and wind technologies, making these variable renewables one of the primary drivers in capacity additions in the continent.

The fact that variable renewable resources are widespread and distributed means smaller countries can achieve, in a cost-efficient way, a larger share of renewables of as high as over 40% of the total electricity generation.

Figure 1.2: Projections and Evolution of Continental level Installed Capacity per Technology 2020-2040



- **Resilience of the electricity supply mix**

  Diversifying supply sources though the addition of various renewable energy technologies also contributes to the resilience of the electricity supply mix.

  In countries like Burundi, South Sudan and Uganda, a scenario analysis assuming low availability of hydro leads to the introduction of bioenergy in the power generation mix. Complementing hydropower with other renewable technologies is emerging as a cost-efficient way to mitigate hydro related risks.

  In CAPP, hydropower is projected to be the main source of electricity in the power pool by 2030 and beyond. However, the share of other renewables is significantly increased; some scenarios project that, by 2030, solar PV capacity will reach 24% and wind capacity 7% of the total.

- **Future emergence of ancillary services**

  As VRES penetration increases, ancillary services are required to secure system stability and reliability. Technical teams are aware, and this is built into current and future studies.

  Storage systems are an important consideration for better flexibility of the system, and progress in this domain is paving the way for increased contributions of variable renewable energy systems.

1.2.3. Exchanges of electricity

Exchanges of electricity are studied by analysing the net transfer capacity of the interconnections between countries in a Power Pool, and the total amount of electricity exported from the countries in a Power Pool.

- **Substantial increase in electricity exchanged between countries**

  In all scenarios, the quantities of electricity exchanged between countries increases significantly over 2020 – 2040, supported by a considerable increase of the interconnection capacities. Flows in SAPP and EAPP are projected to increase by a factor of 4 or even 5 over these twenty years. Similarly, in WAPP, the exchanges are projected to increase by a factor of 4, while in CAPP the projected increase between 2020 and 2030 is almost ten-fold.

- **Better, greener, cost-effective interconnections**

  Investments in interconnection infrastructure projects is crucial for cross-border exchange of electricity, and consequently for a single market for electricity trading to operate smoothly. The studies reviewed indicated that the currently committed and planned interconnection projects are expected to contribute significantly to increase the exchange volume by four or five times from the current level in the next twenty years. This is important for the development of integrated electricity markets at both the regional and continental levels.

  More interconnection capacities are needed to achieve the high level of exchanges. However, if the currently committed and planned interconnections are actually implemented, and if constraints and bottlenecks are removed, more investments in capacity are cost-effective, as in the case of the twenty EAPP and SAPP countries.

  Cross-border interconnections within the CAPP are needed for the region to exploit its huge hydro potential to export hydroelectricity to the other Power Pools. The same stand within and between SAPP and WAPP regions. Within CAPP, increased interconnections would also influence the generation mix: RES electricity will be able to flow among countries, reducing the need for more conventional (mainly gas-fired) capacity - especially in countries like Rwanda and Angola.

  The exchanges of electricity modelled in the different studies indicate that the increase in interconnection capacity, and the resulting increased flow of electricity among countries, lead to the reduction of the overall system cost at the Power Pool level –and, consequently, at the continental level.

- **More bi-directional flows**

  Findings also reveal that the level of trade between countries is sensitive to the level of VRES penetration. In most cases, power flows are in one direction, with surplus generation channelled towards countries with deficits. However, bi-directional flows occur on some connections as the level of VRES increases towards 2040. There is a strong correlation between the installed capacity of solar PVs and electricity exchanges -as was seen in the case of South Africa, where imports are considerably reduced during daylight hours, when local PVs are generating.

1.3. CHALLENGES AND RECOMMENDATIONS FOR FUTURE STUDIES

- **Need for a common approach to assumptions and planning time horizon**

  Consistent input assumptions and time horizons in the development of the scenarios in general, and the Ten-Year Network Development Plan (TYNDP) in particular, are of paramount importance. The case of DRC is a telling example: DRC belongs to both EAPP and SAPP; the country's projected hydropower capacity for the year 2030 is at 9GW according to the EAPP Masterplan, versus 14GW in the SAPP Masterplan.

- **Need to factor in bidirectional flows and storage**

  Optimising the use of VRES can help cover local demand. However, a large penetration of variable renewables requires strong interconnections to ensure flexibility in the power system. The current situation of "pure" exporting and importing countries will no longer be the case according to the projections, as bi-directional flows through interconnections will ensure the achievement of a minimised cost for the power system.

  The use of storage options should be further examined in the future scenario analysis to enhance the introduction of variable renewable energy technologies.

  So far, the storage options included in the scenario analysis seem to be limited to small-scale technologies. Utility-scale storage and Power-to-X options could offer further advantages, and should be analysed in more detail in future studies.

- **Need to explore extensions beyond Africa**

  Finally, a crucial point to be further explored in future scenario analysis, is the possible expansion of interconnection capacities beyond the continent, linking Africa to Europe and the Middle East.

1.4. RECOMMENDATIONS: THE PATHWAY TO 2040

The AUESO scenario analysis identifies key opportunities and challenges for policy pathways towards 2040. These add on to the "*Action Plan for Harmonised Regulatory Framework for the Electricity Market in Africa*"[2] and the "*Strategy for the Development of a Harmonised Regulatory Framework for the Electricity Market in Africa*"[3], in which a number of opportunities and challenges have been developed into a roadmap with short (2020-2025), medium (2026-2030) and long-term (2031-2040) steps for the creation of the AfSEM.

Key observations and recommendations emanate from the study, to overcome the challenges in achieving the African Single Electricity Market (AfSEM):

- There is need for **an integrated system and a holistic approach** to be adopted in the analysis of existing scenario-based studies. This consideration is one of the key drivers of the Continental Masterplan (CMP) Phase 2[4], and the motivation for estabishing the African Single Electricity Market (AfSEM).
- A **common approach to assumptions and time horizon** will be highly beneficial for the update of the AfSEM Roadmap, Action Plan and Strategy, and Technical & Operational Readiness documents.
- In terms of market readiness and development of regional electricity markets, the design of the AfSEM should **deploy mini-grids and stand-alone systems in parallel to the extension of the main grid.**
- In urban areas, mini-grids can play an important role in ensuring access to electricity to areas that cannot be easily reached by the main grid; **in rural areas, decentralised solutions** can provide most of the additional connections through mini-grids and stand-alone systems.
- The scenarios reviewed in the AUESO study assume a least-cost optimisation of the system in a perfectly competitive market. This implies that **market liberalisation and utility restructuring in Africa is necessary to promote wholesale competition**, in order to achieve the required cost optimisation as calculated by the models.

[2] African Union. (2021). Action Plan for Harmonised Regulatory Framework for the Electricity Market in Africa. Available online: https://au.int/en/documents/20210618/action-plan-harmonised-regulatory-framework-electricity-market-africa

[3] Africa Union (2021). Strategy for the Development of a Harmonised Regulatory Framework for the Electricity Market in Africa. Available online: https://au.int/sites/default/files/documents/40438-doc-Strategy_HarmonisedRegulatoryFrameworkElectricityMarket.pdf

[4] The overall objective of the CMP Phase 2 is to carry out modelling and planning studies for the continental power system. The specific objectives include establishment of a harmonised and integrated continental level modelling approach which will be used to identify priority power generation and transmission projects up to 2040.

1. PERSPECTIVES DU SECTEUR DE L'ÉLECTRICITE EN AFRIQUE – RÉSUMÉ DES RÉSULTATS

Les **Perspectives du Secteur de l'Électricité en Afrique** (PSEA ou AUESO en Anglais) visent à présenter, comparer et contraster les différents scénarios énergétiques appliqués au secteur de l'électricité en Afrique et utilisent pour cela une méthode largement adoptée par les institutions internationales.

Bien que ces scénarios énergétiques ne soient pas des prédictions de l'avenir, ils offrent un outil de comparaison entre des résultats alternatifs. Explorer ces scénarios alternatifs développés par les institutions régionales et internationales permet d'accéder à des informations essentielles concernant l'évolution du secteur électrique africain.

L'étude comparative de ces scénarios alternatifs révèle par ailleurs, les opportunités et les difficultés qui pourraient avoir un impact sur les décisions politiques et stratégiques affectant le secteur de l'électricité en Afrique - en particulier dans le cadre de **l'AfSEM**, le nouveau **marché unique africain de l'électricité,** et de ses activités actuelles visant à connecter tous les marchés électriques régionaux du continent.

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Le marché unique africain de l'électricité (AfSEM)

Lancé par l'Union Africaine (UA) avec le soutien de l'Union Européenne (UE), il s'agit du nouveau marché de l'électricité à l'échelle du continent qui contribuera à fournir une énergie sûre, durable et compétitive.

L'objectif est ambitieux car l'AfSEM a pour objectif de devenir l'un des plus grands marchés de l'électricité au monde. Composé des 55 États membres de l'Union Africaine et de ses organisations et institutions régionales, il desservira une population de plus de 1,3 milliard d'habitants.

Il nécessitera entre 39 et 62 milliards d'euros de financement annuel pour permettre d'accroitre la capacité de production d'électricité d'ici 2030 et satisfaire une demande électrique croissante. Une planification interrégionale coordonnée est donc nécessaire pour réduire les besoins d'investissement et offrir des prix plus compétitifs aux foyers, aux entreprises et aux industries.

L'AfSEM inclut un mécanisme commun de gouvernance de l'infrastructure électrique interconnectée du continent, reliant les cinq pools énergétiques régionaux actuels, par le biais d'un schéma directeur continental de l'électricité (CMP en Anglais) pour faciliter les échanges internationaux d'électricité.

Cette gouvernance inédite au niveau continental est une opportunité pour la transition énergétique en Afrique et les économies d'échelle apportées par l'AfSEM, associées à l'énorme potentiel de l'Afrique en matière d'électricité renouvelable, permettront de tirer parti de solutions innovantes.

L'AfSEM illustre la vision de l'Union Africaine pour un continent prospère et s'inscrit parfaitement dans l'Agenda 2063 de l'UA. Il s'appuie également sur le principe de la Zone de Libre-Échange Continentale Africaine (ZLECA ou AfCFTA en Anglais), qui aspire à créer un marché unique pour les biens et services afin d'approfondir l'intégration économique et catalyser le développement socio-économique du continent.

2015	2017	2021	2023	2040
La Commission de l'Union Africaine (CUA) et l'Union Européenne (UE) s'associent pour lancer l'initiative d'harmonisation des marchés régionaux de l'électricité en Afrique	*La Stratégie et le plan d'action pour l'harmonisation du secteur de l'électricité de la CUA sont adoptés par les chefs d'État et de gouvernement de l'UA*	*Lancement officiel de l'AfSEM (juin) ; Adoption de la stratégie, de la feuille de route, et de la structure de gouvernance de l'AfSEM par les chefs d'État et de gouvernement de l'UA (février)*	*Mise en œuvre progressive de l'AfSEM*	*AfSEM pleinement opérationnel*

1.1. LA METHODOLOGIE

Les Perspectives du Secteur de l'Électricité en Afrique (PSEA ou AUESO en Anglais) sont le résultat d'une recherche bibliographique exhaustive permettant d'identifier les scénarios méritant une enquête plus approfondie, et en particulier concernant les tendances communes.

Tableau 1.1 : Étapes de la méthodologie

1.	Analyse de la situation actuelle du secteur électrique sur le continent africain
2.	Scénarios alternatifs : • Comparaison des hypothèses, des indicateurs et des conclusions des études analysées • Comparaison des projections à l'aide d'indicateurs quantitatifs ; identification des tendances communes et des divergences entre les scénarios
3.	Résultats de l'étude AUESO : • Conclusions communes pour informer la prise de décision politique • Défis et recommandations pour les études à venir
4.	4. Recommandations à l'horizon 2040 : • Principales conclusions alignées au Marché unique de l'électricité en Afrique - Politique et Feuille de Route de l'AfSEM à court, moyen et long terme

1.1.1. Les « scénarios alternatifs » pour le secteur électrique en Afrique

Parce que les différentes études analysées reposent sur des hypothèses de départ différentes, celles-ci ont été clairement identifiées afin de mesurer par la suite leurs effets sur les résultats de l'étude. Les « scénarios alternatifs » inclus dans l'AUESO sont construit sur la base des documents suivants :

- **Les perspectives énergétiques en Afrique** de l'Agence internationale de l'énergie (AIE ou IEA en Anglais). L'IEA présente une vision détaillée et une analyse approfondie du développement du secteur énergétique africain fondées sur leur longue expérience des études prospectives.
- **La série IRENA Planification et Prospective de l'Agence** internationale pour les énergies renouvelables (IRENA). L'IRENA présente une vision axée sur l'intégration optimale des énergies renouvelables dans le mix électrique régional et repose sur des outils de modélisation largement acceptés.
- **La série Energy Projections for African countries** du JRC (Centre commun de recherche de la Commission Européenne). Le JRC se concentre davantage sur la perspective climatique du système énergétique, en présentant des scénarios alignés sur l'accord de Paris. Un outil d'optimisation à moindre coût est utilisé afin de fournir un aperçu des pistes les plus respectueuses du climat pour le secteur de l'énergie. Il propose en outre des recommandations concernant le lien entre l'eau et l'énergie.
- **Les schémas directeurs des pools énergétiques** tels qu'analysés lors de la *Phase 1 - Étude de référence du schéma directeur continental*. Les projections fournies par les pools énergétiques constituent une vue ascendante (bottom-up) du développement du réseau électrique, telle que perçue par des entités directement engagées dans les opérations du réseau. Les informations et les données pertinentes aux schémas directeurs régionaux sont fournies par les pays membres de chaque pool énergétique. Pour l'étude de le *Phase 1 du schéma directeur continental*, les informations actualisées contenues dans le schéma directeur de chaque pool énergétique ont été intégrées à l'analyse.

1.1.2. Les indicateurs

L'étude des « scénarios alternatifs » présente ses résultats sous forme d'indicateurs :

1. La projection de la demande en électricité (GWh)
1. La capacité installées et la production d'électricité par technologie (MW et GWh)
1. Les volumes d'électricité échangés (GWh)

[1] link

1.2. DES RESULTATS COMMUNS POUR SOUTENIR LES POLITIQUES ENERGETIQUES

Malgré la grande variété de scénarios, des tendances communes se dégagent et mènent à des conclusions qui permettent d'aider à la prise de décisions pour le développement du réseau électrique africain de demain.

Malgré la grande variété de scénarios, des tendances communes se dégagent et mènent à des conclusions qui permettent d'aider à **la prise de décisions pour le développement du réseau électrique africain de demain.**

1.2.1. Projection de la demande en électricité

La croissance de la future demande électrique sur le continent a un impact majeur sur la conception du réseau électrique qui doit y répondre : les taux de croissance des différents scénarios sont comparés et les plus gros consommateurs continentaux identifiés. Par ailleurs, les foyers régionaux de forte croissance sont aussi identifiés, suggérant de potentiels marchés émergents et de futurs vecteurs de développement.

- **Un meilleur accès à l'électricité** est considéré comme l'un des facteurs essentiels d'augmentation de la demande. Toutes les études prévoient une augmentation significative de la consommation d'électricité, avec un taux de croissance annuel moyen (TCAM ou CAGR en Anglais) entre 4 % et 6 % sur la période 2020 - 2040 (figure 1-1).

  Améliorer l'accès à l'électricité nécessitera l'extension des réseaux de distribution et de transmission existants, ainsi qu'un approvisionnement fiable, respectueux de l'environnement et à un coût abordable.

Figure 1.1: Taux de croissance annuel moyen de la demande continentale – 2020 à 2040

- **Pôles de demande et marchés émergents**

  La demande au sein du **pool énergétique ouest-africain** (EEEOA, ou WAPP en Anglais) devrait doubler entre 2020 et 2030, puis doubler encore entre 2030 et 2040. Le Nigeria demeure le plus important consommateur sur le périmètre temporel de l'étude, et constitue le principal moteur de cette augmentation avec une demande qui devrait plus que quadrupler entre 2020 et 2040. Le Ghana prévoit également une augmentation significative de sa demande en électricité. Enfin, la demande en Côte d'Ivoire devrait aussi augmenter considérablement, permettant à ce pays de devenir le troisième consommateur en volume du pool énergétique d'ici 2040.

  L'EEEOA/WAPP suit une tendance similaire aux autres régions où les taux de croissance les plus élevés sont affichés par les pays qui consomment aujourd'hui le moins, comme par exemple la Guinée, le Burkina Faso et le Libéria, avec un TCAM compris entre 8 % et 11 % sur la période 2020-2030.

  L'Afrique du Sud continue de dominer la demande du **pool énergétique d'Afrique australe** (SAPP en Anglais), mais sa part relative devrait chuter d'environ 10 % d'ici 2030, et de 5 % supplémentaires pour atteindre moins de 60 % en 2040. Cette diminution est liée à l'augmentation de la demande en Zambie, en Angola, au Mozambique, en Tanzanie et en RDC. Au niveau continental, l'Afrique du Sud devrait rester le deuxième consommateur le plus important du continent après l'Égypte à l'horizon 2040.

  Les projections de la demande d'électricité dans le **pool énergétique de l'Afrique de l'Est** (EAPP en Anglais) suggèrent une continuation de la situation actuelle : l'Égypte demeure le plus important consommateur du pool, avec la Libye en deuxième position. Dans toutes les projections, l'Éthiopie devient le troisième plus important consommateur, suivi de la Tanzanie, du Kenya et du Soudan qui affichent des niveaux de consommation similaires d'ici à 2040.

  De manière générale, l'Algérie devrait rester le plus important consommateur de la région du **Comité Maghrébin de l'Électricité (COMELEC),** suivie du Maroc, de la Libye et de la Tunisie.

  Les projections du **pool énergétique de l'Afrique centrale (PEAC)** présentent un degré élevé de variation d'un scénario à l'autre, principalement en raison des différences dans les projections de la demande des trois plus gros consommateurs d'ici à 2030, à savoir l'Angola, le Cameroun et la RDC.

Le rythme de mise en œuvre des projets d'énergies renouvelables s'accroit sur le moyen et long terme, même dans les projections relativement prudentes des schémas directeurs régionaux.

1.2.2. Capacité installée et production d'électricité par technologie

Le rythme de mise en œuvre des projets d'énergies renouvelables s'accroit sur le moyen et long terme, même dans les projections relativement prudentes des schémas directeurs régionaux. Si l'énergie solaire photovoltaïque (PV) domine les installations d'énergie renouvelable, l'éolien contribuera aussi de manière significative à la croissance de la capacité installée.

Au sein des pays de l'EAPP et du SAPP, les scénarios optimistes montrent une augmentation de la capacité PV agrégée totale d'environ 5 GW par an entre 2020 et 2030, puis presque 19 GW par an entre 2030 et 2040. La capacité éolienne se renforce régulièrement, atteignant 11 GW par an dans l'EAPP et 6 GW par an dans le SAPP.

- **Les technologies clés du futur mix énergétique africain**

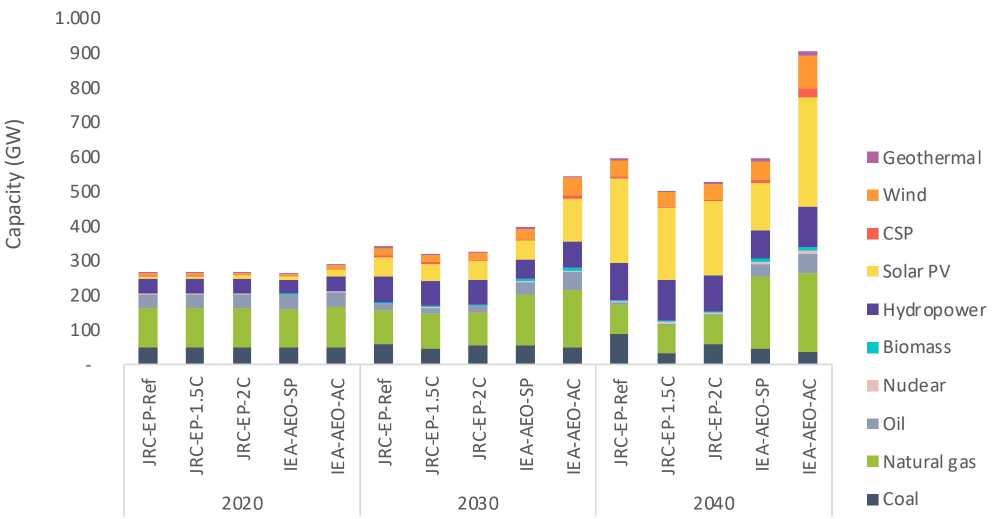
  La capacité de production nécessaire à la satisfaction de la future demande souligne le besoin d'investissements dans le secteur électrique. La vitesse de croissance de la capacité par technologie est importante et permet d'identifier les technologies clés du futur mix énergétique africain. Elle permet également d'identifier la sensibilité de ces choix en fonction de différents narratifs capturant les incertitudes de l'avenir.

  Les scénarios des institutions internationales indiquent dans tous les pools énergétiques, une pénétration plus élevée des énergies renouvelables que celle identifiée dans leur schéma directeur. En effet, les schémas directeurs régionaux se concentrent davantage sur la production conventionnelle et les centrales hydroélectriques, que sur les technologies renouvelables intermittentes.

  Il convient de noter que les analyses actuelles s'accordent sur une réduction continue des coûts d'installation des technologies solaire PV et éolienne, principal moteur de la croissance de la capacité renouvelable sur le continent africain.

  Pour les pôles de croissance de plus petite taille, le déploiement et la distribution des ressources renouvelables intermittentes signifie que ces pôles peuvent augmenter de manière significative la part des énergies renouvelables dans la production totale d'électricité, jusqu'à atteindre presque 40 %.

Figure 1.2: Projections et évolution de la capacité installée au niveau continental par technologie 2020-2040



- **Résilience du mix électrique**

  La diversification des sources d'approvisionnement par l'exploitation de différentes technologies renouvelables contribue également à la résilience du mix électrique.

  Dans des pays comme le Burundi, le Soudan du Sud et l'Ouganda, une analyse des scénarios supposant une faible disponibilité de l'hydroélectricité conduit à l'introduction de la bioénergie dans le mix de production d'électricité. Proposer d'autres technologies renouvelables en complémentarité de l'hydroélectricité, apparaît comme un moyen économiquement durable d'atténuer les risques liés à cette technologie.

  Pour le PEAC, l'hydroélectricité va rester la principale source d'électricité d'ici 2030 et au-delà. Néanmoins, la part des autres énergies renouvelables devrait considérablement augmenter et certains scénarios prévoient que la capacité solaire photovoltaïque et la capacité éolienne atteindront respectivement 24% et 7% de la capacité totale installée d'ici 2030.

- **Émergence des services auxiliaires**

  À mesure que la pénétration des énergies renouvelables intermittentes augmente, de plus en plus de services auxiliaires sont nécessaires pour garantir la stabilité et la fiabilité du réseau électrique. Les équipes techniques en sont conscientes et il en est tenu compte dans les études en cours et à venir.

  Les systèmes de stockage constituent une amélioration importante de la flexibilité du réseau, et les progrès dans ce domaine ouvrent la voie à une contribution accrue des énergies renouvelables intermittentes.

1.2.3. Les volumes d'électricité échangés

Les échanges d'électricité sont étudiés en analysant la capacité nette des interconnexions transfrontalières installées et la quantité totale d'électricité exportée par les pays au sein de chaque pool énergétique.

- **Augmentation des échanges d'électricité entre les pays**

  Dans tous les scénarios, les volumes d'électricité échangés entre les pays augmentent significativement entre 2020 et 2040, et cette croissance est appuyée par un renforcement considérable des capacités d'interconnexion.

  Les flux dans le SAPP et l'EAPP devraient être multipliés par quatre voire cinq sur les deux décennies à venir. De même, dans l'EEEOA/WAPP les échanges d'électricité devraient aussi être multipliés par quatre, tandis qu'au sein du PEAC, ils devraient être décuplés entre 2020 et 2030.

- **De meilleures interconnexions : plus durables, plus efficaces, et plus rentables**

  Les investissements dans les projets d'infrastructure d'interconnexion sont d'une importance capitale pour les échanges transfrontaliers d'électricité et, par conséquent, pour le bon fonctionnement d'un marché unique de l'électricité. L'analyse des différentes études suggère que les projets d'interconnexion actuellement engagés et planifiés devraient contribuer de manière significative à augmenter le volume d'échange au cours des vingt prochaines années, et auront un impact important sur le développement des marchés électriques intégrés aux niveaux régional et continental (augmentation du volume d'échange par un multiple de quatre ou cinq par rapport au niveau actuel).

  Des interconnexions transfrontalières supplémentaires au sein du PEAC sont nécessaires pour que la région puisse exploiter son énorme potentiel hydroélectrique et l'exporter vers les autres pools énergétiques. Il en va de même au sein du SAPP et du WAPP. Il est intéressant de constater que l'augmentation des interconnexions du PEAC influencera également le mix énergétique du pool. En effet, l'électricité d'origine renouvelable pourra circuler plus facilement entre les pays (notamment le Rwanda et l'Angola), réduisant ainsi le besoin de capacités conventionnelles (principalement le gaz naturel).

  Les échanges d'électricité modélisés dans les différentes études indiquent que l'augmentation de la capacité d'interconnexion et l'augmentation des flux d'électricité qui en résulte, conduisent à la réduction du coût global du réseau pour le pool énergétique - et, par conséquent, pour le continent.

- **Croissance des flux électriques bidirectionnels**

  Les analyses révèlent également que le niveau des échanges d'électricité entre les pays est sensible au taux de pénétration des énergies renouvelables. Actuellement, les flux d'électricité sont généralement à sens unique et la production excédentaire est exportée vers les pays déficitaires.

  Cependant, des flux bidirectionnels apparaissent sur certaines interconnexions transfrontalières à mesure que la proportion d'énergies renouvelables augmente dans le mix énergétique. Les résultats révèlent une forte corrélation entre la capacité installée de solaire PV et les échanges d'électricité. Par exemple en Afrique du Sud, les importations sont considérablement réduites le jour lorsque l'électricité est produite en partie via la technologie solaire PV.`

1.3. DEFIS ET RECOMMANDATIONS POUR LES ETUDES A VENIR

- **Nécessité d'une approche commune**

  Il est d'une importance primordiale d'avoir des hypothèses de départ et des horizons temporels cohérents lors de l'élaboration des scénarios, comme dans le cas du plan décennal de développement du réseau européen (TYNDP en Anglais).

  En effet, des écarts persistent encore dans les chiffres du secteur électrique africain. Pour illustration, un pays qui appartient à deux pools énergétiques se voit attribuer une capacité hydroélectrique projetée de X GW pour l'année 2030 par le schéma directeur du premier pool énergétique, contre (X + 50%) GW par le schéma directeur du deuxième.

- **Nécessité de prendre en compte les flux bidirectionnels et le stockage**

  L'optimisation de l'utilisation des énergies renouvelables peut aider à répondre à la demande locale. Cependant, une forte pénétration des énergies renouvelables intermittentes nécessite des interconnexions fortes pour assurer la flexibilité du réseau électrique. Par ailleurs, selon les projections la situation actuelle d'échanges unidirectionnels est vouée à disparaître car les flux bidirectionnels permettront de minimiser le coût global du réseau électrique continental.

  L'utilisation d'options de stockage devrait être examinée plus précisément afin d'améliorer la mesure de l'impact de l'introduction des énergies renouvelables intermittentes. Jusqu'à présent, les options de stockage incluses dans l'analyse de scénario semblent être limitées à des technologies à petite échelle. Le stockage à grande échelle et les options Power-to-X (ou P2X) pourraient offrir d'autres avantages et devraient être analysés plus en détail dans les études à venir.

- **Nécessité d'étudier l'interconnexion de l'Afrique aux réseaux voisins**

  Enfin, un point crucial à approfondir est l'éventuelle expansion des capacités d'interconnexion au-delà du continent, ce qui permettra de relier plus fortement l'Afrique à l'Europe et au Moyen-Orient.

1.4. RECOMMANDATIONS : LA VOIE VERS 2040

L'étude des scénarios alternatifs permet d'identifier les principales opportunités et les défis qui jalonneront la route menant à 2040. Ces recommandations pourront aussi s'appuyer sur *le Plan d'action*[2] et la *Stratégie pour le développement*[3] *d'un cadre réglementaire harmonisé pour le marché de l'électricité en Afrique.*

Les principales observations et recommandations sont :

- **Le besoin d'un réseau intégré et d'une approche holistique.** Cette considération est l'un des principaux moteurs de la Phase 2 du schéma directeur continental[4] et motive la création du marché unique de l'électricité en Afrique.
- **Une approche commune concernant les hypothèses et l'horizon temporel.** Cette approche sera très utile à la mise à jour de la feuille de route, du plan d'action et de la stratégie de l'AfSEM, ainsi qu'à l'élaboration des documents de préparation pour la mise en œuvre technique et opérationnelle du marché.
- **Le déploiement des mini-réseaux et des systèmes autonomes en parallèle aux activités d'extension du réseau principal.**
- **En milieu urbain, les mini-réseaux** peuvent jouer un rôle important en garantissant l'accès à l'électricité dans les lieux qui ne sont pas facilement accessibles par le réseau principal ; **en milieu rural, des solutions décentralisées** peuvent répondre au besoin en connexions supplémentaires avec des mini-réseaux et des systèmes autonomes.
- Les scénarios examinés dans l'étude AUESO supposent une optimisation au moindre coût du réseau dans un marché parfaitement concurrentiel.
- **La libéralisation du marché et la restructuration des sociétés d'électricité en Afrique sont nécessaires** afin de permettre une diminution globale des coûts de production d'électricité.

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2 African Union. (2021). Action Plan for Harmonised Regulatory Framework for the Electricity Market in Africa. Available online: https://au.int/en/documents/20210618/action-plan-harmonised-regulatory-framework-electricity-market-africa

3 Africa Union (2021). Strategy for the Development of a Harmonised Regulatory Framework for the Electricity Market in Africa. Available online: https://au.int/sites/default/files/documents/40438-doc-Strategy_HarmonisedRegulatoryFrameworkElectricityMarket.pdf

4 L'objectif global de la Phase 2 du CMP est de réaliser des études de modélisation et de planification pour le système électrique continental. Les objectifs spécifiques comprennent la mise en place d'une approche de modélisation harmonisée et intégrée au niveau continental qui sera utilisée pour identifier les projets prioritaires de production et de transport d'électricité jusqu'en 2040.

2. INTRODUCTION

2.1 PROJECT BACKGROUND

To achieve a harmonised and Continental African Electricity Market, a collaboration between the African Union Commission (AUC) and EU started in 2015 under the EU's global Technical Assistance Facility (TAF) for sustainable energy, which provided support and expertise to the Department of Infrastructure and Energy (DIE) of the AUC. The collaboration was implemented under four successive phases:

- Phase 1 (2015-2016) involved the development, validation, and adoption by the AU Heads of State and Government of the Strategy and the Action Plan for a "Harmonised Regulatory Framework for the Electricity Market in Africa".
- Phase 2 (2017) covered support to the AUC for the implementation of the Strategy and Action Plan for the following activities: The Coordination Role of the AUC, Development of Continental Transmission Tariff Methodology, as well as an Institutional and Policy Model for Micro and Mini-Grids.
- Phase 3 (2018-2019) saw the development of the Continental Transmission Tariff Calculation Tool for international Bilateral Transactions.
- Phase 4 (2019-2021) provides further support to the AUC for the Implementation, Coordination and Monitoring of the Electricity Harmonisation Regulatory Strategy and Action Plan. This phase comprises a number of activities including Strategic Planning, Action Plan and Guidelines for the African Single Electricity Market (AfSEM), under which the current study and publication have been developed.

To achieve a harmonised and Continental African Electricity Market, a collaboration between the African Union Commission (AUC) and EU started in 2015 under the EU's global Technical Assistance Facility (TAF) for sustainable energy, which provided support and expertise to the Department of Infrastructure and Energy (DIE) of the AUC.

It is important to highlight that the African Single Electricity Market (AfSEM) is a key activity of the AUC, and hence a continuation of the AUC's Harmonisation of Electricity Sector Strategy and Action Plan, which was adopted by the Heads of State and Government of the African Union in 2017. AfSEM, as an overall electricity initiative of the AU, will cover strategic policy and planning aspects of the whole electricity value chain that relate to generation, transmission, distribution and end-use, at the national, regional, and continental level. AfSEM is particularly relevant to the AU's vision for an integrated and prosperous continent, as outlined in its Agenda 2063 development blueprint. It is one of the tools to equip the African Continental Free Trade Area (AfCFTA) towards catalysing the socio-economic development of the continent.

It is important to also note that the creation of an efficient and integrated single electricity market requires the development of the physical ("hard") infrastructure, as envisaged under the "Continental Masterplan (CMP)". The CMP is intrinsically linked to the Policy and Strategic issues (the "soft" aspects). This synergy is expected to ensure the delivery of quality, reliable electricity services to the people of the African continent. AfSEM is also expected create a market that will provide reliable electricity at least cost to consumers, and catalyse a cost-efficient response to the soaring growth of electricity demand. It will thus serve as an essential tool for exploiting the full potential of the continent's renewable energy sources (RES) and help to achieve 100% access to electricity. The challenge of grid stability, associated to the intermittent supply of renewable energies, can be nest addressed through integration of electricity markets.

The integrated market is expected to ensure system stability, providing a reliable, secured electricity supply, as well as contribute to cost-efficient decarbonisation of the energy sector.

Energy system scenarios using energy models are a valuable tool for analysing the evolution of the energy sector. Scenarios help explore vulnerabilities, and seek robust strategies for the future development of energy systems.

2.2. OBJECTIVES OF THE AFRICAN UNION ELECTRICITY SECTOR OUTLOOK

2.2.1. Objectives of energy system scenarios

Energy system scenarios using energy models are a valuable tool for analysing the evolution of the energy sector. Scenarios help explore vulnerabilities, and seek robust strategies for the future development of energy systems. Energy system scenarios use a variety of techniques and approaches to morph alternative energy futures, and, in this way, support decision-making under uncertainty, thus informing policy options.

Energy system scenarios are formulated using energy system models by specifying or altering the model inputs or scenario dimensions. These dimensions can be new values of parameters (e.g., different costs, prices, efficiencies of energy technologies, CO2 mitigation levels etc.), constraints (e.g., availability of imports, capacity of electricity interconnections, resources availability like indigenous renewable energy potentials, natural gas, and crude oil, etc.), availability of new technologies (by changing the year in which a new technology or fuel like hydrogen is available etc.).

It is important to note that energy scenarios are not meant to be "predictions" of the future. Instead, they must be considered **as points of comparison to evaluate alternative outcomes**. Therefore, it is not useful to have a single scenario, rather than a number of alternative scenarios; when compared against each other, alternative scenarios can offer useful insights for the possibilities of energy system development.

2.2.2. Specific Objectives of the African Union Electricity Sector Outlook

The African Union Electricity Sector Outlook (AUESO) aims to present, compare, and contrast different scenarios which have been developed internationally for the electricity sector in Africa by different energy modelling institutions. In this process, it is important to identify and clearly present the different input assumptions used in each study and scenario, and understand their importance and effect on results. Using the scenario outputs, a list of main parameters and indicators will be presented, which can provide insight on the **possible trajectories of the African electricity sector and the associated advantages and possible issues** that could impact on policy and strategy decisions affecting Africa's electricity sector.

The objectives of this study are to:

- Perform an exhaustive literature review of the prospective studies available for the electricity sector of the African continent and select relevant reports for deeper investigation.
- Describe the current situation of the electricity sector on the African continent.
- Present, analyse and compare the main input assumptions used in the different scenarios of the selected relevant reports.
- Compare the projections using various indicators, identify common trends and divergence among the scenarios, and present quantitative indicators which are key for the development of policy.
- Draw the main conclusions in alignment with the AfSEM Policy and Roadmap document in the short, medium, and long-term horizon.

2.3. METHODOLOGY

2.3.1. Current situation of Electricity Sector in Africa

One of the first steps in the development of the AUESO is the description of the current situation, against historical trends of the electricity sector on the African continent. To this end, a set of parameters and indicators are discussed, using statistical data available from the African Energy Commission (AFREC) as the main source.

Worth clarifying is that the purpose of the African Union Electricity Sector Outlook is not to replicate or duplicate statistics collection processes of other institutions, but to present projections for the development of the power system to 2030, 2040 and beyond, based on available, credible, and robust data. Qualitative indicators necessary to describe the current situation are presented in a dedicated section.

2.3.2. Main input assumptions from short, medium, and long-term scenarios identified

Next, the input assumptions and scenario narratives of the selected projections are analysed and presented. Apart from the scenario narratives, the assumptions on some quantitative input parameters are also presented, so that the time horizon of each study reflects the period when the information is available.

In general, pathways for qualitative indicators were used as part of the scenario narratives, as was done in the "Africa case" scenario of the African Energy Outlook[5], where the IEA assumed a certain level of regulatory policies and market integration which could be different from the baseline scenario. During the analysis for the AUESO, these assumptions were identified as well as the pathways of the qualitative indicators they correspond to.

2.3.3. Comparison of the projections and identification of common trends

The AUESO also includes a list of key quantitative parameters and indicators for each selected projection, where a thorough investigation is performed. This is used to study the pathways suggested by each projection for the time horizon of each study (at least until 2030, in most cases until 2040 and in some cases until 2050 subject to data availability).

In the final step of the analysis, a comparison between the different scenarios reveals common trends in the baseline scenarios on the one hand, and plausible alternatives in the different outcomes from the policy scenarios on the other. Common trends and extreme scenarios will be used as input to the policy dialogue for the development of the Pathways for the African Electricity System.

[5] IEA. (2019, November). Africa Energy Outlook 2019.

2.4. SELECTED PROJECTIONS AND SCENARIOS FROM RELEVANT INSTITUTIONS AND PARTNERS

Various institutions have developed energy outlooks with a specific focus on Africa, and have proposed a wide range of projections to describe a possible future for the continent -as well as the pathways leading there. These projections have been based on a set of different scenarios, which were developed by the international modelling institutions to generate many alternative outcomes.

2.4.1. Documentation identified from relevant institutions and partners

The International Energy Agency (IEA) publishes its projections each year in the World Energy Outlook (WEO).[6] Other reports produce tailor-made scenarios adapted to a specific region -such as the IEA African Energy Outlook.[7] Many organisations also offer extensive energy outlooks with advanced scenarios dedicated to one or selected technology/ies. For example, the International Renewable Energy Agency (IRENA) has published a series of reports showing prospects for the integration of variable renewables (VRE) in each African Power Pool, while the EU Joint Research Centre (JRC) has developed specific energy projections for the African continent based on climate targets.[8] For its part, the International Atomic Energy Agency (IAEA) proposes every year the Reference Data Series No. 1 (RDS-1), which contains estimates of energy electricity and nuclear power trends up to the year 2050.[9]

At the regional level, the African Power Pools' Power Systems (generation and transmission) Masterplans are the references to understand the future trends in energy sector, more particularly for electricity. However, they are developed by different organisations and consulting entities; as a result, depending on the specific objectives of each study, the methodology, scenario assumptions, study horizons, and planning approaches may differ.

For an outlook of the current regulatory situation of the energy sector, the World Bank RISE project[10] and the African Development Bank (AfDB) Electricity Regulatory Index[11] are the main references.

Additional prospective studies can therefore be helpful to understand a specific dimension of energy sector such as access to energy, or the assessment of renewable energy resource.

2.4.2. Selected projections and scenarios

Based on the literature review, the following reports were selected for a more detailed examination to provide alternative scenarios for developing the AUESO, and to support the development of the African Single Electricity Market (AfSEM):

- IEA African Energy Outlook
- EU TAF Baseline scenario from the CMP Phase 1 assignment (which was based on the existing Power Pool Masterplans and, in the cases where these were outdated, on updated information received from the Power Pools)
- IRENA Planning and Prospects series
- EU JRC Energy projections for African Countries study

The rationale for the selection of these sources is the following:

1. **IEA** presents an in-depth view and analysis for the development of the African energy sector. It also has long years of experience in producing energy outlooks using a proven modelling framework.
2. **IRENA** presents a view focussing on the prospects for renewable electricity generation in various Power Pools of the African continent, adding the more granular and updated renewable resource and technology data from IRENA to the existing Power Pools' Masterplans. A least cost optimisation tool was used.
3. **JRC** focuses more on the climate perspective of the energy system, presenting scenarios relevant to the Paris Agreement. A least-cost optimisation tool is used, which could provide insights on the most climate friendly pathways for the energy sector, and the analysis is performed on a country level. It also provides in-depth analysis and makes recommendations regarding the water-energy nexus for Africa's energy sector.

[6] IEA. (2020, October). World Energy Outlook 2020.
[7] IEA. (2019, November). Africa Energy Outlook 2019.
[8] Pappis, I., Howells, M., Sridharan, V., Usher, W., Shivakumar, A., Gardumi, F. and Ramos, E. (2019). Energy projections for African countries, Hidalgo Gonzalez, I., Medarac, H., Gonzalez Sanchez, M. and Kougias, I. Editors. EUR 29904 EN. Publications Office of the European Union. Luxembourg. ISBN 978-92-76-12391-0. doi:10.2760/678700. JRC118432.
[9] IAEA. (2020). Energy, Electricity and nuclear power estimates for the period up to 2050. Ref. Data Series 1. Vienna.
[10] WorldBank & ESMAP. (2020). Regulatory Indicators for Sustainable Energy (RISE) Sustaining the momentum. Washington, DC.
[11] African Development Bank - AfDB. (2020). Electricity Regulatory Index for Africa 2020. Abidjan.

4. The projections provided by the **Regional Power Pools** constitute a bottom-up view of the development of the power system, presenting the view of the entities directly connected with the operation of the system. Information and relevant data for the regional Masterplans are provided by the member countries for each Power Pool. This information was integrated during the assignment on "Support to the Development of a Continental Power System (Transmission-Generation) Masterplan" of the EU TAF, and was enhanced using updated information directly from the Power Pools and the member countries, where it was deemed necessary. These projections are referred to as "Baseline scenario from the CMP Phase 1 Study" hereon.

The list of projections studied and analysed in the present report is presented in Table 2.1 below.

Table 2.1: List of projections studied in the present report

Institution	Year	Name
IEA	2019	African Energy Outlook[12]
IRENA	2021	Planning and Prospects for Renewable Power: Eastern and Southern Africa[13]
IRENA	2018	Planning and Prospects for Renewable Power: West Africa[14]
IRENA	2015	Planning and Prospects for Renewable Energy: Africa Power Sector[15]
EU TAF	2020	Baseline scenario from the CMP Phase 1 study, SE4ALL Central and West Africa – Support to the Development of a Continental Power System (Transmission-Generation) Masterplan[16]
EU JRC	2019	Energy Projections for African Countries[17]

[12] IEA. (2019, November). Africa Energy Outlook 2019.
[13] IRENA. (2021). Planning and Prospects for Renewable Power: Eastern and Southern Africa. Abu Dhabi.
[14] IRENA. (2018). Planning and prospects for renewable power: West Africa. Abu Dhabi.
[15] IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi.
[16] EU TAF. (2020). LOT 8.1: Support to the Development of a Continental Power System (Transmission-Generation) Masterplan. Deliverables 2 & 3. Mission ref: CW235.201906 AUC.
[17] Pappis, I., Howells, M., Sridharan, V., Usher, W., Shivakumar, A., Gardumi, F. and Ramos, E. (2019). Energy projections for African countries, Hidalgo Gonzalez, I., Medarac, H., Gonzalez Sanchez, M. and Kougias, I. Editors. EUR 29904 EN. Publications Office of the European Union. Luxembourg. ISBN 978-92-76-12391-0. doi:10.2760/678700. JRC118432.

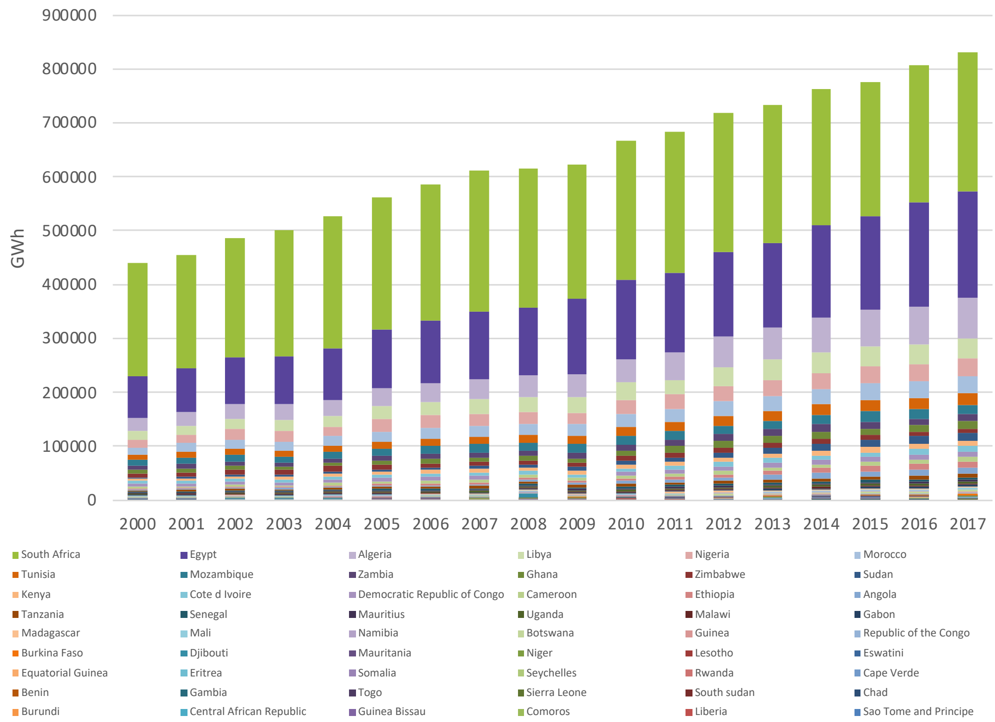
3. CURRENT SITUATION

Electricity demand and supply in Africa has evolved considerably since 2000. An overview of the historical trends of some key indicators of the sector are presented in this Chapter, together with the most up -to-date information on the status of the installed capacities, interconnections, electricity access and regulatory readiness of the electricity market. The effect of the COVID-19 pandemic is also described, based on the detailed analysis from the EU TAF assignment "Support to the AUC to effectively address the impacts of COVID-19 in the African electricity sector and the post COVID-19 recovery".[18]

3.1. ELECTRICITY GENERATION

The average annual growth rate of electricity generation in Africa for the period 2000-2017 was at 3.8%. Generation is predominately located in South Africa and the countries of Northern Africa, with Nigeria being the fifth country in terms of the amount of electricity produced (Figure 3.1).

Figure 3.1 Electricity generation per country (Source: AfREC)[19]



[18] EU TAF. (2021). LOT 10.2: Support to AUC to effectively address the impacts of COVID-19 in the African electricity sector and the post COVID-19 recovery. Deliverable 2. Mission ref: CW235.201906 AUC.

[19] https://au-afrec.org/Fr/administration/menurequette.php

Fuel types used for the generation of electricity over the period 2000 -2017 (Figure 3.2), reveal that although coal was the dominant fuel in 2000, and was used for the production of 47% of the total electricity, its importance has steadily decreased throughout the years, with its share reduced to 30% in 2017. After 2015, the emerging fuel was natural gas. Natural gas absorbed the shares of coal and oil products, while the share of hydropower was almost constant through the whole period. Generation from wind and other renewables just started to become visible after 2010.

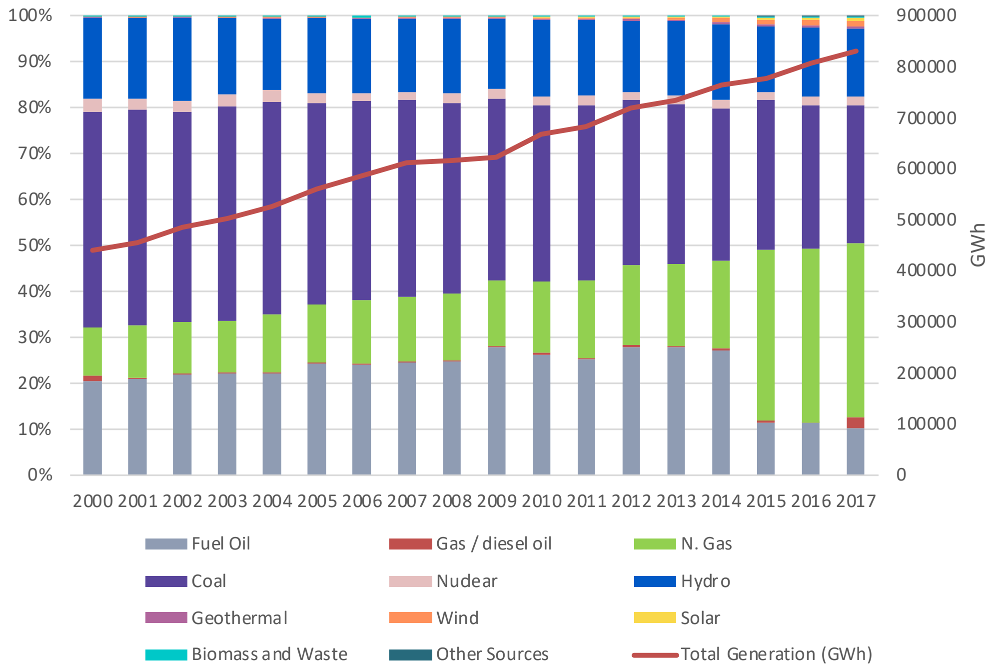


Figure 3.2 Electricity generation per energy source (Source: AfREC)[20]

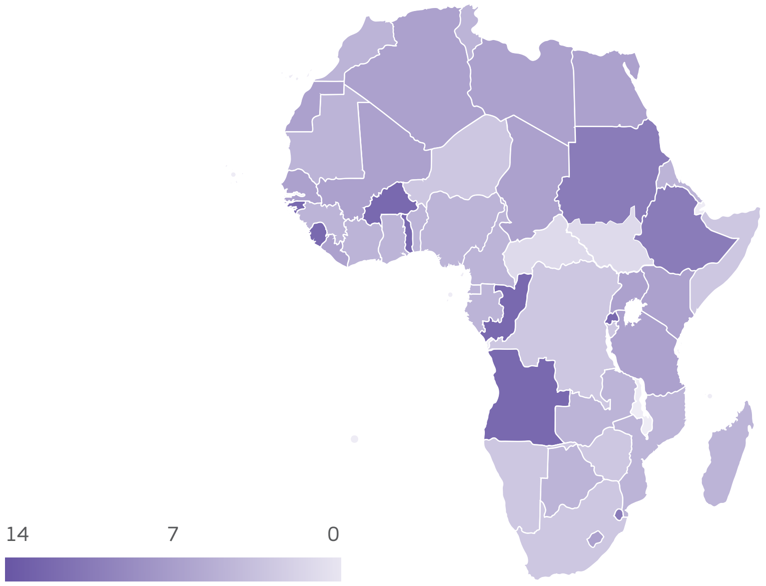
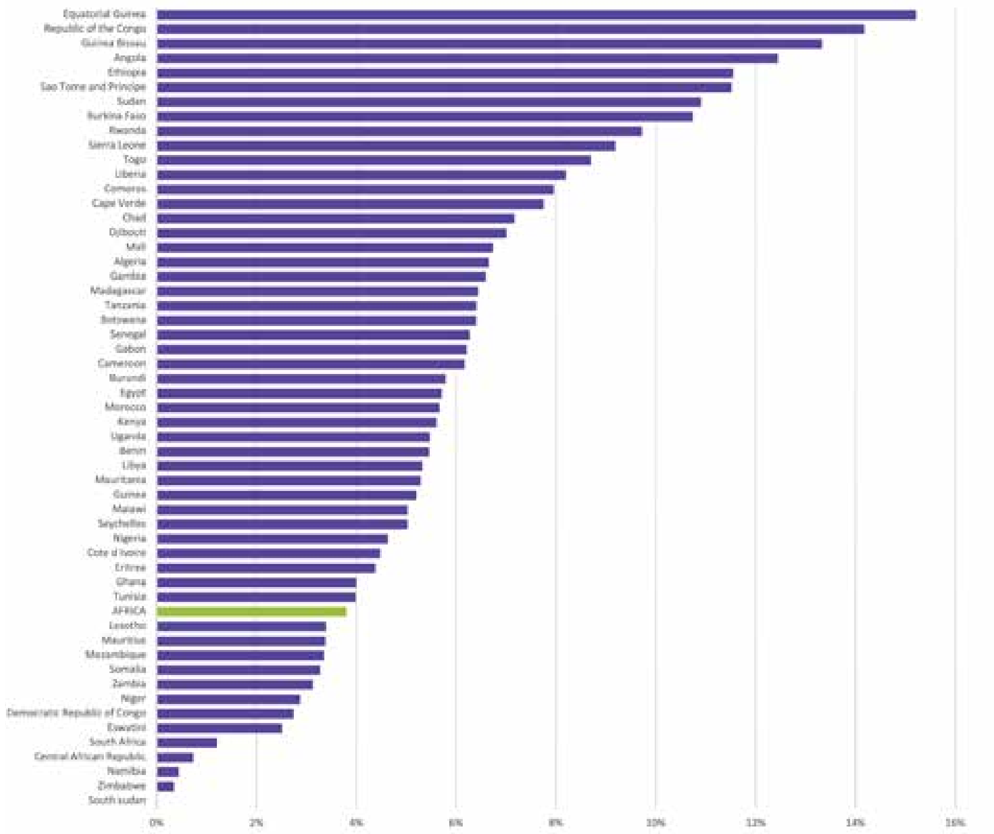


Figure 3.3 Average Annual Growth Rate of Electricity Generation per country between 2000-2017

The average annual growth rate of generation varies widely among African countries (Figure 3 4). It appears that South Africa, the largest producer, has a moderate rate of increase close to 1%, while Egypt, the second largest producer, presents an increase rate of almost 6% - higher than the continent average. The highest average growth rates appear in countries that are small or very small producers. Looking at the geographical distribution of the higher growth rates, these appear to be in Sub-Saharan Africa: mainly on the east and west coasts (Figure 3.3).

[20] https://au-afrec.org/Fr/administration/menurequette.php

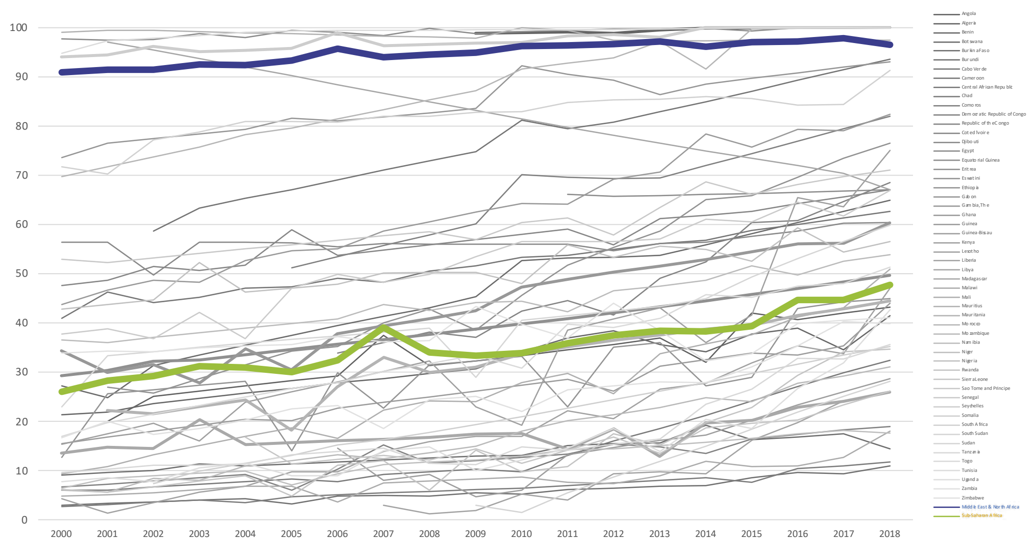
Figure 3.3 Average Annual Growth Rate of Electricity Generation per country between 2000-2017 (Source: AfREC)[21]



3.2. ACCESS TO ELECTRICITY

Access to electricity, and in particular the achievement of universal access to reliable electricity, is one of the greatest challenges for Africa as it is vital for the socio-economic development of the continent. The rate of access to electricity in Sub-Saharan Africa is steadily increasing at an average of 3.4% annually in the period 2000 - 2018 (Figure 3 5). Such an average rate would not be adequate to attain universal access by 2030. Looking more closely at the country level, twenty-five countries in Sub-Saharan Africa are below average, while twenty countries have an access rate between 50% and almost 80%. The remaining nine countries have access rates above 90%- with almost all the countries of Northern Africa having achieved universal electrification (Figure 3.6).

Figure 3.5 Access to electricity 2000 and 2018 (Source: World Bank)[22]



[21] https://au-afrec.org/Fr/administration/menurequette.php
[22] https://data.worldbank.org/

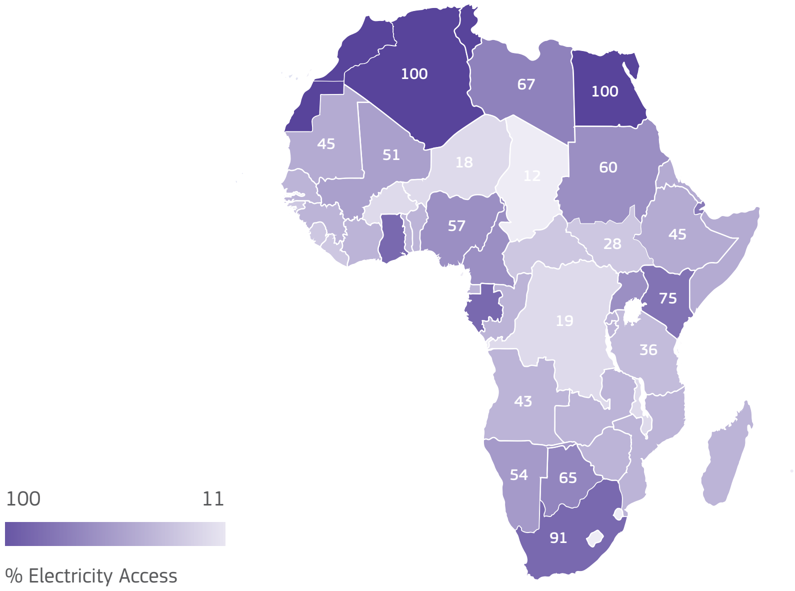


Figure 3.6 Access to electricity in 2018 (Source: World Bank)[23]

3.3. GENERATION CAPACITY

In terms of geographical distribution of electricity generation capacity (Figure 3 7) as presented under CMP Part 1 assignment,[24] it is evident that the existing generation infrastructure is concentrated in the northern and southern parts of the continent.

Egypt had the largest installed capacity (almost 60GW), dominated by gas-fired power plants, representing 27% of the total capacity in the continent as of end 2019.

In 2019, South Africa was in second place, with 52GW installed capacity (24% of the total continental capacity) dominated by coal.[19]

Algeria followed with 22GW (10%) almost exclusively local, gas-fired power plants; Nigeria was in fourth place with about 13GW (6%) and a combination of gas-fired and hydro plants.

Morocco (8.2GW), Libya (6.6GW) and Tunisia (5.1GW) were the remaining Northern African countries which, together with Angola (5.2GW), form the group of countries with more than 5GW capacity; they are closely followed by Ghana (4.8GW), Sudan (4.8GW) and Ethiopia (4.2GW). The difference between the first two countries (Egypt and South Africa) and the others in terms of total installed capacity is significant.

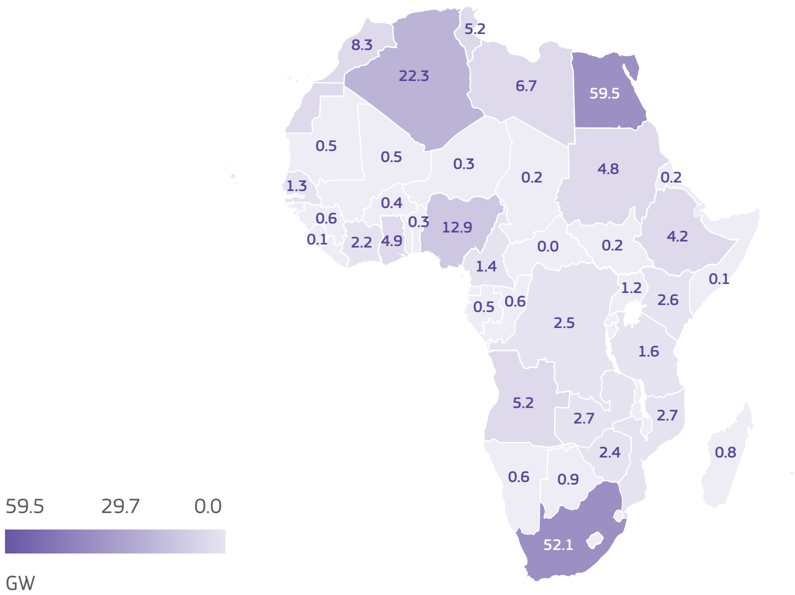


Figure 3.7 Installed generation capacity per country in 2019 (Source: Own elaboration based on the data from EU TAF)[19]

As of the end of 2019, conventional thermal power plants covered about 77% of the installed capacity in EAPP[25](68% gas-fired), while hydro covered 19% of total capacity19. In SAPP, the share of conventional thermal power plants covered 70% of the total capacity (coal-fired covering 58% due to South Africa's figures) and hydro plants accounted for 19%[19]. WAPP was in a similar situation, with about 76% of the total capacity attributed to conventional thermal (gas represented 62%), and hydro accounting for 24%19. In contrast to the other regions, the conventional thermal installed capacity in CAPP represented a mere 38% of total capacity, while hydro was the dominant technology, with 60% of the total capacity -and just over 7GW of hydro plants in the Power Pool[19].

3.4. INTERCONNECTIONS AND EXCHANGES OF ELECTRICITY

interconnecting lines between neighbouring countries is presented as an indication of the overall ability to transfer electricity transnationally.

A relatively large number of interconnections appear in the area of SAPP, while countries in Northern Africa are weakly interconnected, compared to the total installed capacity in the area. The continent is connected to Europe only through Morocco to Spain; and is connected to Jordan through Egypt.

In sub-Saharan Africa, cross-border electricity exchanges are usually based on long-term bilateral agreements between neighbouring countries represented by their power utilities. Power system interconnections and cross-border electricity exchanges evolved around some of the major hydropower resource development projects[20].

In the area covered by WAPP, as the regional market evolved and most of the electricity trades in the sub-region are based on bilateral contracts, it has become necessary to streamline the process and ensure that all future contracts are consistent with best international practice. To this end, the regional regulator (ECOWAS Regional Electricity Regulatory Authority-ERERA), in consultation with the Power Pool and stakeholders, has developed a harmonised transmission tariff methodology for the sub-region[20].

A hybrid approach is used by SAPP, whereby the regional electricity cross-border trading is governed by two modalities:

- Fixed long-term Bilateral Agreements.
- A Short-Term Energy Market (STEM), designed to operate over and above the long-term bilateral contracts.

The SAPP Coordination Centre, among other functions, monitors the operation of electricity trading among operating members and non-members of the Pool regarding bilateral contracts. The settlement of inter-utility power transactions under long-term bilateral trading agreements is governed by conditions attached to the bilateral agreements. STEM was introduced in 2001 as a firm energy market, dealing with short-term energy contracts where electric power is traded on a daily basis for delivery the following day. Since then, it evolved into a Day Ahead Market, Forward Physical (Month Ahead and Week Ahead) and Intra Day Market in 2016.[26]

In the EAPP area, transactions are based on long-term bilateral contracts. EAPP is in the process of implementing a regional, harmonised transmission tariff methodology, and create a function of regional regulatory authority, similar to the ERERA for WAPP. The Power Pool has yet to implement a short-term trading platform, along the example of the SAPP.

In CAPP, transactions are also based on long-term contracts. The Power Pool has yet to implement a regional transmission tariff methodology for long-term bilateral contracts.

[25] The list of counties per Power Pool is presented in Annex 2. The installed capacities in countries which belong in multiple Power Pools are attributed to each Power Pool (i.e. they are reported multiple times).

[26] EU TAF. (2021). LOT 10.2: Support to AUC to effectively address the impacts of COVID-19 in the African electricity sector and the post COVID-19 recovery. Deliverable 2. Mission ref: CW235.201906 AUC.

Figure 3.8 Electricity System Interconnection Transfer Capacities in 2019 (Source: Based on source data from EU TAF)[27]

Using data from AfREC, for electricity imports, exports, and consumption per country, Figure 3.9 presents the ratio of electricity imports over net local on-grid generation, and electricity exports over net local on-grid generation, for those countries reporting imports or exports in 2017 .

For the same year, Figure 3.10(a) presents the percentage of gross electricity consumption (final consumption plus losses) covered by imported electricity (net imports), helping to identify countries heavily depended on imports.

Mozambique is a particular case: in lack of a single interconnected network in the country, there is no option but to export electricity produced in the north to South Africa, and re-import it in the southern part of the country. Certain countries with a relatively low level of consumption like Djibouti, Benin and Eswatini - rely more than 70% on imports to cover consumption. Overall, nine countries import more that 40% of their gross consumption of electricity, which could have a negative impact on their security of supply. Only a handful of countries were net exporters in 2017.[28]

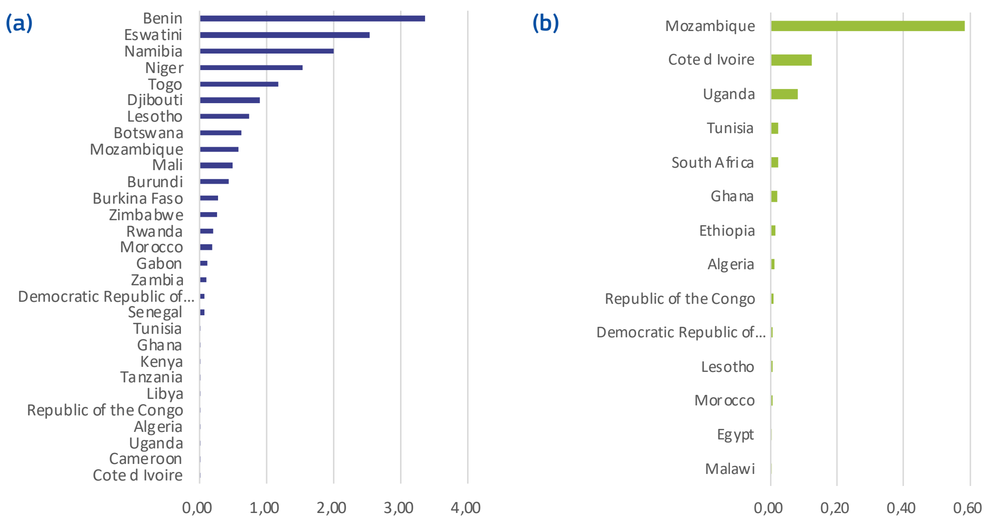


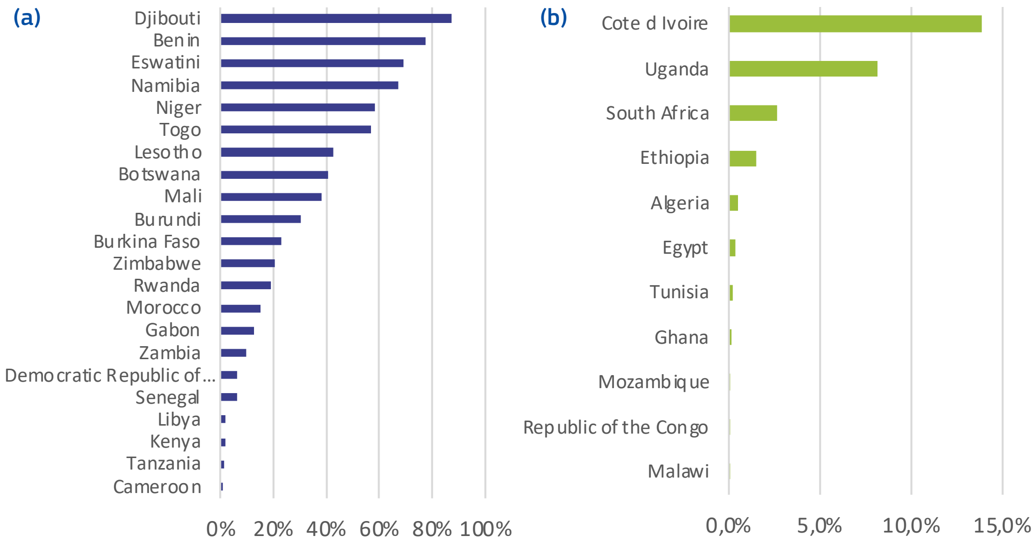
Figure 3.9 Ratio of Electricity Imports (a) and Exports (b) over net generation in 2017 (Source: AfREC)[29]

[27] EU TAF. (2020). LOT 8.1: Support to the Development of a Continental Power System (Transmission-Generation) Masterplan. Deliverables 2 & 3. Mission ref: CW235.201906 AUC.

[28] These are imports and exports, and not net imports or net exports.

[29] https://au-afrec.org/Fr/administration/menurequette.php

Figure 3.10 Electricity Net Imports (a) and Net Exports (b) over gross consumption of electricity in 2017 (Source: AfREC)[30]

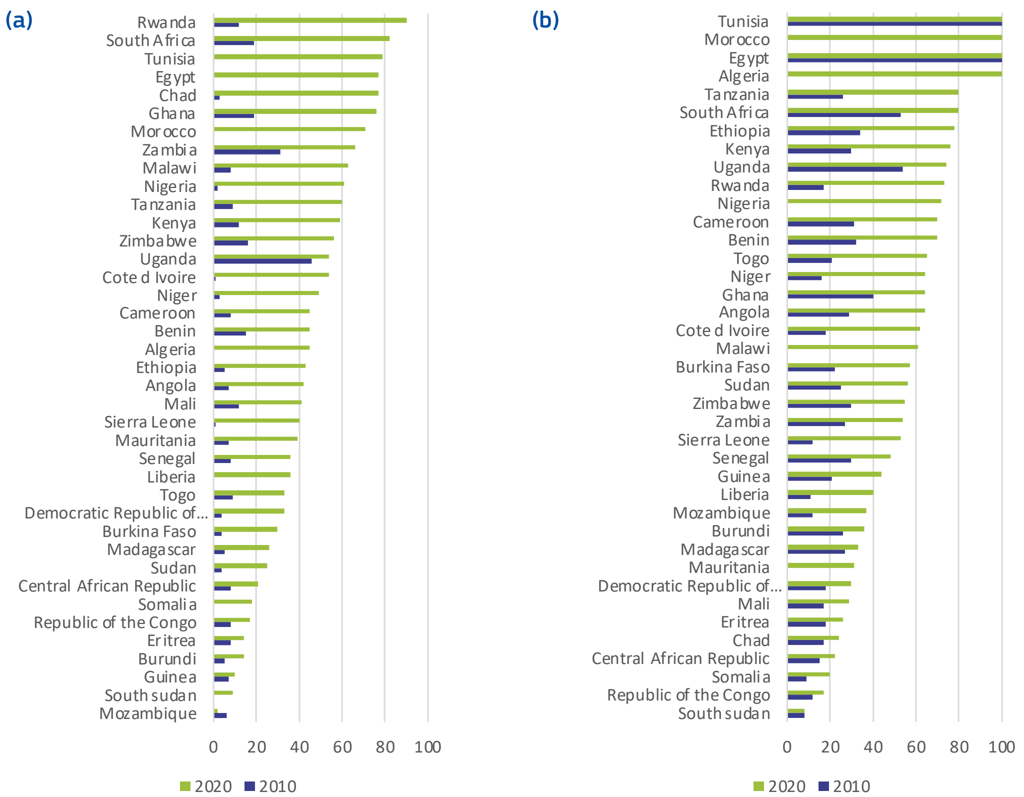


3.5. REGULATORY FRAMEWORK INDICATORS

A single electricity market requires to also go beyond the technical issues of expanding generation capacity and constructing new interconnection lines, and to properly develop the regulatory framework for electricity market operation. Two approaches to monitor such progress are presented below:

RISE (Regulatory Indicators for Sustainable Energy) project from the World Bank covers more than 130 countries and focuses on the identification of barriers that limit the access and the development of sustainable energy. The indicators assess countries' policy support for each of the three pillars of sustainable energy: i) access to electricity, ii) access to clean cooking, iii) energy efficiency, and iv).

Figure 3.11 RISE change between 2010 and 2020 - Renewable energy (a) and Electricity Access (b) (Source: the WorldBank)[31]



[30] https://au-afrec.org/Fr/administration/menurequette.php
[31] World Bank & ESMAP. (2020). Regulatory Indicators for Sustainable Energy (RISE) Sustaining the momentum. Washington, DC.

Figure 3.12 marks the evolution of the indicators for Renewable Energy and Electricity Access from 2010 to 2019 for African countries.

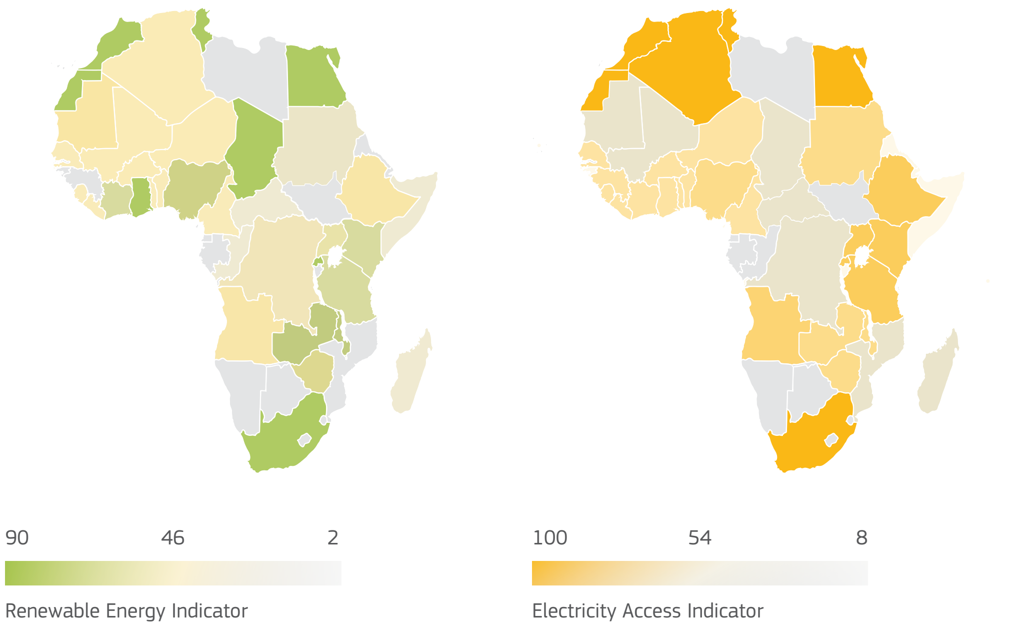


Figure 3.12 RISE values in 2020 (Source: the World Bank)[32]

The AfDB Electricity Regulation Index (ERI) presents detailed analyses for the regulators in 36 African countries. together with specific recommendations. The Electricity Regulatory Index is made up of three pillars: The Regulatory Governance Index (RGI), which assesses the level of development of the legal and institutional set up; the Regulatory Substance Index (RSI), which assesses how the regulator has operationalised the mandates of the legal setup; and the Regulatory Outcome Index (ROI), which assesses the outcomes and impact of the operation of the regulator from the perspective of the regulated entities.

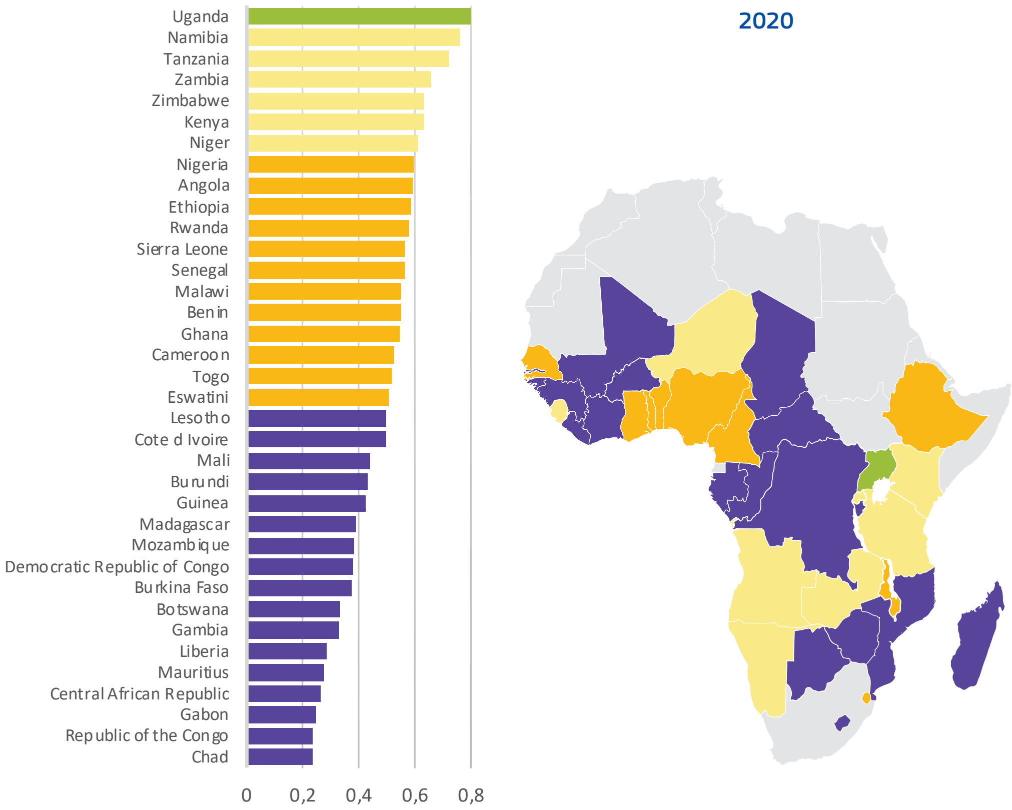
Countries are ranked into four performance ‘bands’, reflecting how developed their electricity regulatory frameworks are:

Score	Interpretation
0.80 to 1.00	High level of regulatory development
0.60 to 0.799	Substantial level of regulatory development
0.50 to 0.599	Medium level of regulatory development
0.00 to 0.499	Low level of regulatory development

Only one country, Uganda, achieved the ‘High level of regulatory development’ in 2020, and six countries achieved the ‘Substantial level of regulatory development’ (Figure 3.13). The vast majority of countries fall under the first two bands of medium and low level of regulatory development. It is also interesting to see the geographical distribution of the countries with high and substantial level of regulatory development, since they are mainly located in the eastern and southern part of the continent. 3.6.

[32] WorldBank & ESMAP. (2020). Regulatory Indicators for Sustainable Energy (RISE) Sustaining the momentum. Washington, DC.

Figure 3.13 AfDB Electricity Regulation Index 2020 (Source: AfDB)[33]



The impact of the COVID-19 crisis on the electricity sector of African countries has been visible both on the supply side -due to issues in production, and on the demand side -due to changes in the demand patterns.

3.6. THE EFFECT OF THE COVID-19 PANDEMIC

The impact of the COVID-19 crisis on the electricity sector of African countries has been visible both on the supply side -due to issues in production, and on the demand side -due to changes in the demand patterns. Within the framework of the "Support to AUC for the implementation, coordination and monitoring of the Electricity Harmonisation Regulatory Strategy and Action Plan", a specific report on "Support to AUC to effectively address the impacts of COVID-19 in the African electricity sector and the post COVID-19 recovery" examined with detail the impacts of the pandemic.[34] One of the crucial findings of this work was the disruption of long-term strategies, leading to setbacks in the increase of access to electricity.

On the supply side, disruptions in maintenance and expansion projects occurred. These are expected to have an effect in the medium and long term. Most African public power utilities experienced deficits in electricity generation and grid functionality due to delayed, or lack of spare parts and equipment, often imported from overseas.[35] In parallel, the restriction in movements of experts to project sites also affected maintenance, as well as development of new projects aimed at improving access to electricity.[36] For example, wind farm constructions ceased in South Africa due to lockdowns, since they were not considered 'essential'.[37]A direct effect of this disruption consisted in delays in implementation of energy strategies, and postponement of planned generation capacity deployment.[28] In certain cases, policy makers decided on support measures for vulnerable customers, such as refraining from cutting off electricity access or even decreasing the price of energy -the cost of which was taken up by the sector operators. Independent power producers' (IPPs) participation in the electricity supply decreased as demand fell, and utilities struggled to honour new and existing PPAs. Some Governments even renegotiated to lower wholesale electricity prices, leading to revenue loss for the IPPs, which impacts their profitability -or even their viability.

[33] AfDB. (2020). Electricity Regulatory Index for Africa 2020. Abidjan.
[34] EU TAF. (2021). LOT 10.2: Support to AUC to effectively address the impacts of COVID-19 in the African electricity sector and the post COVID-19 recovery. Deliverable 2. Mission ref: CW235.201906 AUC.
[35] ECREEE. (2020). The Impact of COVID-19 on the ECOWAS Energy Sector.
[36] Ngwawi, J. (2021). SADC energy sector braces for COVID-19 impact. Retrieved from https://www.sardc.net/en/southern-african-news-features/sadc-energy-sector-braces-for-covid-19-impact/
[37] Wind Energy and Electric Vehicle Magazine. (2020, June). South Africa lifts wind energy project construction shutdown. Retrieved from https://www.evwind.es/2020/06/05/south-africa-lifts-wind-energy-project-construction-shutdown/75032

Demand for electricity, like demand for energy in general, plummeted due to the lockdowns and subsequent economic crisis. According to the IEA, the impact of the pandemic on electricity demand was significant, as a result of the contraction of the economy as well as the restrictions in movements. For example, in South Africa, a considerable 23% drop in electricity demand was recorded between April 2019 and April 2020, with further reductions seen in May (14%) and June (5%) of 2020. Overall, South Africa's electricity demand is expected to decline by more than 5% in 2020 compared to 2019 figures. At the continental level, a demand reduction of around 2% is anticipated.[38] However, despite reduced demand, service quality and energy security did not improve, due to unprepared systems.[39] Furthermore, demand patterns were strongly altered, putting additional pressure on the power systems. A significant drop in the demand of electricity for the industrial and commercial sectors (as people were not going to work because of movement restrictions) was coupled with an increase in demand for household consumption. The increased demand in the health sector could not be met, due to poor access and unprepared systems for such a sudden sectoral demand surge.

According to IEA, the COVID-19 pandemic has already reversed progress in electricity access, with a particular impact on off-grid electrification and challenges in supply chains upstream.[40] The resilience of small, financially vulnerable actors has been heavily tested, while at the same time there is a strong demand for solutions -and investment opportunities emerge. In sub-Saharan Africa, where the number of people without access to electricity has been steadily in decline since 2013, numbers are expected to increase in 2020, pushing many countries farther away from achieving the goal of universal access by 2030. The health crisis and economic downturn caused by COVID-19 is increasing difficulties faced by governments as they look to alleviate energy poverty and expand access to electricity. On the positive side, there was a notable increase in the use of off-grid appliances during the lockdowns, especially in remote areas.[41]

[38] IEA. (2020, December). Electricity Market Report.

[39] EU TAF. (2021). LOT 10.2: Support to AUC to effectively address the impacts of COVID-19 in the African electricity sector and the post COVID-19 recovery. Deliverable 2. Mission ref: CW235.201906 AUC.

[40] IEA. (2020, November). The Covid-19 crisis is reversing progress on energy access in Africa.

[41] Akrofi, M., & Antwi, S. (2020). COVID-19 energy sector responses in Africa: A review of preliminary government interventions. Energy Research & Social Science, 68. doi: https://doi.org/10.1016/j.erss.2020.101681

4. SHORT-, MEDIUM-, AND LONG-TERM SCENARIOS: UP TO 2025, 2030, 2040 AND BEYOND

The evolution of the electricity sector in Africa has been studied by various institutions using different input assumptions and time horizons.

The evolution of the electricity sector in Africa has been studied by various institutions using different input assumptions and time horizons. To compare the conclusions of each study, a deeper analysis of the selected projections is essential, to help understand the rationale behind these scenarios. This chapter presents the timeframe and the geographical scope for the selected projections, as well as the scenario narrative and the cross-analysis of the different scenarios using identified qualitative parameters.

4.1. TIMEFRAME AND GEOGRAPHICAL SCOPE OF THE SELECTED PROJECTIONS

4.1.1. Timeframe of the selected projections

Projections are designed by different institutions so they usually do not have the same starting point and time horizon, which may vary depending on the type of model used and the purpose of the study (i.e. medium-term study up to 2030/2040 or long-term study up to 2050 and beyond).

For each projection, the starting point and the time horizon are presented in Table 4.1. Regarding the "Review of Existing Power Pool Masterplan" developed by the EU TAF in 2020, all data projections are provided by the Power Pools; where data was not available, the EU TAF team addressed this gap by using credible and validated data from other institutions.

Table 4.1: Timeframe of the selected projections

Institution	Date	Projection name	Starting date	Time horizon
IEA	2019	African Energy Outlook	2018	2040
IRENA	2021	Planning & Prospects for Renewable Power: Eastern and Southern Africa	2015[42]	2040
IRENA	2018	Planning & Prospects for Renewable Power: West Africa	2015	2030
IRENA	2015	Planning & Prospects for Renewable Energy: Africa Power Sector	2010	2030
EU TAF	2020	Review of Existing Power Pool Masterplans: CAPP, in the Baseline scenario from the CMP Phase 1 study	2020	2040
EU TAF	2020	Review of Existing Power Pool Masterplans: EAPP, and updated data and projections by EU TAF team in the Baseline scenario from the CMP Phase 1 study	2020	2030[43]
EU TAF	2020	Review of Existing Power Pool Masterplans: SAPP, in the Baseline scenario from the CMP Phase 1 study	2020	2040
EU TAF	2020	Review of Existing Power Pool Masterplans: WAPP. in the Baseline scenario from the CMP Phase 1 study	2020	2033
EU JRC	2019	Energy Projections for African Countries	2018	2065

[42] The base year of this analysis was 2010; results for 2020 were presented.
[43] The EAPP Masterplan published in 2014 features a time horizon to 2040. However, updated information received during the EU TAF assignment has revised this data with a time horizon until 2030.

4.1.2. Geographical scope of the selected projections

As in the case of timeframes of the selected projections, the geographical scope of each study could vary depending on the type of model used, as well as the purpose of the study -e.g. a narrower geographical scope could be used for a more detailed study on energy sector evolution. For each projection, the respective geographical scope for the study is presented in Table 4.2.

The International Energy Agency and the EU JRC modelled the entire continent, as has IRENA in the 2015 study "Planning & Prospects for Renewable Energy: Africa Power Sector". In this study, IRENA aggregated the results of the different regions, but did not use a model for the continent as a whole, as a single unit.

Table 4.2: Geographical scope of the selected projections (islands are not considered).

Institution	Date	Projection name	Geographical Scope
IEA	2019	African Energy Outlook	All countries
IRENA	2021	Planning & Prospects for Renewable Power: Eastern and Southern Africa	Angola, Botswana, Burundi, D.R.C., Djibouti, Egypt, Eswatini, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, South Sudan, Sudan, Tanzania, Uganda, Zambia, Zimbabwe
IRENA	2018	Planning & Prospects for Renewable Power: West Africa	Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo
IRENA	2015	Planning & Prospects for Renewable Energy: Africa Power Sector	All continental countries
EU TAF	2020	Review of Existing Power Pool Masterplans: CAPP, in the Baseline scenario from the CMP Phase 1 study	Angola, Burundi (also in EAPP), Cameroon, C.A.R., Chad, D.R.C (also in SAPP and EAPP)., Congo, Equatorial Guinea, Gabon, Rwanda (also in EAPP), Sao Tomé
EU TAF	2020	Review of Existing Power Pool Masterplans: EAPP, and updated data and projections by EU TAF team in the Baseline scenario from the CMP Phase 1 study	Burundi (also in CAPP), D.R.C (also in SAPP & CAPP), Djibouti, Egypt, Ethiopia, Kenya, Libya (also in COMELEC), Rwanda (also in CAPP), Sudan, Tanzania (also in SAPP), Uganda
EU TAF	2020	Review of Existing Power Pool Masterplans: SAPP, in the Baseline scenario from the CMP Phase 1 study	Angola, Botswana, D.R.C (also in EAPP & CAPP). Eswatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania (Also in EAPP), Zambia, Zimbabwe
EU TAF	2020	Review of Existing Power Pool Masterplans: WAPP, in the Baseline scenario from the CMP Phase 1 study	Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo
EU JRC	2019	Energy Projections for African Countries	All countries

4.2. THE SCENARIO NARRATIVE BEHIND THE SELECTED PROJECTIONS

4.2.1. IEA – African Energy Outlook

Within the African Energy Outlook developed by the IEA, two scenarios were used, and are presented in Table 4.3. The first one, called "Stated Policies", explores the evolution of the entire energy sector with the existing and announced policies - this scenario describes the reference case. The other one, called "Africa Case", incorporates the African Union Vision 2063 and identifies the best pathway to achieve specific targets, such as the key Sustainable Goals in 2030.

Table 4.3: Scenarios developed in IEA African Energy Outlook (2019)[44]

Name	Scenario narrative
Stated Policies (SP)	The SP scenario provides a measured assessment of where today's policy frameworks and announced policies, together with the continued evolution of known technologies, might transform the energy sector in sub-Saharan Africa in the coming years. This scenario does not focus on achieving any particular outcome: it simply looks into the future on the basis of announced policy ambitions in various sectors.
Africa Case (AC)	The AC scenario is built on the premise of AU Agenda 2063 and considers each country's own vision for economic growth, based on regional economic blueprints, and typically incorporating an accelerated industrial expansion. It also incorporates key sustainable development goals by 2030, including achieving full electricity and clean cooking access, as well as significant reductions in pollution-related premature deaths.

4.2.2. IRENA – Planning & Prospects for Renewable Power Series

IRENA's most recent report on the "Planning & Prospects for Renewable Power" series provides analyses of the synergies within the African Clean Energy Corridor, and insight on how this initiative could transform the electricity sector in the Eastern and Southern Africa Power Pools. This study explored the impact of renewable energy integration, exogenous events which could impact the hydropower resources and the consolidation of transmission network for cross-border trading.

Table 4.4: Scenarios developed in IRENA Planning and Prospects for Renewable Power: Eastern and Southern Africa (2021)[45]

Name	Scenario narrative
Reference (Ref)	The Ref scenario serves as a baseline for the alternative scenarios, and is unconstrained in that it neither stipulates any specific renewable energy penetration in the power system of ACEC countries, nor any CO2 reduction targets. The interconnector expansion in the scenario is limited to currently identified projects, some of which are already committed.
Limited penetration of VRE to 20% (VRELim)	The VRELim scenario shows the implications of limiting the pace of solar PV and wind deployment in the region (20% share of variable renewable electricity in the regional generation mix in 2040). The inability to implement projects is due to non-cost reasons, and the limitation only pertains to overall production, aggregated over the entire region.
50% share of variable renewables in the regional generation mix in 2040 (VREHigh)	The VREHigh scenario investigates the outcomes and additional investments needed under a more ambitious deployment target for solar PV and wind, compared to the Ref scenario (50% share of variable renewable electricity in the regional generation mix in 2040 is imposed exogenously as a target).
Dry year (HyDry)	The HyDry scenario is based on expert opinion, and presents cases where hydropower output is reduced due to limited production per capacity relative to the Ref scenario. In terms of modelling approach, the capacity factors of hydropower plants are reduced to reflect low hydrological flows.
Delayed hydro (HyDel)	The HyDel scenario is also based on expert opinion, and presents cases where hydropower output is reduced due to delays in the construction of planned hydropower generation projects relative to the Ref scenario. In terms of modelling approach, the projects are delayed based on their sizes: the start years of projects with capacities above 250 MW are delayed by five years, while those with capacities of more than 1 000 MW are delayed by ten years.
Unlimited interconnector capacity expansion scenario (TxNoLim)	The TxNoLim scenario investigates the impact on the power supply mix when capacity build limits on certain interconnectors are fully removed after 2030. The rationale for the choice is that a number of these interconnectors are along the PIDA North–South Power Transmission corridor. The scenario seeks to identify potential transmission infrastructure projects that can facilitate regional integration in line with the PIDA's aim.

[44] IEA. (2019, November). Africa Energy Outlook 2019.

In IRENA's 2018 study for the West African Power Pool, three scenarios were developed. This study focuses on the development of renewable energy and aims to quantify the impact of regional targets versus national targets.

Table 4.5: Scenarios developed in IRENA Planning and Prospects for Renewable Power: West Africa (2018)[46]

Name	Scenario narrative
Reference (Ref)	The Ref scenario considers the deployment of renewable electricity plants in the absence of national or regional targets, based on a detailed project pipeline with cost competitiveness as the key driver for the deployment of various technologies. This scenario is an update of the Renewable Promotion Scenario from the 2013 version of the same analysis, and assumes a supportive institutional environment, in which policies and market developments allow for rapid reductions in renewable energy costs that are consistent with global observations and past trends.
EREP Target (EREP)	The EREP scenario imposes a region-wide minimum target on the Ref Scenario in line with EREP targets: increasing the share of grid-connected renewable energy in the region's overall electricity mix (defined as the share of renewable energy capacity as a percentage of peak load) to 35 % in 2020, and 48 % in 2030, which respectively include 25 % and 29 % of medium-sized/large hydropower (ECREEE, 2013).
National targets (NT)	Rather than a region-wide target, the NT scenario sets minimum country-level targets for the percentage of renewable energy in total domestic generation, based on specific input from national experts. In the absence of such inputs, targets are based on national SEforALL Action Agenda documents.

"IRENA report Planning & Prospects for Renewable Energy: Africa Power Sector", published in 2015, is a summary of the five studies conducted by IRENA for each region of the African continent between 2013 and 2015. All the regional scenarios are developed using the same global methodology (Table 4.6), before including the specificities of the region. IRENA noted that the more recent analysis for Southern, Eastern, and Western Africa as discussed above overwrites the analysis presented in the 2015 publication.

Table 4.6: Scenarios developed in IRENA Planning and Prospects for Renewable Energy: Africa Power Sector (2015)[47]

Name	Scenario narrative
Main scenario 1	Main scenario 1 integrates fast renewable-energy cost reductions as a result of renewable-promotion policies, and depicts a renewable-oriented transformation of the power systems.
Main scenario 2	Main scenario 2 presents a contrast of the first main scenario with marginal deployment of renewable energy. Power systems are depicted with increased reliance on fossil fuels as sources.
Alternative scenarios	Alternative scenarios are dictated by policy questions specific only to the region.

Additional details are provided in the synthesis report regarding the modelling scenarios used for the CAPP and the COMELEC.

For the CAPP, IRENA has developed five scenarios to cover the future challenges of the region. The reference scenario is fossil fuel-based, with a limited deployment to current level (i.e. 2015) for renewable electricity technologies and trade within the region or with other Power Pools. The four other scenarios foresee a cost decrease in renewable energy technologies, and various degrees of regional integration for trading covering: no growth in trade; trade only within the CAPP; trade within the CAPP and export to SAPP and WAPP trade with SAPP and WAPP. Only the Full Integration scenario (FI) is presented in this report and considers a cost decrease for renewable energy technologies, as well as trading within CAPP, as well as with SAPP and WAPP.

For the COMELEC, IRENA has developed three scenarios to understand the evolution of the region.

[46] IRENA. (2018). Planning and prospects for renewable power: West Africa. Abu Dhabi.
[47] IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi.

Table 4.7: Scenarios developed in IRENA Planning and Prospects for Renewable Energy: Africa Power Sector for the COMELEC (2015)[48]

Name	Scenario narrative
Frozen Future (FF)	The FF scenario considers a limited implementation of renewable energy policies
Progressive Technology (PT)	The PT scenario contrasts with the first one and proposes successful renewable-energy policies resulting in cost reductions for building renewable generation capacity.
Diversification and environmental investment (DIVE)	The DIVE scenario is based on the PT scenario by assuming a higher price for natural gas aligned on international market rates.

However, as individual reports for CAPP and COMELEC were not published by IRENA, and due to the limited information on the input assumptions, the projections for CAPP and COMELEC should be considered only as indicative. IRENA is currently updating the models for both these regions, and the full reports are to be published in the coming months.

4.2.3. Power Pools – Generation & Transmission Masterplans

Each Power Pool Generation and Transmission Masterplan developed various planning scenarios specific to the region, and proposed several sensitivity studies to handle uncertainties. In the "EU TAF Review of the Existing Power Pool Masterplans", extensive consultations were conducted both with the Power Pools and other institutions to collect the most up to date information, to address the data gap, and update the Masterplans. Focus on the power demand scenarios have been presented and summarised in Table 4.8.

Table 4.8: Scenarios developed within EU TAF– Review of Existing Power Pool Masterplans (2020)[49]

Name	Scenario narrative
Low (Lo)	The Lo scenario uses a conservative approach to forecast the power demand (peak and annual demand) in regard to the BC scenario.
Base Case (BC)	The BC scenario is the reference scenario for power demand.
High (Hi)	The Hi scenario uses an optimistic approach to forecast the power demand (peak and annual demand) in regard to the BC scenario.

4.2.4. EU JRC – Energy Projections for African Countries

The EU JRC proposes three scenarios. The conservative base case scenario expects no implementation of additional renewable energy policies after 2017. The 1.5°C and the 2°C scenarios identify the best pathway to meet the long-term goal of a mean global temperature increase over pre-industrial levels, below 1.5°C and 2°C respectively, aligned with the climate targets under the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement. The 1.5°C and the 2°C scenarios are based on the "EU JRC Global Energy and Climate Outlook (GECO)" study of 2018, whereby a quantitative analysis combines global energy systems and macroeconomic modelling.[50]

Table 4.9: Scenarios developed in EU JRC – Energy Projections for African Countries (2019)[51]

Name	Scenario narrative
Reference (Ref)	The Ref scenario considers the national energy policies that were in place until 2017, without considering new policies for renewable energy after this date. With the Ref. scenario, the aim was to extrapolate the current situation into the future to project a plausible African energy system where energy policies are assumed not to evolve.
1.5°C scenario (1.5C)	The 1.5C scenario considers emission targets that are consistent with a likely chance of meeting the long-term goal of a mean global temperature increase over pre-industrial levels below 1.5°C (UN 2015). In this scenario, the CCS technology is considered.
2°C scenario (2C)	The 2C scenario considers emission targets that are consistent with a likely chance of meeting the long-term goal of a mean global temperature increase over pre-industrial levels below 2°C (UN 2015). In this scenario, the CCS technology is considered.

[47] IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi.

[48] EU TAF. (2020). LOT 8.1: Support to the Development of a Continental Power System (Transmission-Generation) Masterplan. Deliverables 2 & 3. Mission ref: CW235.201906 AUC.

[50] Keramidas, K., Diaz Vazquez, A., Weitzel, M., Vandyck, T., Tamba, M., Tchung-Ming, S., Soria-Ramirez, A., Krause, J., Van Dingenen, R., Chai, Q., Fu, S. and Wen, X. (2020). Global Energy and Climate Outlook 2019: Electrification for the low carbon transition. Luxembourg: Publications Office of the European Union. ISBN 978-92-76-15065-7. doi:10.2760/350805. JRC119619.

[51] Pappis, I., Howells, M., Sridharan, V., Usher, W., Shivakumar, A., Gardumi, F. and Ramos, E. (2019). Energy projections for African countries, Hidalgo Gonzalez, I., Medarac, H., Gonzalez Sanchez, M. and Kougias, I. Editors. EUR 29904 EN. Publications Office of the European Union. Luxembourg. ISBN 978-92-76-12391-0. doi:10.2760/678700. JRC118432.

4.3. DEFINITION OF THE MAIN PARAMETERS TO COMPARE THE SCENARIOS

To compare the projections coming from different starting points, geographical scopes and time horizons, it is essential to select and group key parameters under categories. This will help to later identify the main trends of energy sector transformation. The categories identified are the sectors considered, demand forecast, resource potential and cost projections, as well as the modelling approach.

4.3.1. Category 1: Sectors considered

Each study is developed within a certain context and for a specific purpose. Therefore, analysing the type of sectors considered in each study can help to better understand the underlying rationale.

For example, the broad analysis of the entire energy sector provides a holistic view of the full sector, considering interdependencies between power, transport, industry, services, and residential sectors. On the other side, a study focused only on the power sector may appear more simplistic, but it will offer a precise, deeper view of the electric system, to help decision makers develop new policies specific to the particular sector. Alternatively, some studies can also analyse only specific sectors (e.g. power and water) to investigate a unique interdependency.

4.3.2. Category 2: Demand forecast

Energy demand is one of the main elements that will influence the way the energy will be produced and the type of technology that will be used. In that context, some parameters can be identified among the projections to better understand how the energy demand has been forecasted in each study:

- Type of drivers used to estimate demand forecast (e.g. GDP growth, population)
- Introduction of specific targets on energy efficiency
- Socio-economy categories of end-users considered

4.3.3. Category 3: Resource potential, commodity price and technology cost projections

For demand forecast, the potential of available resources together with commodity prices and technology cost projections will strongly influence the way energy can be supplied to meet demand. In that context, some parameters could be identified among the projections to better understand how the potential of resources for both renewable energy and fossil fuels, the commodity prices and the technology costs were forecast. These include:

- Assessment of the resource potential (e.g. technical or economic potential)
- Discount rate and commodity price projections (e.g. oil, coal, natural gas, biomass prices)
- Technology cost projections (e.g. investment cost, fixed and variable O&M costs)

4.3.4. Category 4: Modelling approach

The modelling approach focuses on the details and methodology selected to address the different aspects of energy modelling in the study. In that context, some parameters could be identified among the projections to better understand how the modelling was done:

- Generation (e.g. possibility to invest in generic power unit, type of candidate power projects)
- Cross-border trading (e.g. bilateral agreement or evolution towards an integrated power market)
- Transmission & Distribution losses and reserve margin
- Off-grid systems (e.g. minigrid and solar system)
- Renewable energy and hydropower
- Others (e.g. battery storage, carbon tax, CCS, hydrogen).

4.4. OVERVIEW OF THE MAIN INPUT ASSUMPTIONS

The objective of this overview is to identify the sectors covered, to better understand the scope of work of each study, and extract the key trends among the input assumptions using the categories defined in Chapter 4.3.

4.4.1. Category 1: Sectors considered

The sectors considered for each projection are presented in Table 4.9, and are not scenario dependant. The selected report from IEA provides the reference projections in terms of evolution for the energy sector, with a strong focus on modelling of demand, and a deep understanding of the interactions between the various components of the sector - such as power, transport, industry, services and residential aspects.

On the other hand, the selected reports from IRENA and the Review of the Existing Power Pool Masterplans by the EU TAF Team only considered the power sector, but derived from energy models. The EU JRC projection is the only one that considered the water sector to quantify the interdependency and nexus between the production of electricity and water in the context of climate change and modification of the water cycle.

Table 4.9: Sectors considered in the selected projections.

Institution	Projection	Scenario	Energy	Power	Water
IEA	African Energy Outlook	All	Yes	Yes	No
IRENA	Planning and Prospects: Africa Power Sector	All	No	Yes	No
IRENA	Planning and Prospects: West Africa	All	No	Yes	No
IRENA	Planning and Prospects: Eastern and Southern Africa	All	No	Yes	No
EU TAF	Review of Existing Power Pool Masterplans in the CMP Phase 1 study	All	No	Yes	No
EU JRC	Energy Projections for African Countries	All	Yes	Yes	No

4.4.2. Category 2: Demand forecast

The analysis of the demand forecast using the key variables is presented in Table 4.10 where only the IEA's African Energy Outlook proposes several demand scenarios (Stated Policies –SP, and Africa Case -AC).

The evolution of GDP is difficult to compare, due to limited access to data. However, a difference of two points can be observed between the Stated Policies and the Africa Case scenarios of the African Energy Outlook, which implies the implementation of the AU Agenda 2063 is expected to strongly boost the economy of the continent. In comparison, a more conservative approach is assumed in the JRC study, due to the different modelling horizon (2040 for the IEA study versus 2070 for the JRC study). Also, it should be mentioned that an average GDP value cannot fully capture the complexity of the African continent and its heterogeneity. For instance, the WAPP Masterplan assumed a forecasted GDP growth of 7.4% for Sierra Leone, but only 1.7% for Nigeria -leading to an average GDP growth of 5.5.% for the region.

Variations on population evolution are limited among the selected projections, as they all referred to the same source (United Nations). However, the definition of demand category and how final electricity is consumed has an important impact on the results. In the IEA study and the first IRENA reports, demand was detailed by sector, with precise representation of the final end-users (i.e., industry, urban commercial, rural) while the other studies used an aggregated demand. IRENA however changed its methodology for assessing demand because of challenges in ensuring accurate data at that level of disaggregation.

Finally, energy efficiency targets are only explicitly implemented in the IEA model to quantify the impact of energy efficiency policies developed at continental level. The other reports used a limited approach, whereby energy efficiency targets were integrated only as a reduction of losses in the transmission and distribution systems, or as a lower growth rate for the electricity demand.

Table 4.10: Demand projection parameters in the different selected projections.

Institution	Projection	Scenario	GDP[52]	Pop.	Category	EE target
IEA	African Energy Outlook	SP	+4.3%	UN projections	Final end-user	Yes
IEA	African Energy Outlook	AC	+6.1%	UN projections	Final end-user	Yes
IRENA	Planning and Prospects: Africa Power Sector	All	NA	UN projections	Final end-user	No
IRENA	Planning and Prospects: West Africa	All	NA	UN projections	Final end-user	No
IRENA	Planning and Prospects: Eastern and Southern Africa	All	NA	UN projections	Aggregated	No
EU TAF	Review of Existing Power Pool Masterplans in the CMP Phase 1 study	All	+5.5% (WAPP)	UN projections	Aggregated	No
EU JRC	Energy Projections for African Countries	All	+3.6%	UN projections	Aggregated	No

[52] Real GDP growth assumptions expressed as compound average annual growth rate (CAAGR).

In addition, each study identifies key drivers regarding the evolution of demand in the African continent. In terms of geographical drivers, Nigeria, Ethiopia, and Egypt are leading the continent's energy demand according to IEA and JRC. At the regional level, Nigeria, Ghana, and Ivory Coast are leading the electricity demand in the West Africa region, while Ethiopia and Egypt are leading the electricity demand in the Southern and East Africa regions. Only IEA explores the demand evolution in more detail, through two different scenarios. The IEA study identifies the development of the service sector as well as the deployment of cooling as the key drivers of future electricity demand. Due to the different geographical disaggregation of the studies, specific country-level demand profiles are considered in the studies of IRENA, JRC, and the Power Pool Masterplans, while in the case of IEA the publication this is not clear.

4.4.3. Category 3: Resource potential, commodity prices and technology cost projections

Analysis of the resource potential, evolution of commodity prices, and technology cost projections based on various criteria are presented in Table 4.11. In terms of resource potential, all the selected studies referred to IRENA as their main source for renewable energy potential. For fossil fuel reserves, the sources varied -but the information usually came from the country's Ministry of Energy.

Commodity prices and technology costs are sensitive information and might be difficult to access. Most of the commodity price projections are aligned with the IEA database, except in the IRENA African Clean Energy Corridor (ACEC) study, where prices were based on the last SAPP Masterplan (2017). Technology costs usually rely on internal databases (IEA, IRENA[53]), and use a different rationale to explain cost evolution over time. In all the selected studies, overnight costs for matured technologies such as thermal and hydropower plants were assumed to be constant, while decreasing costs assumptions were used for RES technologies.

Table 4.11: Resource potential, commodity price and technology cost projections in the different selected projections.

Institution	Projection	Scenario	RES resource potential	Commodity prices	Technology cost
IEA	African Energy Outlook	All	IRENA	IEA	IEA
IRENA	Planning and Prospects: Africa Power Sector	All	IRENA	IEA	IRENA
IRENA	Planning and Prospects: West Africa	All	IRENA	IEA	IRENA
IRENA	Planning and Prospects: Eastern and Southern Africa	All	IRENA	SAPP	IRENA and SAPP and EAPP Masterplans.
EU TAF	Review of Existing Power Pool Masterplans in the CMP Phase 1 study	All	IRENA	NA	NA
EU JRC	Energy Projections for African Countries	All	JRC-GECO study	JRC-GECO study (POLES model)	JRC-GECO study (POLES model)

4.4.4. Category 4: Modelling approach

An analysis of the modelling approach is presented in Tables 4.12 and 4.13 to identify the available supply options to meet demand, and to better understand the outputs of each study. This analysis is not intended to provide the details of the modelling approach or compare the type of mathematical formulation used, but rather to highlight the focus of each study.

In terms of generation, a detailed and precise representation of electricity-producing power plants (i.e., existing, commissioned, planned, and projected) is available with a robust approach on the representation of thermal power plant operation (e.g., availability, construction time, efficiency).

For cross-border trading, different methodologies were used between the models. As not all the countries were modelled, this approach is quite limited in the IEA study. In the same vein, modelling for electricity exchange is also limited in most Masterplans -except SAPP. In the WAPP and EAPP Masterplans, modelling was indeed undertaken, which in turn has resulted in the identification of the key transmission system bottlenecks, along with those projects that need to be addressed and implemented in order to facilitate future trading and exchanges. The Africa Power Sector and WAPP reports of IRENA, as well as the JRC study, only considered existing and planned projects as possible options. The IRENA ACEC study is the

[53] For some technologies/plants, where available, IRENA also used cost data from the SAPP and EAPP Masterplans.

only study that proposed a set of additional interconnection projects, which could be selected by the model if they made economic sense.

Modelling of transmission and distribution losses is limited in the IEA report, mainly due to the fact that the objective of the study is the energy sector as a whole - not only the power sector, which can result in minor oversimplifications. A more advanced approach is used in the other outlooks with an evolution of the losses along the time horizon, and a split per category. Due to the complexity of how the reserve margin is represented, most studies use a constant value. No power reserve is modelled in the JRC study. During the review of existing Power Pools Masterplans, the EU TAF team identifies that SAPP used the following criteria:

- **Security criterion:** Minimum level of generation capacity is equal to or greater than 100% of demand
- **Reliability criterion:** Reserve capacity obligation of 10.6% of annual peak demand from thermal systems and 7.6% from hydro / mixed systems

In the same vein, EAPP used a reliability criterion whereby a requirement was included in the model stipulating that all the countries must have domestic capacity equal to 110% of the yearly peak demand.

Table 4.12: Modelling approach for generation, cross-border trading, Transmission & Distribution (T&D) losses, and reserve margin in the different selected projections

Institution	Projection	Scenario	Generation	Cross-border Trading	T&D losses Reserve
IEA	African Energy Outlook	All	Advanced	Information not available	Limited
IRENA	Planning and Prospects: Africa Power Sector	All	Advanced	Only planned projects	Advanced Limited
IRENA	Planning and Prospects: West Africa	All	Advanced	Only planned projects	Advanced Limited
IRENA	Planning and Prospects: Eastern and Southern Africa	All	Advanced	Advanced	Advanced Limited
EU TAF	Review of Existing Power Pool Masterplans	All	Advanced	Only planned projects	Advanced N/A
EU JRC	Energy Projections for African Countries	All	Advanced	Only planned projects	Advanced No

For Generation, the "Advanced" qualification refers to the integration of different categories/status to model the power assets (existing, committed, candidate, generic).

For Cross-Border trading, the "Advanced" qualification refers to modelling the exchange of electricity, where generic transmission projects are considered in addition to planned projects.

For T&D losses and Reserve, the "Advanced" qualification refers to use of variable losses over the time horizon (time series), while "Limited" qualification is used when the losses are constant.

One out of two people in African still have no access to electricity. The inclusion of off-grid systems in the energy projection is key to address the challenge of universal access to energy.[54] Among the projections, only the IEA used a specific tool (OnSSET) to identify the evolution of the share of demand supplied by off-grid systems versus the main grid. According to the IEA Africa Case scenario, nearly 10% of electricity demand will be supplied by mini-grids and standalone systems by 2040.

To model renewable technologies, IRENA's Africa Power Sector and WAPP reports used aggregate profiles -which reduced the robustness of the modelling. In the JRC and the IRENA ACEC study, where a specific zoning methodology has been developed to select the optimal site of operation, the hourly level data was aggregated to representative "time slices".

Battery storage is modelled in some reports such as IEA, IRENA West African Power Pools and the EU JRC Energy Projections. Battery storage is usually associated with solar PV technology.

Finally, only the JRC study proposed the implementation of a carbon tax and the use of CCS technology for thermal assets. Interestingly, this study does not propose large-scale batteries as a storage solution to support RES intermittent power production.

[54] IEA. (2020). SDG7: Data and Projections. Paris.

Table 4.13: Modelling approach for off-grid systems, RES and hydropower, and other in the different selected projections

Institution	Projection	Scenario	Off-grid systems	RES	Battery storage	Other
IEA	African Energy Outlook	All	Advanced	Information not available	Yes	Information not available
IRENA	Planning and Prospects: Africa Power Sector	All	No	Limited	NA	NA
IRENA	Planning and Prospects: West Africa	All	No	Limited	Rural PV	NA
IRENA	Planning and Prospects: Eastern and Southern Africa	All	No	Advanced	No	NA
EU TAF	Review of Existing Power Pool Masterplans	All	NA	NA	NA	NA
EU JRC	Energy Projections for African Countries	All	No	Advanced	Rural PV & CSP	CCS & carbon tax

4.4.5. Findings from the analysis of the main input assumptions

Analysis of the input assumptions for the selected projections will help identify the type of studies and aspects that affect the evolution of the African electricity sector. The main findings from the analysis of the input assumptions are as follows:

- The IEA African Energy Outlook presents a very detailed forecast of energy demand, and tries to capture the future trends in Africa -such as urbanisation of the population, or the development of off-grid systems.
- The detailed evolution of the regional and continental power systems is identified under different approaches: Base case (Masterplans), increased integration of renewable energies (IRENA), and climate change impact (JRC).
- The relationship between the power sector and the water sector in the context of increased average temperature and climate change effect is an angle to be considered, as per the JRC study, which leads to additional pressure on water resources in Africa.[55]

[55] Niang, I. et al. (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge.

5. COMPARATIVE PRESENTATION OF ALTERNATIVE SCENARIOS

Following the discussion of the main input assumptions of the alternative scenarios, key quantitative indicators for the development of energy policies are selected and presented among the projections for the short, medium, and long-term horizons.

Following the discussion of the main input assumptions of the alternative scenarios, key quantitative indicators for the development of energy policies are selected and presented among the projections for the short, medium, and long-term horizons. How these indicators evolve will help identify possible pathways for the development of the electricity sector in Africa.

5.1. KEY QUANTITATIVE INDICATORS FOR THE DEVELOPMENT OF POLICY

The indicators selected in the studies discussed under Chapter 4, which will be further analysed in the sections below, are the following:

1. Demand Projection

Developments in the demand of electricity are crucial for the analysis of the power system. As discussed in Chapter 4, different background assumptions were used in order to project the demand for electricity at the country level.

These were then aggregated to produce the demand level for the entire continent. In the analysis which follows, the largest consumers are identified, since they will be important for shaping the overall demand in the Power Pools. Furthermore, the countries which, show a large increase in the projected demand (highest CAGR) are identified as potential emerging and driving markets.

2. Installed capacity & electricity generation

Generation capacity required to cover the projected demand is one of the main indicators that drives the need for investments in the power sector. In studying the evolution of capacities of different technologies in the different scenarios, it is possible to identify the key technologies in the future energy mix, as well as assess how sensitive these choices will be.

3. Exchanges of electricity

In order to understand the future evolution of electricity exchange under different scenario assumptions, two macro-level metrics will be presented in the following section:

- the net transfer capacity of the interconnections between countries in a Power Pool, as a measurement of the existing infrastructure for electricity exchanges; and
- the total amount of electricity exported from the countries in a Power Pool, as a measurement of the total quantity of electricity exchanges.

Additional key indicators do exist and could have been included in the current analysis, but have not been considered due to insufficient information. Such indicators could, however, be considered for future reports. Additional indicators are grid accessibility, grid connection share, consumption of electricity per capita, installed capacity per capita, ratio of population supplied by off-grid systems, among others.

When presenting the quantitative indicators, one of the main considerations in the selected studies was data availability. The non-availability of data for some indicators limited the analysis, since the different studies varied in geographical coverage and time horizons. Therefore, only indicators which could be obtained for common geographical areas/regions and with common timeframes, are presented in the next section.

Table 5.1 is the legend on the coding used hereon for the different scenarios analysed. The basic scenario narratives and nomenclature/codes used are given in Tables 4.3 to 4.8.

Institution	Projection	Scenario Name	Scenario Code in the graphs
IEA	African Energy Outlook	Stated Policies	IEA-AEO-SP
		Africa Case	IEA-AEO-AC
IRENA	Planning and Prospects: Africa Power Sector CAPP	Full Integration	IRENA-CAPP-FI
	Planning and Prospects: Africa Power Sector NAPP	Progressive Technology	IRENA-NAPP-PET
		Frozen Future	IRENA-NAPP-FF
		Diversification	IRENA-NAPP-DIVE
	Planning and Prospects: West Africa	Reference	IRENA-WAPP-Ref
		Regional Targets	IRENA-WAPP-EREP
		National Targets	IRENA-WAPP-NT
	Planning and Prospects: Eastern and Southern Africa	Reference	IRENA-ACEC-Ref
		VRE 20%	IRENA-ACEC-VREIim
		VRE 50%	IRENA-ACEC-VREHigh
		Dry Year	IRENA-ACEC-HyDry
		Delayed Hydro	IRENA-ACEC-HyDel
		Unlimited Interconnections	IRENA-ACEC-TxNoLim
		Unlimited Interconnections 2035	IRENA-ACEC-TxNoLim2035
EU TAF	Review of Existing Power Pool Masterplans and collected country level information	Baseline	MP-PP-BC
		Low	MP-PP-Lo
		High	MP-PP-Hi
EU JRC	Energy Projections for African Countries	Reference	JRC-EP-Ref
		1.5°C	JRC-EP-1.5C
		2°C	JRC-EP-2C

Table 5.1 Scenarios nomenclature used in the following analysis.

5.2. EVOLUTION OF THE INDICATORS AMONG THE PROJECTIONS

As discussed, the different studies vary in terms of starting year, time horizon, and geographical coverage. To present consistent, comparative graphs, it was necessary to distinguish between studies looking at the continental level, and those studies zooming-in at the level of Power Pools or countries.

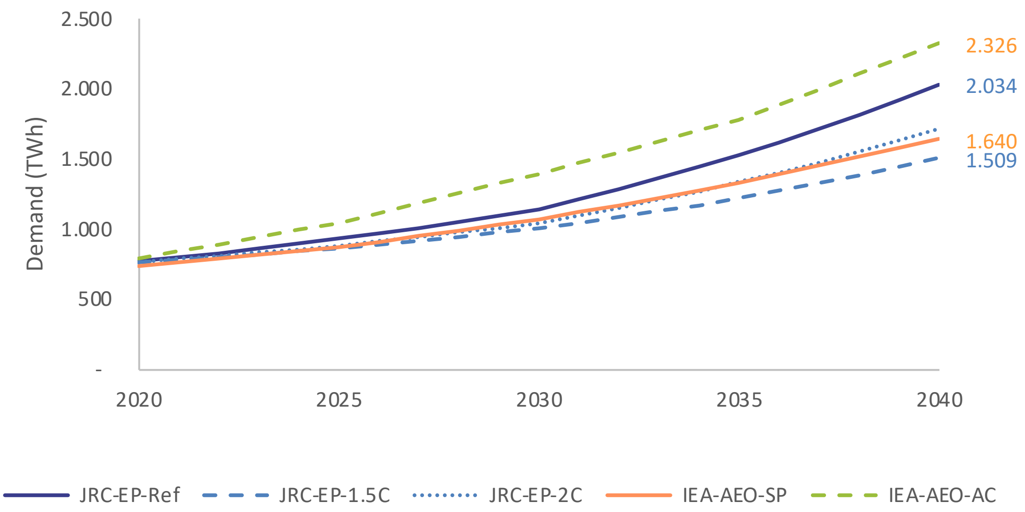
Another issue identified during the analysis was the fact that the projections for countries belonging to more than one Power Pools appeared to not be consistent in the Masterplans of the different Power Pools. This created issues of consistency and data accuracy when summing country-level information to calculate regional, and hence continental-level parameters. All these issues reinforce the case for the development of a Continental Masterplan on a uniform basis with consistent inputs, which can be used to draw conclusions at the continental level.

5.2.1. Demand projection

Comparing electricity demand projections at the continental level from the different studies was challenging, due to inconsistencies for those countries which belong to multiple Power Pools in the projections of the respective Power Pool Masterplans, as well as in the scenarios from IRENA (which used demand projections provided by the Power Pools).

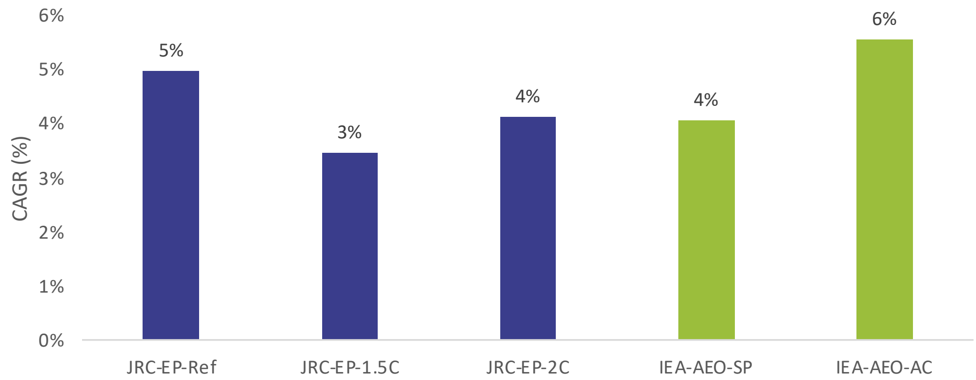
Furthermore, the Power Pool Masterplans as well as the studies of IRENA for the regional Power Pools were based on different input assumptions, different starting years and different time periods, making it impossible to aggregate the regional results and produce continental-level projections. Therefore, for consistency reasons, the results at a continental level are presented from the scenarios of IEA and JRC (Figure 5.1), while the analysis at Power Pool level is performed using the results of the analysis from JRC, IRENA and the review of the existing Power Pool Masterplans.

Figure 5 1 Electricity demand projection at continental level.



Comparing the projected CAGR (Figure 4 2) for the next twenty years of the scenarios, it is estimated that it will be close to 4%, similar to the CAGR observed in the period 2000-2017 (Figure 2 4). It is only in the IEA Africa Case that this is expected to have a moderately higher CAGR of 6%.

Figure 5 2 Compound annual growth rate of continental demand 2020-2040



Due to the different timeframes of the analyses (see Table 4.1) it is only possible to present consistent comparative graphs for the demand at the level of Power Pools until 2030. Values for 2040 are reported when they are available in the relevant studies and the CAGR is calculated for the period 2020 to 2030, to allow comparison between countries and studies.

The graphs show the demand for the Baseline scenario from the CMP Phase 1 study (MP), the Reference scenario of the JRC analysis (JRC) and the final demand which is derived from the sent-out demand used in all the scenarios analysed in the IRENA studies (IRENA), assuming 20% distribution losses. The differences in the demand projections in the graphs are as expected, since the input assumptions for each study are rather different; nonetheless, the comparative presentation offers useful insights on the possible trajectories of electricity consumption.

East African Power Pool

The projections of electricity demand in EAPP (Figure 5.3) show a continuation of the current situation: Egypt is the dominant consumer of electricity in the Power Pool, although its share falls from around 60% in 2020, to less than 55% by 2030.

The projections in the JRC reference scenario show a moderate increase of demand in Egypt (CAGR of 2% between 2020-2030), compared to the Power Pool Masterplans and the IRENA scenarios (of CAGR close to 5%). Libya is consistently the country with the second largest demand in the Power Pool, with an increasing relative share and a CAGR of 7 - 8% in the period 2020-2030 (Figure 5.4).[56]

[56] The projections in the study by IRENA were based on data from 2014, therefore do not account for the current economic situation in Libya. IRENA is currently updating the scenario analysis for the Northern Africa countries.

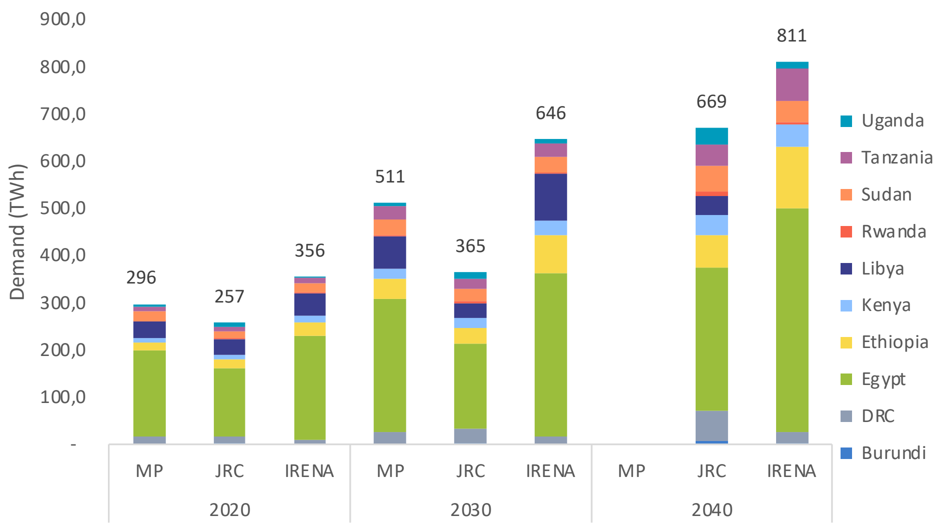


Figure 5.3 Demand projections per country for EAPP 2020-2030-2040

(*) No data is available in the MP projection for 2040.Libya is not included in the IRENA's projection for 2040.[57]

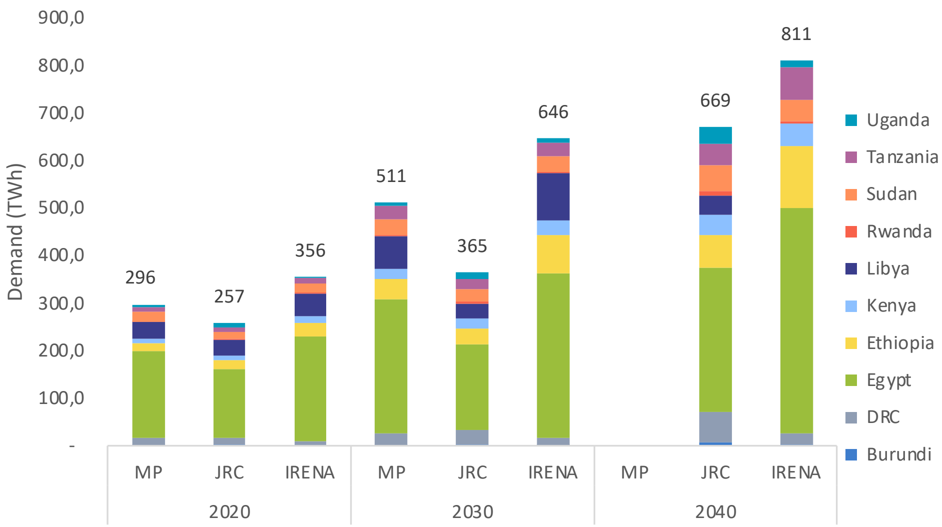


Figure 5.4 CAGR of demand per country in EAPP 2020-2030

In all the projections, Ethiopia is emerging as the third largest consumer, having one of the highest CAGR (between 8% and 11% depending on the study), with Tanzania, Kenya and Sudan following with similar levels of consumption.

Apart from Ethiopia, Tanzania exhibits a dynamic growth (CAGR between 6% to 10%), followed by Uganda (CAGR between 5% to 10%), Kenya (6% to 9%) and Libya (close to 8%) (Figure 5.4). It is noteworthy that in the Power Pool projections Rwanda exhibits a CAGR of 10% while the projected growth in the other studies is considerably lower.

Southern African Power Pool

In SAPP, the projections of demand between the different studies roughly coincide, especially regarding South Africa -which continues to dominate the demand in the region, but its relative share is lower: from close to 75% in 2020, to around 65% by 2030, and less than 60% for 2040. The increase of the demand in Zambia, Angola, Mozambique, Tanzania and DRC, is filling this void left in the Power Pool demand (Figure 5.5). South Africa is projected to remain the second largest consumer in the continent after Egypt over the entire horizon until 2040 (Figure 5.5 and Figure 5.3).

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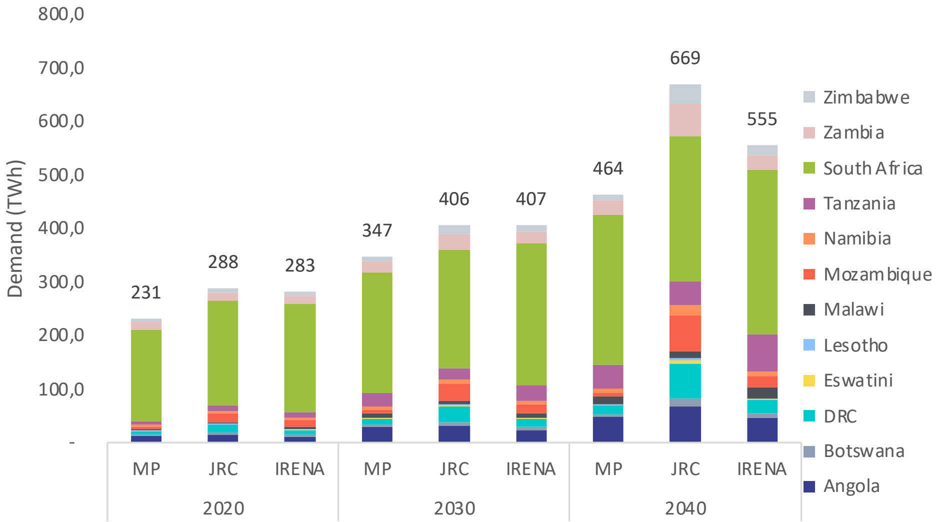
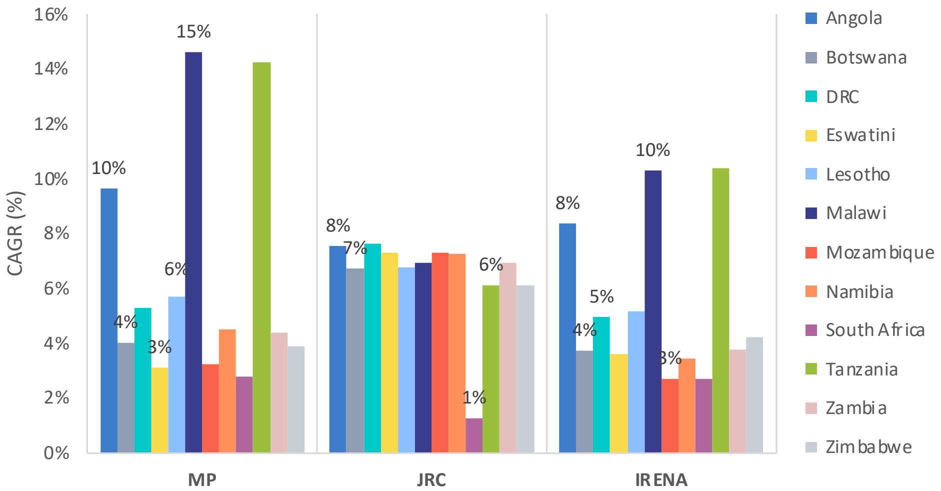
[57] The IRENA report presents the sent-out demand. The final energy demand presented in this graph was calculated assuming 20% total losses. The sent-out demand, which was estimated in the Baseline scenario of CMP 1, was used to calculate the final demand presented in the graphs assuming the same level of losses (20%).

Figure 5.5 Demand projections per country for SAPP 2020-2030-2040



Consistent with the analysis of EAPP, Tanzania shows one of the most dynamic increases (CAGR between 6% and 14% across the studies), with a demand that is projected to reach 30TWh in 2030, and almost 70TWh by 2040 in some studies (Figure 5.6). Malawi, despite its rather limited contribution to the regional demand, appears to be the country with the highest increase in rates (CAGR of 10% to 15%), while Angola appears to be another market projected to feature a significant increase in demand (CAGR of 8% - 10%).

Figure 5.6 CAGR of demand per country in SAPP 2020-2030



West African Power Pool

The overall demand in WAPP is projected to double in all the studies between 2020 and 2030, and this trend is expected to persist between 2030 and 2040 (Figure 5.7). Nigeria remains the largest consumer in the entire time horizon and is the main driver of this increase with a demand expected to more than quadruple between 2020 and 2040.

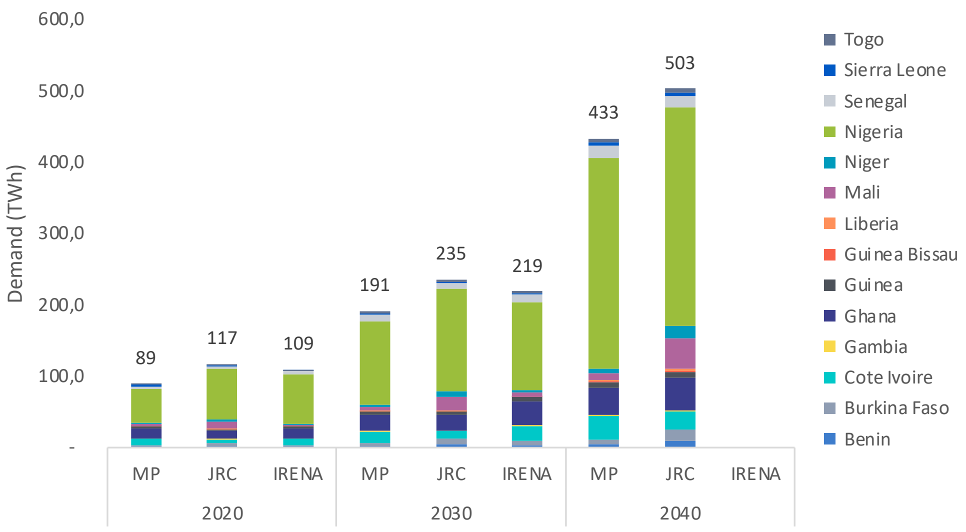


Figure 5.7 Demand projections per country for WAPP 2020-2030-2040

(*) No data is available in IRENA's projection for 2040. A new study is currently being developed with a time horizon to 2040.

Ghana is also showing an increase in electricity demand, although the CAGR projected at 4% - 8% in the different studies is not one of the largest in the region. In general, the CAGR of electricity demand is consistently above 5% across all countries in the Power Pool, in all the studies.

It follows a trend similar to the other regions where the highest growth rates are exhibited by smaller consumers, for example Guinea, Burkina Faso, and Liberia (CAGR between 8% and 11% between 2020 and 2030. Ivory Coast is the other key country in the region which is projected to increase its demand considerably, and become the third largest consumer in the Power Pool (Figure 5 8).

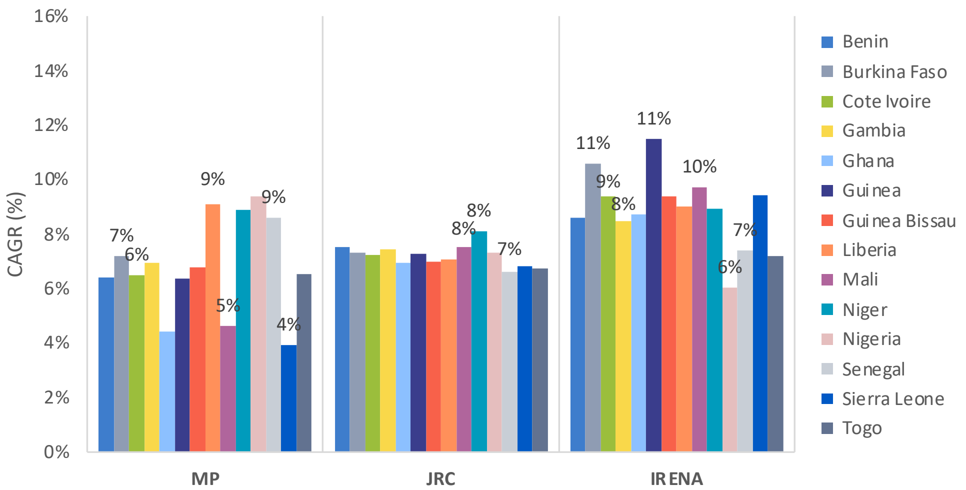


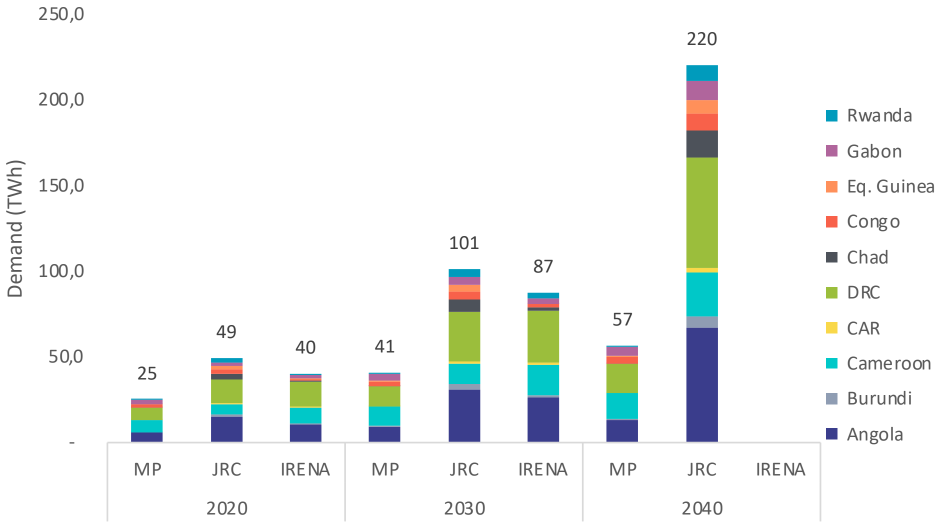
Figure 5.8 CAGR of demand per country in WAPP 2020-2030

Central African Power Pool

The projections for CAPP feature a high degree of discrepancy between the different studies, mainly due to the demand of the three largest consumers in 2030 -namely Angola, DRC and Cameroon. Projections in the Baseline scenario of CMP Phase 1 (MP) are considerably lower than those of JRC and IRENA studies; this should be further investigated to be fully understood. It is expected that the results from CMP2 will provide better insight of the demand projection for the Power Pool.

The relative contribution of the large consumers covers around 80-85% of the total Power Pool demand according to the projections of the Power Pools and IRENA, whereas in the JRC analysis this is reduced to close to 70%, with more countries such as Chad, Equatorial Guinea, Rwanda and Burundi exhibiting higher demand in 2030 (see Figure 5.9).

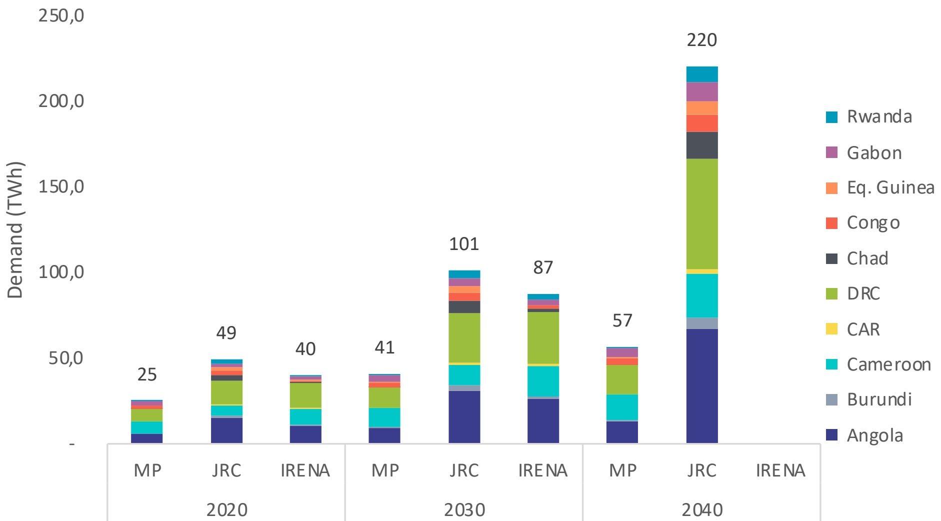
Figure 5.9 Demand projections per country for CAPP 2020-2030-2040



(*) No data is available in the IRENA's projection for 2040. A new study is currently being developed with a time horizon to 2040.

The growth rates of the demand projected in the IRENA studies are higher than those assumed in the other studies (Figure 5 10), with CAGRs above 10% projected for Rwanda, CAR and Chad.

Figure 5.10 CAGR of demand per country in CAPP 2020-2030



Comité Maghrébin de l'Électricité (COMELEC)/NAPP

In the COMELEC, country-level information does not exist to project demand beyond 2030. Furthermore, there is some discrepancy between the projections which could be explained by two elements: the COMELEC is not a functional Power Pool yet, and the study of IRENA was carried out in 2014 and is currently being updated. As a result, for the Baseline scenario of CMP Phase 1, the information was collected from the individual countries, so the input assumptions were not necessarily harmonised. Overall, Algeria is projected to remain the largest consumer in the region, followed by Morocco, Libya and Tunisia (Figure 5.11).

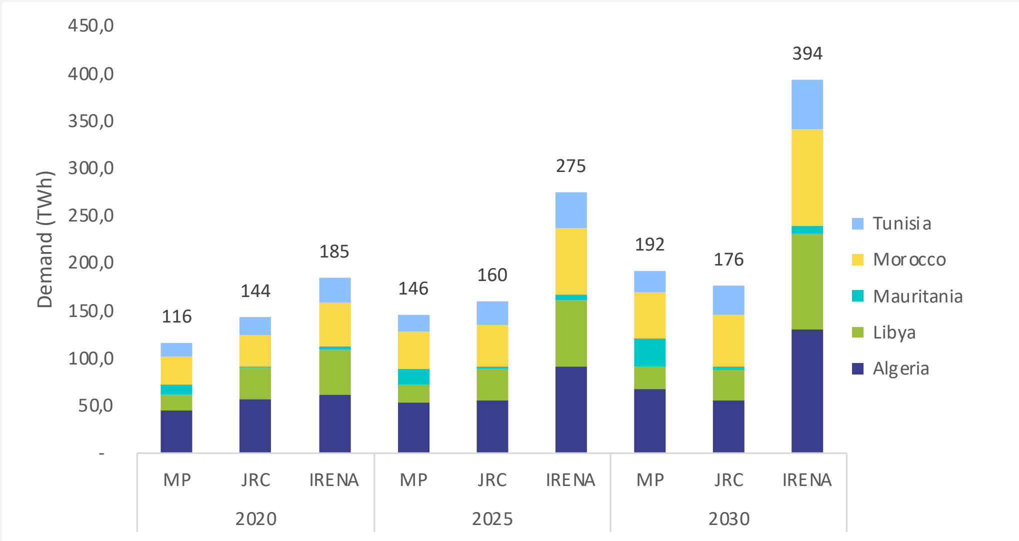


Figure 5.11 Demand projections per country for COMELEC 2020-2030-2040

(*) No data is available for projection until 2040. A new study is currently being developed by IRENA with a time horizon to 2040.

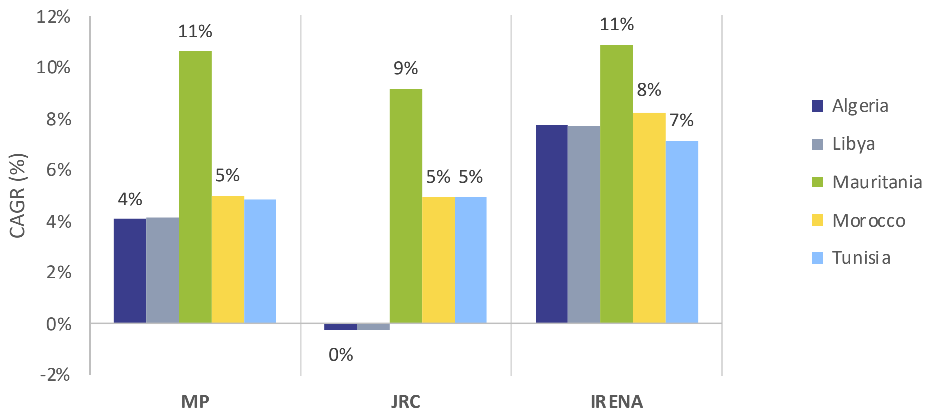


Figure 5.12 CAGR of demand per country in COMELEC 2020-2030

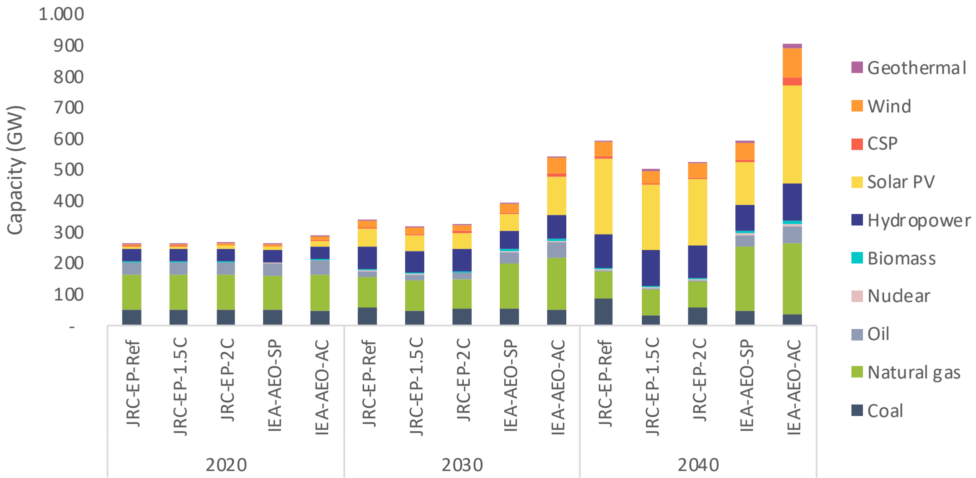
Mauritania is projected to have the highest CAGR for demand in the region (Figure 5.12) and is projected to surpass Libya in terms of demand by 2030, according to data collected from the in-dividual countries.

5.2.2. Installed capacities & electricity generation per technology.

The evolution of the installed capacity of thermal power plants at the continental level, according to the scenarios of the JRC and IEA Africa Outlook report, is projected to be dominated by gas-fired units until 2040. An exception lies in the Reference scenario of the JRC, where coal appears to play an important role, (Figure 5.13).

The share of renewable energy in the total installed capacity is projected to reach close to 50% by 2030 in all projections, apart from the "Stated Policies" of the IEA where it is projected to reach 40% in 2030 and increase to 50% by 2040 (Figure 5.14). This is an indication that existing policies should be enhanced in order to promote, as well as enhance the scale and scope of the use of renewables.

Figure 5.13 Projections of continental level installed capacity per technology

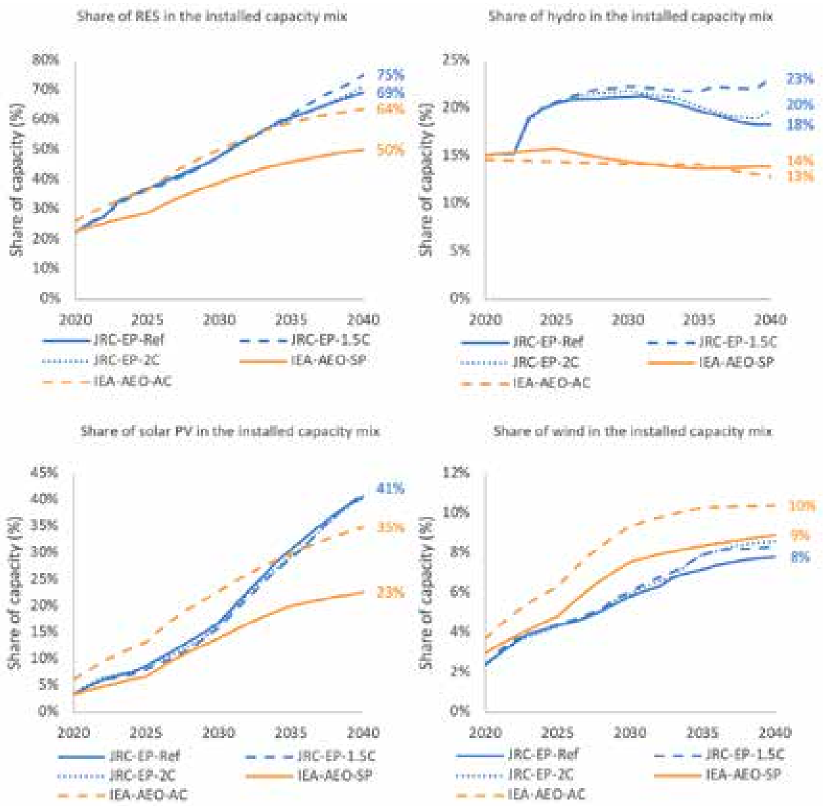


The installed capacity of hydropower is projected to double between 2020 and 2040 in the IEA-AEO-ST scenario, and almost triples during the same period in the IEA-AEO-AC scenario, which is a trend observed in all the JRC scenarios as well. The projections for the share of hydropower made by JRC are consistently more optimistic than those in the IEA scenarios, where their share never exceeds a level of 16%.

An important observation is the increase in the installed capacity of PVs, especially in the decade between 2030 and 2040, where a four- or five-fold increase can be seen in all scenarios, reaching more than 300GWs by 2040 in the "Africa Case" scenario of the IEA, and becoming the technology with the highest installed capacity in the continent. This large increase leads to shares in the installed generation capacity close to 40% for all the JRC scenarios, and a maximum of 35% for the IEA scenarios in 2040. CSP, on the other hand, does not seem to exceed the limit of around 10GW in all the projections by 2040- apart from IEA-AEO-AC, where it reaches a level of 26GW.

Finally, wind is a technology that consistently appears with a capacity above 20GW in 2030, reaching a maximum of 51GW in IEA-AEO-AC, doubling its capacity between 2030 and 2040. In general, there appears to be a ceiling of about 10% for the capacity of wind in all the studies.

Figure 5.14 Share of RES in total generation capacity per technology.



The findings for electricity generation per technology on the continental level (Figure 5.15), reveal the role natural gas is expected to play in covering the elevated demand, In all projections apart from the JRC-EP-Ref, the share of natural gas-produced electricity evolves from 40% in 2020, to about one third in 2030, and 20%-35% in 2040 (depending on the scenario examined).

The share of RES is expected to continuously increase, reaching above 55% in all scenarios apart from the Reference/Stated Policies scenarios by 2040, and almost 65% in the 1.5oC scenario of JRC (Figure 5.16).

In the policy scenarios, hydropower and PVs are projected to contribute to levels between 20% and 24% (hydro contribution is further increased to 28% in the 1.5oC scenario, driven by the stricter environmental constraints). The share of wind-generated electricity is projected to be close to 10% in all policy scenarios, which is consistent with its share of installed capacity.

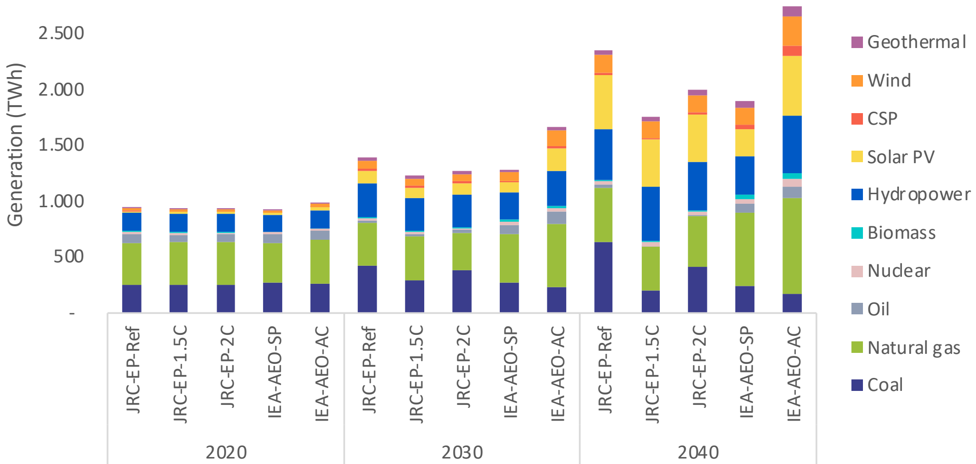


Figure 5.15 Projections of continental level generation per technology

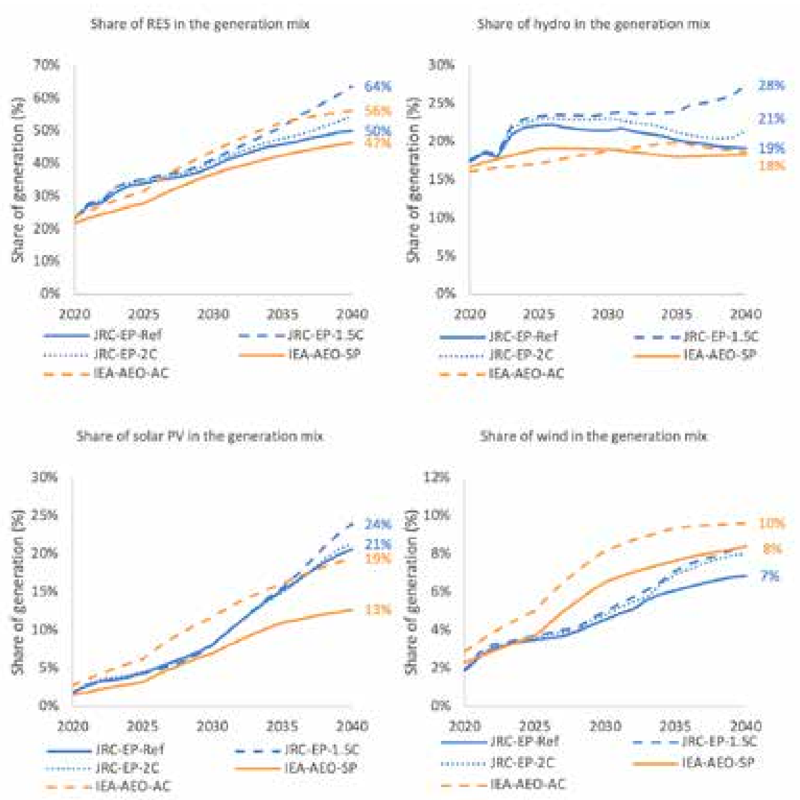
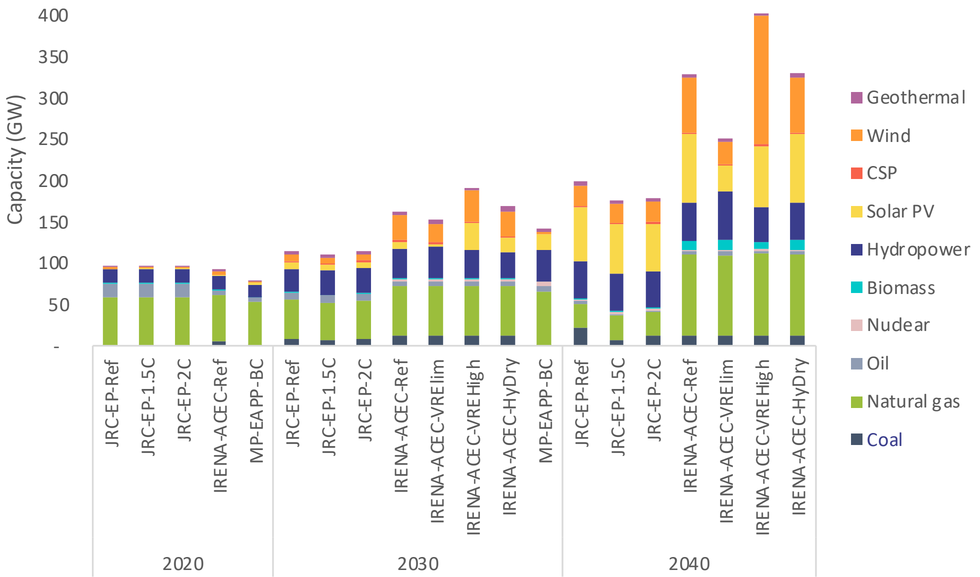


Figure 5.16 Share of RES in total electricity generation per technology.

East African Power Pool

At the level of the Power Pools, studies used as a reference are: the analysis of the relevant Masterplans used for the Baseline scenario developed under CMP Phase 1; the scenario analyses performed by the JRC; the scenario analyses performed by IRENA for the different Power Pools. Although there are currently no coal-fired power plants present in EAPP, almost all the projections included some coal capacity in 2030 and 2040 (apart from the Baseline scenario of CMP Phase 1) (Figure 5.17). Natural-gas-fired plants are the dominant thermal capacity in the Power Pool, with a capacity which is expected to double between 2020 and 2040 in all the IRENA scenarios. The relatively lower installed capacity and generation (Figure 5.19) projected in the JRC scenario is consistent with the lower projections of demand in the region (see Figure 5.3). Renewable energy sources in all studies are projected to increase their shares to above 45% in 2030 (Figure 5.18),reaching as high as 55% in the VREHigh scenario of IRENA, and increasing even further to above 65% in 2040 (apart from the scenarios with limitations to the variable renewables penetrations).[58]

Figure 5.17 Projections of installed capacity per technology in EAPP



(*) No data is available in the MP projection for 2040[59] and Libya is not included in the IRENA's projection for 2040.

There is potential for new hydropower installations in the Power Pool, with a capacity that is projected to more than double between 2020 and 2040 in the scenarios of JRC and IRENA. The relative share in the total installed capacity is however not expected to increase and, in some cases, it even decreases (Figure 5.18). The Baseline scenario of CMP Phase 1 projects a slightly higher share for hydro in 2030 compared to all other projections.[45]

The penetration of PVs in the power mix is projected to pick up as of 2025, and grow at a high rate- at least until 2035- for all scenarios, reaching up to 25% in the IRENA scenarios and 34% in the JRC scenarios. It is worth noting that the Baseline scenario developed under CMP Phase 1 envisages an earlier uptake of PVs, rising to levels higher than the other reference scenarios in 2030, reaching towards the VREHigh scenario.

On the other hand, wind is not a technology that is projected to increase considerably: its share of the energy mix remains at 2% by 2030, whereas in the IRENA reference it is projected to reach 20% by 2040, and almost 40% in the VREHigh scenario.[60] The projections of JRC are in general more conservative regarding the share of wind capacity in the 2040 mix.

[58] N.B.: There is no available data in the projections of the EAPP Masterplan for 2040 – therefore, the line is assumed constant in the graph after 2030.
[59] Although the EAPP Masterplan published in 2014 extends to 2040, the updated information received by the EU TAF team during CMP 1, presented in this graph, only extends to 2030.
[60] In this scenario the overall level of VRE was set exogenously at 50% as a target.

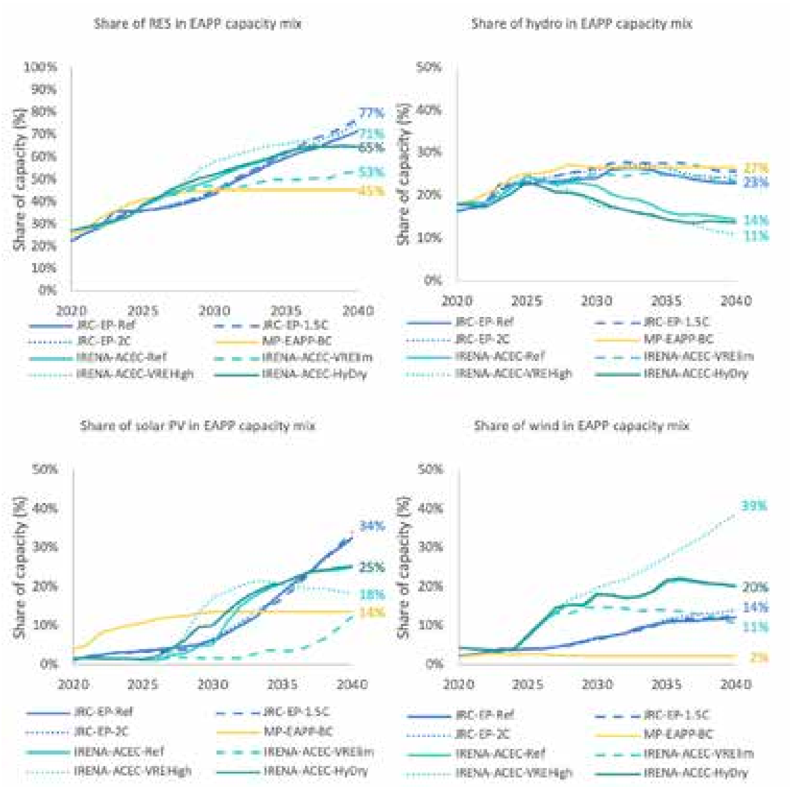


Figure 5.18 Share of RES in the total installed capacity in EAPP

Natural gas is the predominant fuel of fossil-fuel produced electricity in 2030 and 2040 (Figure 5.19), together with coal in some scenarios. In all scenarios, the overall share in electricity generation is consistently above 40% in 2030 (Figure 5.20), reaching more than 54% under the high VRES scenario. In 2040, the share soars to 76% in the high VRES scenario - and is close to 60% in the most conservative scenarios as well (Figure 5 20), apart from the limited VRE scenario -where the share of natural gas does not exceed 47%.

Across all scenarios, there is no significant change in the share of hydropower in the generation mix between 2020 and 2040. But the starting point differs among scenarios: 15% for IRENA "Dry year" scenario, up to almost 22% under the 1.5oC scenario of the JRC. Generation from PVs is projected to increase after 2025, with a highest value of just below 20% in 2040 (Figure 5.20). Wind generation is also expected to increase after 2025, projected to 20% in the Reference scenario of IRENA by 2040, with a possible maximum of 35% in the High VRE scenario (in this scenario the overall VRE target is set exogenously at 50%, so this high share of wind is largely forced by the overall target). The projections of JRC are more conservative for wind, showing shares between 11% and 14% in 2040. At the country level,

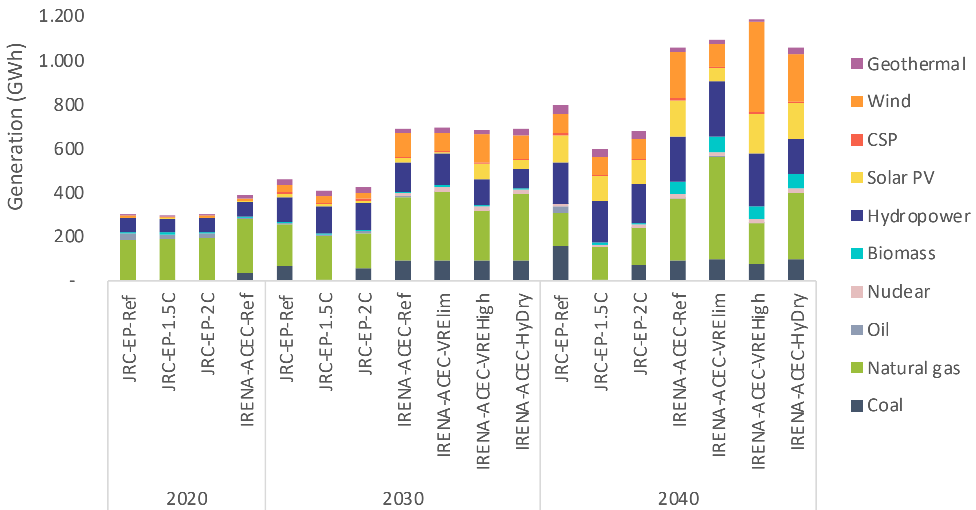
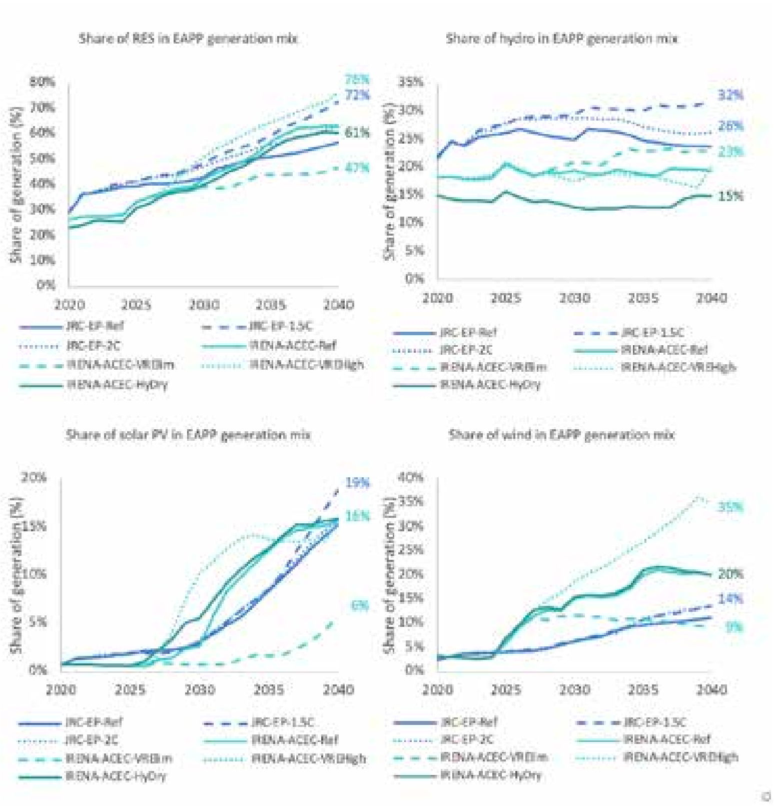


Figure 5.19 Projections of electricity generation per technology EAPP

(*) It was not possible to acquire data from the EAPP Masterplan on generation per technology type. Libya is not included in the IRENA's projection for 2040.

Figure 5.20 Share of RES in total electricity generation in EAPP



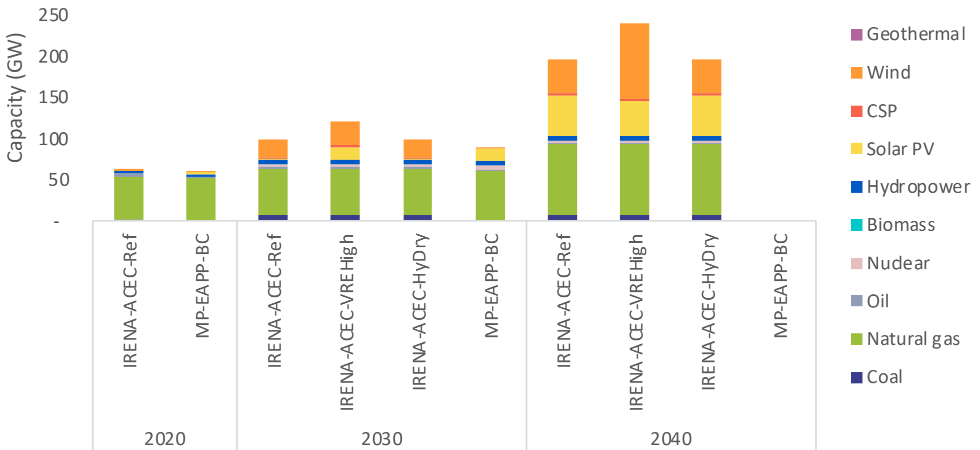
the largest consumers or emerging consumers in the Power Pools were identified under the demand analysis chapter. A more thorough look into these countries is attempted, using the scenarios from the Power Pools and the scenarios of IRENA, as these are the most updated projections.

In EAPP, Egypt will remain the largest consumer until 2040. Figure 5.21 presents the installed capacity per technology in Egypt, deriving from two IRENA scenarios, apart from the reference scenario: namely the high VRE scenario and the “Dry year” scenario. The effect on the hydro capacity of Egypt is visible.

Natural gas-fired power plants are the main thermal capacity, reaching 86GW in 2040, but a minor capacity of coal (8GW) appears in the IRENA scenarios, together with almost 4.8GW of nuclear power. Hydro capacity is expected to increase to 5GW, but there is no further potential to be utilised until 2040. Across all scenarios, the largest new capacity additions appear in solar PV and in wind.

It is important to note that in 2030, wind is the main renewable addition according to the projections by IRENA. This is the case apart from the VREHigh scenario, where 15GW of solar PV are also added; and in the MP-EAPP-BC case, almost exclusively solar PV is introduced in the system. In 2040, solar PV capacities are increased considerably -almost 50GW added in the ten years between 2030 and 2040. In the VREHigh scenario, the capacity of solar PV reaches 43GW, and over 90GW of wind plants are installed in 2040 (an addition to more than 60GW over the same decade).

Figure 5.21 Projections of installed capacity per technology in Egypt



(*) No data is available in the EAPP projection for 2040.

Another country in the region with a consumption projected to increase is Ethiopia. Ethiopia is projected to become the third, and in some scenarios the second, largest electricity consumer in EAPP. In this analysis, the “Dry year” scenario and the “Delayed hydro” scenarios of IRENA are compared to the IRENA-ACEC-Reference and High VRE, and to the Baseline of CMP Phase 1.

The main new capacity additions between 2020 and 2030 are hydropower plants. The MP-EAPP-BC projects 15GW of hydro in 2030 and relatively small capacities of solar PV and wind (2GW and 1GW respectively). Geothermal is one of the other important domestic renewable resources, and a capacity of 5GW appears in 2030 in the “Delayed hydro” scenario, in order to cover the capacity gap, apparently saturating the existing potential.

In 2040, 6GW of natural gas-fired thermal plants appear in all IRENA scenarios, together with 4GW of biomass-fired plants. Solar PV becomes the main capacity addition between 2030 and 2040, reaching anywhere between 16 and 18GW, while in the VRE High scenario about 18GW of wind is added in the same decade. Hydropower plant capacities are further increased, but only reaching a maximum of 20GW in the high VRE scenario.

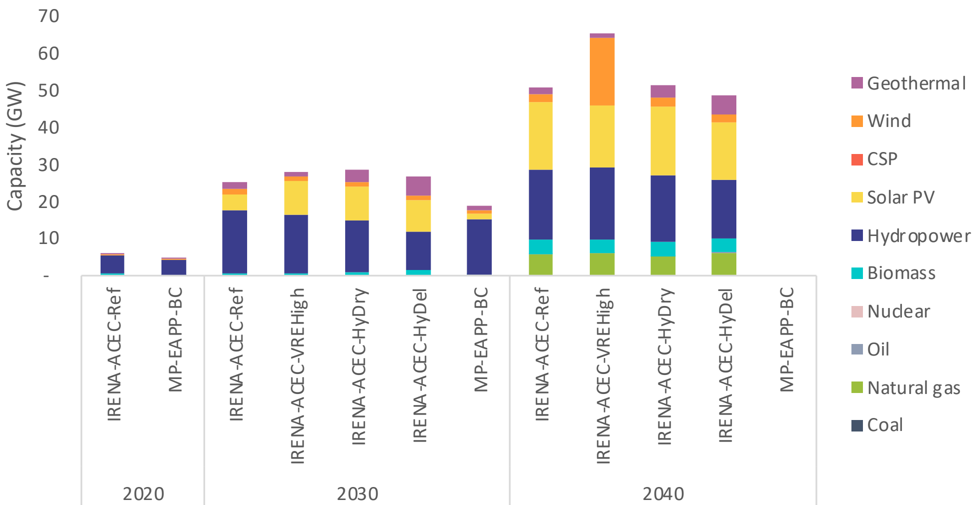


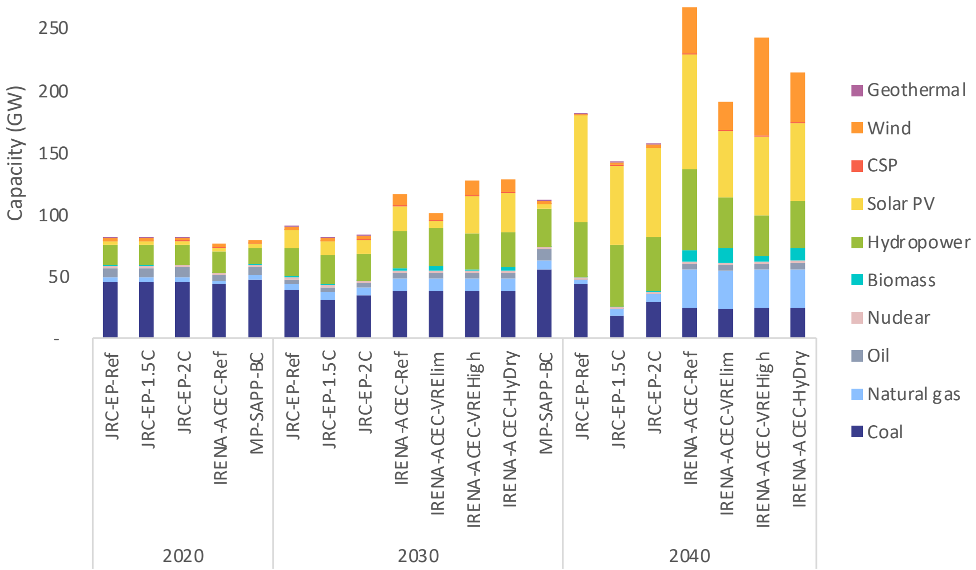
Figure 5.22 Projections of installed capacity per technology in Ethiopia

(*) No data is available in the EAPP projection for 2040.

Southern African Power Pool

Coal plays an important role in the electricity generation of SAPP countries. The projections according to the SAPP Masterplan (MP-SAPP-BC in Figure 5.23) foresee a continuation of this trend, and an increase in the coal-installed capacity in 2030. In all the other scenarios, coal capacities in 2030 remain at the same level as in 2020, with capacity additions of natural gas and hydro plants, and different levels of investment in wind and solar PV -depending on the scenario narrative. Hydro capacity is projected to increase from the 2020 level of about 18GW to 30GW in 2030 (28% of total installed capacity), and reach 65GW in 2040 in the Reference scenario of IRENA. Between 2030 and 2040, installation of solar PV is projected to be around 60GW.

Figure 5.23 Projections of installed capacity per technology in SAPP



The overall share of RES in the installed capacity steadily increases in all the scenarios of IRENA and JRC, reaching levels between 68% and 82% in 2040 (Figure 5.24), while the corresponding electricity generation by RES varies between 52% and almost 70% (Figure 5.26). The projections in the Power Pool Masterplan are relatively conservative for RES, which reach a level of 34% of installed capacity in 2030, with hydro accounting for the largest share (28%).

The installed capacity of solar PV increases after 2025, reaching 30% of the total installed generation capacity in 2030, which contributes close to 20% of the total generated electricity (Figure 5.26). In 2040, the scenarios of IRENA project an installed capacity share of 28%-35% and a contribution to the electricity generation mix of between 16% and 18% in 2040. The JRC scenarios are more optimistic, projecting an increase in the installed capacity share to 45% and the share in the electricity generation mix to 26% in 2040.

The findings and observations for wind plants are rather diverse. The scenarios elaborated by IRENA foresee a share of installed capacity between 14% (Reference) and 33% (High VRE), with a corresponding contribution to electricity generation between 15% and 28% by 2040. On the other hand, the scenarios of the JRC and SAPP Masterplan are very conservative for wind, with a percentage of 2% for capacity and 1% contribution to generation.

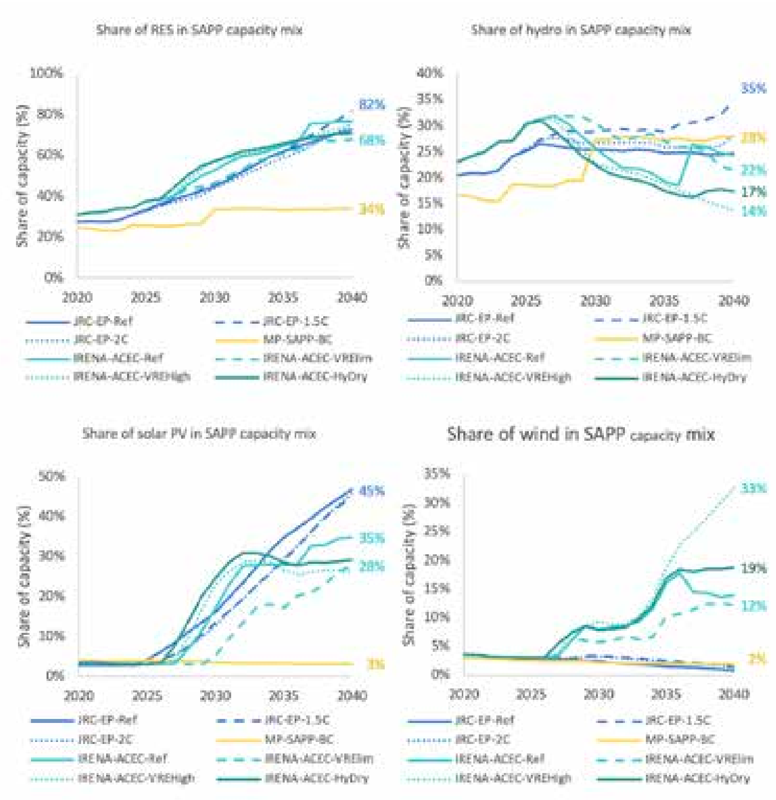


Figure 5.24 Share of RES in the total installed capacity in SAPP

(*) There is no available data in the projections of the SAPP Masterplan for 2040 therefore the line is assumed constant in the graph after 2030.

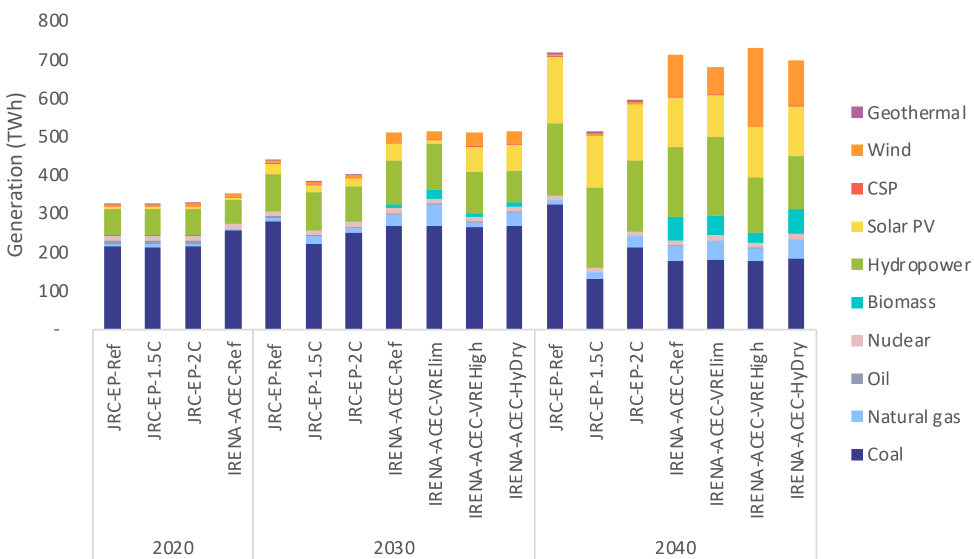
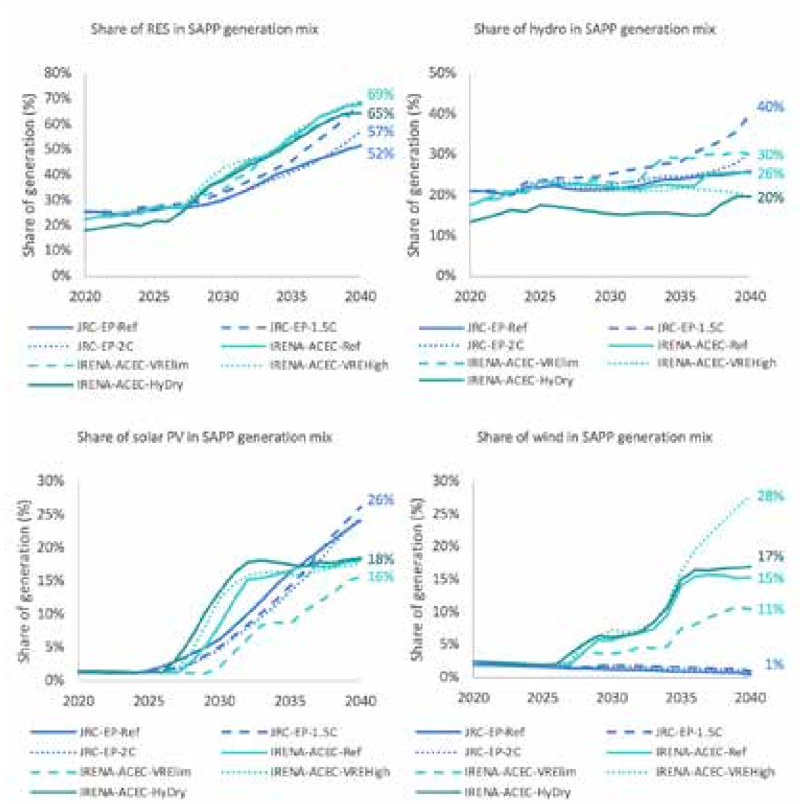


Figure 5.25 Projections of electricity generation per technology SAPP

(*) It was not possible to acquire data from the SAPP Masterplan on generation per technology type.

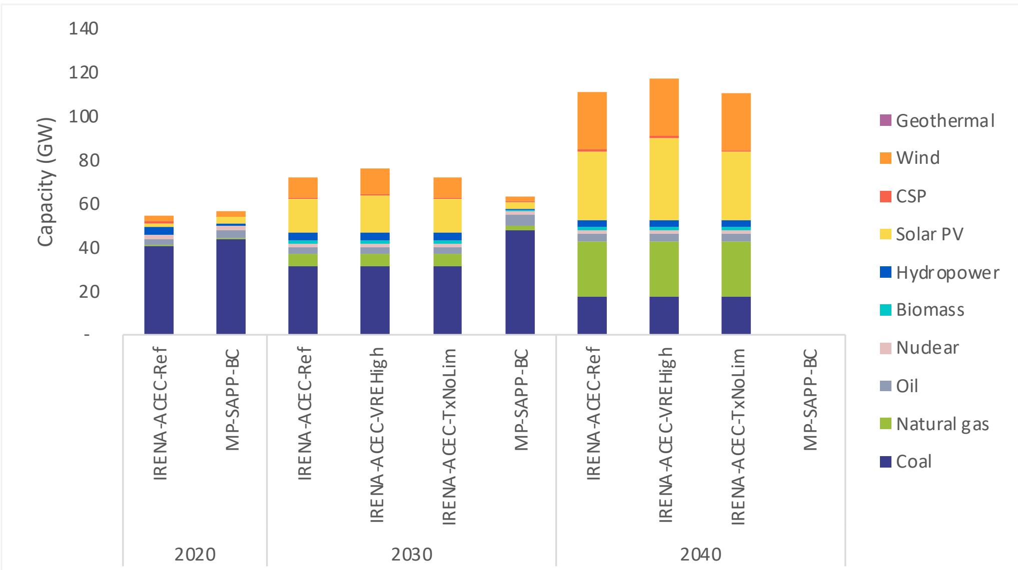
Figure 5.26 Share of RES in total electricity generation in SAPP



South Africa is the largest consumer in SAPP, with electricity generation currently dominated by coal-fired power plants. This trend in the SAPP is projected to continue in 2030 per the Regional Masterplan scenarios (Figure 5.27). However, in the IRENA scenarios natural gas power plants are introduced in 2030, and become the dominant thermal generation technology in 2040.

Apart from the Reference and the High VRE scenarios, scenario comparison includes the runs without limits in the interconnections (TxNoLIm), since South Africa is already strongly interconnected with its neighbouring countries. Solar PV emerges by 2030 with capacities around 15-17GW in the IRENA scenarios, which is doubled to above 30GW by 2040. Wind is projected to reach 9-12GW in 2030, and then triple to 26GW in 2040.

Figure 5.27 Projections of installed capacity per technology in South Africa



(*) There is no available data in the projections of the Baseline scenario of CMP Phase 1[61]

[61] The updated information collected by EU TAF during CMP Phase 1 only covered the period until 2030.

Tanzania is another country in the Power Pool with a demand projected to considerably increase. In Figure 5.28, the scenarios from IRENA, the Baseline scenario of CMP Phase 1, as well as the Baseline scenario of CMP Phase 1 for EAPP (MP-EAPP-BC) are presented. It should be noted that the demand projections for Tanzania in the SAPP analysis are much higher than those used in the EAPP analysis in the CMP Phase 1 data.

One can observe that the projections of the installed capacities are rather different between the two Power Pools, where the main conventional generation source in the SAPP is coal, and the main fossil fuel generation in the EAPP is from natural gas. In addition, the EAPP scenario is more favourable to hydropower than the SAPP scenario.[62]

The scenarios of IRENA show a considerable increase of hydro by 2030 (reaching 3GW), only to come to a halt in 2040. The penetration of solar PV in 2030 is moderate in these scenarios, while it is not even considered in the Power Pool Masterplans. In the High VRES scenario of IRENA, the power generation sector is completely transformed by 2040 - with a biomass-fired power plant capacity of 2GW, solar PV capacity between 5GW and 7GW, and wind making a dramatic entrance at 4GW in the reference scenario, and reaching as high as 17GW (Figure 5 28).

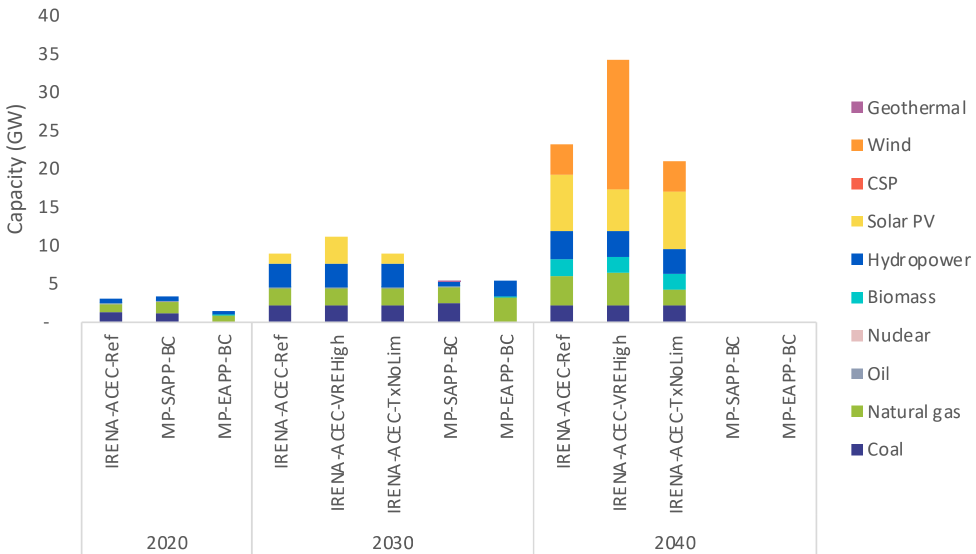


Figure 5.28 Projections of installed capacity per technology in Tanzania

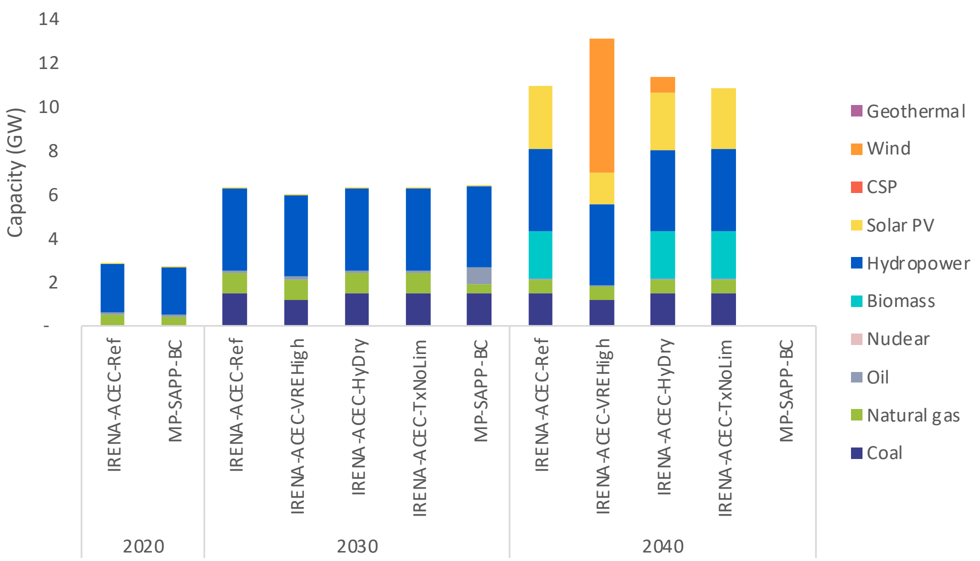
(*) There is no available data in the projections of the SAPP and EAPP Masterplans for 2040

With six different borders, Mozambique has a strategic position to boost the interconnection of the Southern Africa region. The country is currently heavily dependent on hydropower for electricity generation. The installed capacity of hydro is projected to increase from 2GW in 2020 to 4GW in 2030 in all the studies presented in Figure 5 29. Coal capacity, non-existent today, is planned to reach 2 GW in 2030. The remaining capacity is natural gas-fired, with minimal penetration of solar PV and wind.

These technologies are introduced in the period from 2030 to 2040, when solar PV reaches 3GW in the Reference scenario, while wind reaches 6GW in the High VRES scenario. Biomass-fired power plants also appear with a sizeable capacity of 2GW in the Reference scenario, replacing the high capacity of wind in the High VRES scenario for the same year.

[62] This is yet another example which underlines the need for a consistent, continental-level Masterplan.

Figure 5.29 Projections of installed capacity per technology in Mozambique



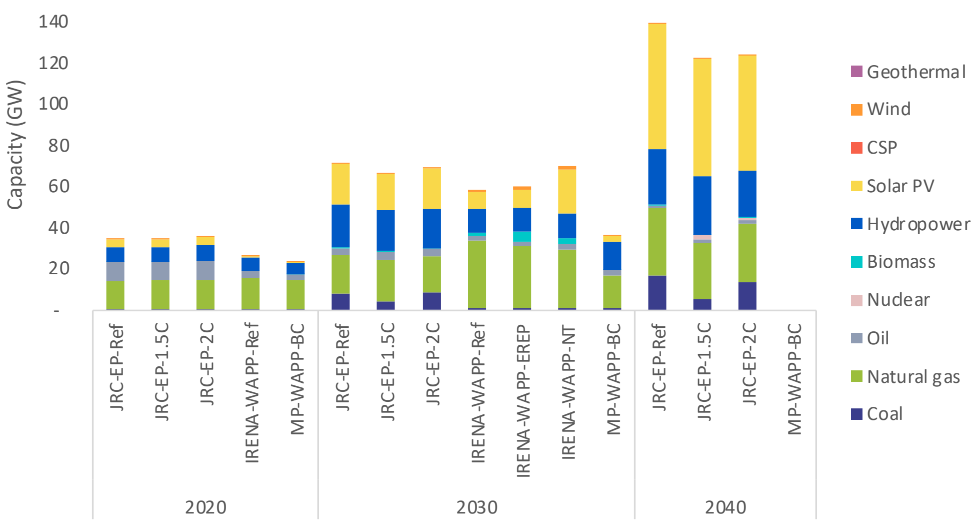
(*) There is no available data in the projections of the SAPP Masterplan for 2040

West Africa Power Pool

In 2020, the power system in WAPP is based on natural gas and oil-fired conventional plants, as well as hydro plants. IRENA's projections for 2030 show a dramatic increase of gas-fired plants, almost double the 2020 figure, a moderate increase of hydro capacity, and the introduction of solar PV at various levels depending on the scenario (Figure 5.30). Biomass also appears as an option -but not in the Reference scenario. The WAPP Masterplan's projections are more conservative for the required total installed capacity, with almost equal levels of gas-fired and hydro plant capacities, and a moderate introduction of PVs and wind.

Finally, the JRC scenarios for 2030 introduce 4GW - 9GW from coal-fired plants in 2030, and their capacity increases further in 2040. The analyses of IRENA and the CMP Phase 1 do not extent beyond 2030[63], so only results for the JRC scenarios are presented in Figure 5.30 for 2040. These show a significant increase of the capacity of solar PV, reaching levels of 55GW - 60GW. The study period for the WAPP Masterplan ends in 2033 for all the analyses carried out.

Figure 5.30 Projections of installed capacity per technology in WAPP



(*) There is no available data in the projections of the WAPP Masterplan and the scenarios by IRENA for 2040

[63] IRENA is currently updating the relevant study for WAPP, extending the time horizon and enhancing the methodology applied for the estimation of RES potentials.

The share of RES in the installed capacity in 2030 varies, ranging from almost 40% in the Reference scenario of IRENA and 44% in the WAPP projections, to about 57% in the policy scenarios of IRENA and the scenarios of the JRC (Figure 5.31). In energy terms, the electricity generated by renewables ranges between 25% and 46% of the total electricity generation in the Power Pool in 2030 (Figure 5.33).

Hydro is the main contributor in this share of renewable electricity. The Power Pool Masterplan projects a 37% share of hydro capacity in the total installed capacity. The respective expectations are rather low for solar PV (7%), and especially wind (1%) for 2030 (Figure 5.31). The shares of hydro power in the other studies are relatively lower: around 19% of capacity and 15% of total electricity generated in the IRENA scenarios, and 30% in JRC scenarios. Solar PV capacity ranges between 14% and 31% in the most optimistic IRENA scenarios, while electricity generation from PVs ranges between 6% and 15% of the total generation in 2030.

The potential of wind in the region is rather limited; even in the optimistic scenarios of IRENA, the installed capacity does not exceed a 3% share, and energy generation is not expected to exceed 2% by 2030.

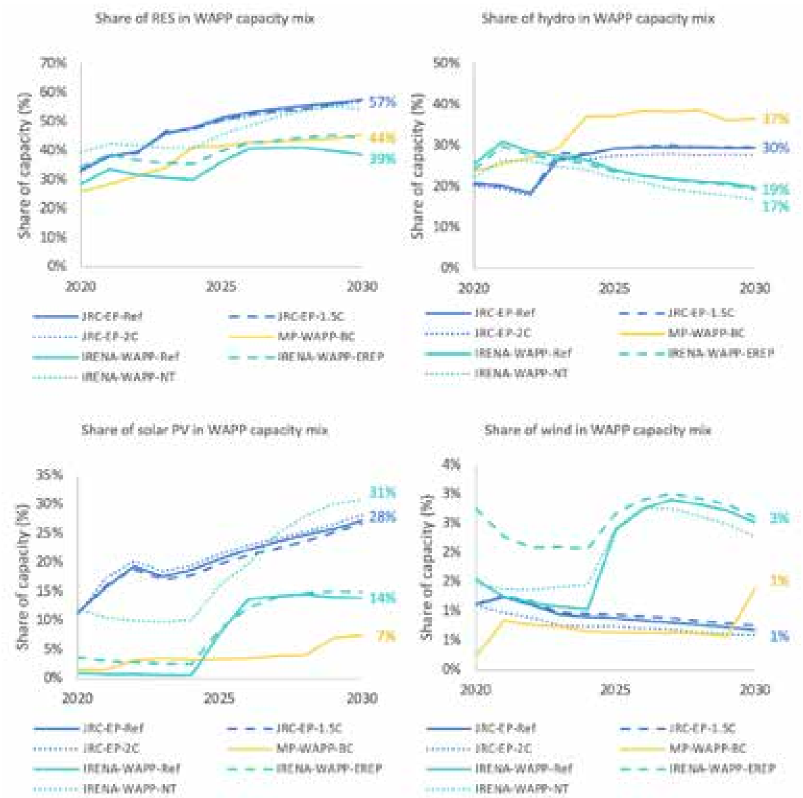


Figure 5.31 Share of RES in the total installed capacity in WAPP

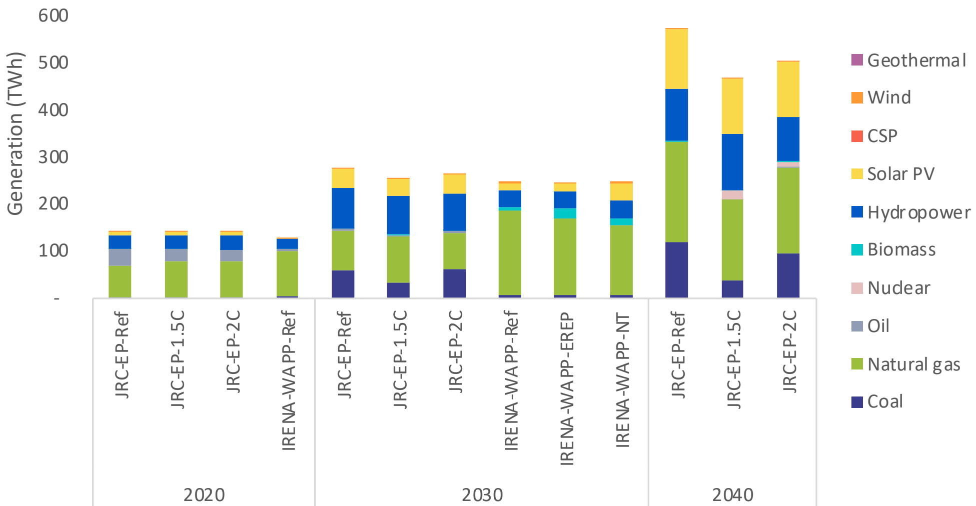


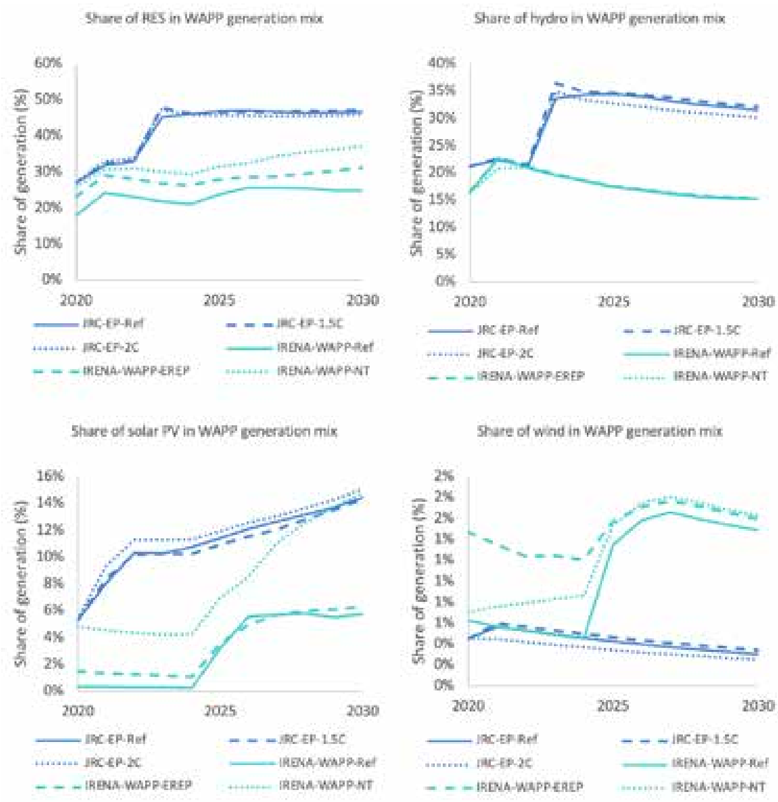
Figure 5.32 Projections of electricity generation per technology in WAPP

(*) There isno available data in the projections of the scenarios by IRENA for 2040. It was not possible to acquire data from the WAPP Masterplan on generation per technology type.

In the IRENA and Power Pool projections, the largest share of electricity generated in 2030 comes from natural gas units (Figure 5.32), while in the JRC scenarios coal has a (relatively small) contribution, which increases in 2040.

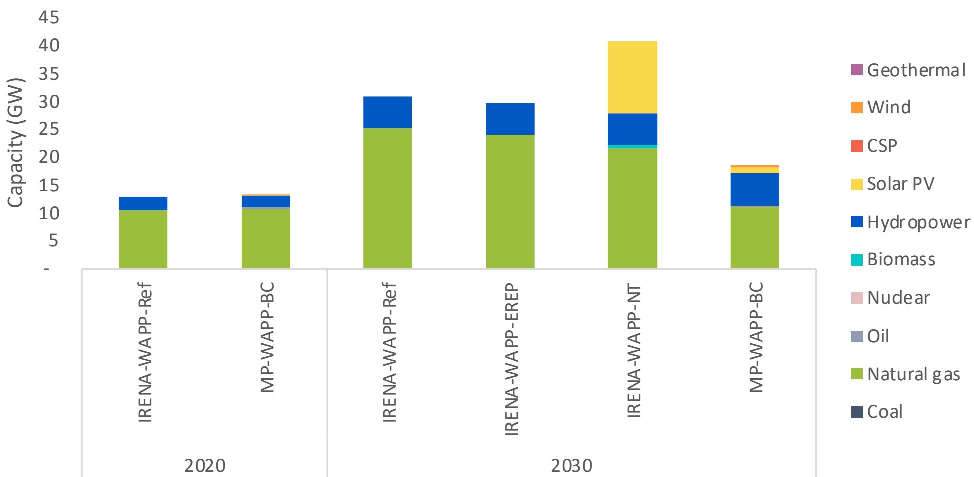
Electricity from biomass-fired power plants appears mainly in the IRENA-WAPP-EREP[64] scenario, reaching around 8% of the total generation in 2030.

Figure 5.33 Share of RES in total electricity generation in WAPP



The key consumer of electricity in WAPP is **Nigeria**, covering about 60% of the demand in the Power Pool in 2020 and projected to account for at least 50% of the total demand until 2040. Natural gas is the dominant fuel for electricity generation in the country, and the trend is projected to continue, with gas-fired units covering most of the future needs for electricity generation in 2030 in the Reference scenarios. Hydro capacity is expected to increase compared to the 2020 level, up to 6GW in 2030. It is important to note that solar PV only appears at a noticeable level in the National Targets scenario of IRENA (IRENA-WAPP-NT), reaching 13GW.

Figure 5.34 Projections of installed capacity per technology in Nigeria



[64] This is a result of the regional target on the minimum capacity of RES plants applied in this scenario.

Central African Power Pool

Oil-fired capacities in CAPP will be gradually decommissioned toward 2030 in the various scenarios, apart from the CMP 1 Baseline study where the capacity remains at the same level as in 2020. Hydro is obviously being considered as the main resource in region. In all studies, the capacity of hydro power plants is projected to increase considerably between 2020 and 2030-at least doubled, and almost tripled in the MP-CAPP-BC (reaching 20GW). The JRC scenario projection for 2040 showed an even higher increase, more than doubling the capacity between 2030 and 2040 (Figure 5.35).

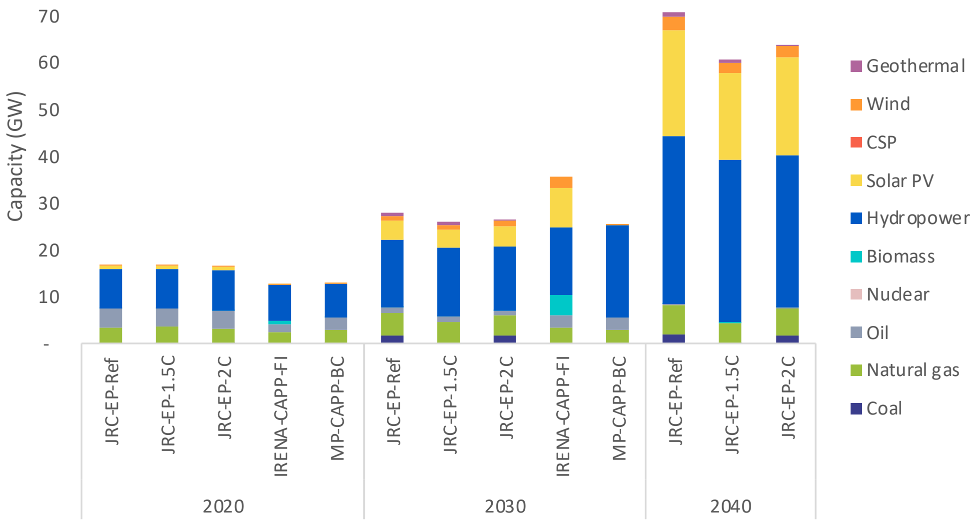


Figure 5.35 Projections of installed capacity per technology in CAPP

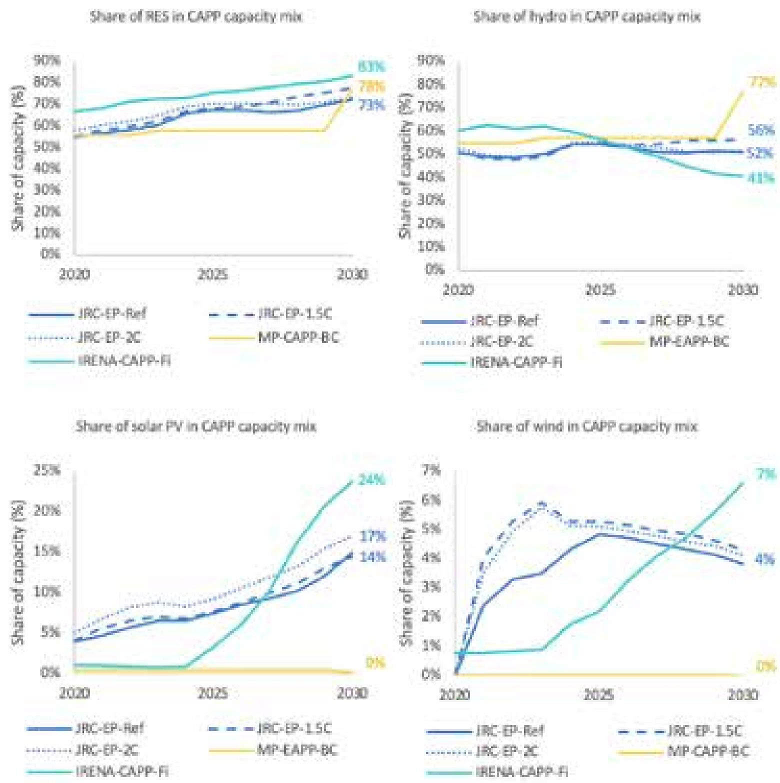
(*) There is no available data in the projections of the CAPP Masterplan and the scenarios by IRENA for 2040.

The share of RES capacity in CAPP is already rather high due to the region's large hydro capacities, and is projected to increase further due to the further exploitation of hydro, reaching 78% in the CAPP Masterplan scenarios and 83% in the optimistic scenarios by IRENA. The corresponding electricity generation ranges between 66% and 81% of the total electricity generation (Figure 5.38).

As mentioned above, in the Baseline study of CMP 1 almost all of the RES figures are accounted for by hydro. However, this is not the case for the JRC and IRENA scenarios. Solar PV is projected to cover 24% of the total capacity, generating 15% of the electricity in the IRENA-CAPP full integration scenario.[65] The potential for wind energy appears to be relatively limited in the region-: the optimistic IRENA scenario projects 7% of the installed capacity and 5% of the electricity generation to come from wind plants by 2030. The projections of JRC are less optimistic, anticipating shares of 4% and 3% respectively (Figure 5.36 and Figure 5.38).

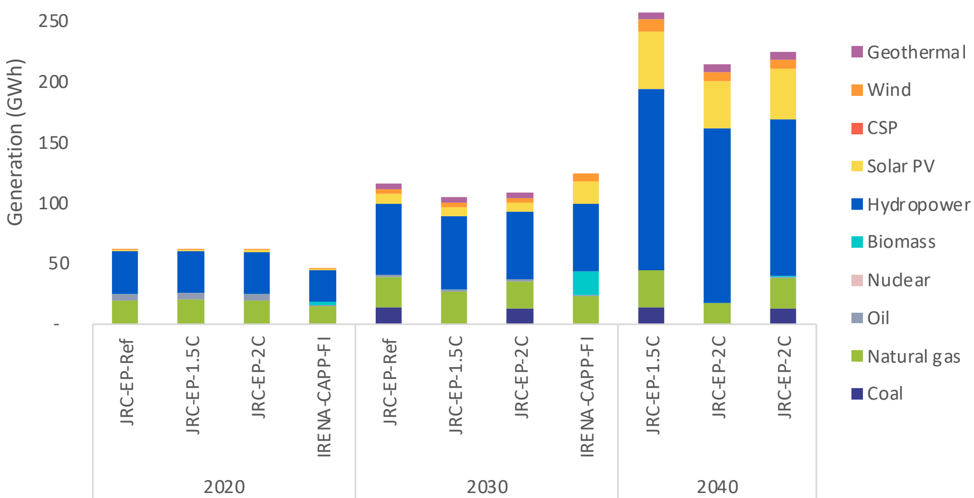
[65] The scenario assumes full trade with SAPP and WAPP. The scenario work of IRENA for CAPP was published in 2015 (IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi), and it is currently under revision extending the time horizon and enhancing the methodology applied relative to the estimation of RES potentials.

Figure 5.36 Share of RES in the total installed capacity in CAPP



It is noteworthy that biomass-fired power plants appear in the projections of IRENA -around 4GW in 2030-, but not in the other studies, whereas coal (with CCS) appears in some of the JRC scenarios. The main source of electricity generation in the Power Pool is, and continues to be, the large hydro plants (Figure 5.37).

Figure 5.37 Projections of electricity generation per technology in CAPP



(*) There isno available data in the projections of the scenarios by IRENA for 2040. It was not possible to acquire data from the CAPP Masterplan on generation per technology type.

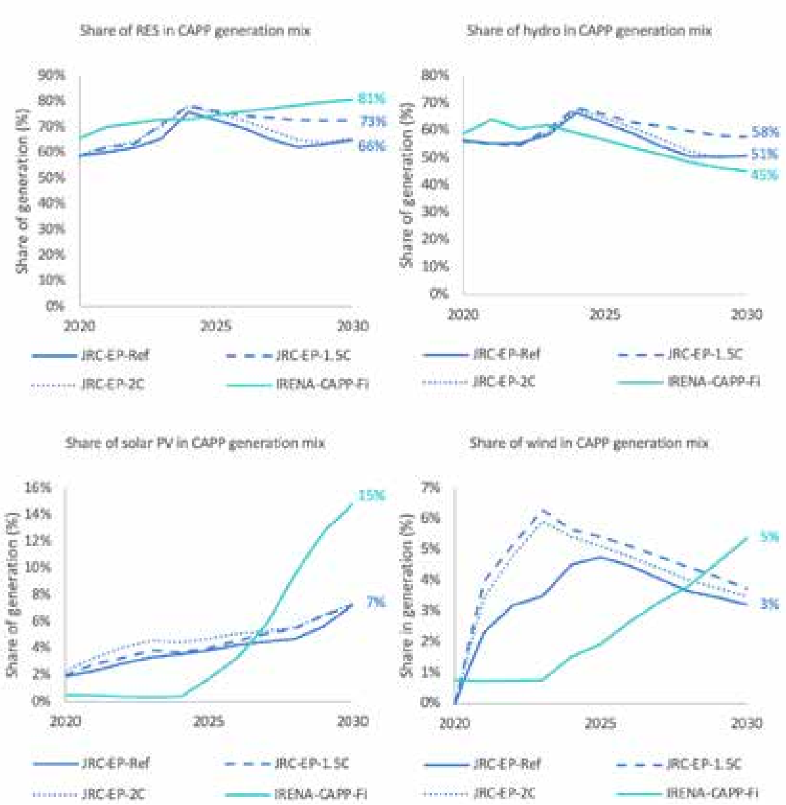


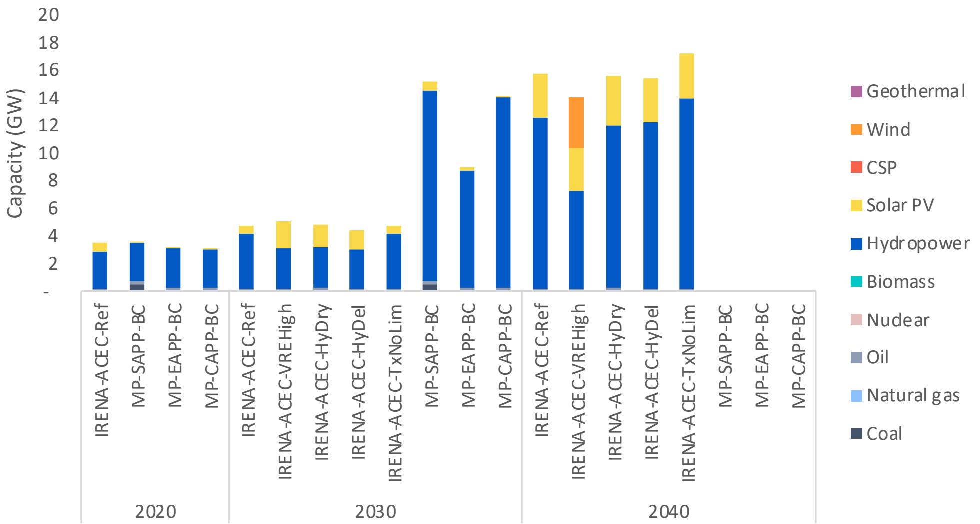
Figure 5.38 Share of RES in total electricity generation in CAPP

The Democratic Republic of the Congo (DRC) is a unique case, since it is the only country in the continent which belongs to three Power Pools -SAPP, EAPP and CAPP, and is home to some of the largest hydro potential. Figure 5.39 presents the installed capacities in the country as they are projected in the Baseline study of CMP 1 and the projections in the latest scenarios by IRENA[66] for EAPP and SAPP, which all include DRC. As already mentioned in previous instances, there are differences between the Masterplans of the regional Power Pools as to the projected scenarios for countries which belong to multiple Power Pools; this can be clearly noted in Figure 5.39.

The common trend in all studies is the further utilisation of this important hydro potential. The Power Pool Masterplans have projected that this would be possible by 2030, reaching somewhere between 9GW and 14GW of installed hydro capacity. The recent scenarios by IRENA have projected that this is economically optimal by 2040, and solar PV could be exploited as of 2030. In the Reference scenario of IRENA, PVs are projected to reach 3GW in 2040, while in the High VRES scenario wind plays an important role, reaching 4GW -with a relevant reduction of hydro capacity. It is important to highlight that, in the scenario where there are no limits in the interconnection capacities (IRENA-ACEC-TxNoLim), hydro power reaches its maximum capacity of 14GW, exploiting the possibilities of exporting electricity though increased interconnections. In the other scenarios hydro capacity reaches 12GW.

[66] IRENA. (2021). Planning and Prospects for Renewable Power: Eastern and Southern Africa. Abu Dhabi.

Figure 5.39 Projections of installed capacity per technology in DRC

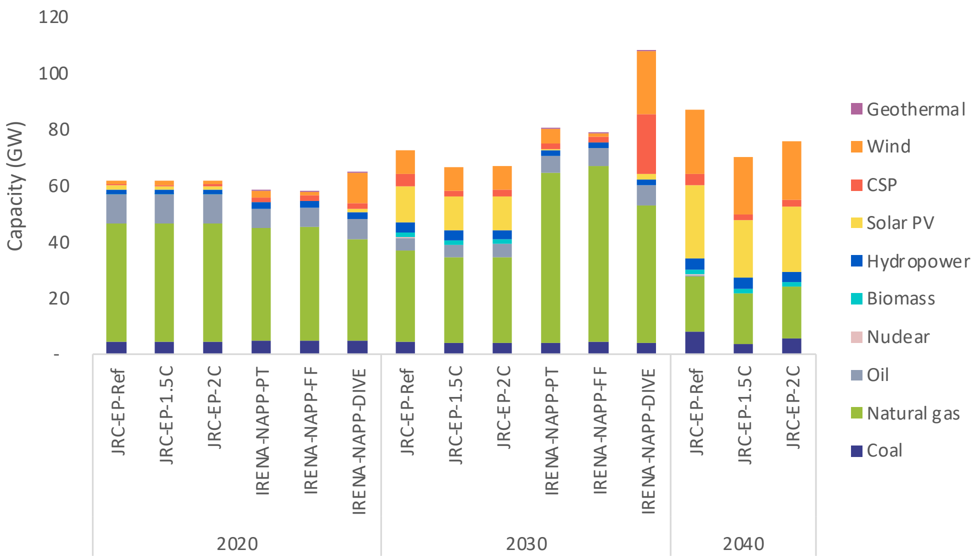


Comité Maghrébin de l'Électricité (COMELEC)

COMELEC does not operate as an organised Power Pool, and does not have a common Masterplan. For this reason, it was not possible to collect consistent information on the capacity expansion plan of the countries in the region, or obtain specific information on the type of technologies that can be deployed to cover the projected demand.

Figure 5.40 presents i) the scenario analysis performed by IRENA[67] in 2015 for the North African countries, which is currently being revised using an extended time horizon, updated information, and enhanced RES potential analysis, and ii) the scenarios of the analysis performed by JRC, where country-level results are aggregated to produce values at the regional level of COMELEC.

Figure 5.40 Projections of installed capacity per technology in COMELEC



The capacity mix in 2020 includes mainly gas-fired and oil-fired power plants, and a small share of coal-fired power plants -mainly in Morocco. Hydro capacity is rather limited and is not projected to increase considerably (Figure 5.40), with the relative share being less than 5% (Figure 5.41) and the electricity produced covering up to 7% of the total electricity generation (Figure 5.43).

The total share of renewable capacity is projected to remain at the same level in two of the IRENA scenarios, while in the Diversification scenario (IRENA-NAPP-DIVE) it increases to levels comparable to the JRC scenarios, i.e. above 40% in 2030, with an electricity generation of close to 40% (Figure 5.43).

[67] IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi

An interesting finding is that the contribution of solar PV in the installed capacity is projected to be negligible in the scenarios of IRENA for 2030, while in the JRC scenarios PVs cover 18% of installed capacity and generate around 11% of the electricity in 2030. In the Diversification scenario (IRENA-NAPP-DIVE) there is a considerable increase of CSP -20% of the total capacity and 22% of the generation-, and wind -20% of the capacity and 17% of the generation- by 2030. In the projections of JRC, PVs and wind are the main RES technologies which are introduced as of 2030, and dominate the installed capacity in 2040, while the contribution of CSPs is rather limited.

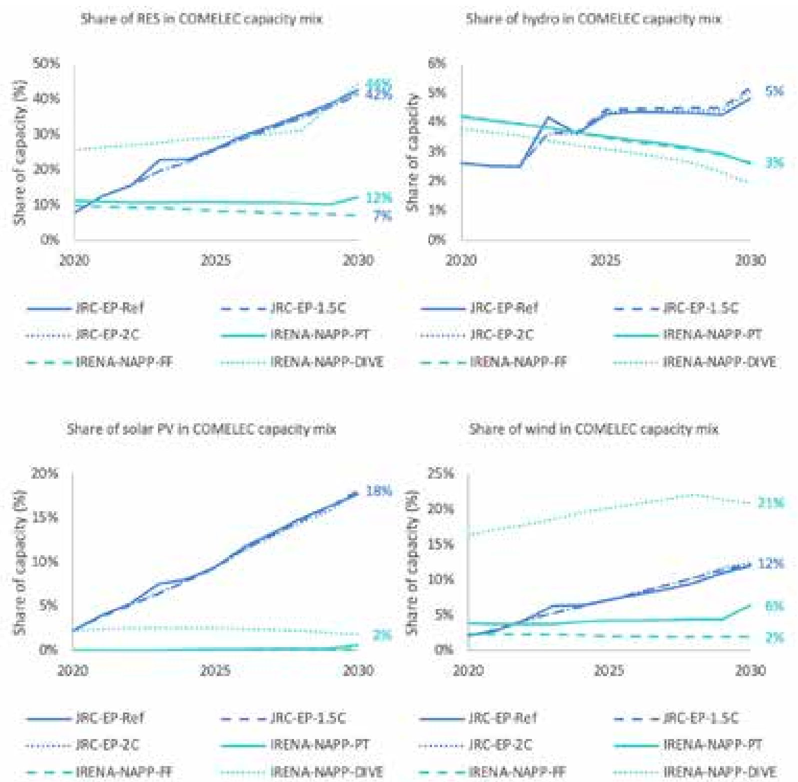


Figure 5.41 Share of RES in the total installed capacity in COMELEC

In 2030, projections converge to natural gas covering the largest share of electricity generation (Figure 5.42). More diversification is seen in the JRC scenarios, where solar PV, wind, hydro and CSP contribute to the generation and increase their share by 2040.

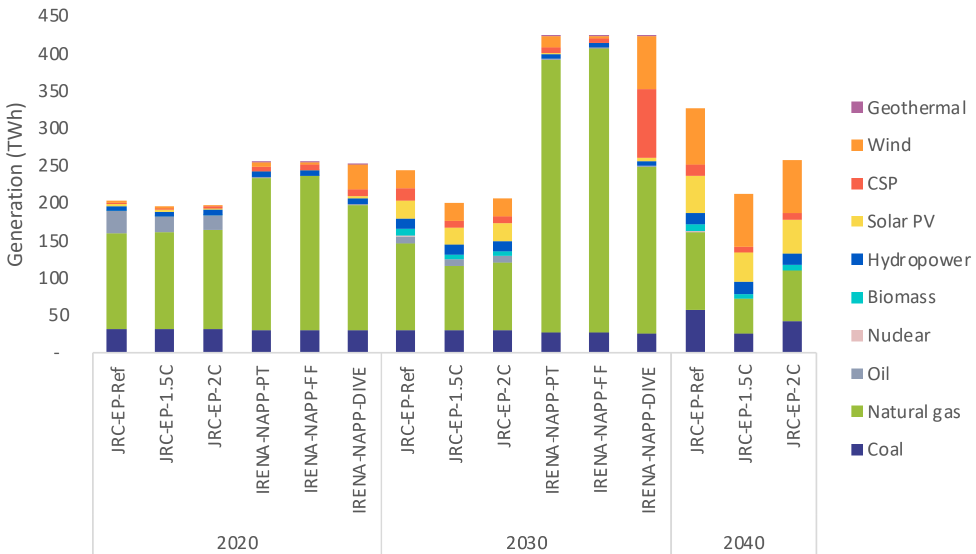
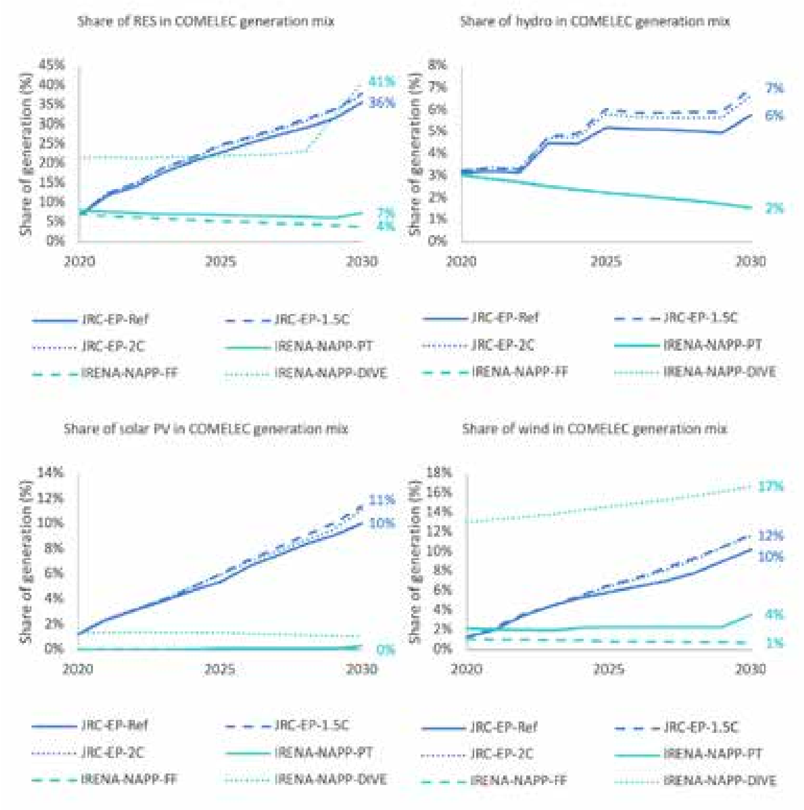


Figure 5.42 Projections of electricity generation per technology in COMELEC

Figure 5.43 Share of RES in total electricity generation in COMELEC



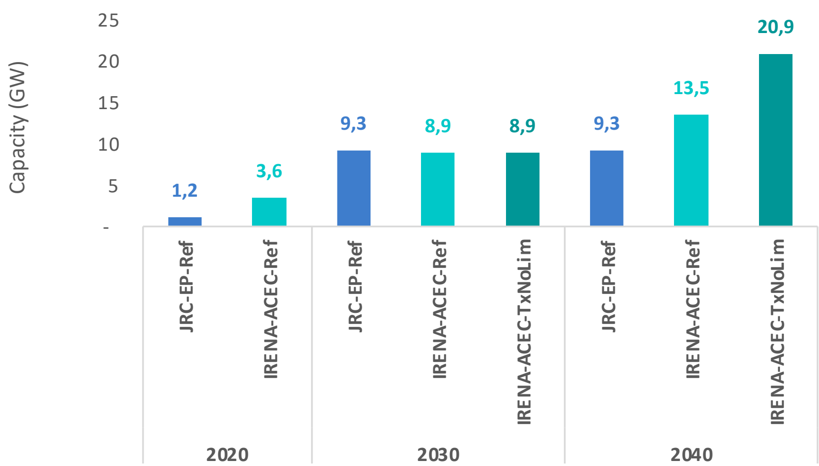
5.2.3. Exchanges of electricity

A first quantitative indicator regarding the exchange of electricity within a Power Pool is the total capacities for the interconnection[68] transmission lines. The evolution of this capacity indicates whether there can be an increase in exchanges in the scenario under consideration.

As already discussed in Chapter 3, the scenario narratives vary significantly in their projections of interconnection capacities. Under certain scenarios, only known and planned interconnections are included, while in others the model can extend the capacity in the future if economically viable.

East African Power Pool

Figure 5.44 Sum of Interconnection Capacities in EAPP



[68] The interconnectors in these studies are modelled as bidirectional, which means that they allow the flow of electricity in both directions between the two countries.

The sum of the interconnecting capacities in EAPP (including the interconnecting capacities with neighbouring Power Pools) is projected to triple between 2020 and 2030, reaching around 9GW across all studies (Figure 5.44). This increase is due to the addition of interconnections between Burundi with Tanzania (423MW), DRC and Burundi (396MW) DRC and Rwanda (91MW), Egypt and Sudan (1.7GW), Sudan and Ethiopia (2GW), Tanzania and Kenya (600MW), and the interconnection of Uganda with South Sudan (194MW), in the decade between 2020 and 2030.

The Reference scenario of IRENA projects a further increase of the capacity to 13.5GW in 2040, through the increase of existing and new connections. Of the existing connections, DRC-Burundi increases to 748MW, DRC-Rwanda increases to 713MW, Sudan-Ethiopia increases to 2.5GW, Uganda-South Sudan increases to 227MW; new connections between DRC and Uganda (388MW), as well as Djibouti with Ethiopia (200MW) are also foreseen. Furthermore, there is a projected interconnection of 1.6GW between DRC and Angola, strengthening the interconnection between Power Pools (see Annex 3 - Table A3.1 for details).

It is worth pointing out that when the scenario allows the model to decide on new interconnections (IRENA-ACEC-TxNoLim), the Power Pool's total capacity increases to almost 21GW in 2040. This is due to increased capacity of the connections that appear in the Reference scenario (between Kenya and Ethiopia to 4.4GW, Sudan and Ethiopia to 4.5GW, Burundi and Tanzania to 1.1GW, and Tanzania with Kenya to 880MW), and also due to new interconnections between DRC and Tanzania (1.3GW), Ethiopia and Eritrea (627MW), and the interconnection of Ethiopia with Somalia (609MW) (see Annex 3 - Table A3.1 for details).

In the CMP Phase 1, several priority transmission projects have been identified in EAPP, which are similar to the analysis presented above.[69] In the short term the priority projects include DRC-Rwanda (100MW), DRC-Burundi (49MW), Egypt–Sudan (300MW), Ethiopia-Kenya (1,1GW), Kenya-Tanzania (2GW), Ethiopia-Sudan (1GW), Tanzania-Uganda (209MW), Uganda-Kenya (300MW) and Uganda-Rwanda (342MW), together with Rwanda-Burundi (27MW), which is under construction. In the medium term, further reinforcement of DRC-Burundi (96MW) and DRC-Rwanda (96MW) are identified, and for the longer term the line Burundi-Rwanda (300MW) is included.

The sum of exports (total exported volume of electricity per year) from all the countries in the Power Pool is a macroscopic indication of the amount of electricity which is exchanged at an annual level. It further identifies the countries with the largest potential to export electricity, due to overcapacity compared to their internal demand. Figure 5.45 shows the results of the different scenarios in the latest publication by IRENA.[70] Apart from the Reference scenario, the comparison presents the results of the High VRES scenario, the "Dry Year" scenario, and those of the scenario in which the model can invest in new interconnection capacities (if economically viable). The total amount of electricity traded does not increase dramatically between 2020 and 2030, despite the increase in interconnection capacity. The volumes exchanged show a high increase between 2030 and 2040 -more than triple, in some cases. Although in 2020 Kenya is the only exporter in the region, in 2030 other countries slowly emerge.

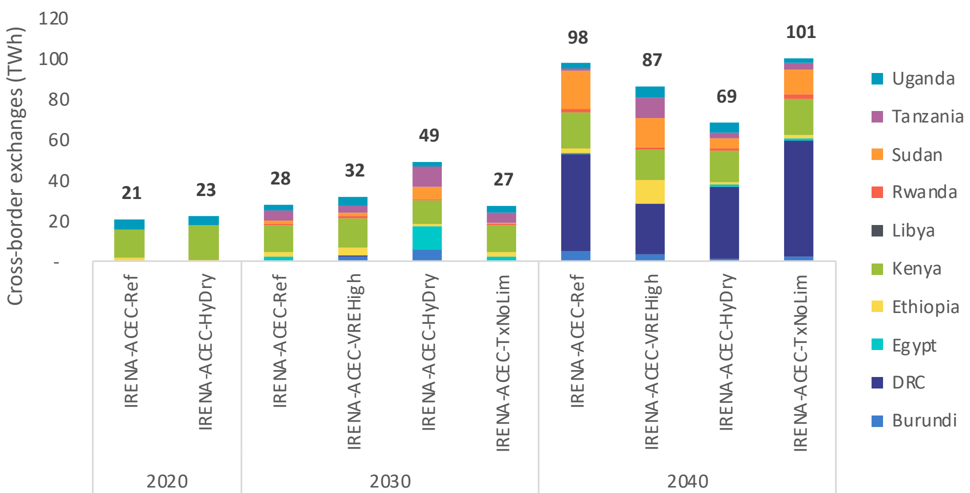


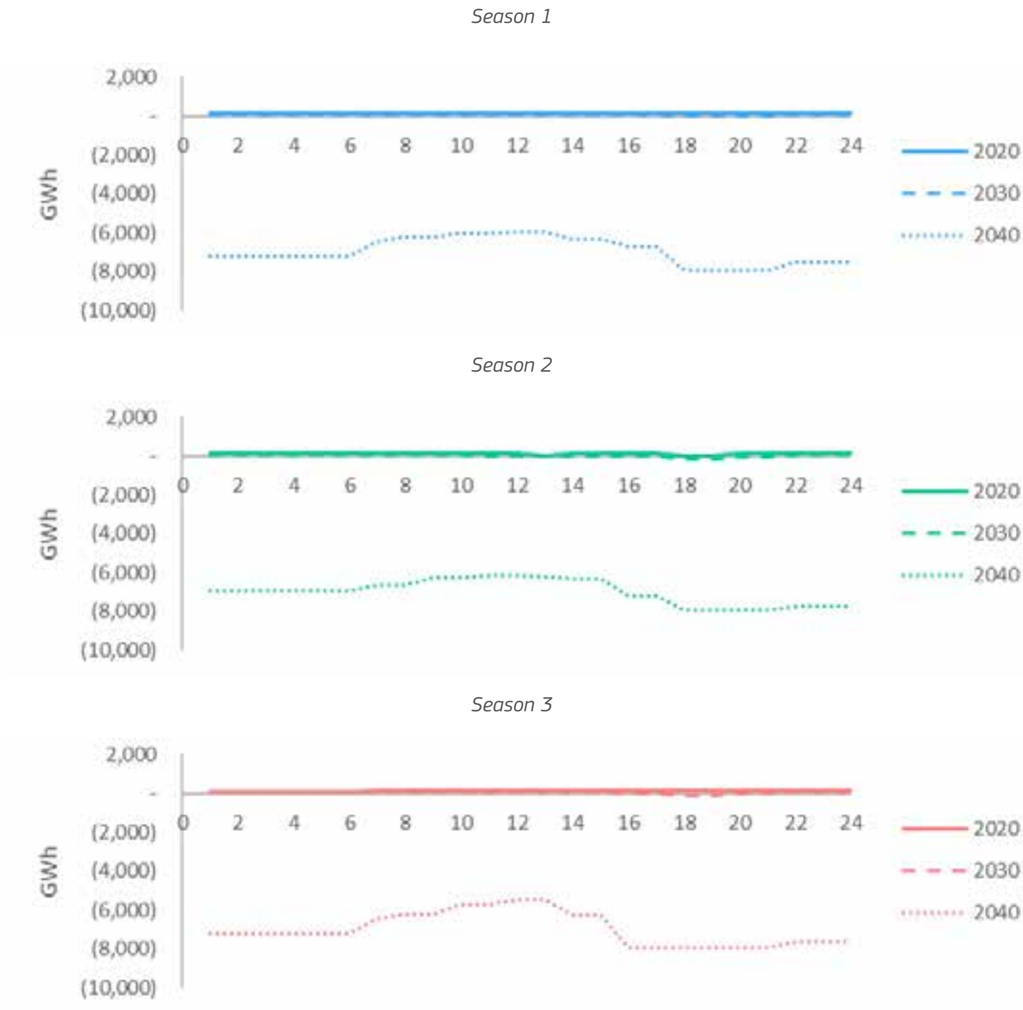
Figure 5.45 Sum of electricity exports in EAPP

[69] See Section E1.10 in the report EU TAF. (2020). LOT 8.1: Support to the Development of a Continental Power System (Transmission-Generation) Masterplan. Deliverables 2 & 3. Mission ref: CW235.201906 AUC

[70] It was not possible to obtain this detailed information from the published scenario results of the JRC study, since only net imports were reported. Furthermore, the study by IRENA is very recent (published in 2021) and is considered to be the most updated on current statistics and existing plans and policies.

It is important to highlight the contribution of exports from Egypt in the "Dry year" scenario in 2030. However, the export landscape changes completely in 2040, with the DRC expected to export the largest amounts of electricity in the Power Pools (relatively reduced in the "Dry-year" and High VRES scenarios, due to the lower hydro production in these cases). Sudan, Ethiopia and Tanzania emerge as exporters of electricity, more visibly in the High VRES scenario.

Figure 5.46 Hourly net electricity imports in DRC for the IRENA-ACEC-TxNoLim scenario[71]



(*) Negative values correspond to net exports.

In the IRENA analysis, the variation of generation and net imports has been calculated at an hourly level for three characteristic time periods in a year (labelled "seasons"[72] in the graphs below). In Figure 5.46, the hourly variation of net imports in DRC can be seen for the scenario foreseeing unlimited expansion of interconnection capacities (IRENA-ACEC-TxNoLim), for years 2020, 2030 and 2040, and for each of the three seasons. The transition of DRC to a main exporter in the region by 2040 is clearly depicted, with net exports taking place at almost the same level, during the 24 hours of a typical day period in all the seasons. The level of exports is reduced in the period between 6:00 (SAST)[73] and 18:00 (SAST) in the period of January to August, and 6:00 to 16:00 in September-December, since generation is used to cover the local demand.

[71] The time in the graph is South African Standard Time (SAST)
[72] In this study, the year is divided into three seasons: season 1 covers January-April, season 2 May-August and season 3 September-December. Each season is represented with an average day, with ten time slices.
[73] SAST: South African Standard Time

A more interesting pattern emerges in Figure 5.47 for the case of Sudan (in scenario IRENA-ACEC-TxNoLim), which is another emerging exporter in the region. In 2020, there is a relatively small level of imports, constrained by the non-availability of interconnecting capacity. The addition of hydro, wind and solar PV capacity in 2030 (3.6GW hydro, 1.5GW wind, 1GW solar PV) and the further addition of hydro, PV, wind and biomass in 2040 (4.2GW hydro, 2.5GW PV, 8.2GW wind and 2GW biomass), combined with the increased interconnection with neighbouring countries, changes this picture (Figure 5.47).

The first net exports appear in 2030 during the hours of low local load in January-April. Then, in 2040, the net exports take place during the whole "typical day"[74] in the period January-April and September-December. In the hot season (May-August), there is a need for net imports during the hours 13:00-15:00 and after 20:00, a pattern associated with the higher load and lower availability of the (mainly) RES local generation.

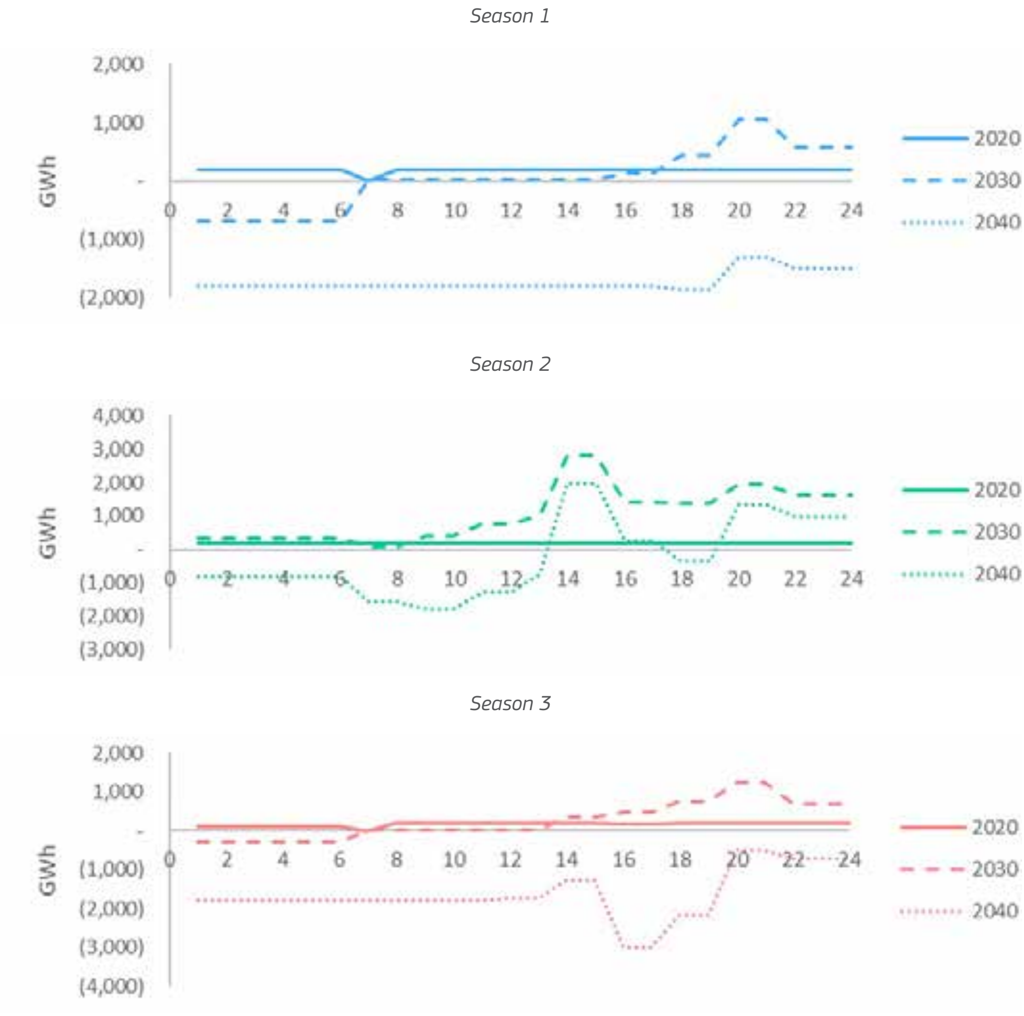


Figure 5.47 Hourly net electricity imports in Sudan for the IRENA-ACEC-TxNoLim scenario

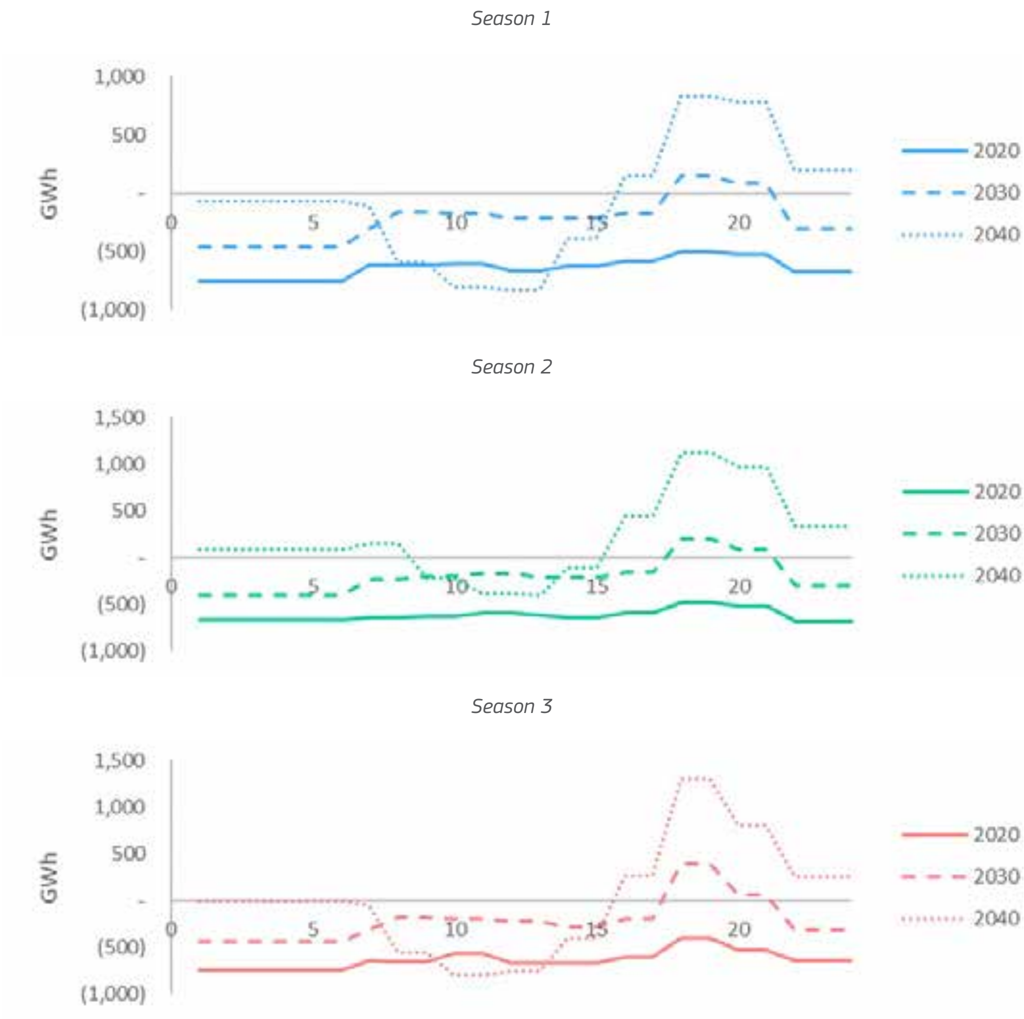
(*) Negative values correspond to net exports.

Bi-directional flows also appear in countries that are currently net exporters, such as Uganda (see Figure 5.48 for scenario IRENA-ACEC-TxNoLim). The rather flat exporting line of mainly hydro-generated electricity in 2020 is replaced in 2030 with net exports, which are lower during the day, to cover the local demand -and even imports of electricity during the evening peak of the system.

The curve is completely transformed in 2040, when the system is projected to have 2.2GW of hydro and 1.4GW of solar PV. It can be seen that the generation from solar PV during the day hours allows for higher levels of electricity exports between 8:00-15:00, but the after-noon/evening system peak, together with the reduced and eventual zero generation of solar PV, lead to net imports of electricity after 18:00.

[74] Whole typical day means that Sudan is exporting electricity all day long and not just few hours per day like in 2030.

Figure 5.48 Hourly net electricity imports in Uganda for the IRENA-ACEC-TxNoLim scenario



(*) Negative values correspond to net exports.

This type of analysis is important to identify not only the level of annual energy exchanges, but also the flows of electricity in the interconnections during typical seasons and days, which can help to identify bottle necks, generation issues because of high penetration of variable renewa-bles, and needs for storage options to be considered.

Southern African Power Pool

The countries in the SAPP region already have relatively strong interconnections, which are projected to increase further until 2040. The unlimited new interconnections scenario does not introduce new capacities, compared to the ACEC-HyDel scenario (Figure 5.49), which means that the already planned interconnections appear to be adequate for the operation of the system in the Power Pool. There are a number of new interconnections projected in the Reference scenario of IRENA, including Zimbabwe-South Africa 500MW in 2030, Zambia-Tanzania 750MW in 2030, Mozambique-Malawi 1.8GW in 2040, Zambia-Malawi 1.4GW in 2040, South Africa-DRC 2.5GW in 2040, Zimbabwe-Botswana increased to 2GW in 2040 (see Annex 3 - Table A3.1 for details).

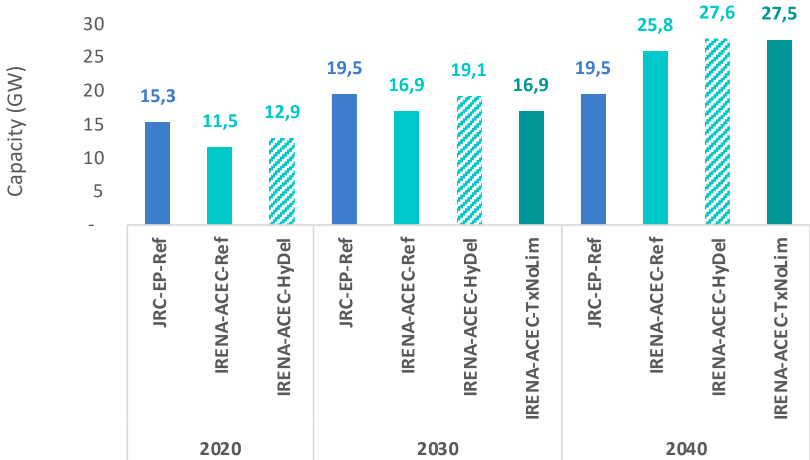


Figure 5.49 Sum of Interconnection Capacities in SAPP

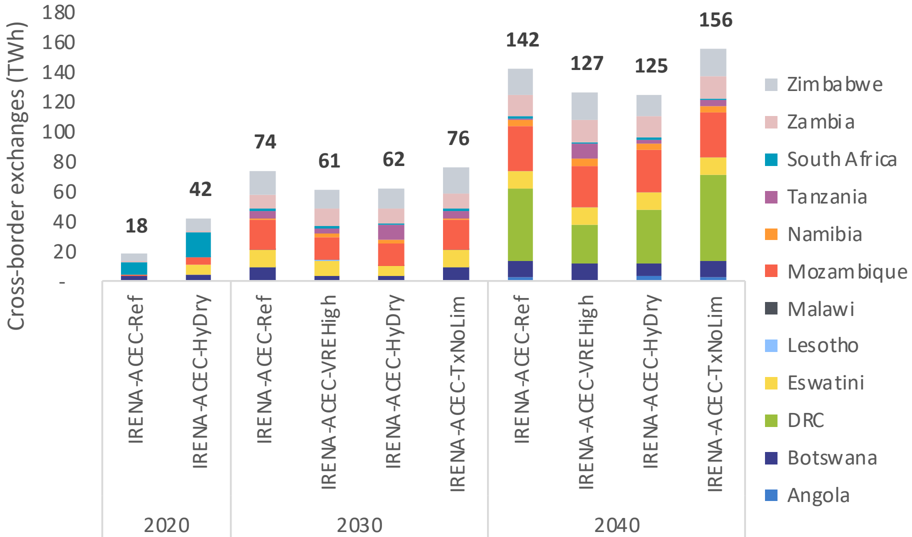


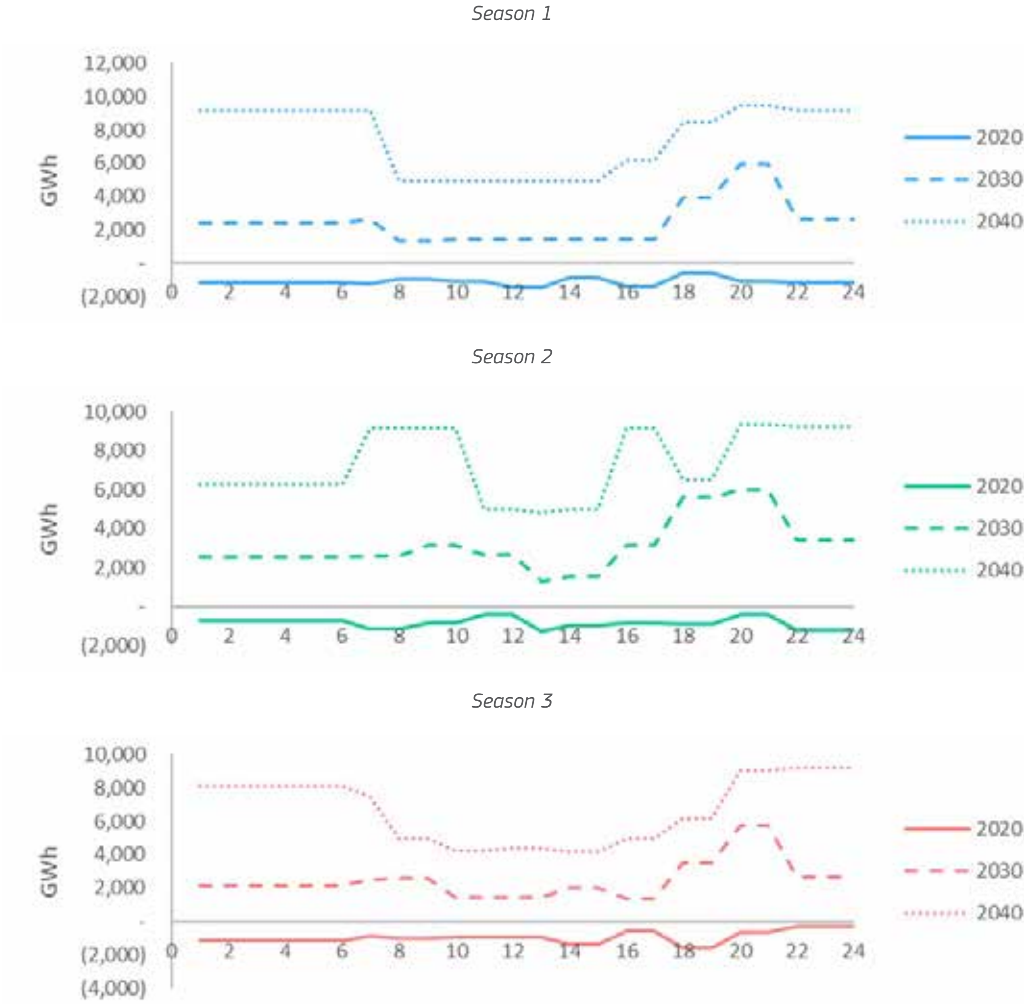
Figure 5.50 Sum of electricity exports in SAPP

The CMP Phase 1 report[54], identifies as short-term priority transmission projects the lines Zambia-Tanzania (200MW) and Malawi-Mozambique, while for medium-term priority identifies lines DRC-Zambia (2GW), DRC-Angola (1.1GW), Zambia-Tanzania-Kenya (2GW), Zimbabwe-Zambia-Botswana-Namibia (300MW), Botswana-South Africa (800MW) Angola-Namibia (700) and Malawi-Tanzania. Finally, for the long term (2031-2040), the following connections were listed: DRC-South Africa (3GW), DRC-Angola (500MW), DRC-Zambia, Zambia-Malawi, Zambia-Mozambique (900MW), Mozambique-Tanzania and South Africa-Namibia.

The level of exported quantities in the countries of the Power Pool increases considerably -almost doubles- between 2030 and 2040 (Figure 5.50). DRC is part of SAPP, and therefore the export activity reported in the previous paragraphs is also visible here. Mozambique appears as an exporter from 2030 onwards, together with Zambia and Zimbabwe. South Africa, on the other hand, becomes a net importer of electricity after 2030, and imports even higher quantities in 2040under all scenarios.

Figure 5.51 shows the hourly variation of net imports in 2030, appearing mainly in the afternoon peak hours. The pattern changes again in 2040, when the installed capacity of PVs generate electricity locally in the daylight hours (limited during season 2: May-August) and therefore the need for imports is lower during this period.

Figure 5.51 Hourly net electricity imports in South Africa for the IRENA-ACEC-TxNoLim scenario



(*) Negative values correspond to net exports.

West African Power Pool

The analysis of WAPP electricity exchanges is performed comparing the reference scenario of the JRC study[75] with the three different scenarios in the IRENA study[76], with a time horizon until 2030. As can be seen in Figure 5.52, the total interconnection capacity in the region is not projected to increase noticeably in the period between 2020 and 2030, remaining at a value around 10GW. The main additions in the Reference scenario of IRENA are the increase of capacity between Benin and Nigeria (from 0.7GW in 2020 to 1.4GW in 2030), between Benin and Togo (from 1GW to 1.2GW), and the addition of an interconnection between Benin and Niger at 33MW, and Burkina Faso and Niger at 300MW.

In the CMP Phase 1 analysis, the project identified as priority for the short-term was the coastal backbone of Ghana –Togo -Benin, the connection of Côte d'Ivoire –Liberia -Sierra Leone -Guinea under construction, together with the loop Senegal -The Gambia -Guinea Bissau -Guinea, followed by Guinea -Mali, Nigeria –Niger –Benin –Togo -Burkina Faso, and Nigeria-Benin-Togo-Ghana-Côte d'Ivoire. Further projects in the medium term were identified between Liberia -Côte d'Ivoire, Côte d'Ivoire- Mali, and further strengthening of Benin –Togo -Ghana and Côte d'Ivoire -Ghana. The long-term horizon includes the Western Backbone of Senegal -The Gambia -Guinea Bissau –Guinea -Mali, to reach Ghana -Burkina Faso -Mali, and the interconnection between WAPP and Northern Africa through Morocco and between WAPP (Nigeria) and CAPP (Inga).

[75] Pappis, I., Howells, M., Sridharan, V., Usher, W., Shivakumar, A., Gardumi, F. and Ramos, E. (2019). Energy projections for African countries, Hidalgo Gonzalez, I., Medarac, H., Gonzalez Sanchez, M. and Kougias, I. Editors. EUR 29904 EN. Publications Office of the European Union. Luxembourg. ISBN 978-92-76-12391-0. doi:10.2760/678700. JRC118432.

[76] IRENA. (2018). Planning and Prospects for Renewable Power: West Africa. Abu Dhabi

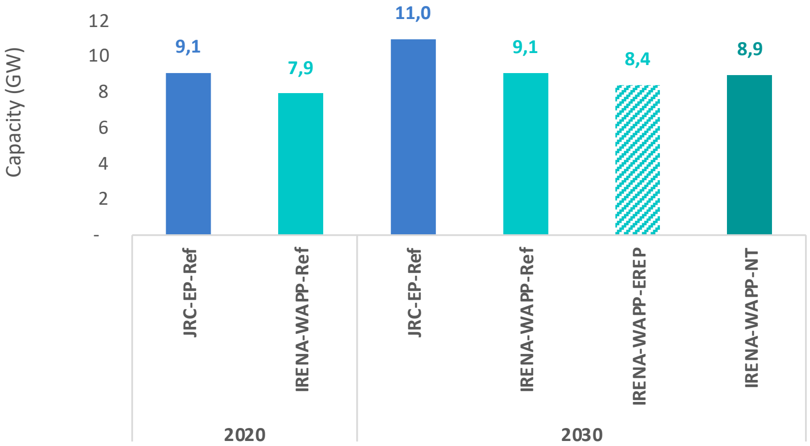


Figure 5.52 Sum of Interconnection Capacities in WAPP

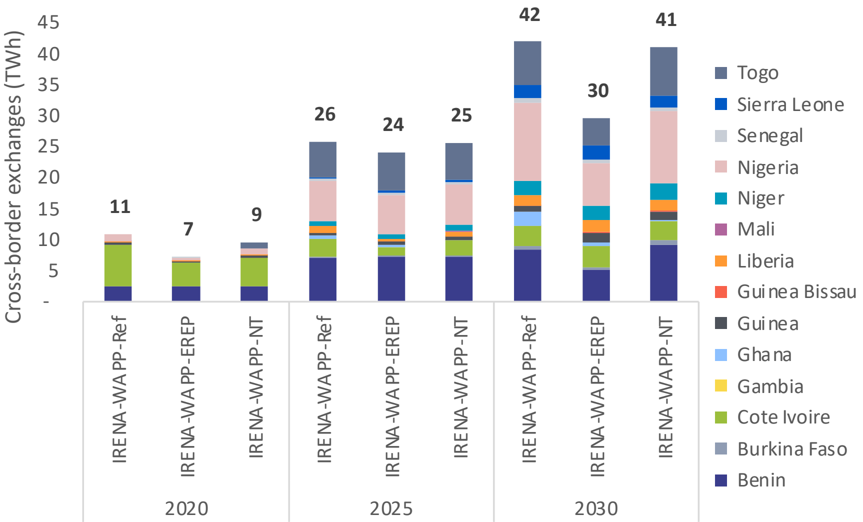


Figure 5.52 Sum of electricity exports in WAPP

Total exports of electricity increase in all projections, roughly doubling every decade along the time horizon (Figure 5.52). Nigeria and Ivory Coast are net exporters in 2025 and 2040, and Benin and Togo are net importers (in the graph below only their exports are presented). It is interesting to note that this increase in electricity exchange does not require significant new interconnection capacity in the region.

Central African Power Pool

The available studies for CAPP include the JRC analysis and the IRENA (2015) study[77], which is currently under revision. Although the JRC study projects a tripling of the interconnecting capacities in the Power Pool (Figure 5.53), the IRENA "Full Integration" scenario only shows a marginal increase to this capacity (mainly through the increase of the capacity between Cameroon-Chad to 120MW, Eq. Guinea-Cameroon to 120MW, and the addition of a 26MW connection for DRC-CAR).

In the CMP Phase 1 study, short-term priority transmission projects in CAPP include lines Angola-Congo-DRC (800MW), Congo-Gabon (600MW), Cameroon-Chad (200MW) and Cameroon-Equatorial Guinea (200MW). For the medium term, three projects were identified, namely the interconnector Angola –DRC –Congo –Gabon -Equatorial Guinea -Cameroon, the connection CAR-DRC and Angola -Congo. Finally, for the long-term connection with DRC, the main projects were DRC -Nigeria, Southern DRC -Eastern DRC, DRC –Rwanda and DRC -Angola.

In the IRENA scenarios, Cameroon is a net exporter in 2025 and 2030, and DRC appears again as the largest net importer when analysing the CAPP region (Figure 5.54). It should be noted that an integrated analysis for the continent is needed in order to examine in detail the export options of countries like DRC, which belongs to multiple Power Pools, and is projected to feature a sharp increase in the available generation capacity. Equatorial Guinea and Chad are also projected to be net exporters by 2030 (Figure 5.54).

[77] IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi.

Figure 5.53 Sum of Interconnection Capacities in CAPP

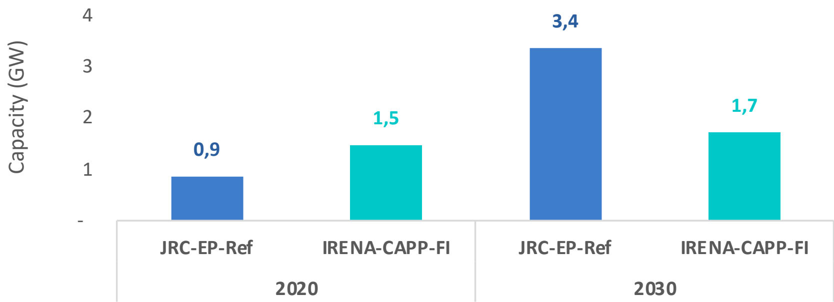
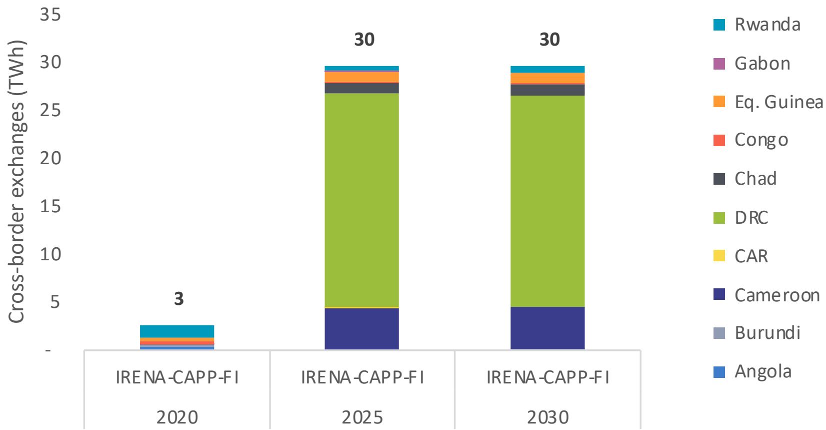


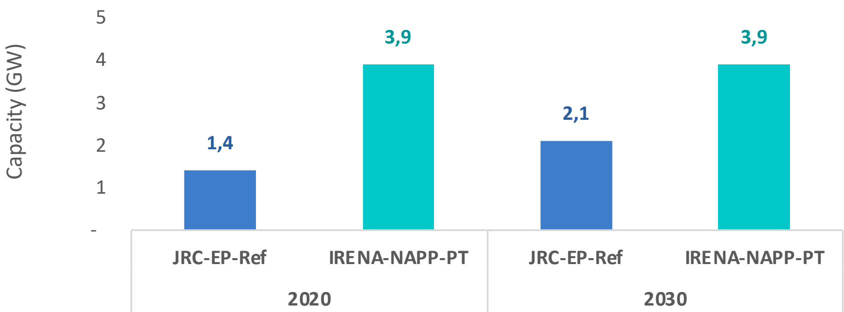
Figure 5.54 Sum of electricity exports in CAPP



Comité Maghrébin de l'Électricité (COMELEC)

The projections for the COMELEC countries are rather conservative as far as interconnection capacities are concerned (Figure 5.55). The capacity shown in the graph includes the Morocco -Spain line at a nominal capacity of 1.4GW, as well as lines Tunisia -Algeria (1.5GW), Egypt -Libya (180MW), and Algeria -Morocco (800 MW).

Figure 5.55 Sum of Interconnection Capacities in COMELEC



In the analysis performed under the CMP Phase 1 study[54], short- and medium-term priority projects have been identified -including Algeria -Morocco (1GW), Algeria -Tunisia (300MW), Libya -Egypt (180MW), Libya -Tunisia (500 MW), and Morocco -Mauritania (300MW). It is also important to note that within the priority projects, the interconnection with Europe is also included -via lines Algeria -Italy (1GW), Algeria -Spain (1GW), Morocco -Spain (600MW), and Tunisia -Italy (600 MW).

The projected electricity exports from the countries in the region (Figure 5.56) heavily depend on the scenario narrative. The IRENA "Frozen Future" (IRENA-NAPP-FF) scenario projects Algeria to export the largest share of electricity in the region.

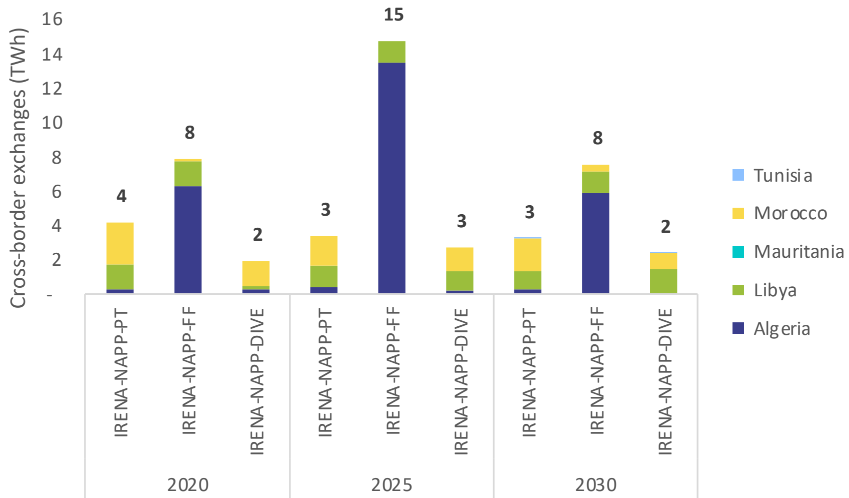


Figure 5.56 Sum of electricity exports in COMELEC

5.3. KEY CONCLUSIONS AND COMMON PATHWAYS

Although the studies which are presented in the previous sections have different input assumptions and diversified scenarios, there are some common trends that can help draw conclusions in support to "no-regret" policy decisions for the development of the African power system.

The construction rate of renewable energy projects increases in the medium and long terms, even in the rather conservative projections of the Power Pool Masterplans. Looking at the continental level in the IEA's Africa Case scenario (Figure 5.58), it is clear that the capacity additions of solar PV is expected to dominate all renewable energy installations.

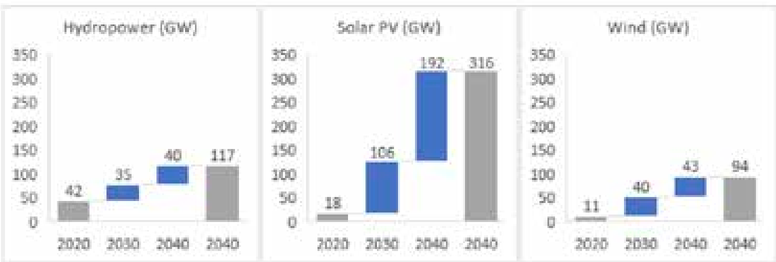


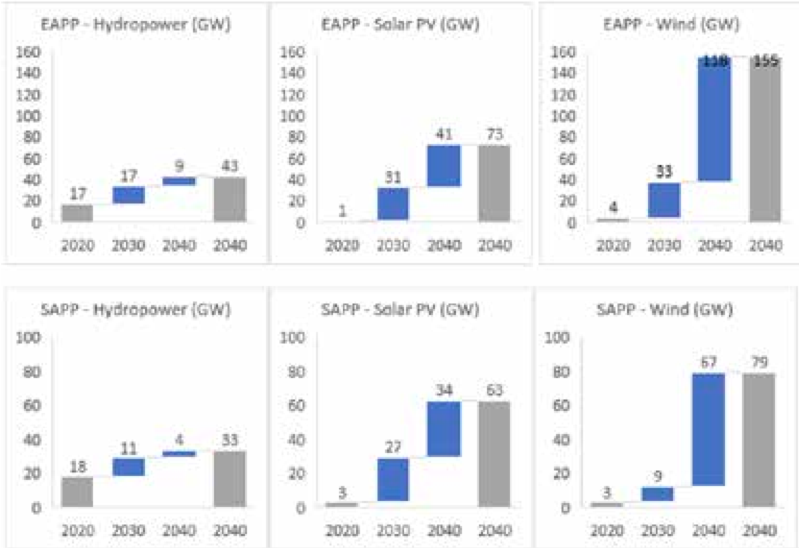
Figure 5.58 Capacity additions at the continental level in the Africa Case scenario of IEA (2019)

The optimistic scenarios of IRENA (High VRE scenario, where the overall target for VRE was set exogenously to 50%, driving a large penetration of wind and PV) show an increase of the installation rate of PVs from about 5GW per year between 2020 and 2030 to almost 19GW per year in the period after 2030 for the African Clean Energy Corridor (ACEC) region. In this study, the projections for additions of wind capacity are even more optimistic over the same period, as depicted in Figure 4.59.

In general, the scenarios of JRC and IRENA show higher penetration of variable renewables in all the Power Pools, compared to the projections of the Power Pool Masterplans, which focus more on conventional generation and hydro plants. The fact that variable renewable resources are widespread and distributed means smaller countries can achieve a larger share of renewables in a cost-efficient way – with shares as high as 40% or more in electricity generation.

The current trends of projected reduction costs for PV and wind technologies constitute these variable renewables one of the primary drivers in capacity additions in the continent. At the same time, the addition of various renewable energy technologies contributes to the diversification of supply sources, and hence the resilience of the electricity supply mix. As VRES penetration increases, ancillary services are required to secure system stability and reliability - the Power Pools are aware, and the technical teams are integrating this need into their analyses. Apart from flexible conventional power plants, storage systems are an important option for increasing the flexibility of the system, paving the way for a higher contribution of variable renewable energy systems.

Figure 5.59 Capacity additions in EAPP and SAPP in the High VRE scenario[78] of IRENA (2021)



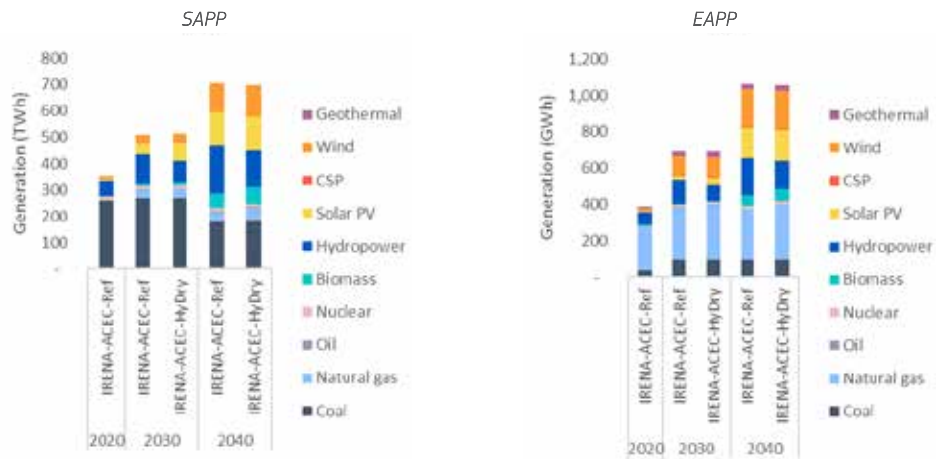
Large hydro power plants are a proven technological option in Africa. Countries with strong hydro potential can benefit, to plan a robust operation of their power system, as hydro systems are dispatchable, and hydro dams can be used for storage. However, systems which are heavily dependent on hydro power are vulnerable, as periods of drought could affect security of supply. Complementing hydropower with other renewable technologies is a cost-efficient way to mitigate such hydro-related risks.

In the "Dry year" scenario of IRENA (IRENA-ACEC-HyDry), significant reductions in the share of hydroelectricity can be offset by alternative renewable energy resources to further diversify the power system (Figure 5.60). For instance, in countries like Burundi, South Sudan and Uganda, low availability of hydro leads to the introduction of bioenergy in the power generation mix.

In CAPP countries, solar and wind resources are less promising compared to other parts of Africa; however, six countries in the region have domestic gas resources, and the Power Pool is home to almost 60% of Africa's total hydro potential. Hydropower is projected to be the common source of electricity in the Power Pool until 2030. However, the share of other renewables is significantly increased.

In COMELEC countries, the current scenario projections foresee a continuation of the trend of new gas-fired capacities, while the renewable energy projected to increase is wind. Balancing and reserve services would be provided by large quantities of electricity from gas-fired plants.

Figure 5.60 Comparison of generation in the Reference and "Dry Year" scenarios of IRENA (2021)



In all scenarios discussed in Section 4.2.3, the quantities of electricity exchanged between countries increases significantly in the period between 2020 and 2040, supported by a considerable increase of the interconnection capacities. Flows in SAPP and EAPP are projected to increase by a factor of 4 or 5

[78] A target of 50% VRE is set exogenously in this scenario, which drives the large penetration of wind and PV capacities.

(depending on the scenario) over these twenty years. Similarly, in WAPP, the exchanges are projected to increase by a factor of 4, while in CAPP the projected increase between 2020 and 2030 is almost tenfold.[79]

The projections for COMELEC are somehow more conservative, apart from the "Frozen Future" scenario elaborated by IRENA -which shows an increase of almost four times in the period 2020-2030. It is expected that these scenario outcomes for the studies reviewed for the AUESO, would be further investigated under the CMP 2, based on uniform assumptions and validated data from the Power Pools and stakeholders.

However, the required increase in interconnection capacities in order to accommodate this level of exchanges may not be as significant, if the currently committed and planned interconnections are actually implemented – as these will support the projected increase in exchanges. If constraints and bottlenecks are removed, more investments in capacity are cost effective- as appears in the "Unlimited Interconnection" scenario (in the twenty EAPP and SAPP countries). In WAPP, the development of almost all the cross-border transmission projects in the pipeline, proves beneficial across all scenarios analysed. Interconnections are utilised to contribute to lower overall system costs in the Power Pool.

Cross-border interconnections within CAPP and with SAPP, WAPP are needed to exploit the huge hydro potential and export hydroelectricity to the other Power Pools (WAPP and SAPP). Within CAPP, increased interconnections would impact the generation mix, offering the possibility to transfer RES electricity among countries, and reducing the need for more conventional (main gas-fired) capacity in countries like Rwanda and Angola.

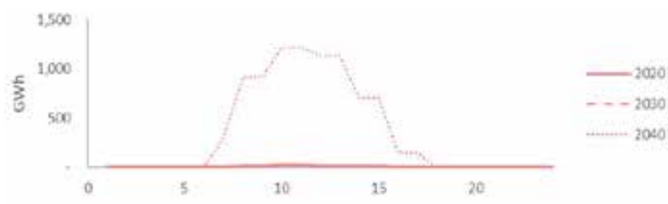
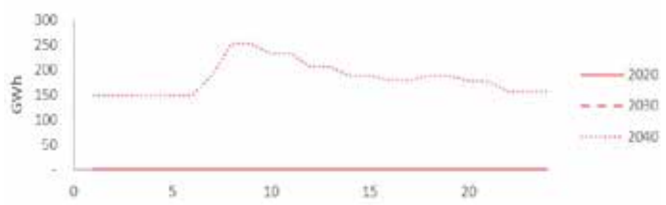
Type of supply	Hourly generation for the average day of season 3 (September-December)
Solar PV	
Wind	
Net imports	

Figure 5.60 Hourly generation of PV, Wind and Net electricity imports (example for Uganda in the IRENA-ACEC-TxNoLim scenario (2021))

As the studies reveal, the level of trade between countries is sensitive to the level of VRE penetration in the country. In most cases, power flows are in one direction: from countries with surplus generation towards countries with deficits. However, bi-directional flows occur on some connections as the level of VRE increases towards 2040. This behaviour is linked to the generation from PVs during the daylight hours, and the evening peaks that appear in the demand (see Figure 5.60 for an example for Uganda).

Countries mainly exporting electricity during the day could import electricity during the evening peak hours (see the example of Uganda in the previous section). This shows that there is a strong correlation between the installed capacity of PVs and the electricity exchanges, as was seen in the case of South Africa (Figure 5.51), where the level of imports are considerably reduced during the daylight hours, when local PVs are generating.

[79] As DRC is the main exporter in CAPP, an integrated study is necessary in order to investigate the operation of the power system taking into account all the Power Pools in which DRC belongs to.

6.CONCLUSIONS: PATHWAY TO 2040

In the following paragraphs, an attempt is made to connect the insights provided by the scenario analysis from the present study with the issues identified based on the Action Plan and the Strategy, while analysing the relevant opportunities and key challenges.

Based on the "Action Plan for Harmonised Regulatory Framework for the Electricity Market in Africa"[80] and the "Strategy for the Development of a Harmonised Regulatory Framework for the Electricity Market in Africa"[81], a number of opportunities and challenges have been identified at the short (2020-2025), medium (2026-2030) and long-term (2031-2040) towards the creation of the African Single Electricity Market (AfSEM). In the following paragraphs, an attempt is made to connect the insights provided by the scenario analysis from the present study with the issues identified based on the Action Plan and the Strategy, while analysing the relevant opportunities and key challenges.

Update of Action Plan and Strategy and Technical & Operational Readiness

One of the steps in the short term (2020-2025) is the preparation and adoption of "*National ten-year transmission network development plans [...]*". In the medium term (2026-2030) "*Regional network codes and, likewise, regional ten-year transmission network development plans should be agreed upon*", and in the long term (2031-2040) "*A continental ten-year transmission network development plan and continental interconnection target should be agreed upon as should a continental grid code*"[75]. The analysis in Chapter 4 has clearly shown that it is of paramount importance to have consistent input assumptions, and time horizon in the development of the Ten-Year Network Development Plan -TYNDPs. This will ensure consistent scenarios, which will lead to robust conclusions for the development of the national power systems. Consistency should be maintained not only at the Power Pool level, but also at the continental level. It will lead to proper consideration of options for countries that are considered pivotal, and which belong to multiple Power Pools -and therefore are projected to play important roles in electricity exchanges and trade in the future (DRC is an example of such a country with a projected hydropower capacity of 9GW in the EAPP Masterplan versus 14GW in the SAPP Masterplan for the year 2030).

Access to electricity

Access to electricity is considered in the demand projections discussed in Chapter 4, through the input assumptions for different scenarios: especially in the Africa Case scenario of the IEA Africa Energy Outlook, whereby universal access to electricity is expected to be achieved in 2030, and represents a quarter of demand growth to 2040.[82] However, all the studies point to a significant increase in electricity consumption in the continent, which will require the development of distribution and transmission networks, and a reliable supply of affordable and environmentally friendly electricity. This should however be complemented by effective supply, as well as demand-side management practices. The expected growth of urban areas offers an opportunity to boost electricity access, but also increased challenges for the development of infrastructure and ensuring the quality of electricity supply.

Resilience: Accelerator for cleaner, greener solutions

The study of the IRENA scenarios with "Dry year" assumptions, where the capacity factors of the hydropower plants are reduced to reflect low hydrological flows, has demonstrated that risks associated with the uncertainties of hydropower can be mitigated through a combination of increased variable renewable energy capacity and interconnection capacities. Examples include the development of geothermal technology in Ethiopia, or biomass power plants in Burundi, as well as deepening the penetration of RES in all countries, to catalyse the transition to low carbon electricity sector in Africa. In the studies examined so far, the storage options considered were limited to small-scale technologies; utility-scale storage and Power-to-X options could offer further advantages, and should be analysed in more detail in future studies.

[80] African Union. (2021). Action Plan for Harmonised Regulatory Framework for the Electricity Market in Africa. Available online: https://au.int/en/documents/20210618/action-plan-harmonised-regulatory-framework-electricity-market-africa

[81] African Union. (2021). Strategy for the Development of a Harmonised Regulatory Framework for the Electricity Market in Africa. Available online: https://au.int/en/documents/20210618/strategy-development-harmonised-regulatory-framework-electricity-market-africa

[82] IEA. (2019, November). Africa Energy Outlook 2019. Paris.

Plan-based investment approach

One of the important points in the Policy Paper and Roadmap for AfSEM stated that "*The creation of the single electricity market in a time when many AU Member States have ambitious national targets for installed generation capacity should be "smart." Whole power system dynamics need to be considered and avoid being fragmented in a project-focused approach*". The need for an integrated system and holistic approach was clear in the analysis of the existing scenario-based studies. It is one of the key drivers of the CMP Phase 2, and the motivation for the establishment and operationalisation of the AfSEM.

Market Readiness and Development Regional Electricity Markets

The exchanges of electricity modelled in the different studies, discussed in Section 4.2.3, indicate that the increase in the interconnection capacity and resulting improved flow of electricity between countries, lead to the reduction of the overall system cost at the levels of Power Pools –and, consequently, at the continental level.[83]

An important insight was gained from the analysis of hourly flows of electricity during typical days: the large penetration of variable renewables would require strong interconnections in order to ensure flexibility in the power system, and optimise the use of VRE to cover local demand. This also enables the large hydro projects to provide flexibility at a regional scale, complementing the VRE. The current situation of "pure" exporting and importing countries is no longer the case. Bi-directional flows through interconnections, such as in Uganda, will help minimise power system costs.

Certain scenarios analysed provide a strong indication on the future utilisation of committed and planned projects, as well as possible candidate interconnection projects that could further en-hance electricity trade. For example, in the African Clean Energy Corridor -ACEC region addi-tional generic capacity is foreseen to strengthen the link for Sudan-Ethiopia-Kenya and DRC-Tanzania-Malawi. The modelling work envisaged in the framework of CMP Phase 2 is expected to identify key interconnection projects that would further enhance trade and support the opera-tion of a single market at the continental level under AfSEM.

The design of the AfSEM, besides focusing on the grid-based solutions, should take into account the deployment of off-grid technologies -such as mini-grids-, to accelerate electricity access for all users. According to the findings in the IEA Africa Energy Outlook for the "Africa Case" scenar-io, the least-cost pathway for full access by 2030 is to deploy mini-grids and stand-alone sys-tems in parallel to the extension of the main grid. In urban areas, mini-grids can play an important role in ensuring access to electricity to areas that cannot be easily reached by the main grid. In rural areas, decentralised solutions can provide most of the additional connections through mini-grids and stand-alone systems.

Market Opening and Liberalisation of the Markets

All scenarios discussed in Chapter 4 are based on the background theoretical assumption of a least cost optimisation of the system in a perfectly competitive market. Therefore, market liberalisation and utility restructuring to promote wholesale competition is an important step towards achieving the cost optimisation calculated by the models.

Capacity Readiness: Unconstrained Electricity Transmission Access

Investment in interconnection infrastructure projects is crucial for cross-border exchange of electricity to happen, and consequently to create a single market for electricity trading. The studies reviewed indicated that the currently committed and planned interconnection projects are expected to contribute significantly to higher exchange volumes by four or five times from the current level in the next twenty years. This is important for the development of integrated electricity markets at both the regional and continental levels. One crucial point not considered in the studies reviewed, and to be further explored, is the possible expansion of interconnection capacities between Africa and Europe, and between Africa and the Middle East. Such interconnections across continents could play an important role in the development of electricity trade in Africa and beyond, further enhancing the provision of reliable electricity to the continent.

[83] IRENA. (2021). Planning and Prospects for Renewable Power: Eastern and Southern Africa. Abu Dhabi.

ANNEXES

ANNEX 1. LITERATURE REVIEW: LIST OF REFERENCES

Table A1.1: List of references for the literature review of the African Union Electricity Sector Outlook

Author	Year	Title	Description
IEA	2019	African Energy Outlook[84]	Analysis of how the energy sector can deliver the sustainable development goals and spur economic growth ambitions of AU Agenda 2063 versus today's policy
IEA	2017	Energy Access Outlook[85]	Analysis of how the energy sector can deliver universal access to energy (UN SDG7) versus today's policy framework.
IRENA	2013	Southern African Power Pool: Planning and Prospects for Renewable Energy[86]	The study describes the transition of national power systems to a renewable-oriented future up to 2050.
IRENA	2013	West African Power Pool: Planning and Prospects for Renewable Energy[87]	
IRENA	2015	Africa Power Sector: Planning and Prospects for Renewable Energy[88]	Summary of IRENA's first attempt to systematically assess the prospects for renewable energy deployment in the African power sector by 2030.
IRENA	2015	Africa 2030: Roadmap for a Renewable Energy Future[89]	Outlines a roadmap to double the share of renewables in the world's energy mix within the next 15 years. It is based on a country-by-country assessment of energy sector evolution.
IRENA and LBNL	2015	Renewable Energy Zones for the Africa Clean Energy Corridor[90]	Multi-criteria Analysis for Planning Renewable Energy (MapRE) combining geospatial, statistical, energy engineering and economic methods to identify and value RES resources.
IRENA	2018	Planning and Prospects for Renewable Power: West Africa[91]	The study describes the transition of national power systems to a renewable-oriented future up to 2030.
IRENA	2020	Scaling Up Renewable Energy Deployment in Africa[92]	Assess the progress in the implementation of IRENA's various programmes in the Sub-Saharan Africa region and, to the extent available data allows, measures the impact they created on the ground at the regional and national levels.
IRENA	2021	Planning and Prospects for Renewable Power: Eastern and Southern Africa[93]	The study describes the transition of national power systems to a renewable-oriented future up to 2040.

[84] IEA. (2019, November). Africa Energy Outlook 2019. Paris.
[85] IEA. (2017, October). Energy Access Outlook 2017. Paris.
[86] IRENA. (2013). Southern African Power Pool: Planning and Prospects for Renewable Energy. Abu Dhabi.
[87] IRENA. (2013). West African Power Pool: Planning and Prospects for Renewable Energy. Abu Dhabi.
[88] IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi.
[89] IRENA. (2015). Africa 2030: Roadmap for a Renewable Energy Future. Abu Dhabi.
[90] IRENA and LBNL. (2015). Renewable Energy Zones for the Africa Clean Corridor. Abu Dhabi.
[91] IRENA. (2018). Planning and Prospects for Renewable Power: West Africa. Abu Dhabi.
[92] IRENA. (2020). Scaling Up Renewable Energy Deployment in Africa. Abu Dhabi.
[93] IRENA. (2021). Planning and Prospects for Renewable Power: Eastern and Southern Africa. Abu Dhabi.

AFREC	2019	Designing the African Energy Transition[94]	Assess the current energy sector situation and presentation of AU programs
AfDB	2019	Estimating Investment Needs for the Power Sector in Africa 2016-2025[95]	Answer to the question how much investment is needed to realise the African Development Bank's (AfDB) New Deal on Energy for Africa (the New Deal)?
AfDB	2020	Electricity Regulatory Index for Africa[96]	Countries ranked into four performance 'bands', reflecting how developed their elec-tricity regulatory frameworks are and to what extent they align with international best prac-tice.
World Bank	2020	RISE 2020 Regulatory Indicators for Sustainable Energy: Sustaining the Momentum[97]	Assess countries' policy support for each of the three pillars of sustainable energy – access to electricity, access to clean cooking (for 55 access-deficit countries), energy efficiency, and renewable energy.
World Bank	2020	Rethinking Power Sector Reform in the Developing World[98]	Visit and refresh the thinking on power sector reform approaches for developing countries. Also forward looking, considering the implications of new social and environmental policy goals, as well as emerging technological disruptions.
IAEA	2020	Energy, Electricity and Nuclear Power Estimates for the Period up to 2050[99]	Present the global and regional projections for energy and electricity up to 2050 with a strong focus on nuclear power.
EU JRC	2019	Energy Projections for African Countries[100]	Modelling countries individually and connected via gas & electricity trade to identify the cost-optimal solution to satisfy each country's total final energy demand.
USAID Power Africa	2018	The Roadmap: a guide to reaching 30,000 Megawatts and 60 million connections[101]	Presentation of Power Africa and stakeholders' engage-ments and future activities to reach universal access in 2030.
Power Africa & Tony Blair Institute	2019	West Africa Power Trade Outlook: Power Africa Senior Advisors Group Programme[102]	Modelling and analysing the opportunities that trading in West Africa presented and the challenges that would need to be addressed to realise these opportunities.
PIDA	2012	African Generation & Transmission Masterplan	Strategy and planning of least-cost regional investment program to supply the demand. The EU TAF synthesis of the Generation and Transmission Masterplans developed in 2020 was used for the African Union Electricity Sector Outlook.[103]
ECCAS	2006	CAPP Generation & Transmission Masterplan	
COMESA	2014	EAPP Generation & Transmission Masterplan	
SADC	2017	SAPP Generation & Transmission Masterplan	
ECOWAS	2018	WAPP Generation & Transmission Masterplan	
AfDB and UNEP	2017	Atlas of Africa Energy Resources[104]	Combine scientifically reliable data sources to provide a complete view of Africa's energy needs, resources, and opportunities. Comparative satellite images illustrate the positive and negative changes that have taken place over the years.

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PBL Netherlands Environmental Assessment Agency	2017	Towards Universal Electricity Access in Sub-Saharan Africa [105]	Analyse the technology and investment requirements for achieving universal electricity access in Sub-Saharan Africa in the context of global climate policy.
Earth Watch	2019	Global Energy System based on 100% RE – Power, Heat, Transport and Desalination Sectors[106]	Outline a 1.5°C scenario with a cost-effective, cross-sectoral, technology-rich global 100% renewable energy system that does not build on negative CO2 emission technologies. The scientific modelling study simulates a total global energy transition in the electricity, heat, transport and desalination sectors by 2050.

ANNEX 2. COUNTRIES PER POWER POOL

Table A2.1: List of countries per Power Pool.

Country	Power Pools to which the country belongs		
Algeria	COMELEC		
Angola	CAPP	SAPP	
Angola	SAPP		
Benin	WAPP		
Botswana	SAPP		
Burkina Faso	WAPP		
Burundi	CAPP	EAPP	
Cabo Verde	NA		
Cameroon	CAPP		
CAR	CAPP		
Chad	CAPP		
Comoros	NA		
DRC	CAPP	EAPP	SAPP
Congo	CAPP		
Cote Ivoire	WAPP		
Djibouti	EAPP		
Egypt	EAPP		
Eq. Guinea	CAPP		
Eritrea	NA		
Eswatini	SAPP		
Ethiopia	EAPP		
Gabon	CAPP		
Gambia	WAPP		
Ghana	WAPP		
Guinea	WAPP		
Guinea Bissau	WAPP		
Kenya	EAPP		

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[106] http://www.energywatchgroup.org/new-study-global-energy-system-based-100-renewable-energy/

Lesotho	SAPP	
Liberia	WAPP	
Libya	EAPP	COMELEC
Madagascar	NA	
Malawi	SAPP	
Mali	WAPP	
Mauritania	COMELEC	
Mauritius	NA	
Morocco	COMELEC	
Mozambique	SAPP	
Namibia	SAPP	
Niger	WAPP	
Nigeria	WAPP	
Rwanda	CAPP	EAPP
Sao Tome	CAPP	
Senegal	WAPP	
Seychelles	NA	
Sierra Leone	WAPP	
Somalia	NA	
South Africa	SAPP	
South Sudan	NA	
Sudan	EAPP	
Tanzania	EAPP	SAPP
Togo	WAPP	
Tunisia	NAPP	
Uganda	EAPP	
Zambia	SAPP	
Zimbabwe	SAPP	

ANNEX 3. INTERCONNECTION CAPACITIES SCENARIO RESULTS

Table A3.1: Projected interconnection Capacities in IRENA "Planning and prospects for renewable power: Eastern and Southern Africa" (2021)

Interconnection						Capacity (MW)		
	Country	To Country	Power Pools			2020	2030	2040
Reference Scenario	Angola	Namibia	CAPP	SAPP		-	700	700
	Burundi	Tanzania	CAPP	EAPP		-	423	1,109
	DRC	Angola	CAPP	EAPP	SAPP	-	-	1,663
	DRC	Burundi	CAPP	EAPP	SAPP	-	396	748
	DRC	Rwanda	CAPP	EAPP	SAPP	-	91	713
	DRC	Uganda	CAPP	EAPP	SAPP	-	-	388
	Djibouti	Ethiopia	EAPP			-	-	200
	Egypt	Sudan	EAPP			-	1,732	1,732
	Eswatini	Mozambique	SAPP			1,613	1,613	1,613
	Eswatini	South Africa	SAPP			1,344	1,344	1,344
	Ethiopia	Djibouti	EAPP			180	180	180
	Ethiopia	Kenya	EAPP			2,000	2,000	2,000
	Mozambique	Malawi	SAPP			-	-	1,800

Reference Scenario	Mozambique	Tanzania	SAPP			-	-	300
	Rwanda	Tanzania	CAPP	EAPP		-	-	181
	South Africa	Botswana	SAPP			549	1,349	1,349
	South Africa	DRC	SAPP			-	-	2,500
	South Africa	Lesotho	SAPP			217	217	217
	South Africa	Mozambique	SAPP			2,586	2,586	2,586
	South Africa	Namibia	SAPP			991	991	991
	Sudan	Ethiopia	EAPP			200	2,070	2,521
	Sudan	South Sudan	EAPP			-	29	29
	Tanzania	Kenya	EAPP	SAPP		-	600	600
	Uganda	Kenya	EAPP			400	400	400
	Uganda	Rwanda	EAPP			363	363	363
	Uganda	South Sudan	EAPP			-	194	227
	Uganda	Tanzania	EAPP			431	431	431
	Zambia	DRC	SAPP			120	120	120
	Zambia	Malawi	SAPP			-	105	1,355
	Zambia	Mozambique	SAPP			200	200	200
	Zambia	Namibia	SAPP			350	650	650
	Zambia	Tanzania	SAPP			-	750	750
	Zimbabwe	Botswana	SAPP			1,630	2,030	2,030
	Zimbabwe	Mozambique	SAPP			500	900	900
	Zimbabwe	South Africa	SAPP			-	500	500
	Zimbabwe	Zambia	SAPP			1,400	1,800	1,800
No Interconnection Limits Scenario	Angola	Namibia	CAPP	SAPP		-	700	700
	Burundi	Tanzania	CAPP	EAPP		-	423	1,109
	DRC	Angola	CAPP	EAPP	SAPP	-	-	1,663
	DRC	Burundi	CAPP	EAPP	SAPP	-	396	748
	DRC	Rwanda	CAPP	EAPP	SAPP	-	91	744
	DRC	Uganda	CAPP	EAPP	SAPP	-	-	388
	DRC	Tanzania	CAPP	EAPP	SAPP	-	-	1,347
	Djibouti	Ethiopia	EAPP			-	-	368
	Egypt	Sudan	EAPP			-	1,732	1,732
	Eswatini	Mozambique	SAPP			1,613	1,613	1,613
	Eswatini	South Africa	SAPP			1,344	1,344	1,344
	Ethiopia	Djibouti	EAPP			180	180	180
	Ethiopia	Kenya	EAPP			2,000	2,000	4,405
	Ethiopia	Eritrea	EAPP			-	-	627
	Ethiopia	Somalia	EAPP			-	-	609
	Malawi	Tanzania	SAPP			-	-	619
	Mozambique	Malawi	SAPP			-	-	1,800
	Mozambique	Tanzania	SAPP			-	-	300
	Rwanda	Tanzania	CAPP	EAPP		-	-	181
	South Africa	Botswana	SAPP			549	1,349	1,349
	South Africa	DRC	SAPP			-	-	2,500
	South Africa	Lesotho	SAPP			217	217	217
	South Africa	Mozambique	SAPP			2,586	2,586	2,586

No Interconnection Limits Scenario	South Africa	Namibia	SAPP			991	991	991
	Sudan	Ethiopia	EAPP			200	2,081	4,514
	Sudan	South Sudan	EAPP			-	29	29
	Tanzania	Kenya	EAPP	SAPP		-	600	881
	Uganda	Kenya	EAPP			400	400	400
	Uganda	Rwanda	EAPP			363	363	363
	Uganda	South Sudan	EAPP			-	194	222
	Uganda	Tanzania	EAPP			431	431	431
	Zambia	DRC	SAPP			120	120	120
	Zambia	Malawi	SAPP			-	105	736
	Zambia	Mozambique	SAPP			200	200	200
	Zambia	Namibia	SAPP			350	650	650
	Zambia	Tanzania	SAPP			-	750	750
	Zimbabwe	Botswana	SAPP			1,630	2,030	2,030
	Zimbabwe	Mozambique	SAPP			500	900	900
	Zimbabwe	South Africa	SAPP			-	500	500
	Zimbabwe	Zambia	SAPP			1,400	1,800	1,800

Table A3.2: Projected interconnection Capacities in IRENA (2018). Planning and Prospects for Renewable Power: West Africa. Abu Dhabi

			Capacity (MW)		
Scenario	**Country**		**2020**	**2030**	**2040**
IRENA-WAPP-Ref	Benin	Niger	-	-	33
	Benin	Nigeria	686	686	1,402
	Benin	Togo	1,000	1,000	1,133
	Burkina Faso	Cote Ivoire	327	327	327
	Burkina Faso	Ghana	332	332	332
	Burkina Faso	Mali	306	306	306
	Burkina Faso	Niger	-	100	301
	Cote Ivoire	Ghana	982	982	982
	Cote Ivoire	Liberia	338	338	338
	Cote Ivoire	Mali	320	320	320
	Gambia	Guinea-Bissau	329	329	329
	Gambia	Senegal	341	341	341
	Ghana	Togo	1,093	1,093	1,093
	Guinea	Guinea Bissau	310	310	310
	Guinea	Liberia	338	338	338
	Guinea	Senegal	286	286	286
	Guinea	Sierra Leone	334	334	334
	Liberia	Sierra Leone	303	303	303
	Mali	Senegal	100	100	100
	Niger	Nigeria	169	169	169
IRENA-WAPP-EREP	Benin	Niger	-	-	45
	Benin	Nigeria	686	686	811
	Benin	Togo	1,000	1,000	1,000
	Burkina Faso	Cote Ivoire	327	327	327
	Burkina Faso	Ghana	332	332	332

IRENA-WAPP-EREP	Burkina Faso	Mali	306	306	306
	Burkina Faso	Niger	-	111	333
	Cote Ivoire	Ghana	982	982	982
	Cote Ivoire	Liberia	338	338	338
	Cote Ivoire	Mali	320	320	320
	Gambia	Guinea-Bissau	329	329	329
	Gambia	Senegal	341	341	341
	Ghana	Togo	1,093	1,093	1,093
	Guinea	Guinea Bissau	310	310	310
	Guinea	Liberia	338	338	338
	Guinea	Senegal	286	286	286
	Guinea	Sierra Leone	334	334	334
	Liberia	Sierra Leone	303	303	303
	Mali	Senegal	100	100	100
	Niger	Nigeria	169	169	169

Table A3.3: Projected interconnection Capacities in IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi.

			Capacity (MW)		
Scenario	Country		2020	2025	2030
IRENA-CAPP-FI	Angola	DRC	35	35	35
	Burundi	DRC	375	375	375
	Burundi	Rwanda	430	430	430
	Cameroon	CAR	-	7	7
	Cameroon	Chad	1	121	125
	DRC	CAR	-	-	26
	DRC	Congo	60	60	60
	DRC	Rwanda	522	522	522
	Eq. Guinea	Cameroon	31	120	120
	Gabon	Eq. Guinea	4	4	15

Table A3.4: Projected interconnection Capacities in IRENA. (2015). Africa Power Sector: Planning and Prospects for Renewable Energy. Abu Dhabi.

			Capacity (MW)		
Scenario	Country		2020	2025	2030
IRENA-NAPP-PT	Algeria	Morocco	800	800	800
	Egypt	Libya	180	180	180
	Morocco	Spain	1,400	1,400	1,400
	Tunisia	Algeria	1,500	1,500	1,500