Eastern African Power Pool
Power balance statement

2020 edition, covering the years 2021-2030

13-02-2021

Frontpage: The Koka hydro plant in Ethiopia

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Foreword

A power balance statement is a tool designed to provide early warnings about potential security of supply issues. The EAPP planning code defines the power balance statement. It focuses on *remaining capacity*, i.e. available generation capacity minus the peak demand in a normal year. This calculation is undertaken each year for a 10-year period. The power balance statement will be issued by the Planning Committee at the end of September each year. Members of the planning committee are listed in appendix 1.

This is the second EAPP power balance statement and it covers the years 2021-2030. Improvements in data and methodology have been incorporated into this year's version and are also planned for the following years' statements.

The activities are supported by the World Bank within the project entitled *Technical assistance to support operational readiness to the EAPP.* This technical assistance project is managed by Tractebel, in cooperation with Energinet, Ea Energy Analyses and Dr Fatma Moustafa (local consultant). Ea Energy Analyses, in close cooperation with the Planning Committee, is responsible for developing the methodology and producing the first and second annual power balance statement.

1 Executive summary

Introduction

The Eastern Africa Power Pool (EAPP) is comprised of 11 Member States: Burundi, the Democratic Republic of the Congo (DRC), Djibouti, Egypt, Ethiopia, Kenya, Libya, Rwanda, Uganda, Sudan, and Tanzania.

Electricity demand is growing rapidly in the EAPP countries, and in 2020 the total forecasted peak will be 58 GW, and this is expected to grow up to 95 GW by 2030 (see Figure 1). This strong electricity demand growth is mainly driven by the expected economic growth in the region and the plans to increase the electrification rates in the region.

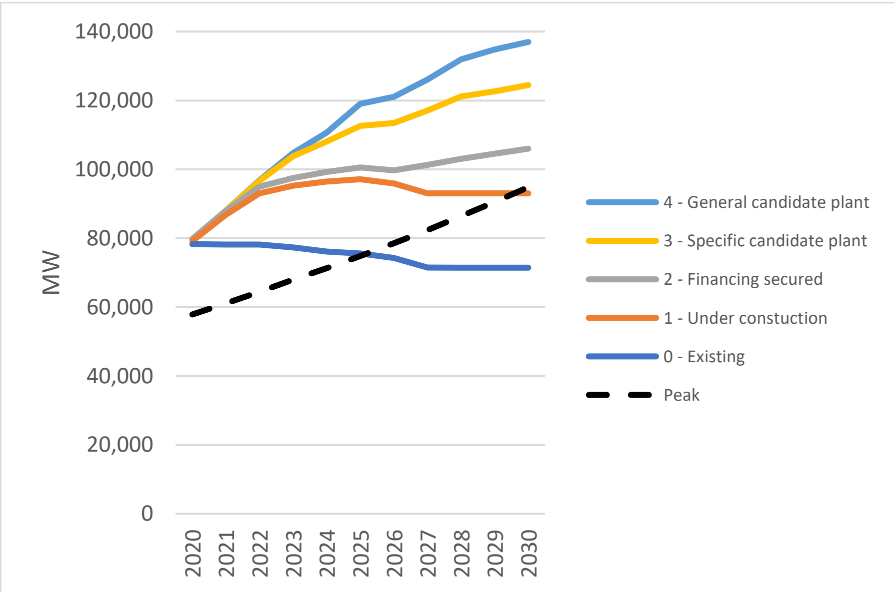


Figure 1: Excepted development in the EAPP peak demand and generation capacity available during peak demand[1].

The EAPP covers a large geographical area characterised by a diverse power generation mix (e.g. natural gas is predominant in the North, hydro in the middle and mixed in the South). The combination of hydroelectric power plants and fossil fuel-based power stations results in an important spread in marginal generation costs, therefore creating a strong incentive for cross-border power exchanges (aiming at maximizing the benefits of a diverse generation portfolio – "portfolio effect"). The benefits from cross-border power exchanges tend to increase with the planned expansion of variable renewable energy generation (mainly wind and solar power), which is expected to witness a growth in installed capacity from 4 GW in 2020 to 29 GW in 2030.

[1] See table 2 for the applied capacity factors.

Growing interconnection

Within a few years, all EAPP countries will be interconnected and may assist each other in ensuring a high level of security of supply. If plans for new transmission lines are realised as planned, the entire EAPP area will be connected by 2025. Differences in the load profiles, as well as differences in generation structure, may be used to generate mutual benefits.

High risk in the short term

The present power balance analysis indicates potential security of supply risks in 2021 for the DRC, Ethiopia, Libya, Rwanda, Sudan and Tanzania.[2] When only considering *existing projects* (generation and transmission), based on anticipated electricity demand growth, these countries have forecasted capacity deficits in 2021. For the DRC, Libya, Sudan and Tanzania the deficits during peak demand are all in the range from roughly 1,000 to 1,500 MW. The potential benefit from electricity imports is limited due to lack of generation and transmission capacity. Only Libya can realise a reduction in its capacity deficit via the import of electricity during peak hours.

However, if all projects currently *under construction* with completion dates in 2021 are realised on time, and full import capability is included, the forecasted capacity deficits are reduced significantly. In such a case, only the DRC and Sudan risk having a capacity deficit in 2021 (in the order of 835 and 236 MW respectively).

Improvements in medium term

In 2025, when including possible contribution from electricity import, and assuming that projects currently *under construction* are completed on time, the DRC and Sudan both face a high risk of capacity deficits. Kenya and Sudan benefit from import during peak demand. When extending the generation potential to include projects where *financing is secured* as well, then only the DRC has a negative capacity balance. However, in Kenya and Sudan a 15% reserve margin cannot be fulfilled.

In the long term: Dependency on timely completion of all projects

By 2030, if *all planned projects* (i.e. those under construction, with finance secured, specific candidate, and general candidate projects) come to fruition, then all countries will have a positive remaining capacity.

When only considering projects currently *under construction*, without assistance via imports from their neighbours, six countries (the DRC, Kenya, Libya, Rwanda, Tanzania and Sudan) will have significant capacity deficits. Including

[2] See chapter 4. Detailed results can be found in Table 7.

imports in the analysis reduces the deficit significantly in Kenya, and marginally in Rwanda and Tanzania.

Continued focus on planning of new generation and transmission projects, and the timely completion of planned projects, must have the highest priority if security of electricity supply should satisfy modern society requirements. Put in another manner, delays in implementing the planned projects may challenge the security of electricity supply in many of the EAPP countries.

Other benefits

Cross-border transmission capacity can reduce capacity deficits – but can also encourage economic operation of electricity systems, including sharing of reserves and economic dispatch of generation. The analyses indicate that many countries have difficulties in fulfilling a reserve margin of 15%[3] solely via national generation.

Cross border exchange of electricity will also become increasingly beneficial as wind and solar power increase their market share.

Development of Power balance Statement

The annual power balance statements are an important part of the continuous monitoring of development in electricity generation, demand, and transmission within the EAPP region.

The power balance statement will be updated annually, and the focus for next year's statement includes improved data quality. Information about future generation and transmission projects, as well as demand prognoses, are crucial for the quality of the power balance statement and this information should be fully updated and evaluated in an impartial fashion. Data collection meetings held at each member utility is considered as an efficient way to improved data.

Parallel to the work with the current Power Balance Statement, an EAPP wide power system model has been developed (PPS/E). Results from this work in included in appendix 2. The transfer capacities for the cross-border connections deviate in some cases from the values that has been used in the report. For next year's Power Balance Statement, these values should be used.

[3] Note, a 15% reserve margin has been selected for the current analysis and applied to all countries. One of the suggestions for future improvements of the power balance statement is implementing a country specific margin.

Comparison with last year's Power Balance Statement

In comparing the 2020 PBS with the 2019 version, the expected peak demand has been reduced significantly, and capacity deficit has been reduced in Egypt, Rwanda and Uganda[4].

[4] See Table 8 in chapter 5 for more details.

2 Introduction

Eastern African Power Sector Landscape

The Eastern Africa Power Pool (EAPP) is comprised of 11 Member States: Burundi, the Democratic Republic of the Congo (DRC), Djibouti, Egypt, Ethiopia, Kenya, Libya, Rwanda, Uganda, Sudan, and Tanzania. Djibouti has not been included in the report because of lack of data.

Rapid growth in electricity demand

Electricity demand is growing rapidly in the EAPP countries, and in 2020 the total forecasted peak will be 58 GW, and this is expected to grow up to 95 GW by 2030 (see Figure 1). This strong electricity demand growth is mainly driven by the expected economic growth in the region and the plans to increase the electrification rates in the region.

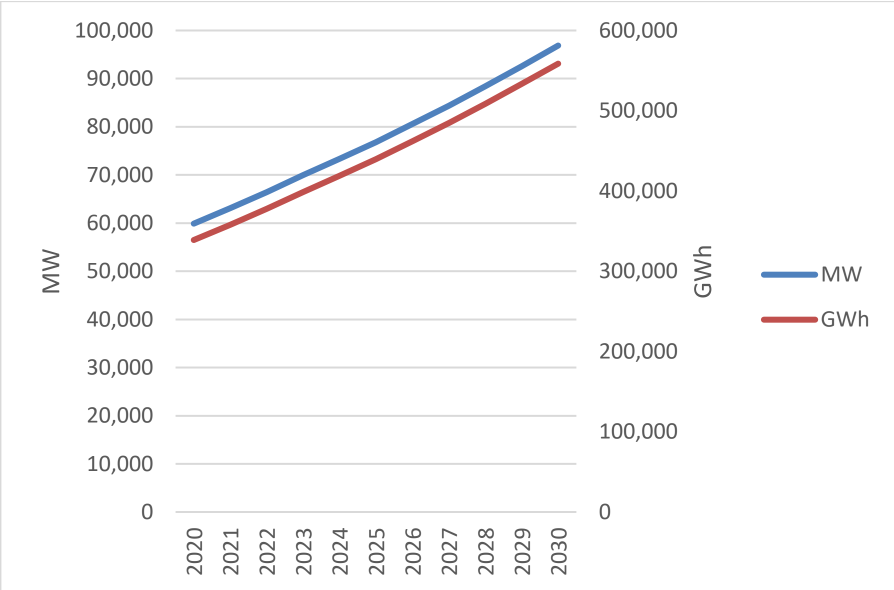


Figure 2: Excepted development in the EAPP yearly demand and peak demand.

The EAPP covers a large geographical area characterised by a diverse power generation mix (e.g. natural gas is predominant in the North, hydro in the middle and mixed in the South). The combination of hydroelectric power plants and fossil fuel-based power stations results in an important spread in marginal generation costs, therefore creating a strong incentive for cross-border power exchanges (aiming at maximizing the benefits of a diverse generation portfolio – “portfolio effect"). The benefits from cross-border power exchanges tend to increase with the planned expansion of variable renewable energy generation (mainly wind and solar power), which is expected to witness a growth in installed capacity from 4 GW in 2020 to 29 GW in 2030.

Growing interconnection

New transmission lines are coming into operation within the next years, and it is expected that the entire EAPP area will be interconnected by 2025. The sum of internal EAPP cross border lines is 654 MW in 2020, increasing to 4,720 MW in 2025 (see Table 1). Except for a DRC/Burundi/Rwanda interconnection project, no new cross-border transmission lines are yet included after 2025. However, new projects are underway, e.g. as part of the Victoria ring.

These capacity data are based on input from member countries. After the data collection, the Power System Analysis has found new values based on detailed PSS/E analyses. These are listed in appendix 2. In next year's Power Balance Statement, the consolidated capacities from the Power System Analysis should be used.

Security of Supply

Security of electricity supply is crucial for economic development, and all of the EAPP countries have experienced challenges at one point in delivering reliable electricity supply. Rapid growth in electricity demand often requires a doubling of generation capacity every seven to ten years. As a result, even minor delays in construction of new generation and transmission capacity may challenge the security of supply.

Interconnection	2020 MW	2025 MW
Burundi		
DRC_E	4	53
RWA		27
DRC - Eastern		
BDI	4	53
RWA	4	104
UGA		140
Egypt		
LBY	240	240
SDN	80	300
Ethiopia		
DJI	180	180
KEN		1,100
SDN	200	1,200
Kenya		
ETH		1,100
TZA		500
UGA	70	370
Libya		
EGY	240	240
Rwanda		
BDI		27
DRC_E	4	104
UGA	5	357
Sudan		
EGY	80	80
ETH	200	1,200
Tanzania		
KEN		500
UGA		279
Uganda		
DRC_E		140
KEN		300
RWA		347
TZA		279
Sum	**654**	**4,720**

Table 1: Existing and planned cross-border transmission capacity within EAPP[5].

The EAPP Planning code (EAPP, 2011) focuses on the difference between the available generating capacity and the demand. This is called the *Remaining Capacity* and is calculated under normal climatic conditions. The remaining capacity represents the reserves available that can be used to cover electricity demand that results from demand greater than that forecasted, as well as outages of generation or transmission units.

[5] The capacity is the maximum transfer capacity during safe operation (Net transfer capacity, NTC). Note lines are mentioned in both directions. The sum only includes the one-way capacity.

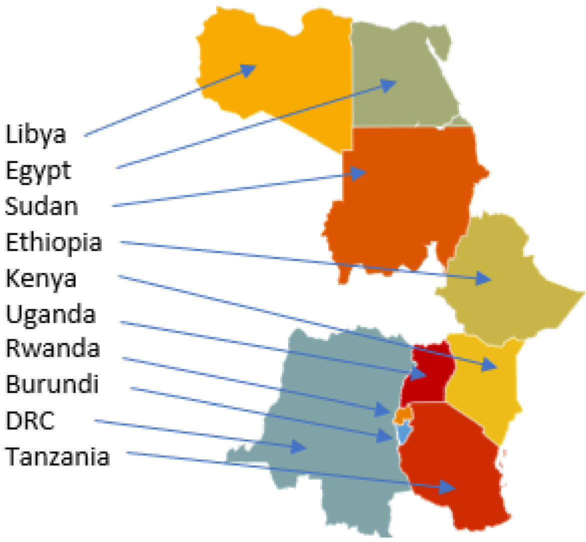


Figure 3: The ten analysed EAPP countries. Djibouti will be included when data is available.

Establishing a data foundation

Detailed information has been collected for all of the EAPP member countries. This includes existing generation and interconnector capacity, and annual electricity demand. The information has been collected for the next 10 years (2021-2030). Some of the information used in the power balance statement is also used in the detailed grid analyses (another subtask in the World bank project), and effort has been made to harmonise data.

Generation and transmission project pipeline

Future generation and transmission projects have each been assigned to one of the four following categories of development status:

1. Construction started[6]
2. Finance secured, and construction expected to start in a specific year
3. Specific candidate project, location and design determined
4. General candidate project

This allocation is crucial to address that the risk of delays is higher for e.g. candidate projects, than for projects under construction. Together with the status, a starting year for operation of the project is described. This indicates the year where the project is active at the *start of the year* (January). A project completed in e.g. September 2020, would have start year of 2021.

Country specific balances computed

A capacity (MW) and energy (GWh) balance has been computed for each country. The capacity balance studies the balance under peak demand, while the energy balance studies the annual balance. For countries dominated by thermal generation (such as Libya and Egypt) capacity is typically the largest

[6] In a few cases a project (e.g. a transmission line) has been completed but is not yet in use. Such projects have been labelled as under construction and the expected year of actual use has been utilised.

challenge, while countries dominated by hydro generation (such as the DRC and Ethiopia), typically have an excess of capacity, but may have restrictions on an energy basis because the generation from hydro plants is limited by the inflow.

Estimation of capacity credit

In the absence of specific data, default assumptions are utilised for capacity credit (generation during peak demand) and maximum full-load-hours. The values utilised in the study are displayed in Table 1. E.g. solar PV is assumed not to generate during peak demand, as most countries have an evening peak.

	Energy balance: Max full-load-hours (%)	Capacity balance: Capacity credit (generation during peak demand)
Thermal	7,000 hours (80%)	100%
Nuclear[7]	7,800 hours (90%)	100%
Geothermal	7,800 hours (90%)	100%
Hydro, reservoir	5,000 hours (57%)	100%
Hydro, run of river	3,500 hours (40%)	50%
Waste	4,400 hours (50%)	50%
Wind[8]	3,000 hours (35%)	5%
Solar	2,000 hours (23%)	0%

Table 2: Assumptions used if no specific information exists.

For hydro plants with reservoir, annual generation has been obtained for all existing plants, and these plants are assumed to generate at 100% during the peak demand hour.

In undertaking the calculations, the capacity of interconnectors is set to the maximum capacity during safe operation – or according to standard practices on that line. Maximum capacity during safe operation is also called net transfer capacity (NTC) and may be significantly lower than the installed capacity. NTC depends on the surrounding system (e.g. strength of grid) and may vary over time.

Demand prognoses

Predicting future electricity demand in countries where demand may double within a 10-year period is challenging, and as a result estimated values are highly uncertain. Data has been collected to form a central prognosis, and to reflect this uncertainty, high and low alternatives have also been established.

[7] See: (World Nuclear Association, 2019)
[8] In Egypt, wind power generation during the peak hour has been studied for the last 8 years. Between 2% and 60% of the installed wind power capacity generated during the peak hour. The median value is 18%. The 20% percentile (that will happen one out of five years) is 5%. More data should be collected in the future.

The current power balance statement focuses on the central electricity demand prognosis. Some countries have generation plans that alter according to the electricity demand prognosis (i.e. with a high electricity demand prognosis, the timetable for completion of some generation units is shifted forward), but this dynamic between demand growth and generation planning has not yet been included in the current power balance as the data required to do so is not yet available for the majority of countries.

Demand figures for countries using fiscal years (July to June), were converted to calendar years (January to December).

Import during peak demand

The power balance situation is analysed both in a situation without import/export, and in situation where it is possible to transmit electricity. When permitted, import/export is assumed to be undertaken if technically possible. From an economic viewpoint, this is a reasonable assumption if the only alternative for the importing country is curtailment of electricity demand, as this has a very high socio-economic cost. The economic value of import in this case is the economic value associated with the avoided loss of load.

Power Balance for EAPP as a whole

The development in total peak demand and generation is illustrated in Figure 2. In 2020, total existing generation is larger than the total peak demand, however in just a few years the balance depends on the realisation of new generation. These initial results will be further analysed in the next chapters, taking the specific national situations and transmission capacity availability into account.

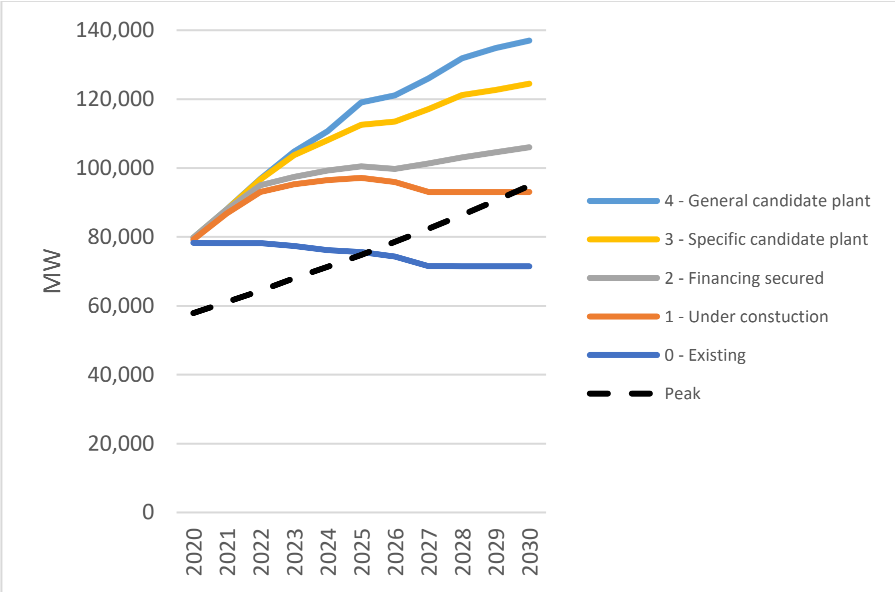


Figure 4: Projected development of total peak demand (MW) for the ten countries (black dashed line) and expected development in total generation capacity (MW) for the ten countries. The capacity is the expected capacity during the peak hour. The capacity factors utilised are displayed in Table 2.

3 Power balance – without contribution from import

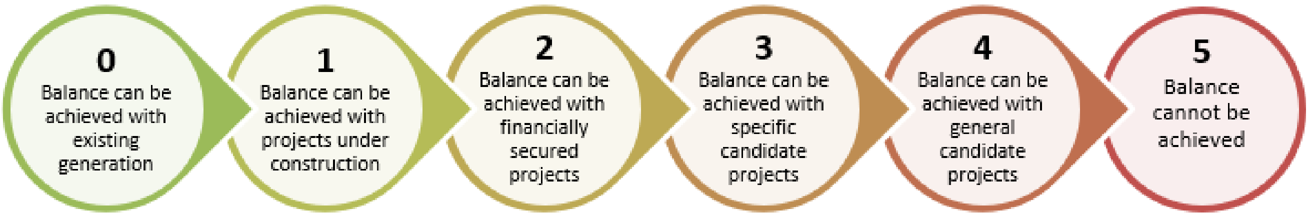
In preparing the power balance statement the primary inputs are detailed information about future electricity demand and generation capacity for each country. This chapter provides analysis of the power balance without electricity imports, while the following chapter includes the option to exchange electricity.

An indicator of the power balance per country is shown in Table 3 utilising a scale from 0-5 as described below. Note that the DRC consists of three different synchronous areas (plus a number of smaller isolated islands) and is represented via three regions: West, South and East.[9]

Indicator values

The numbers in the table (0-5) reflect the following:

0. Balance can be achieved with existing generation
1. Balance can be achieved when also including projects where construction has started
2. Balance can be achieved when adding projects where financing has been secured, and construction is expected to start in a specific year
3. Balance can be achieved when also including specific candidate projects, where location and design are determined
4. Balance can be achieved when adding general candidate projects
5. Balance cannot be achieved.



The *Ideal reference* shown in the grey column furthest to the right in Table 3 should be understood as a simple, normative indication of a secure development, with a slow increase in the indicator value. I.e. in the first couple years it is sensible that only existing generation shall be assumed to cover electricity demand, while as we proceed further into the future it is reasonable to start including projects that are under construction (with a buffer to allow for

[9] 52% of total DRC demand is in West, 35% in South, 6% in East and 7% in other areas (2019). Currently Libya is also operated with an Eastern and a Western system that is not synchronous. However, this is expected to normalise again, and Libya is analysed as one area.

testing, etc), followed by projects that have secured financing and construction is scheduled to start, and finally specific and general potential projects. Results in the table are highlighted when their indicator value is worse than this *ideal reference*.

MW	Burundi	DRC			Egypt	Ethiopia	Kenya	Libya	Rwanda	Sudan	Tanzania	Uganda	Ideal reference
		E	W	S									
2021	0	5	0	5	0	1	0	1	1	2	1	0	0
2022	1	3	5	5	0	1	1	1	1	2	1	0	0
2023	1	3	5	5	0	1	3	1	1	2	1	0	1
2024	1	3	2	5	0	1	3	1	1	2	1	0	1
2025	1	3	2	5	0	1	3	1	2	2	1	0	2
2026	1	3	2	5	0	1	3	1	2	2	1	0	2
2027	1	3	2	4	0	1	3	3	2	3	1	0	3
2028	1	3	2	4	0	1	3	3	3	3	3	1	3
2029	1	3	2	4	0	1	3	3	3	3	3	1	3
2030	1	3	2	4	0	1	3	3	3	4	3	1	4

GWh	Burundi	DRC			Egypt	Ethiopia	Kenya	Libya	Rwanda	Sudan	Tanzania	Uganda	Ideal reference
		E	W	S									
2021	0	5	5	5	0	5	0	0	1	1	1	0	0
2022	0	3	5	5	0	2	0	0	1	1	1	0	0
2023	1	3	5	5	0	1	1	1	1	1	1	0	1
2024	1	3	5	5	0	1	3	1	1	1	1	0	1
2025	1	3	2	5	0	1	3	1	1	1	1	0	2
2026	1	3	2	5	0	1	3	1	2	2	1	0	2
2027	1	3	2	5	0	1	3	1	2	2	1	0	3
2028	1	3	2	5	0	2	3	1	2	2	3	1	3
2029	1	3	2	5	0	2	3	1	3	2	3	1	3
2030	1	3	2	5	0	3	3	1	3	2	3	1	4

Table 3: National power balance without import/export. Upper table: Capacity balance during peak demand (MW), Lower table: Yearly energy balance (GWh). Cells are highlighted when the indicator is worse than the ideal reference.

In the short term (2021-2022), Egypt and Uganda have a sufficient power balance, that is to say that balances (both in MW and GWh) can be achieved with existing generation (0). Other countries, such as Burundi, Ethiopia, Kenya, Libya, Rwanda, and Tanzania, will depend on the timely completion of projects under construction (1), while Sudan will may have to also rely on projects where finance has been secured, but where construction has not yet started (2). Finally, the DRC is not expected to have adequate generation capacity to meet peak demand for the first two years (5). As a result, if imports are not available in a tight situation it may be necessary to curtail electricity demand.

In the medium term (2023-2026), and in the absence of import possibilities, the DRC will continue to face challenges, while Kenya will likely have to rely on specific candidate projects coming online as planned.

In the longer term (2027-2030), most countries have a good balance, i.e. they are more or less in line with the ideal reference, which now includes specific candidate projects starting from 2027 (and general projects in the final year). During these years it is forecasted that only DRC-South will have challenges where balance cannot be achieved without imports.

4 Power balance – with imports

With existing transmission capacities (as outlined in Table 3), the EAPP will be divided into six "islands" (countries with connections) in January 2020:

- The DRC (West and South)
- Burundi, Rwanda, DRC (East)
- Egypt, Libya
- Kenya, Uganda
- Ethiopia, Sudan, Djibouti
- Tanzania

DRC West and DRC South are two synchronous systems connected with a DC line. The other five islands are each a synchronous system, thus giving seven synchronous systems in total.

Figure 5: The six EAPP islands in 2020. Only existing lines are included. Note that the DRC should be divided into both West and South, as well as East.

Table 4 displays a 2020 situation relying solely on existing lines. This results in the 6 'islands' as depicted in Figure 5.

MW		Bu-rundi	DRC E	DRC W	DRC S	Egypt	Ethio-pia	Kenya	Libya	Rwand a	Sudan	Tanza-nia	Uganda
Burundi			4							0		0	
DRC	E	4		0	0					4		0	0
DRC	W		0		480								
DRC	S		0	480									
Egypt									240		80		
Ethiopia								0			200		
Kenya							0					0	70
Libya						240					0		
Rwanda		0	4									0	0
Sudan						80	200		0				
Tanzania		0	0					0		0			0
Uganda			0					70		5		0	

Table 4: Assumed transmission capacities (MW) in 2020 - existing lines. White cells indicate neighbouring countries.

However, when all transmission projects currently under construction are taken into account, then all EAPP countries would be connected by 2025 (either via AC or DC links). Tanzania will join in 2021 and the DRC in 2025.

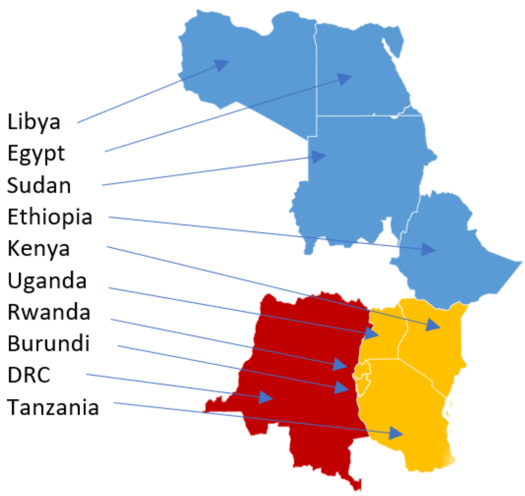


Figure 6: Expected synchronous areas in 2025. Note that the DRC should be divided into three synchronous areas: West, South and East. DRC East will be synchronous with the yellow area.

Dependent on the specific technology decisions undertaken, the EAPP will in 2025 then have 4 synchronous areas:

- Libya, Egypt, Sudan, Ethiopia, Djibouti
- Kenya, Tanzania, Uganda, Burundi, Rwanda, DRC/East
- DRC/East
- DRC/South

The assumed transmission capacities between countries in 2025 is displayed in Table 5 (this includes existing lines and those under construction).

MW	Burundi	DRC E	DRC W	DRC S	Egypt	Ethiopia	Kenya	Libya	Rwanda	Sudan	Tanzania	Uganda
Burundi		4							27		0	
DRC E	4		0	0					104		0	0
DRC W		0		480								
DRC S		0	480									
Egypt								240		300		
Ethiopia							1,100			200		
Kenya						1,100					500	370
Libya					240					0		
Rwanda	27	104									0	347
Sudan					300	200		0				
Tanzania	0	0					500		0			70
Uganda		0					370		347		70	

Table 5: Assumed transmission capacities (MW) in 2025 – existing lines and lines under construction. White cells indicate neighbouring countries.

Looking further ahead, Table 6 displays the anticipated transmission capacities in 2030 based on the completion of all potential projects.

MW	Burundi	DRC E	DRC W	DRC S	Egypt	Ethiopia	Kenya	Libya	Rwanda	Sudan	Tanzania	Uganda
Burundi		149	0	0					27		0	
DRC E	149		0	500					200		0	140
DRC W		0		1,480								
DRC S		500	1,480									
Egypt								240		300		
Ethiopia							1,100			1,200		
Kenya						1,100					500	370
Libya					240					0		
Rwanda	27	200									0	347
Sudan					300	1,200		0				
Tanzania	0	0					500		0			279
Uganda		140					370		347		279	

Table 6: Assumed transmission capacities (MW) in 2030 based on all potential projects. White cells indicate neighbouring countries.

Procedure to minimise capacity deficit

A simple procedure has been developed to compute the capacity potential d eficit after maximum use of transmission capacity. The procedure works with any configuration of EAPP wide transmission network (e.g. as indicated in Table 4 to Table 6). The optimisation minimises the total capacity deficit, while respecting the capacity of transmission lines. A country will first cover its own demand, and then all excess capacity (after holding back capacity to cover the reserve margin[10]) will then be offered to other countries in order to reduce any capacity deficit. In practice, this means that generation capacity is first used to cover local demand, secondly to supply neighbours and finally to supply other countries prioritising countries nearby.

EAPP wide results

If only existing generation and transmission are considered (and without the possibility to import electricity from countries outside EAPP), the EAPP wide deficit would increase from 4,000 MW in 2020 to 29,000 MW in 2030. The addition of projects currently under construction will reduce the deficit to 12,000 MW.

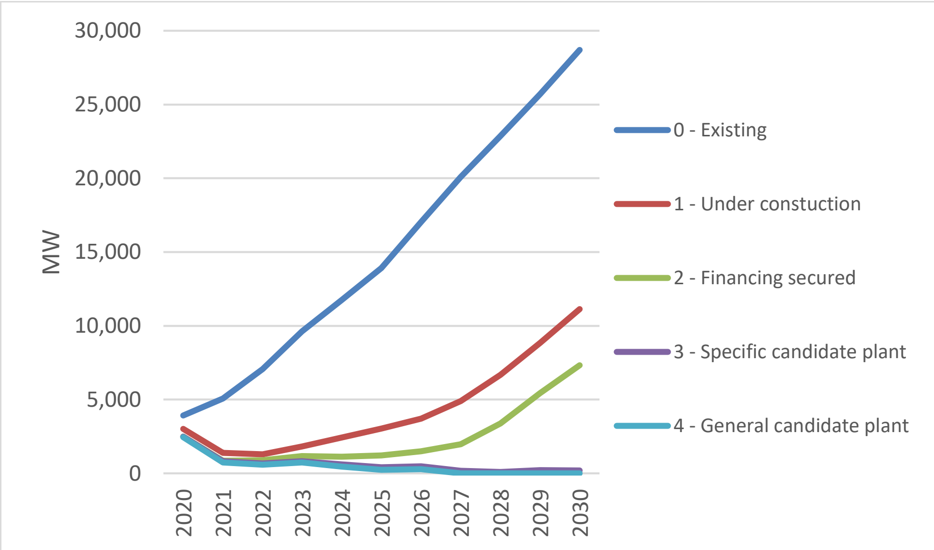


Figure 7: Capacity deficit for all EAPP countries with different assumptions concerning future projects (generation and transmission), in a situation without electricity import/export.

The capacity deficit can in some cases be reduced by electricity imports from neighbouring countries.[11] Referred to here as the 'benefit from import during peak demand', for this benefit to exist several conditions must be fulfilled:

- A capacity deficit must exist.

[10] Transmission lines are not used to fulfil reserve margins. The reserve margin is defined as the total local generation capacity minus local peak demand. This is a simplification, that means that reserves are not delivered by interconnectors. This simplification may be relaxed in future work.
[11] Wheeling of electricity can take place from other countries.

- Another country must have surplus capacity available for export, and a country will only export if the national reserve margin is fulfilled.
- The required transmission capacity must exist between the relevant countries.

The resulting benefits of allowing electricity imports/exports (depicted as a reduction in capacity deficit) are illustrated in Figure 8.

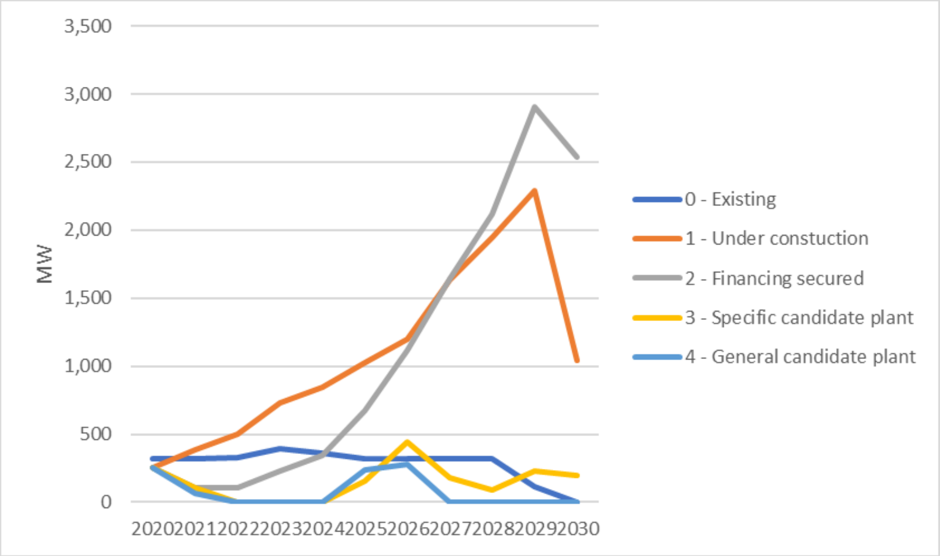


Figure 8: Benefit of import (MW) for all EAPP countries (depicted as a reduction in capacity deficit) given different assumptions concerning future generation and transmission projects.

When only existing generation and transmission projects are considered, then there is no benefit associated with the import/export of electricity after 2025. This is because with growing electricity demand, and no new capacity, there will not be any countries with the required export capacity.

The largest calculated benefits associated with import/export are realised when also including projects that are under construction and where financing is secured. When considering this classification of projects, allowing for imports/exports reduces the capacity deficit by more than 2,500 MW in 2030.

When all planned projects are included, there are no reductions in capacity deficits due to trade (after 2025), because all countries can then supply their own peak demand.

MW	Burundi	DRC			Egypt	Ethiopia	Kenya	Libya	Rwanda	Sudan	Tanzania	Uganda
		East	West	South								
2021												
Only existing (0)												
CD1	0	120	0	852	0	181	0	1,334	36	1,479	1,080	0
CD2	0	120	0	852	0	181	0	1,094	36	1,479	1,080	0
RMD	x	x	x	x		x	x	x	x	x	x	
Under construction (1)												
CD1	0	120	0	732	0	0	0	0	0	544	0	0
CD2	0	13	0	732	0	0	0	0	0	264	0	0
RMD	x	x	x	x			x	x		x		
2025												
Under construction (1)												
CD1	0	134	338	995	0	0	414	0	1	1,149	0	0
CD2	0	27	338	995	0	0	0	0	0	649	0	0
RMD		x	x	x			x		X	x		
Finance secured (2)												
CD1	0	134	0	670	0	0	414	0	0	0	0	0
CD2	0	27	0	517	0	0	0	0	0	0	0	0
RMD		x		x			x			X		
2030												
Under construction (1)												
CD1	0	180	881	1,631	0	0	1,340	3,493	158	2,494	955	0
CD2	0	177	881	1,631	0	0	595	3,493	131	2,494	885	0
RMD		x	x	x			X	x	x	x	x	
Finance secured (2)												
CD1	0	180	0	378	0	0	1,340	3,493	78	904	955	0
CD2	0	149	0	0	0	0	100	3,253	0	404	885	0
RMD		x		x			x	x	x	x	x	
Specific candidate projects (3)												
CD1	0	0	0	72	0	0	0	0	0	124	0	0
CD2	0	0	0	0	0	0	0	0	0	0	0	0
RMD				x				x	x	x		
General candidate projects (4)												
CD1	0	0	0	0	0	0	0	0	0	0	0	0
CD2	0	0	0	0	0	0	0	0	0	0	0	0
RMD				x							x	

Table 7: Power balance. CD1 = Capacity Deficit before import. CD2 = Capacity Deficit after import. RMD = Reserve Margin Deficit ("x" indicates that the 15% reserve margin is not fulfilled). Selected years (2021, 2025, and 2030) and selected project status for generation and transmission (Existing projects (0), Under construction (1), Finance secured (2), and Specific candidate projects (3) and General candidate projects (4))

Detailed country specific results

Table 7 displays the power balance for selected combinations of years and project status. The capacity deficit is illustrated both in a situation with and without electricity import/export. It is important to note that export only takes place from a country with a reserve margin exceeding 15%.[12]

2021

For 2021, the following observations can be made:

- If only considering existing projects, then the DRC, Ethiopia, Libya, Rwanda, Sudan and Tanzania may all have security of supply issues, with the size of this varying from roughly 36 MW in Rwanda to nearly 1.5 GW in Sudan.
    - Electricity import from Egypt can reduce deficits in Libya, but far from solve the problem entirely.
    - For the other countries with supply issues, imports cannot be assumed available to assist the situation, because there is no surplus capacity in the neighbouring countries (when a 15% domestic reserve margin is required in all countries).
    - Only Egypt and Uganda have a reserve margin above 15%.

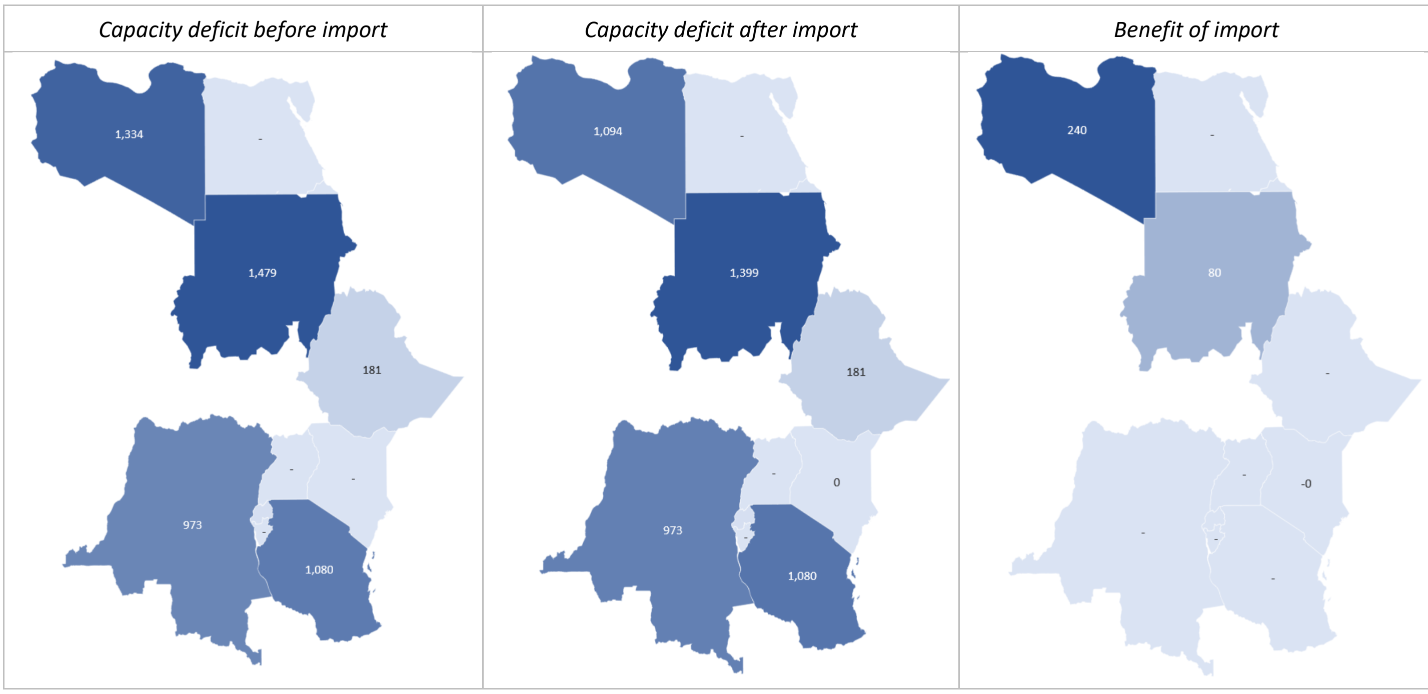


Figure 9: Capacity deficit and benefit of import. 2021, only existing projects (MW). Values for DRC has been summed across the three regions.

[12] Note that this is a capacity balance where national peak demand has been considered, but the seasonal timing of the peak has not been considered. The seasonal variation of the peak demand will be studied in next year's power balance statement.

- When including projects that are currently under construction (but expected to be completed by 2021), and the ability to import/export, all countries are fine, except the DRC and Sudan.
    - Via electricity imports, Sudan's capacity deficit is more than halved.
    - Projects under construction may be delayed, and this can therefore threaten the security of supply in Ethiopia, Libya, Rwanda, and Tanzania as well.
    - Burundi, The DRC, Kenya, Libya and Sudan have reserve margins below 15%.

2025

For 2025, the following observations can be highlighted:

- If only projects that are currently under construction are considered, the DRC, Kenya, Rwanda and Sudan have capacity deficits in the absence of imports.
    - For Kenya and Rwanda this deficit can be resolved by relying on electricity imports during peak demand. This is possible as there is both generation capacity in neighbouring countries, and sufficient transmission capacity to these countries.
    - Sudan can reduce it's deficit by 500 MW (corresponding to a nearly 45% reduction) by import

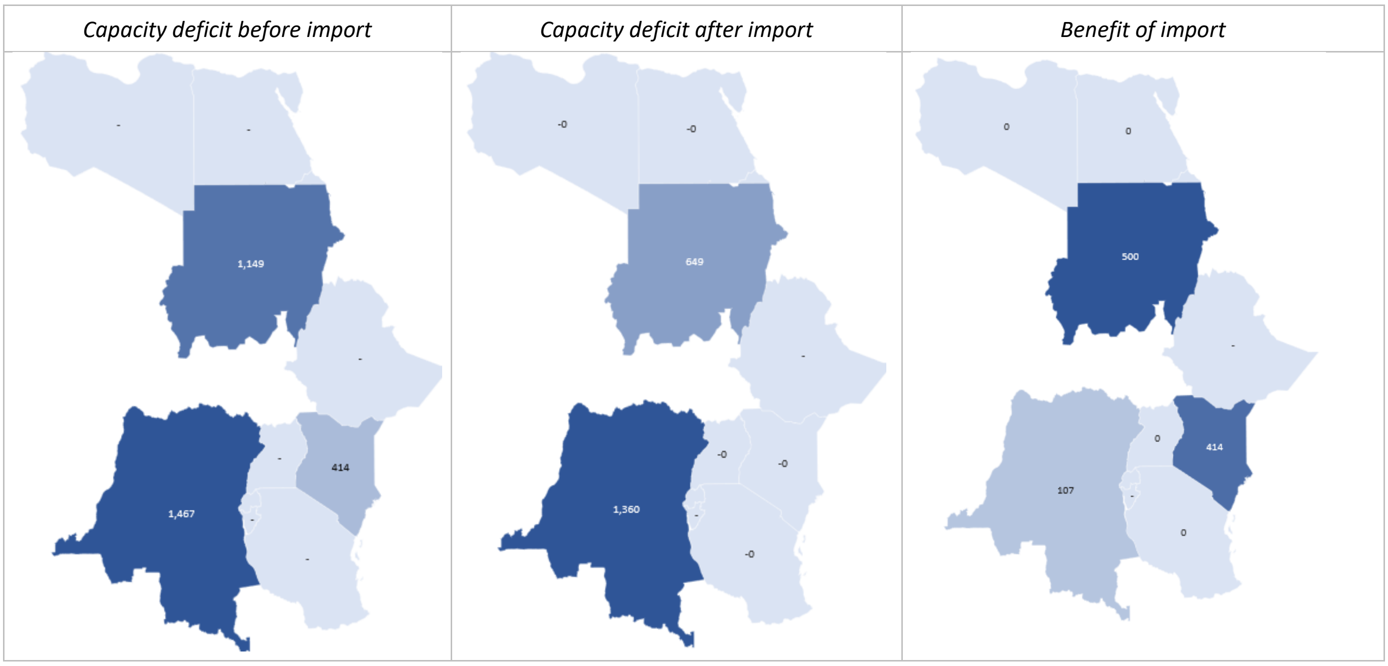


Figure 10: Capacity deficit and benefit of imports in 2025 when including projects under construction (MW). Values for DRC has been summed across the three regions.

- When also including projects that have secured financing the situation improves. However, even with potential import, the DRC and Kenya still has a capacity deficit.
    - The DRC, Kenya, Rwanda and Sudan have a reserve margin below 15%.

2030

For 2030, the following findings can be highlighted:

- When existing projects as well as both those under construction and with finance secured are considered:
    - Libya has a very large deficit of nearly 3.5 GW.
    - The DRC, Kenya, Rwanda, Sudan and Tanzania all have deficits as well
    - A number of countries benefit from imports, for example Sudan (500 MW reduction), Rwanda's is reduced to 0 (from 78 MW), the DRC's is greatly reduced (from 558 MW to 150), while Libya and Tanzania also see slight reduction. However, Kenya in particular benefits from electricity import, as its deficit is reduced to 18% of what it would otherwise have been (from 1,497 to 257 MW)
    - Only Burundi, Egypt, Ethiopia and Uganda have a reserve margin above 15%.

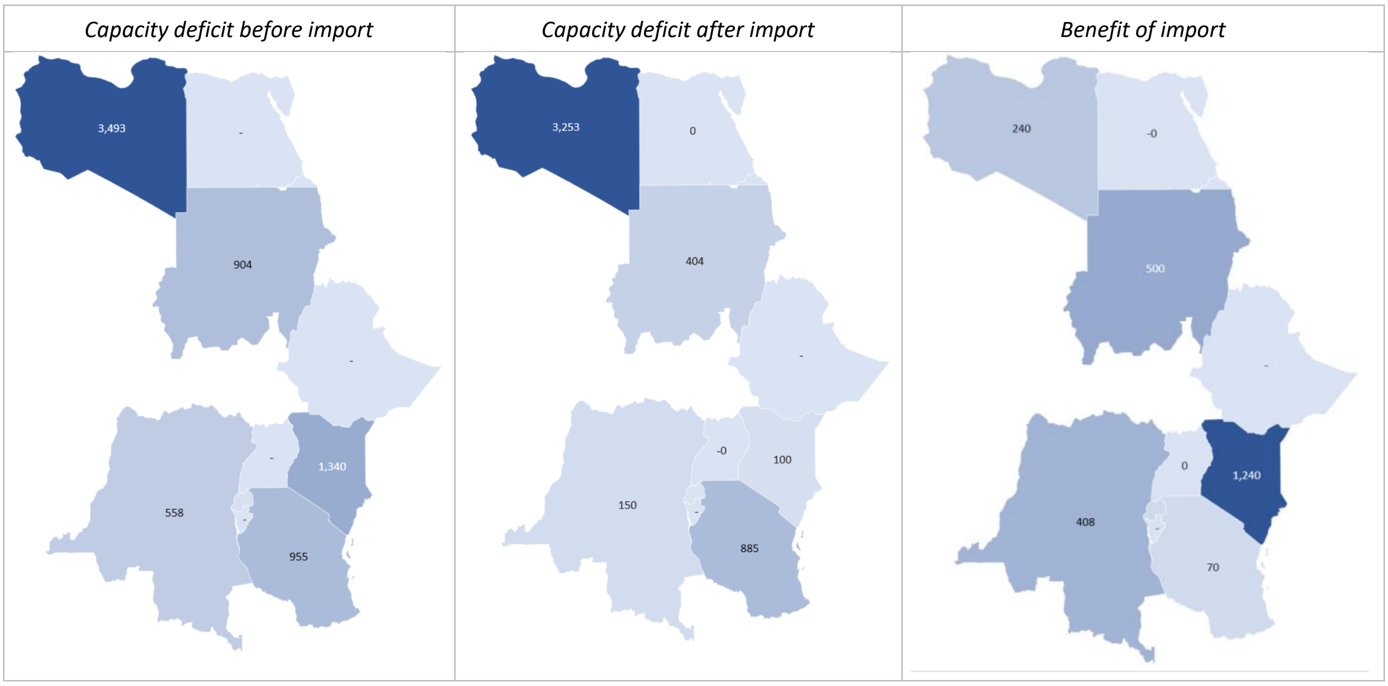


Figure 11. Capacity deficit and benefit of imports in 2030 when including projects with finance secured (MW). Values for the DRC have been summed across the three regions.

- Assuming all specific candidate projects come to fruition, all countries are in good shape. All countries have a positive capacity balance – even without import.

Key message

The above analysis highlights the reliance on projects that have not yet commenced construction in order to minimise potential security of supply issues. Given that projects often incur delays for one reason or the other, it is recommended to:

1. Accelerate the process of moving projects from one project stage to the next, i.e. from specific candidate to financing secured
2. Focus on completing each project phase on schedule
3. Start the planning process as early as possible.

5 Comparison with 2019 PBS

Power Balance for EAPP as a whole

In comparing the 2020 PBS with the 2019 version, the figure below highlights the fact that input data for estimated peak demand has not changed much, but there have been adjustments to both existing generation capacity (which is slightly higher), and the totals as the other 3 categories of future generation capacity are added (which are all lower).

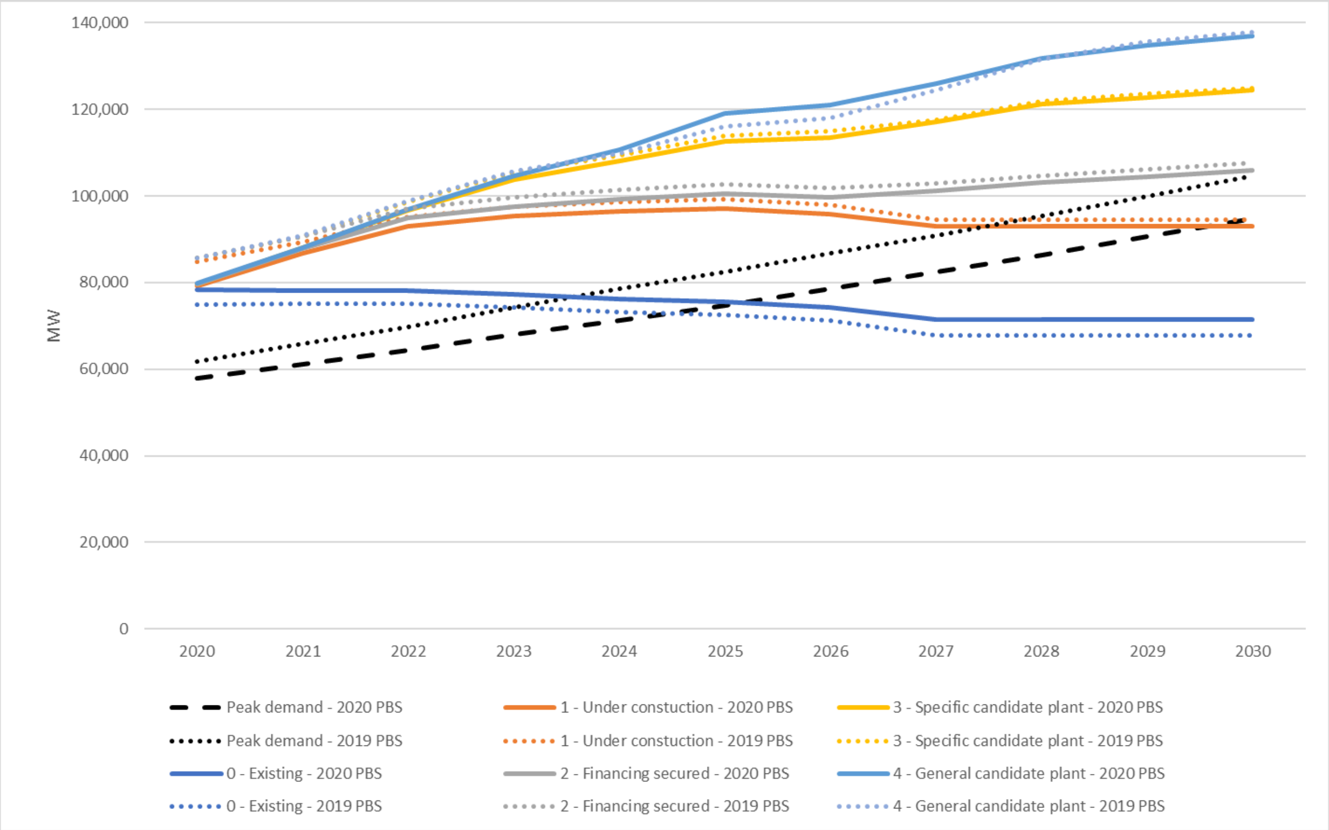


Figure 12: Projected development of total peak demand (MW) for the ten countries (black lines) and expected development in total generation capacity (MW) for the ten countries based on the 2019 and 2020 Power Balance Statements (PBS).

Individual country power balance without import

Table 8 below compares the individual power balances without import, and displays values from the previous PBS in brackets where they have changed since last year. For countries whose power balance is improved, such as Burundi, Egypt, Kenya, Rwanda, and Uganda, this is indicated by a green shading. Meanwhile, countries with a lower power balance, such as the southern portion of the DRC and Tanzania, this is indicated by a deep red shading. Note that the ideal reference values (far right column) were also updated.

MW	Burundi	DRC			Egypt	Ethiopia	Kenya	Libya	Rwanda	Sudan	Tanzania	Uganda	Ideal reference
		E	W	S									
2021	0	5	0	5	0	1	0	1	1	2	1	0	0
2022	1	3	5	5	0	1	1	1	1	2	1	0	**0 (1)**
2023	1	3	5	5	0	1	3 (1)	1	1	2	1	0	1
2024	1	3	2	5	0	1	3	1	1 (2)	2	1	0	**1 (2)**
2025	1	3	2	5	0	1	3	1	2	2	1	0	2
2026	1	3	2	5	0	1	3	1	2 (3)	2	1	0 (1)	**2 (3)**
2027	1	3	2	4	0 (1)	1	3	3	2 (3)	3	1	0 (1)	3
2028	1	3	2	4	0 (1)	1	3	3	3	3	3 (1)	1	3
2029	1	3	2	4	0 (2)	1	3	3	3 (5)	3	3 (1)	1	3
2030	1	3	2	4	0 (2)	1	3	3	3 (4)	4	3 (1)	1	4

GWh	Burundi	DRC			Egypt	Ethiopia	Kenya	Libya	Rwanda	Sudan	Tanzania	Uganda	Ideal reference
		E	W	S									
2021	0 (5)	5	5	5	0	5(1)	0 (1)	0	1	1	1	0	0
2022	0 (1)	3	5	5	0	2(1)	0 (1)	0	1	1	1	0	**0 (1)**
2023	1	3	5	5	0	1	1 (2)	1	1	1	1	0	1
2024	1	3	5 (2)	5 (4)	0	1	3	1	1	1	1	0	**1 (2)**
2025	1	3	2	5 (4)	0	1	3	1	1	1	1	0	2
2026	1	3	2	5	0	1	3	1	2	2	1	0	**2 (3)**
2027	1	3	2	5	0	1	3	1	2	2	1	0	3
2028	1	3	2	5 (4)	0	2	3	1	2	2	3 (1)	1	3
2029	1	3	2	5 (4)	0	2	3	1	3	2	3 (1)	1	3
2030	1	3	2	5 (4)	0 (1)	3	3	1	3	2	3 (1)	1	4

Table 8: National power balance without import/export. Upper table: Capacity balance during peak demand (MW), Lower table: Yearly energy balance (GWh). Cells are highlighted when the indicator is worse than the ideal reference. Values in brackets are those from last year's PBS if they have changed. Green shading indicates a positive development in the power balance, while the deep red indicates a deterioration relative to last year.

6 Improving future power balance statements

The primary observation gleaned from developing the first two EAPP power balance statements is that much of the data related to the future is uncertain, and that the highest possible effort should be made to achieve accurate and updated information. This includes both demand prognoses and information (e.g. status and start year) about new generation and transmission projects.

Data

A number of improvements could be made related to data. Useful data that would improve the quality of the analysis would for example include:

- The Net Transfer Capacity (NTC) has been evaluated by use of an EAPP wide PSS/E model. The results have not been used in this version of the Power Balance Statement. Next year the computed NTC should be used.
- Hourly electricity demand profiles for all countries. This would allow for a study of the timing of the peak demand hour across countries. Currently, the working assumption is that most countries currently have a night peak, though with some seasonality. More detailed information about the differences in the timing of peak demand can be useful when assisting neighbouring countries during peak demand. This grows in relevance as the countries become increasingly interconnected.
- Individual reserve margins per country. Within this analysis, a standard rate of 15% is used for all countries. A starting point could be to define the critical incidence per country and for each synchronous zone (N-1). This can be the largest single error, e.g. the loss of the largest generation unit or transmission line. In addition, historical statistics about planned and unplanned outages could be helpful in defining appropriate reserve margins. Reducing reserve margins could pave the way for increased export during critical hours.

Method

Potential improvements to the methodology used for preparing the power balance statement could also include:

- Adding dry hydro year considerations. For countries largely reliant on hydro, production can vary greatly from year to year due to variations in precipitation. Based on historical inflow data a standardised dry year could be defined. Section 0 provides an example of how much hydro production can vary by looking at Ethiopia as an example.
- Preparing a monthly power balance to reflect the limited energy that can be generated from hydro plants. This would require more data, but would provide a more realistic picture of the power balance challenges in countries with considerable power supply from hydro.

    - In the current analyses the power balance without contribution from import is done in both energy (GWh) and capacity (MW) (chapter 3). However, the EAPP wide analysis is only performed based on capacity (MW) (chapter 4).
- Develop a simple method to include the potential for import from non-EAPP countries during peak demand.
- Improve the methodology so that reserve margins requirements can also be (partly) be fulfilled by interconnectors.

Within the current work, other power balance statements have been studied, e.g. (ENTSO-E, 2018b), (Wright, 2018) and (Ea Energy Analyses, 2016). In the long-term, stochasticity should be included in the analyses. The method used by ENTSO-E could act as inspiration regarding implementation of stochastic methods (EAPP, 2019, b).

Importance of dry years, Ethiopia as a case study

The electricity generation mix in Ethiopia is dominated by hydro, and therefore annual electricity production is susceptible to changes in precipitation from one year to the next. The figure below provides an overview of the total hydro inflow (in millions of cubic meters) into the Ethiopian system from 1961 to 1997.

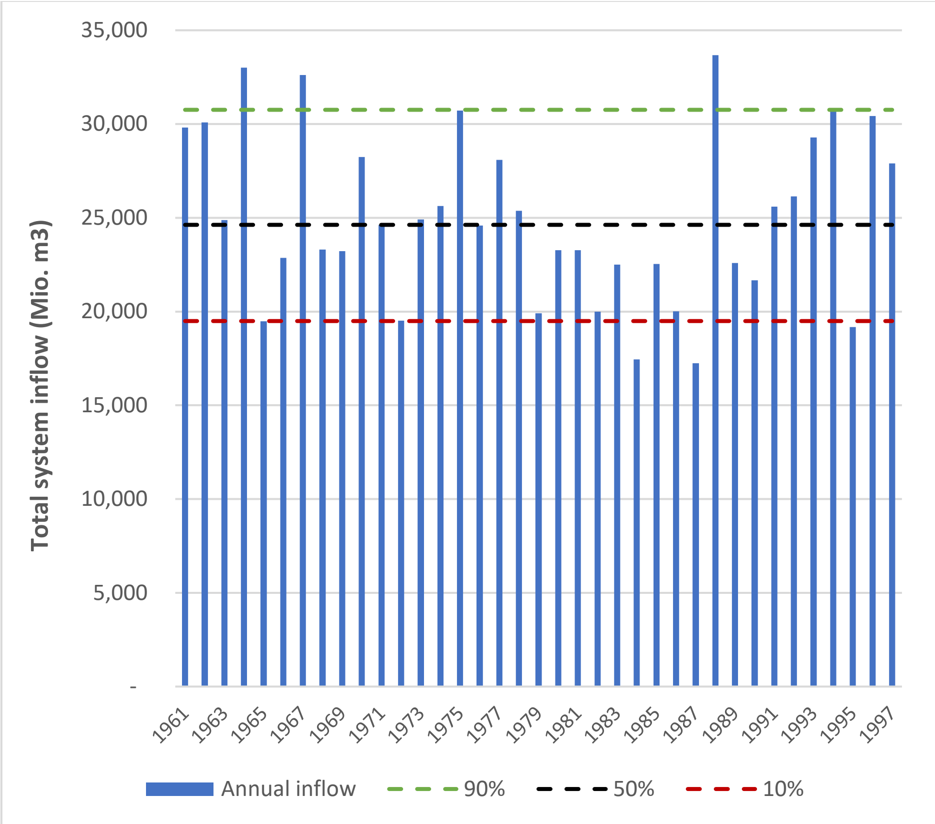


Figure 13: Total hydro inflow in Ethiopia from 1961 to 1997.

Over this almost 40-year period, the highest inflow was nearly 34 billion m^3, the lowest was nearly half of this, slightly more than 17 billion m^3, and the average was 25 billion m^3. The figure also displays values for the 90th, 50th, and 10th percentiles (green, black and red dotted lines respectively). The 10th percentiles represent the dry year that can be expected in one out of ten years.

The calculations presented in this report are all based on a ‘normal’ hydro year, which in the Ethiopian example above, would correspond roughly to the black dotted line. However as illustrated by the red dotted line, it is quite likely that over a 10 year-period there will be a year that witnesses inflow that is more than 25% lower than this ‘normal’ year. Recalling Table 3, which displayed the National annual energy balances without import/export, the table below revisits the figures for Ethiopia given hydro production values for a ‘normal’ year, and a dry year that could be expected roughly once every 10 years. Here it is assumed that this results in roughly 25% less power generation from hydro.

GWh	Ethiopia normal	Ethiopia “10%”	Ideal reference
2021	5	5	0
2022	2	2	0
2023	1	2	1
2024	1	1	1
2025	1	2	2
2026	1	2	2
2027	1	3	3
2028	2	3	3
2029	2	3	3
2030	3	3	4

Table 9: National annual energy balance without import/export for Ethiopia given a normal year, and a year with 25% less hydro production (GWh). Cells are highlighted when the indicator is worse than the ideal reference.

As can be seen from the table, in a situation without import, Ethiopia could risk facing serious security of supply issues if a dry year occurred in 2021 and other plants could not increase their generation significantly. If this instead occurred in 2022 or 2023, then Ethiopia would be more reliant on projects that have currently only secured financing to be complete.

This simple example illustrates the relevance of including ‘dry’ year simulations in future power balance statements.

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Appendix 1: EAPP Planning committee

Members per October 2020.

Substantive	
Eng. Alex Gerald	TANESCO – Tanzania
Eng. Harrison Sungu	KETRACO – Kenya
Eng. Erastus Kiruja	KPLC – Kenya
Eng. Rachel Arinda Baalessanvu	UETCL – Uganda
Eng. Haroun Mohamed Serebil Khalil	SETCO – Sudan
Eng. Adil Ali Ibrahim	MWRE – Sudan
Eng. Ermias Bekele	EEP - Ethiopia
Mr. Nestor Nitunga	REGIDESO – Burundi
Eng. Claver GAKWAVU	EUCL – Rwanda
Eng. Hiba Zayed	EEHC – Egypt
Eng. Mohamed Abdulaziz Mohamed Alashhab	GAEREL – Libya
Eng. Elvis Babala Felo	SNEL – DR Congo
Mr. Jonson Njeru	KENGEN – Kenya
Alternate	
Eng. Antony Mushyoka	KETRACO – Kenya
Eng. Amos Nabaala	KPLC – Kenya
Ms. Diana Nakabugo	UETCL – Uganda
Eng. Wondwosen Teshome	EEP – Ethiopia
Mr. ARAKZA Audifax	REGIDESO – Burundi
Eng. Ronald NTARE	EUCL – Rwanda
Eng. Rania Mohamed Raafat	EEHC – Egypt
Eng. Saleh Omar Ramadhan Osman	GAEREL – Libya
Mr Mudiampimpa Bienko	SNEL – DR Congo
Eng. Beatrice Musyoka	KENGEN – Kenya

Appendix 2: Capacities in the Power System Analysis report

The Net Transfer Capacity has been evaluated by use of an EAPP wide PSS/E model. The transfer capacity evaluation was performed in two steps:

- Static analysis: to identify the Total Transfer Capacity, TTC, for under normal and N-1 operation
- Dynamic analysis: to check if the system can withstand a fault applied to the interconnection and keep operating in a stable way

With that analysis, the TTC's were obtained. After that, using the Transmission Reliability Margin, TRM, calculated in the Frequency Stability Analysis, one can derive the Net Transfer Capacity, NTC, of each interconnection.

The results are indicative values for the specific scenarios evaluated. In cases in which the TRM is higher than the TTC, there is no valid NTC and the result is presented as "Not applicable" (N/A). Usually, these are cases in which the internal network violates a loading or voltage criteria and constrains the TTC.

For more details, see the Power System Analysis report (task 4).

Note that the vales for Rwanda, Burundi and DRC East (indicated by a * in the two tables below) can't be directly compared because the shared power plants of these countries in the Power Balance Statement have been divided and artificial located at each country.

The computed capacities have not been applied in the years Power Balance Statement. However, should be used as a starting point for next year's statement.

From/To	BDI*	DRC/E*	EGY	ETH	KEN	LBY	RWA*	SDN	TZA	UGA
BDI *	-	9 (4)	-	-	-	-	62 (0)	-	-	-
DRC/E *	16 (4)	-	-	-	-	-	90 (4)	-	-	-
EGY	-	-	-	-	-	140 (240)	-	236 (80)	-	-
ETH	-	-	-	-	170 (0)	-	-	193 (200)	-	-
KEN	-	-	-	N/A (0)	-	-	-	-	-	N/A (70)
LBY	-	-	N/A (240)	-	-	-	-	-	-	-
RWA *	70 (0)	30 (4)	-	-	-	-	-	-	-	66 (5)
SDN	-	-	N/A (80)	263 (200)	-	-	-	-	-	-
TZA	-	-	-	-	-	-	-	-	-	-
UGA	-	-	-	-	80	-	80	-	-	-

Table 10: NTC's 2020. In parenthesis the capacity used in this Power Balance Statement.

From/To	BDI*	DRC/E*	EGY	ETH	KEN	LBY	RWA*	SDN	TZA	UGA
BDI *	-	11 (53)	-	-	-	-	25 (27)	-	6 (0)	-
DRC/E *	31 (53)	-	-	-	-	-	48 (104)	-	-	N/A (140)
EGY	-	-	-	-	-	140 (240)	-	330 (80)	-	-
ETH	-	-	-	-	1,250 (1,200)	-	-	516 (1,200)	-	-
KEN	-	-	-	N/A (1,200)	-	-	-	-	450 (550)	81 (370)
LBY	-	-	465 (240)	-	-	-	-	-	-	-
RWA *	28 (27)	17 (104)	-	-	-	-	-	-	0 (0)	22 (357)
SDN	-	-	N/A (240)	148 (1,200)	-	-	-	-	-	-
TZA	48	-	-	-	313 (500)	-	-	-	-	13 (279)
UGA	-	125 (140)	-	-	280 (300)	-	77 (347)	-	39 (279)	-

Table 11: NTC's 2025. In parenthesis the capacity used in this Power Balance Statement.