New Just: Paths to Affordable Energy Transition in Eastern and Southern Africa

Analytical report

kept

March 2024

Foreword

Dear Sir or Madam,

We are very pleased on behalf of Kept to present the results of our study on the energy sector in Eastern and Southern Africa.

According to expert estimates, up to 25% of the world's population will live in Africa by 2060, while the vast majority of countries in Africa are already facing significant electricity, environmental and climate challenges. These include existing energy poverty, low levels of electrification, leading to low income and critical dependence on wood and charcoal, resulting to widespread forest destruction and environmental degradation in the region. The development of the electricity sector can solve a wide range of problems on the African continent, while also contributing to the achievement of the United Nations Sustainable Development Goals.

As part of our study, we examined the opportunities and consequences of various approaches to building power systems in Africa both on the basis of an inclusive energy mix – fossil fuel, nuclear and renewable energy generation – and exclusively on the basis of renewable energy sources. Kept experts analyzed the availability of energy resources and technologies, as well as their possible role in the development of the energy sector of the countries under consideration. Our professionals assessed changes in the electricity consumption, energy poverty, carbon footprint depending on the forecasted energy mix until 2060, and developed a number of proposals to improve energy planning processes and adjust related financing and ESG policies.

We invite everyone to read this study, which, together with other international studies on the African region, should further stimulate reflection and debate on the continent's future development. The African energy sector's investment potential is substantial and expected to increase significantly in the coming decades due to the industry's intensive development. We hope that this report's conclusions will will be usuful for negotiations between regulators and businesses, both domestically and internationally.

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> It always seems impossible until it's done.
>
> **Nelson Mandela**

Contents

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Executive summary

Objectives of the study

To assess the feasibility of full electrification for the Eastern and Southern Africa (ESA) region under different energy and climate policy scenarios at the national and regional levels

Regional coverage

Eastern and Southern African power markets, including sample analysis of electricity consumption, generation and costs in 21 countries for three time steps: 2020, 2040 and 2060

1

Plan to scale

The ESA region is the largest untapped electricity market in the world. To reach the GDP level of middle-income countries by 2060, electricity generation has to increase nine times to 5,200 TWh – the size comparable to five power systems of Russia. By 2060, ten large energy markets in the ESA region could emerge, incl. Republic of Congo, Egypt and Ethiopia, together comparable in size to the German power system with generation of 600 TWh per year, and the other seven comparable to the UK power system with generation of 300 TWh.

2

Fossil transition

This scale of transition is only achievable if an inclusive energy mix is utilized. We estimate that around 60% of electricity will need to come from gas and coal, with the remainder coming almost equally from nuclear and renewables. Thus, the African energy market offers significant potential for international cooperation for both fossil and nuclear energy, as well as renewable energy technology suppliers.

3

The role of energy sources

Significant upscale of gas (about 320 GW of new capacities), coal (about 245 GW of new capacities) and mislading is required to make the transition happen. Nuclear power will play a crucial role in stabilizing the gas balance and utilizing fossil resources. Continental countries with low-capacity power systems and weak connections may benefit greatly from nuclear and emerging SMR technologies. Although renewable energy sources (RES) can generate up to 1,100 TWh, which is one-fifth of the energy mix, achieving 100% RES in the region's energy mix is technically and economically unfeasible.

4

Climate and social impacts

Access to electricity and clean cooking remains a key social and environmental issue, with only 48% and 23% of ESA residents, respectively, having access and relying heavily on traditional biomass. Even assuming a 60% fossil electricity share, the real change in emissions compared to business-as-usual in ESA will be negligible. Electrification helps reduce the use of traditional biomass, thereby stopping deforestation and preserving the environment. It is proposed to revise the current ESG policies of international development institutions to provide funding for new fossil generation projects in countries with electricity consumption of less than 1,000 kWh/a per capita, including coal, as they are de facto climate neutral.

5

Affordability

The cost of electrification is significant. To make electricity affordable, it is essential to minimize the cost impact on GDP by developing local supply chains for technology, workforce, financing, and fuel. We estimate the system LCOE for ESA to be USD105–114/MWh, but regional competitiveness varies. We estimate the real cost to GDP to be as low as USD 24–64/MWh, i.e. 2–5 times lower than the System LCOE, if local supply chains are properly managed. Therefore, suppliers of technologies where a high share of localization is possible should be prioritized in the planning phase due to their impact on the socio-economic development of the region.

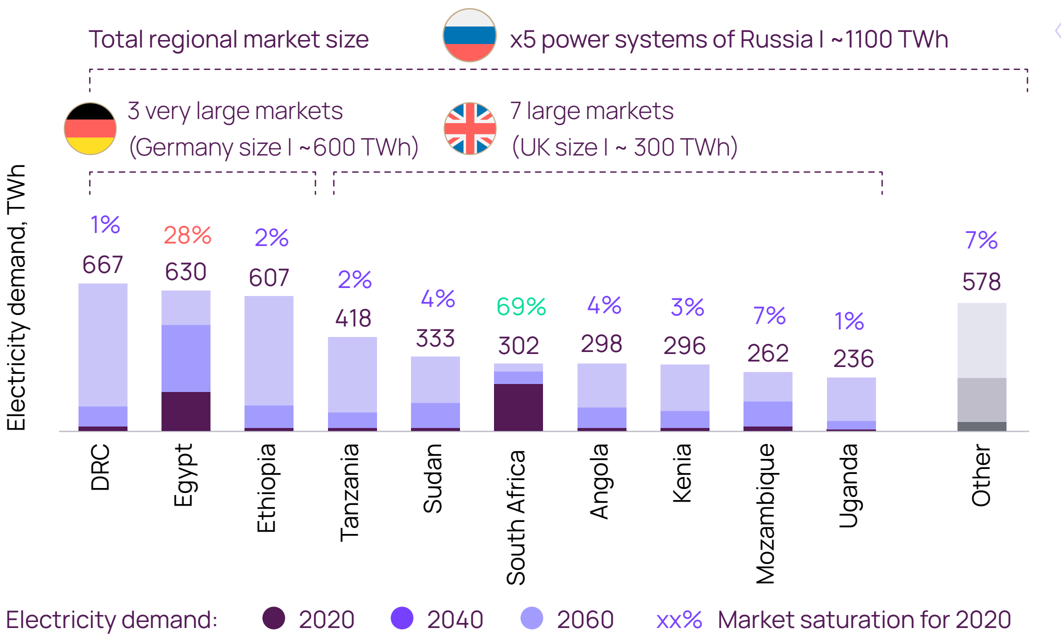
6

Manageability

The transition to modern energy sources is a challenging but manageable task. International cooperation is necessary to achieve this goal. We propose the concept of 'Five Just's' to ensure just energy planning, technology access, ESG and financing policies, as well as equal rights to have a voice in the parties' negotiations.

In this report, we present the results of the research conducted by the Power Analytics team of Kept in August 2023 – March 2024, based on public statistics and other industry information available at the time the report was prepared.

Electricity consumption outlook to 2060



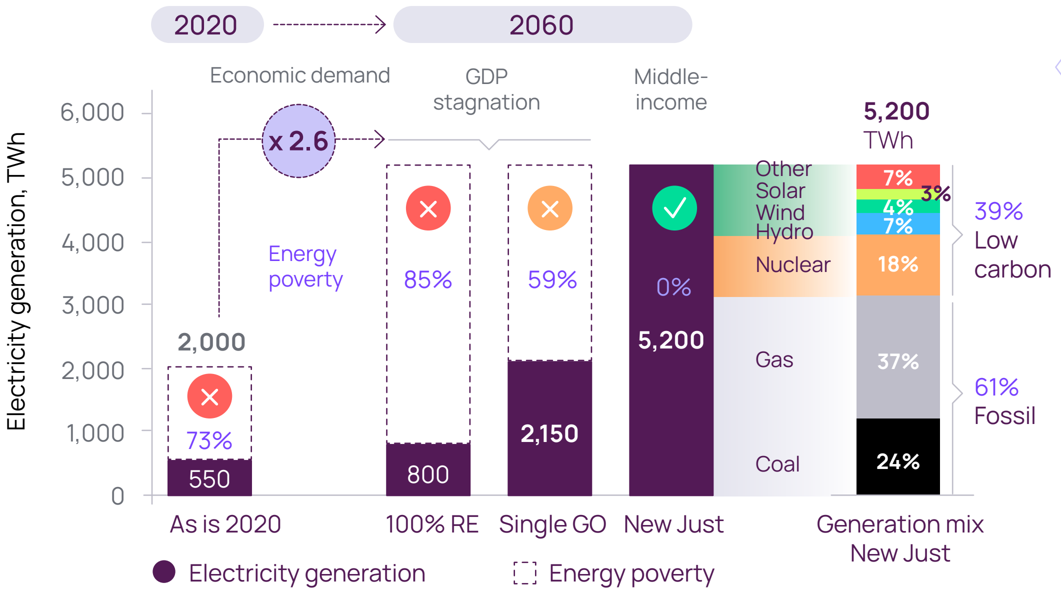
Potential market size by 2060

4,700
TWh
consumption

X9
market growth

10
(8 new)
large emerging markets

Power generation and energy poverty outlook by scenario



*Economic demand of 5200 TWh shown here includes grid losses and auxiliary loads of power generation required to run the power system, thus it is higher than the “net” economic demand of 4700 TWh.

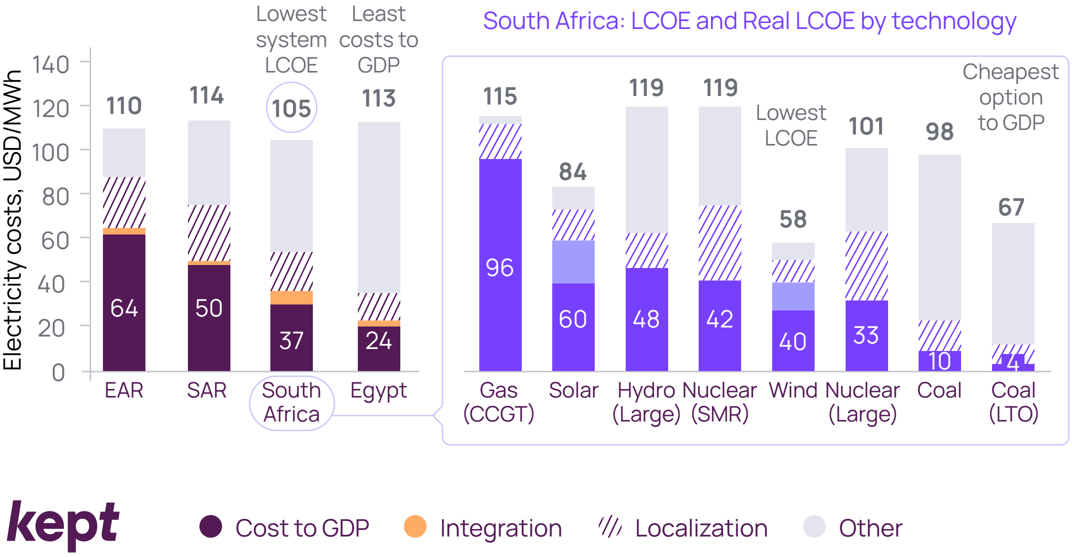
New Just scenario results 2060

5,200*
TWh
generation

100%
electricity & clean cooking access

0%
energy poverty

System costs and Cost-to-GDP by region, 2060 (New Just Scenario)



System costs

Classic least cost planning
105-114
USD/MWh
System LCOE

Affordability focused planning
24-64
USD/MWh
Cost to GDP

Introduction

> There are no rich or middle-income countries with low electricity consumption. So electrification is key to successful social and economic development

Economic development and electricity

Economic development, and in particular, a country's long-term economic growth, and electricity supply are interdependent. The international benchmarking of specific electricity consumption per capita and GDP shown in the figure below reveals that countries with developed economies and decent living standards of the population tend to have high electricity consumption.

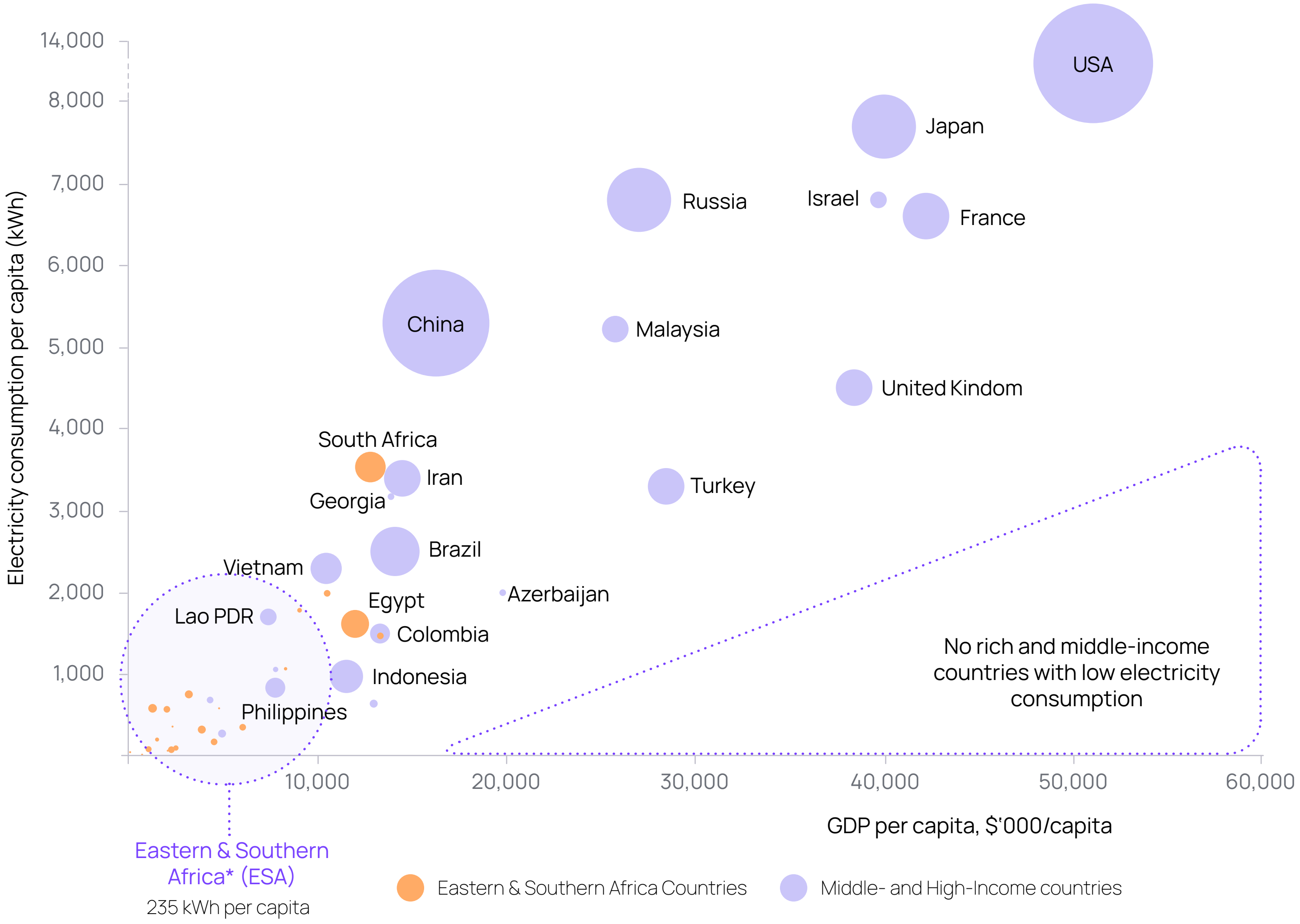
The majority of Eastern and Southern Africa's (ESA) countries are low-income countries, (except of Egypt, the Republic of South Africa and Botswana, where GDP exceeds USD 10,000 per person). Long-term low economic development level in these countries has been accompanied by persistently low living standards, with populations lacking access to electricity, clean cooking, and modern household appliances.

Today, the ESA region is home to more than 8% of the world's population, but accounts for no more than 3% of the world's electricity consumption, with only 48% of the population having access to electricity and 23% to modern clean cooking technologies.

As of 2020, the average electricity consumption does not exceed 600 kWh per annum. In only five ESA countries the consumption is above 1,000 kWh and in other countries, such as Burundi, Congo, Ethiopia, Rwanda, South Sudan, and Uganda, it is less than 100 kWh per capita. So the ESA region needs to consume more energy to ensure economic growth.

This study assesses the feasibility of full electrification options for the region to bring power systems up to middle-income country levels under various energy and climate policies at the national and intergovernmental levels.

GDP & electricity consumption by country, 2020



Note: * Eastern and Southern Africa (ESA) not including South Africa and Egypt .

Source: AEP, IEA, World Bank, Kept analysis

To industrialize and transition to modern economy per capita electricity consumption in African countries must exceed 1,000 kWh per annum

Lens of the study

Electrification has 'different shades' because there is no single global quantitative definition of electricity access or metric for 'full electrification' of economies.

For example, the IEA methodologies only deal with residential electrification KPIs, replicated by some African countries. Access is deemed provided, if a household is connected to electricity with a minimum consumption of 250 kWh per year for a rural household and 500 kWh for an urban household. This is enough for turning on four light bulbs that work four hours a day as well as keeping a cell phone and radio charged. In per capita terms (assuming that a household has five members), it means 50 kWh per capita in rural areas and 100 kWh in urban areas. However, this level of electrification is not enough to use modern appliances. Nor does it take into account the energy required to run modern utilities (water supply, street lighting, fridge or air conditioner, etc), commercial and industrial facilities. It is clear, then, that a large proportion of Africa's population that is nominally provided with 'access' does not in fact enjoy modern standards of living.

Other think tanks, such as the Energy for Growth Hub, provide a broader definition of access to electrification as Modern Energy Minimum (MEM) standards at the level of the entire economy. So the access at the country level is deemed provided, if electricity consumption exceeds 1,000 kWh per capita per year, with at least 300 kWh consumed by households and 700 kWh by the commercial sector.

To define the quantitative KPIs and electrification thresholds required for the African population to achieve a level of well-being consistent with that of a middle-income country, we conducted an international benchmarking of specific electricity consumption, electricity and clean cooking access for countries that have gone through the electrification process in recent decades. The analysis included countries such as Indonesia, the Lao People's Democratic Republic, the Philippines, Thailand, Vietnam, Uzbekistan, Azerbaijan, Brazil, Colombia, Georgia, Turkey, Costa Rica, Turkmenistan and Iran.

Based on the benchmarking results, we set the following electricity consumption targets in this study. These values do not only define access to electricity per se, but also characterize the level of development of a country's economic sector as a whole:

- 1,600 kWh/capita – 100% electrification; M1
- 1,800 kWh/capita – 100% clean cooking; M2
- 2,200 kWh/capita – middle-income economy. M3

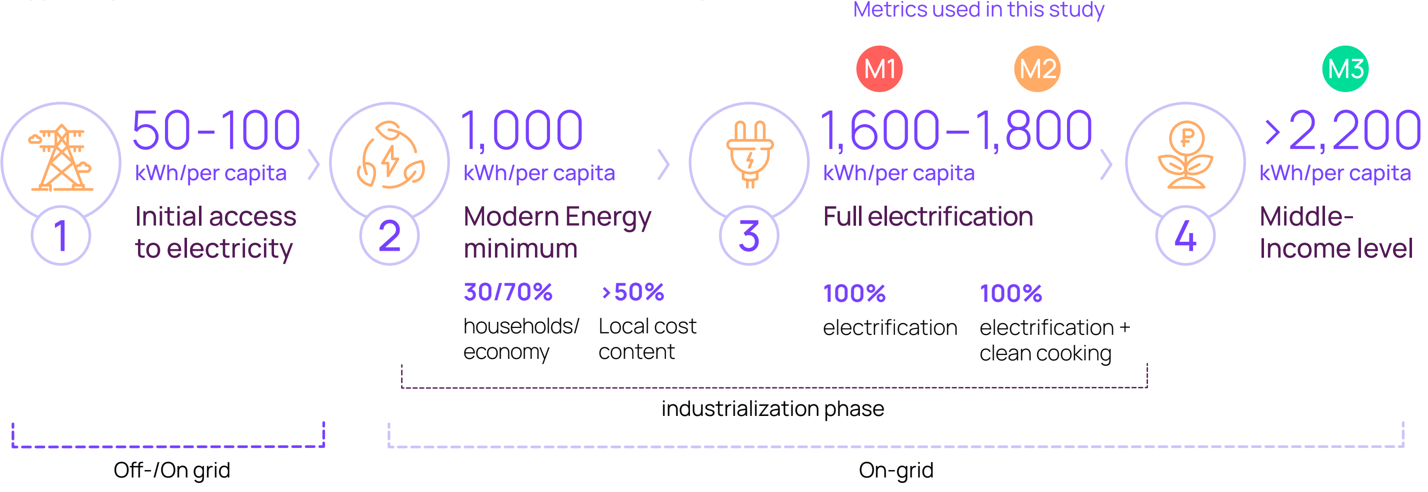
Achieving these targets will be a prerequisite for accelerating the pace of industrialization and the development of the services sector, and will have a direct impact on household incomes and living standards.

The current average electricity consumption in Eastern and Southern Africa (as of 2020) is as low as 235 kWh (excluding South Africa and Egypt) with a downward trend in recent decades. The challenge of increasing per annum per capita electricity consumption is further complicated by population growth. The population is projected to double from current 740 to approximately 1,600 million by 2060.

The other clear conclusion from the international benchmarking is that successful full electrification and industrialization programs have always been based on conventional on-grid solutions with large-scale transmission and distribution systems.

This is important to keep in mind as some countries addressing the issue of access to electricity define electrification as providing access through off-grid systems, most often rooftop solar panels. Clearly, this can serve as an important first step towards the eventual full electrification of a country, but it falls short of providing a satisfactory standard of living for the population and promoting economic growth.

Typical phases of industrialization economic development



Source: World Bank, IEA, The Energy for Growth Hub, Kept analysis

The population of Eastern and Southern Africa is projected to double by 2060 to 1,600 mln people

~740 mln → x2 → >1,600 mln

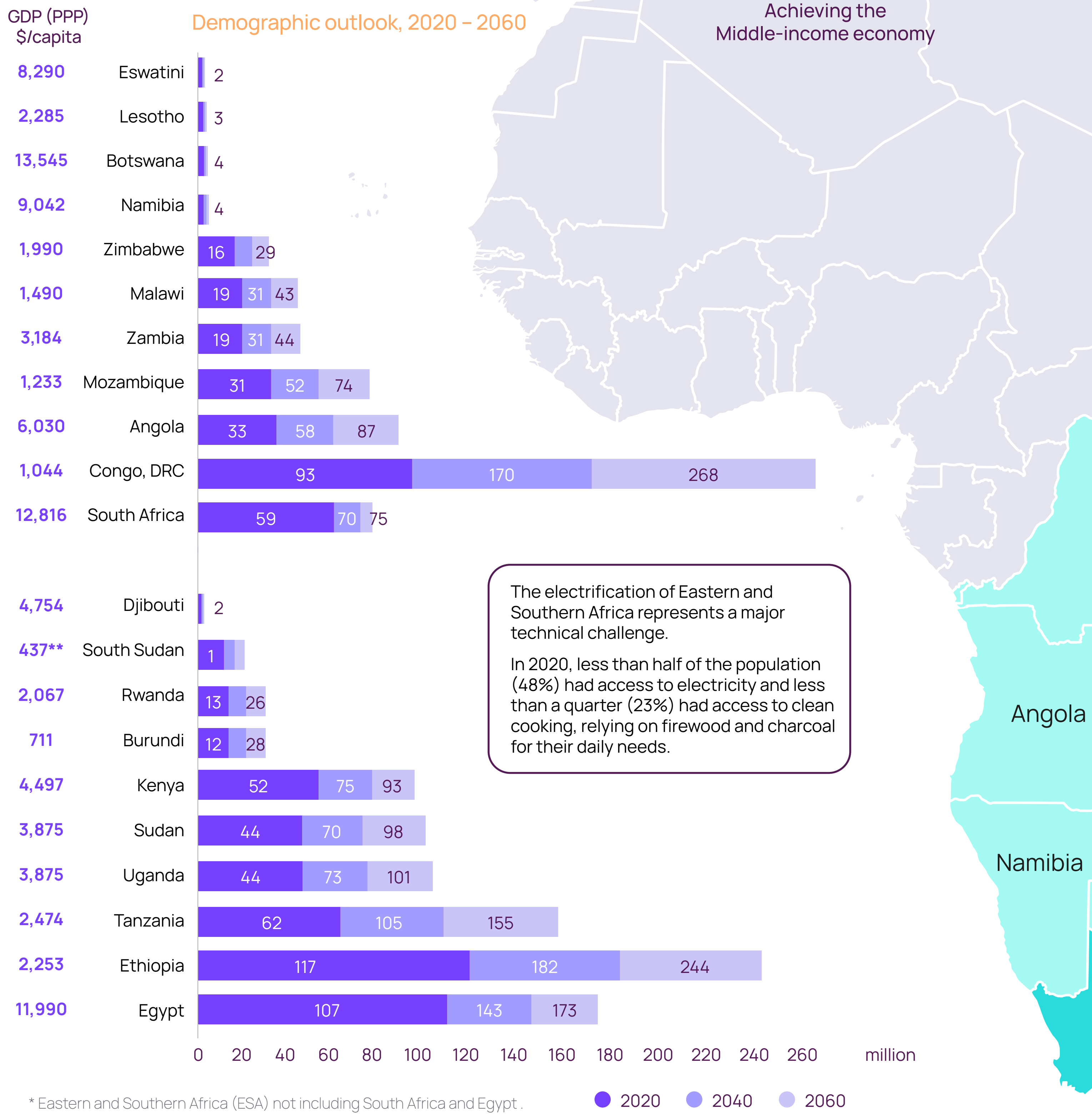
2020 | 2060

The average consumption pre capita, kWh/year

~235* → >2,200

2020 | 2060

Achieving the Middle-income economy



The electrification of Eastern and Southern Africa represents a major technical challenge.

In 2020, less than half of the population (48%) had access to electricity and less than a quarter (23%) had access to clean cooking, relying on firewood and charcoal for their daily needs.

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* Eastern and Southern Africa (ESA) not including South Africa and Egypt .

** 2021

Source: World bank, IEA, IMF, Kept analysis

The average access to electricity of 48% and clean cooking of 23% is critically low to sustain development

ESA regional average

Electricity access

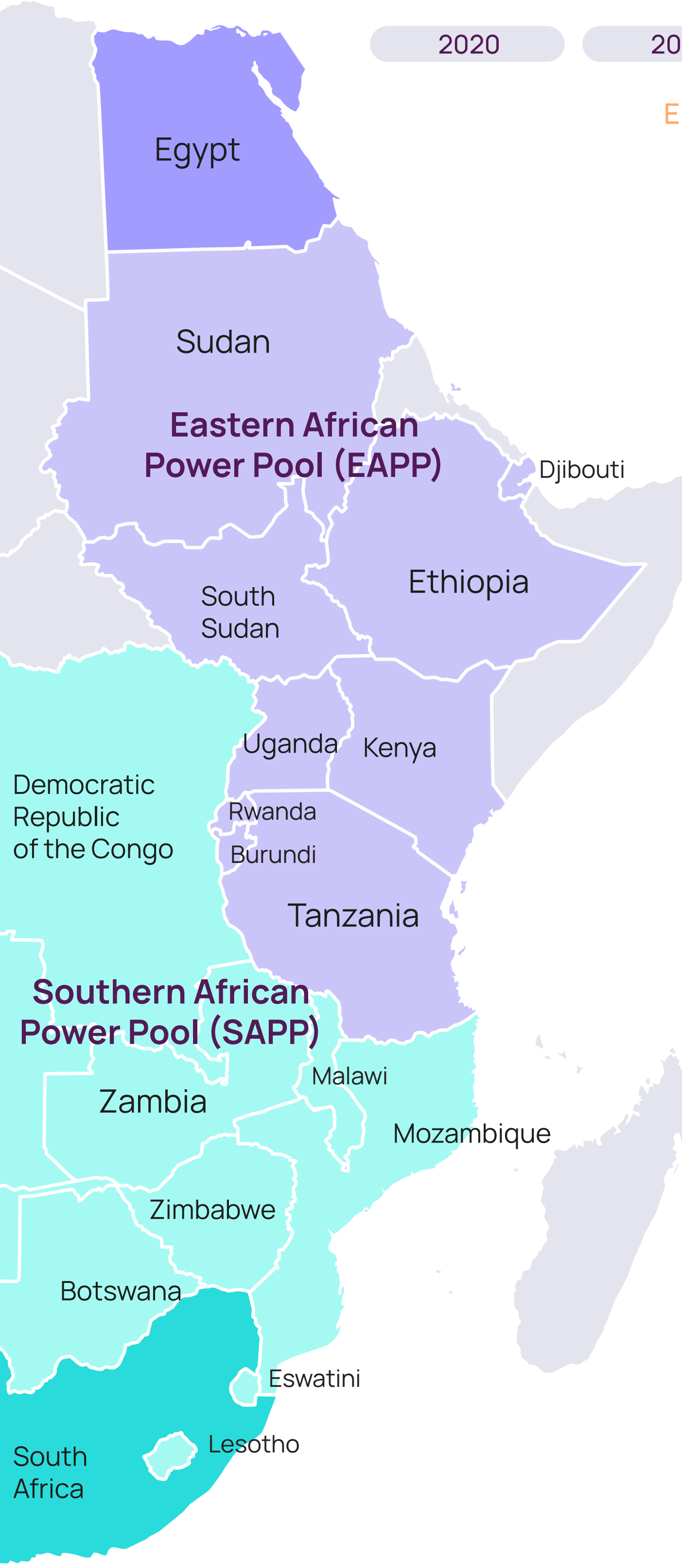
48% ⟶ 100%

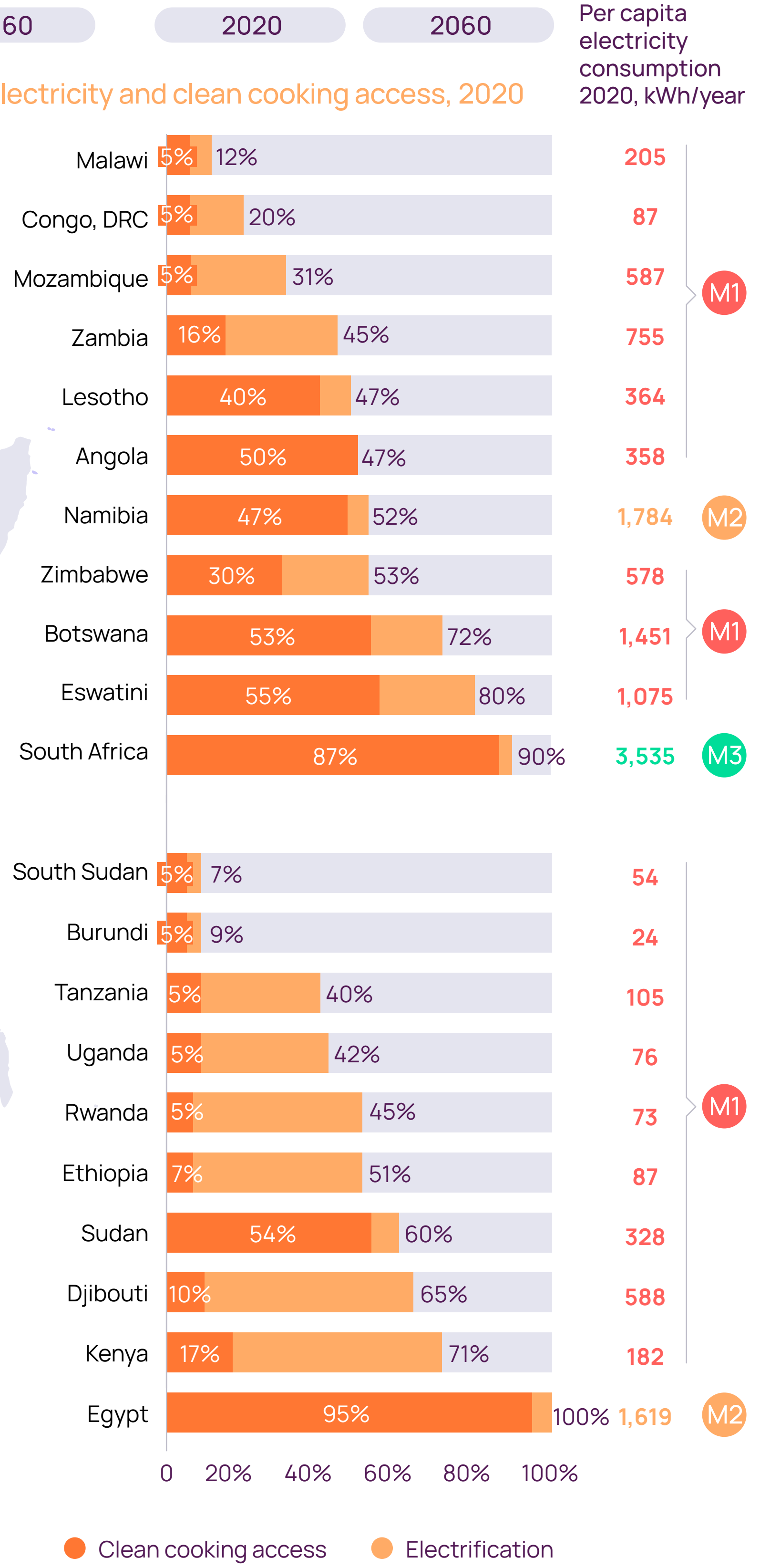
2020 2060

Clean cooking access

23% ⟶ 100%

2020 2060




Electricity and clean cooking access, 2020

Per capita electricity consumption 2020, kWh/year

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Focus of the study on the identification of feasible pathways for electrification of the ESA region

Key questions covered

In order to understand the scale, challenges and feasible pathways for electrification and transition to modern energy sources, the following issues were addressed in the study:

Scale of challenge: How much energy is needed to power the Eastern and Southern African economies; what countries and regions will lead the game by 2060?

Transition paths: What are the likely pathways that national governments will choose to achieve 100% electrification and economic prosperity?

Role of energy sources: How can different energy sources, incl. coal, gas, renewables and nuclear, contribute to generation mix?

Climate impact: How different power sector development pathways will impact the real amount of emissions, the environment and deforestation?

Affordability of transition: What is the real cost of electricity for national GDPs and how can countries make it affordable by developing local supply chains?

Manageability of transition: What are the prerequisites for making the transition happen? What are the key components of the just transition concept for Africa?

This report contains five chapters. Chapter 1 provides an overview of projected electricity demand and the expansion of Africa's energy markets, the methodology of this study. Chapter 2 describes scenarios for the regional electrification and the prospective development of energy systems in accordance with the chosen political agenda. The possible investment potential in the field of energy production from all possible types of resources is also presented. Chapter 3 discusses the impact of the climate agenda on African energy development. Chapter 4 sets out the concept of cost of electricity to GDP and provides an assessment of affordability. Chapter 5 describes the principles of Just Transition implementation.

The analysis is based on publicly available information, including the EAPP and SAPP master plans, as well as materials from other studies. The study results can provide an independent perspective on the development of Africa's energy systems, its path towards electrification and industrialization, and serve as a basis for creating programs and plans for regional and continental energy system planning and development.

Energy modeling approach

In this work, we developed a long-term scenario modeling approach consisting of 5 stages (the framework is shown in the figure right).

At the first stage, a forecast of economic demand and electricity consumption was prepared for 21 countries on an annual basis until 2060. For the analysis, baseline data for each country were prepared: statistical economic data, population, data on electrification and access to clean cooking, parameters and characteristics of the electric power sector, information on available and potential resources in the region.

At the second stage, a forecast of energy supply at the macro-regional level was prepared. To evaluate options of meeting the economic demand, an analysis of the available resources in the region was carried out at the aggregated level of 4 macro-regions. Local fossil and renewable energy resources were identified and estimated. It has been found that the Eastern and Southern African region is rich in all resources, incl. coal (in countries such as South Africa, Mozambique, Tanzania, Botswana), gas (the largest reserves are in Tanzania and Mozambique) and renewables (such as hydro, wind, solar, geothermal energy, etc.). However, the distribution of these resources is uneven, leaving a number of countries that do not have a domestic resource base to rely on imports.

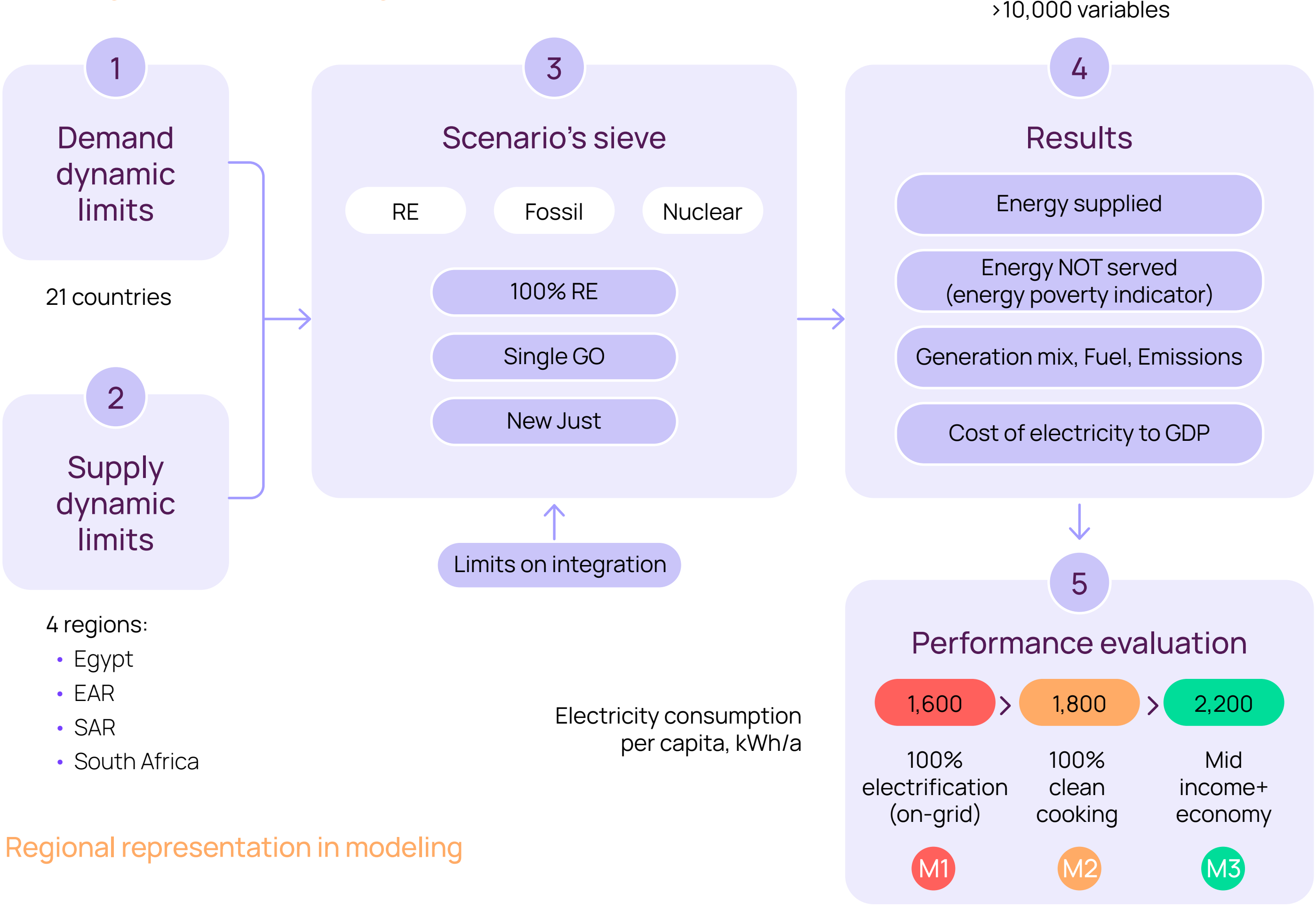
Next, potential energy development scenarios for Eastern and Southern Africa were identified, with their detailed description presented in Chapter 2. Energy modeling was performed taking into account six limits on integration by generation type: resource availability, limited project timelines, integration scope, funding sufficiency, OEM capacity, regulatory constraints. These limits varied depending on the scenario of the development of energy systems. As a result, a forecast of the energy mix was prepared, taking into consideration global and local policies, and determining the extent to which economic demand in the region is satisfied.

The calculations of emissions produced in the energy sector included not only power plants but also basic heating and cooking needs. The cost of electricity production, considering the multiplicative effects on the economy, was calculated based on the prepared energy mixes. Energy capacities and electricity balances, emissions and costs were calculated at an aggregated level for 4 macro regions: Egypt, the Eastern African Region, the Southern African Region and South Africa for 2040 and 2060.

The results of energy modeling calculations were evaluated in terms of the achieved levels of electrification.

Energy and economic modeling methodology

Modeling approach for ESA region



>10,000 variables

1 Demand dynamic limits

21 countries

2 Supply dynamic limits

4 regions:
- Egypt
- EAR
- SAR
- South Africa

3 Scenario's sieve

RE | Fossil | Nuclear

100% RE

Single GO

New Just

Limits on integration

4 Results

Energy supplied

Energy NOT served (energy poverty indicator)

Generation mix, Fuel, Emissions

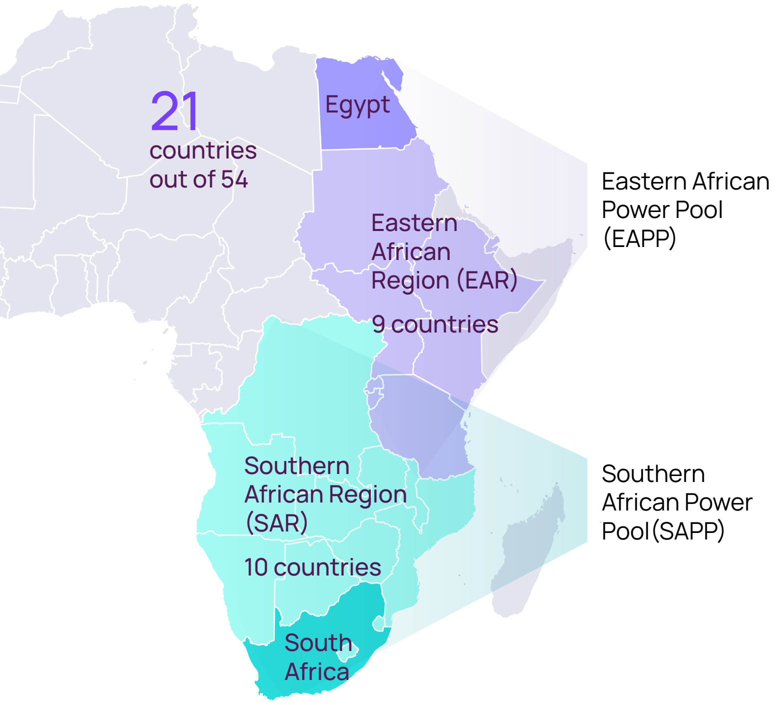
Cost of electricity to GDP

5 Performance evaluation

Electricity consumption per capita, kWh/a

1,600	1,800	2,200
100% electrification (on-grid)	100% clean cooking	Mid income+ economy
M1	M2	M3

Regional representation in modeling



Regional representation

For this study was used regional modeling approach to estimate potential energy balances, electricity costs and share of economic demand served by the scenario.

21 countries out of 54 on the African continent were selected for study and analysis, which were divided into 4 macro-regions (see picture left): the Eastern African region (EAR, 9 countries*), the Southern African region (SAR, 10 countries**), as well as Egypt and South Africa as separate more mature markets.

Note:

*Eastern African Region (EAR): Burundi, Djibouti, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Uganda, United Republic of Tanzania.

**Southern African Region (SAR): Angola, Botswana, Democratic Republic of the Congo (DRC), Eswatini, Lesotho, Malawi, Mozambique, Namibia, Zambia, Zimbabwe.

Table Mountain, Cape Town, South Africa

1

Demand outlook

To reach the GDP mid-income level by 2060, electricity consumption in ESA has to increase 9-fold to 4,700 TWh

Economic demand outlook

To estimate electrification and energy poverty levels in the ESA region, we estimated two separate indicators for electricity demand – economic demand and projected final electricity consumption.

The economic demand for ESA countries was estimated based on population projections and the target level of electricity consumption for middle-income economies of 2,200 kWh/capita. This level of demand is called economic demand and reflects the potential size of the energy markets if all the needs of the population and the economy were met.

The second indicator – final electricity consumption – factors in a share of economic demand, which is likely to be feasibly met considering constraints on transmission and distribution and demand-side development. To estimate the final electricity consumption that would be required to sustain economic growth, we built a forecast based on a differentiated annual growth rate of per capita electricity consumption and projected population dynamics. Depending on the level of per capita electricity consumption in a particular country, the regressing annual growth rate varying from 10% to 0.3% was used. The main assumption was the idea of potential rapid growth of undeveloped markets and a gradual slowdown in consumption growth as the market "saturates" and reaches closer to the level of middle-income countries.

The population of Eastern and Southern Africa as of 2020, according to the World Bank, was 743 million people. According to forecasts, the population in these countries is growing and will reach 1.2 billion by 2040 and 1.6 billion by 2060. So the total population of the region will more than double. The countries with the largest populations will be the DRC, Egypt, Ethiopia, Tanzania and some others.

As of 2020, the electricity consumption in the ESA region was about 510 TWh, while the estimated economic demand was over 1,700 TWh. Assuming the continued population growth in the ESA region, the economic demand will increase to 2,850 TWh by 2040 and to 4,700 TWh by 2060. The final electricity consumption will catch up with the economic demand by 2060. The total market size by 2060 will thus be equivalent to approximately five current Russian energy systems – a nine-fold increase in the power market compared to the 2020 level.

Market landscape by 2060

Currently, there are only two large markets in the region – Egypt and South Africa, with electricity consumption of about 180 TWh and 210 TWh, respectively (2020). The landscape of ESA energy markets is projected to change significantly by 2060. Today's leaders will be overrun by "sleeping giants" with currently low electrification.

Assuming that EAR and SAR markets will reach the middle-income level, 10 large and very large markets with annual consumption of some 300–600 TWh will be formed in the region. The three markets, incl. the Republic of the Congo, Egypt and Ethiopia, may grow to the size of the German power market (600–670 TWh). The other seven countries, incl. Tanzania, Kenia, Angola, starting from a low base may reach the size of the UK power market (240–420 TWh).

The development of power systems and generating capacities in these countries will accompany the rapid growth of large, industrialized industries and the service sector. This will directly stimulate economic and GDP growth, leading to an increase in the well-being of the population of Eastern and Southern Africa. It will also create opportunities for business development, attract investments, and promote the growth of enterprises and industries.

However, energy transition on such a large scale requires addressing the issue of energy resources and their potential role in shaping future power systems. This topic will be discussed in Chapter 2.

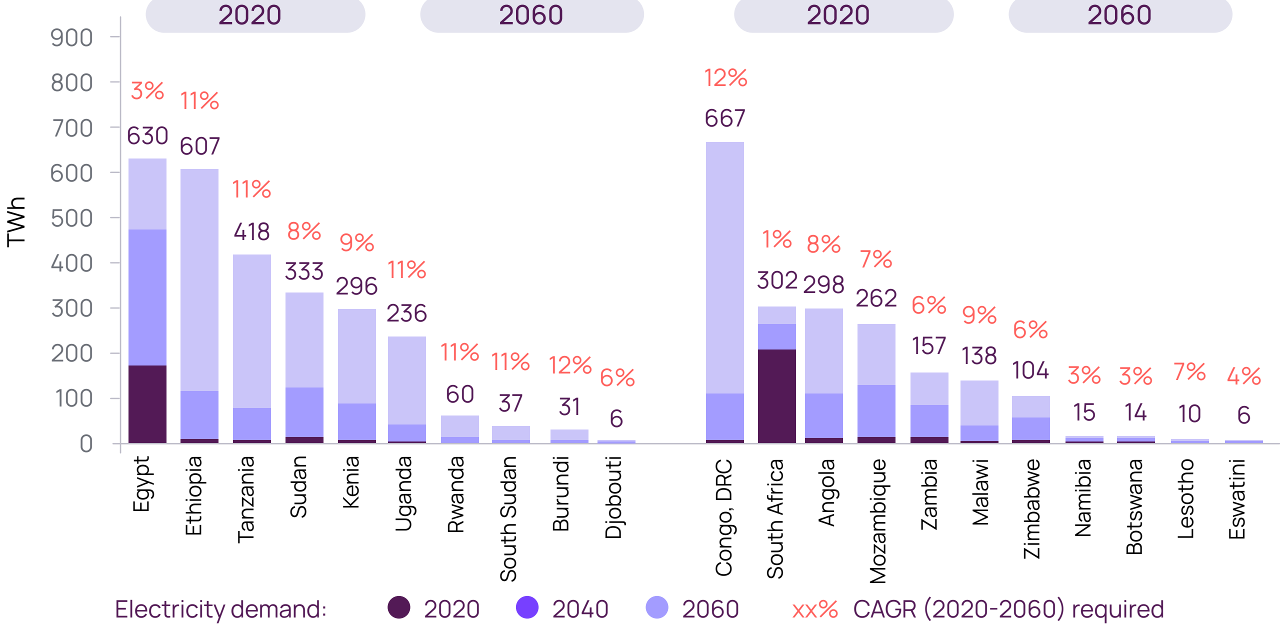
The figures below present an economic demand outlook and development indicators for 21 countries and 4 macro regions through 2060 based on a global analysis of electricity consumption per capita for middle-income countries and the levels of electrification and economic development of countries determined by benchmarks.

10 (8 new) large power markets the size of Germany and the UK could emerge in Eastern and Southern Africa by 2060

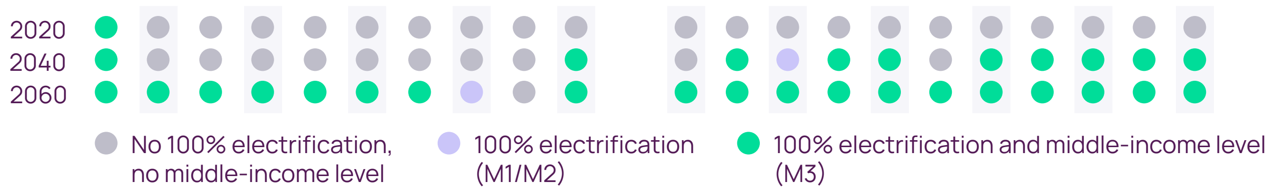
Electricity consumption outlook to 2060

Eastern African Power Pool (EAPP): ~220 TWh → ~2,700 TWh (2020 → 2060)

Southern African Power Pool (SAPP): ~290 TWh → ~2,000 TWh (2020 → 2060)



Probability of achieving per capita consumption metrics by country:



Total economic demand and electricity consumption development in ESA to 2060

	2020		2040		2060
Economic demand	1,720 TWh	x 1.7 →	2,850 TWh	x 1.6 →	4,700 TWh
Electricity consumption	510 TWh	x 3.5 →	1,770 TWh	x 2.6 →	

x 9

The power market size by 2060

10 large national markets (incl. 8 NEW):

ESA market = 5x Russia size markets = 3x Germany size markets + 7x UK size markets

Cd, Eg, Et

Tz, Ke, Ug, Bi, Ao, Mz, Zw

Source: AEP, IEA, IRENA, World Bank, Kept analysis

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Thermal power station

2

Electrification pathways

The interaction between national and international energy and climate policies defines the range of energy resources available to electrify Africa

Strategic electrification pathways

For this study, three strategic scenarios were developed to assess the feasibility of electrification depending on the interaction between national and international policies on fossil, nuclear, renewable energy and climate. The scenarios are as follows:

- 100% Renewables,
- Single GO,
- New Just.

The scenarios generically describe possible national energy pathways for EAPP and SAPP countries, ranging from following the existing mainstream renewable energy agenda to working towards a more equitable, complex and technically and economically feasible path, developed under internationally coordinated policies that take into account African specificities, its diverse resources and the goal of improving the living conditions of African peoples and enhancing Africa's potential for sustainable development.

Specific scenario conditions forming three scenarios include domestic and global financial, climate and technical policy factors influencing the development of various energy sources.

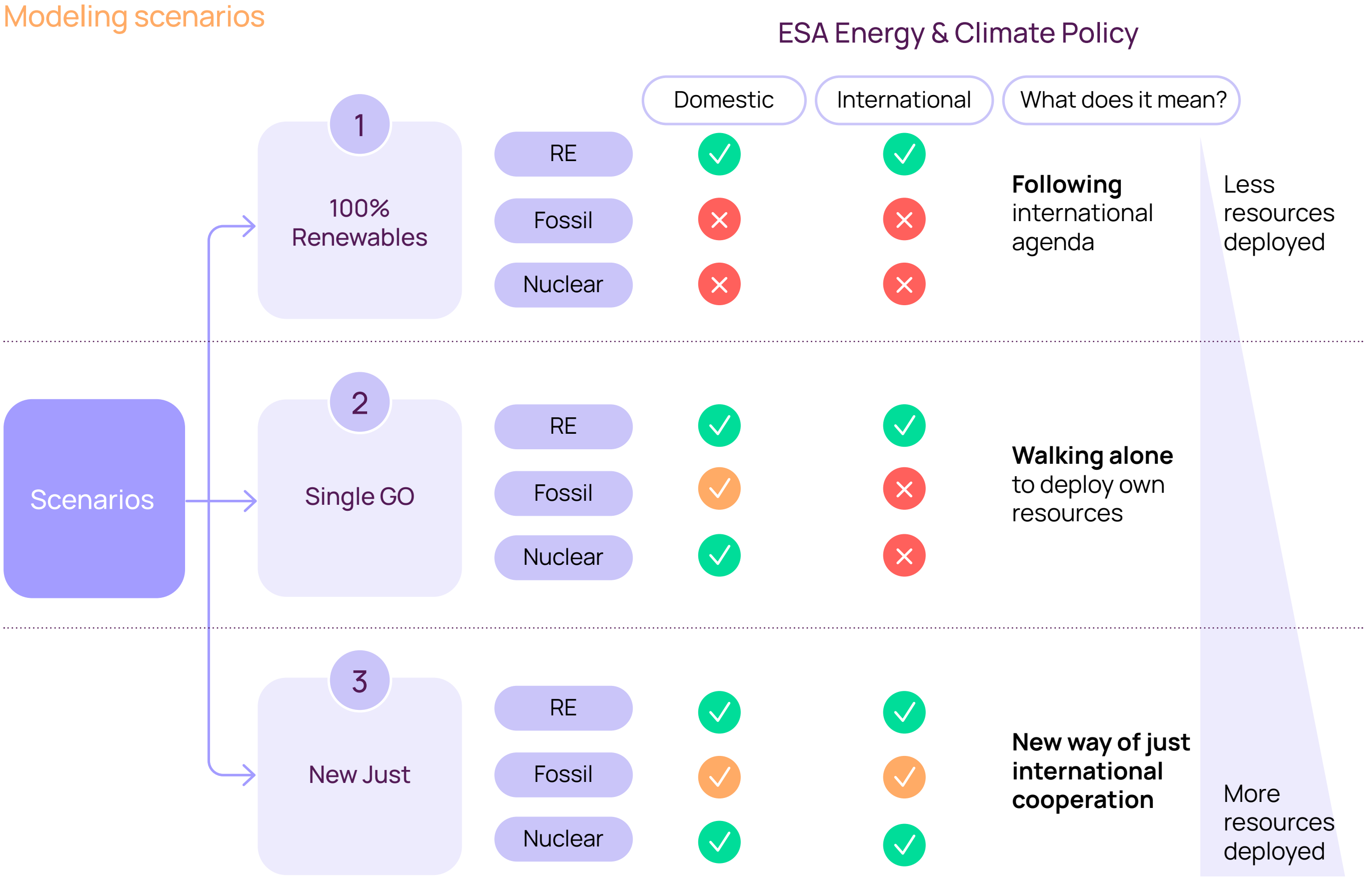
100% Renewables (100% RE): Countries proceed with strategies to develop the power sector based on renewables only. It is assumed that, all coal-fired PPs and 50% of existing gas PPs are to be decommissioned by 2060. No financial and regulatory support for existing or new fossil technologies is assumed.

Single GO: Countries proceed with the national power sector agendas based on the lowest cost option using all resources available. However, the implementation of various types of projects continues to be constrained by global financial and climate restrictions.

New Just: Countries move forward with internationally coordinated power sector agendas, with global financing and climate policies adjusted to enable a Just Transition to 100% acces to electricity (on-grid), clean cooking and industrialization using an inclusive energy mix.

The figure below shows description of the scenarios.

Modeling scenarios



ESA Energy & Climate Policy

Scenarios		Domestic	International	What does it mean?	
1 100% Renewables	RE	✅	✅	**Following** international agenda	Less resources deployed
	Fossil	❌	❌		
	Nuclear	❌	❌		
2 Single GO	RE	✅	✅	**Walking alone** to deploy own resources	
	Fossil	☑️	❌		
	Nuclear	✅	❌		
3 New Just	RE	✅	✅	**New way of just international cooperation**	More resources deployed
	Fossil	☑️	☑️		
	Nuclear	✅	✅		

Electricity generation increases in all scenarios, but energy poverty is eliminated only under specific conditions

Energy supply and poverty outlook

Energy modeling was performed for four ESA macro regions for 2040 and 2060 to understand the share of economic demand, which may be covered under different scenarios of generation mix. The cumulative result for the ESA region compared to the base year 2020 is shown in figures below. Based on the results of the analysis, the following key conclusions were made:

Current situation

As of 2020, the total electricity generation in the four regions was 550 TWh, while the estimated economic demand was 2,000 TWh. Thus, the economic demand exceeded actual generation by almost 4 times. This means that 73% of the total energy demand is not served (a percentage of energy not served is used as a proxy indicator for the level of energy poverty in this study). Two main reasons for this have been identified: a shortage of generating capacities in the energy system and a low level of consumer-side development, as well as the distribution network infrastructure.

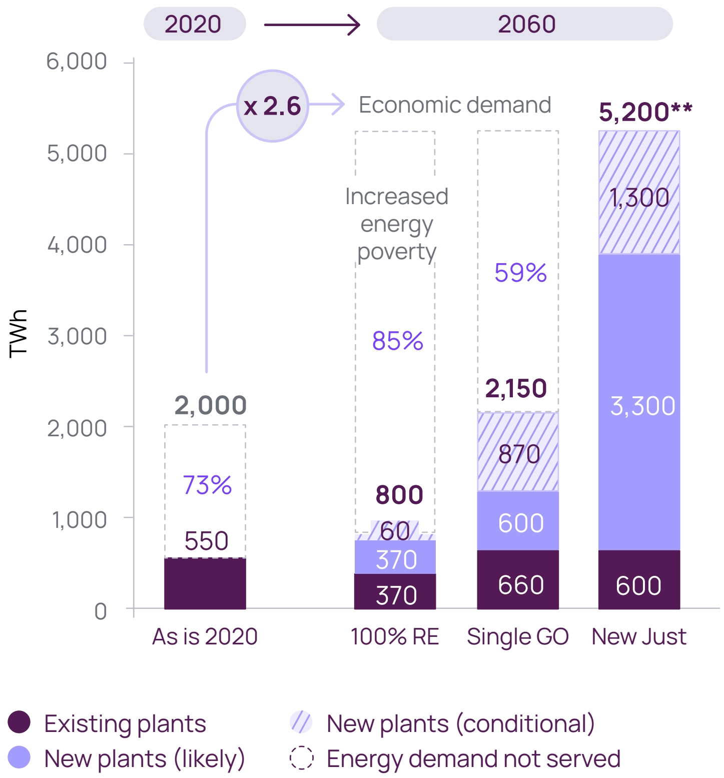
The energy poverty level also varies across the macro regions under review. The best performing regions include South Africa and Egypt with the level of energy not served of c. 7% and 34%, while in SAR and EAR it reaches 84% and 94%. This means that in these two regions the electricity infrastructure is currently almost absent (for details, please refer to the regional outlook in the next section).

Outlook to 2060

The economic demand for ESA increases by almost 3 times by 2060 reaching 5,200 TWh. The key factors include population growth (the annual increase is about 2%) and economic development to the level of middle-income countries. We project that electricity generation by 2060 increases in all three scenarios, but very unevenly. The generation is projected to reach 800 TWh in the 100% RE scenario, 2,150 TWh in the Single Go scenario, and 5,200 TWh in the New Just one. In the 100% RE scenario, the output of existing power plants is expected to reduce to 370 TWh, as coal-fired power plants and some of gas power plants are closed. In the Single Go scenario, the output of the existing facilities increases to 660 TWh through upgrade and improvement in equipment performance. In the New Just scenario, measures are also taken to re-equip and extend the life of existing power plants. In some cases, old plants are replaced with new ones, resulting in a reduction of power generation to 600 TWh. The situation with energy poverty is more complex. Under the worst-case scenario, which is 100% RE, the unserved demand goes up from 73% to 85%. Under the Single Go scenario, the unmet demand reduces slightly, but still remains high at 59%. The only scenario that allows all economic demand to be met by 2060 is New Just with 0% of energy not served. **This means that electricity sector development goals for the ESA region as a whole could only be achieved under the New Just scenario***. Under the 100% RE and Single Go scenarios, the economic development of countries remains slow, the GDP stagnates or even decreases on a per capita basis, and the UN SDGs are not achieved.

* It should be noted that at the regional level, only two regions, South Africa and Egypt, are capable of meeting the full demand under the Single GO scenario.

Electricity generation outlook for ESA



Energy demand NOT served

2020

73% Current status ✗

2060

85% 100% RE ✗

59% Single GO ✗

GDP stagnation or decrease

0% New Just ✓

Energy poverty elimination

Source: Kept analysis.

**Economic demand of 5,200 TWh shown here includes grid losses and auxiliary loads of power generation required to run the power system, thus it is higher than the "net" economic demand of 4,700 TWh projected in Chapter 1

An inclusive energy mix and all kinds of resources are required to reach economic prosperity in the ESA region

Energy mix outlook

Scenario outlook – 100% RE

The scenario assumes power sector development based on renewables only. All coal-fired PPs and 50% of existing gas PPs are to be decommissioned by 2060. The availability of renewable energy was investigated based on the IRENA study from 2021. In this work, the upper end potential of renewable energy is used, the total volume of which is more than 460 GW (including hydropower, solar, wind, biomass, geothermal, etc.). In this scenario, the total installed capacity of the ESA region increases to 204 GW, with electricity generation going up to 800 TWh by 2060. The generation of electricity from fossil fuels is reduced by almost 2.3 times to 155 TWh as a result of the closure of coal and gas power plants due to administrative policies and lack of investment in modernization, service life extension. The generation of electricity from nuclear power plants increases to 46 TWh, since only nuclear power plants currently under construction are set to go online. Electricity generation from RES increases to 600 TWh by 2060. Further integration is limited by the lack of dispatchable generation and does not cover all potentially deployable renewable resources, with further construction of power plants leading to curtailment and increased idle time.

The unserved energy demand increases from 73% to 85%, resulting in a further deterioration of economic and living conditions. Due to unstable energy supplies from renewable sources, the risk of extended load shedding (clear example of deteriorating situation is South Africa) and blackouts increases, and during dry periods, which are frequent in the ESA region, the situation is further complicated by a decrease in hydropower plant capacities. Business suffers significant material and financial losses due to electricity shortages and equipment damage during load shedding.

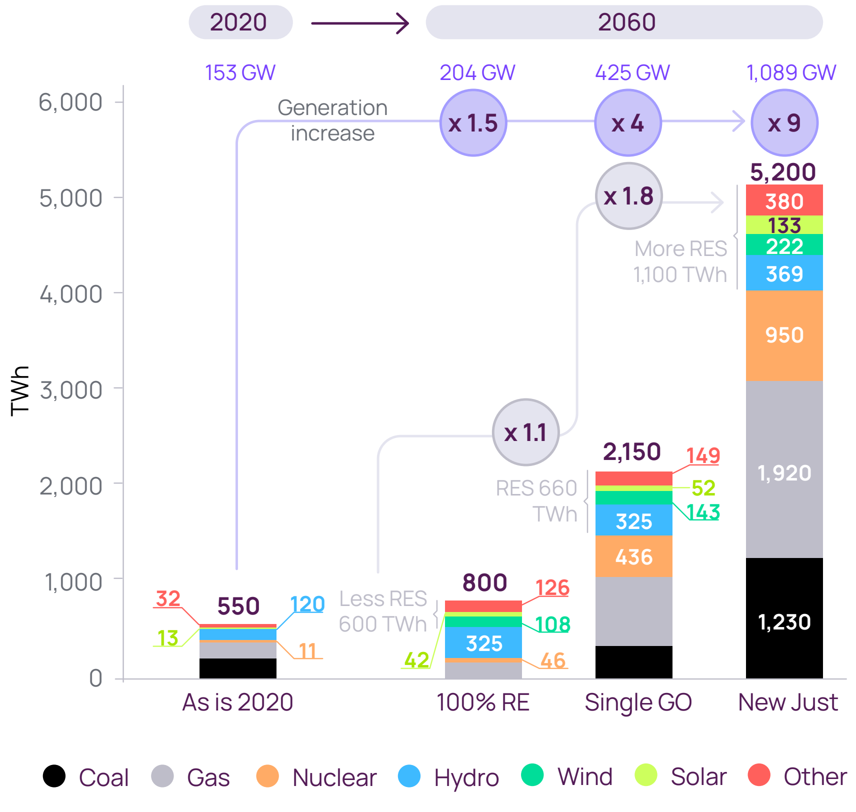
Overall, 100% RE appears to be the worst scenario from both a technical and economic perspective. The average per capita consumption decreases from 735 kWh to 510 kWh. Economic development is impossible, and the countries' GDP is in decline.

Scenario outlook – Single Go

The scenario assumes that national power sectors proceed with agendas based on the lowest cost option using all resources available, but without international development aid. In this scenario, by 2060 the total installed capacity within the ESA region increases to 425 GW and electricity generation to 2,150 TWh. Electricity generation from fossil fuels is 1,041 TWh, while nuclear power plants generate 436 TWh.

The countries are assumed to invest in and finance the modernization and efficiency improvement of their existing power plant fleets. However, there are still insufficient funds to partially replace them with more efficient and economical options. Financial, technological, and resource limitations prevent the countries from developing the necessary infrastructure quickly, supplying resources to countries where they are unavailable. Electricity generation from RES is to reach 660 TWh by 2060, which is more than in the 100% RE scenario due to efforts to conserve existing dispatchable capacities and develop new ones with fossil resources and nuclear technologies.

Generation mix outlook for ESA



Possible Energy mix by 2060

39% Low carbon

- 21% Renewables (1,100 TWh)
- 18% Nuclear (950 TWh)

61% Fossil

- 37% Gas (1,920 TWh)
- 24% Coal (1,230 TWh)

Source: Kept analysis.

Achieving the 100% RES target in the ESA region's energy mix is technically and economically unfeasible

The average per capita consumption almost doubles to 1,370 kWh. However, this is still insufficient to meet the full economic demand, and 59% of the required electricity remains unmet. This means that in some ESA countries the population does not have 100% access to electricity and clean cooking. The economic development of the countries remains slow.

Scenario projection for New Just

The scenario assumes that the countries move forward with electrification based on an internationally coordinated power sector development approach, without any restrictions on fossil and nuclear generation. The total capacity of power plants of all energy systems may reach 404 GW by 2040 and 1,089 GW by 2060. This approach helps meeting the full economic demand for electricity and eliminate energy poverty by 2060. In 2040, however, there will still be a 42% electricity shortage due to the size of the undertaking and the relatively short timeframe. In 2060, the average power consumption in ESA is expected to be 3,330 kWh/person, while in Egypt and South Africa it will exceed 3,650 kWh/person.

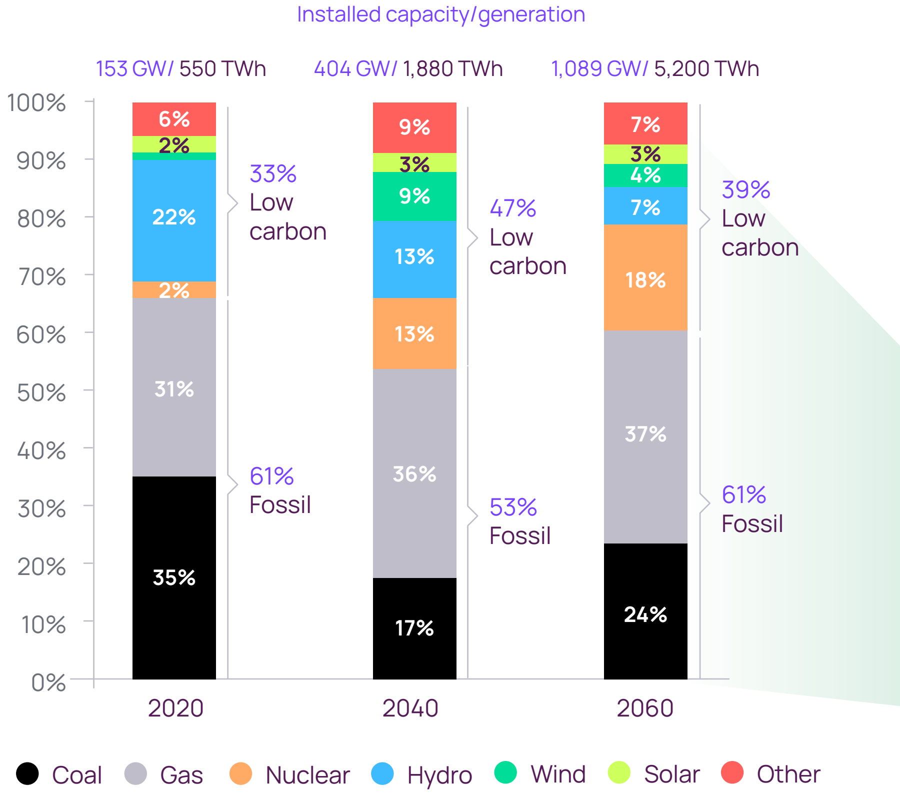
The installed capacity of dispatchable power plants, such as coal, gas and nuclear sources of power, reaches 778 GW by 2060, incl. 128 GW of nuclear generation. The development of these types of technologies is constrained by financing, construction duration, primary resource availability, and the production capacity of equipment manufacturers.

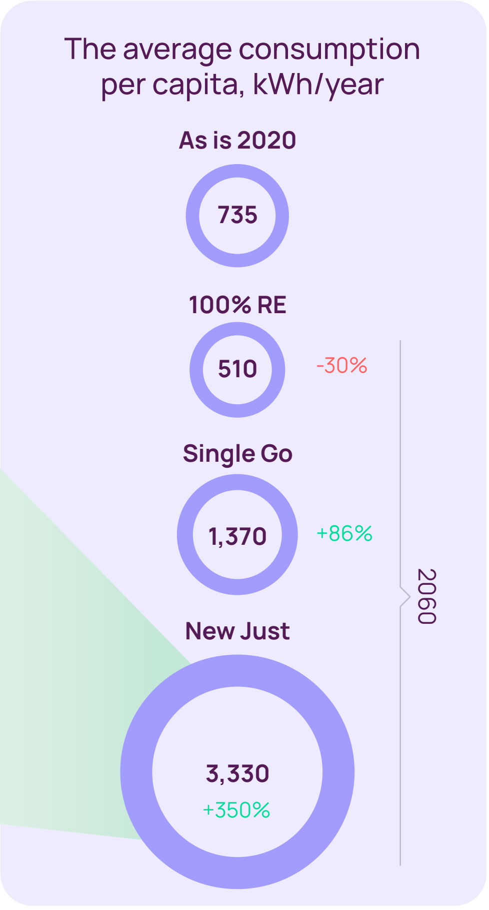
Due to the expansion of dispatchable generation, the installed capacity of RES power plants also increases (as more dispatchable power sources allow to integrate into the energy system higher capacity of intermittent RE sources and may reach 311 GW by 2060, representing almost 1/3 of the total installed capacity.

Thus, about 53% and 61%, or 1,010 TWh and 3,172 TWh of electricity can be generated from fossil energy sources (gas and coal) by 2040 and 2060, respectively. The rest can be provided almost equally by nuclear energy sources and renewables. Nuclear power generation will amount to 946 TWh by 2060, gradually increasing its share in the energy mix to 13% in 2040 and 18% by 2060. Due to a significant increase in dispatchable generation, almost double the level of variable renewables can be integrated compared to the 100% RE scenario, so that renewable electricity generation reaches 1,100 TWh, while meeting the requirements for adequacy and security of electricity supply.

The figure below shows the expected generation mix in 2040 and 2060.

Generation mix structure for ESA (New Just)





Regional outlook: the current level of electricity sector development differs significantly by country

Regional energy modeling results (New Just)

Egypt

	2020 Fact	2040 Forecast	2060 Forecast
Population, mln people	107	143	173
Electricity access, %	100%	100%	100%
Clean cooking access, %	95%	100%	100%
Economic demand, TWh	236	474	630
Electricity generation, TWh	198	539	716
Energy demand not served, %	32%	0%	0%
Installed capacity, GW	59	117	154

Eastern African Region

- Burundi
- Djibouti
- Ethiopia
- Kenya
- Rwanda
- South Sudan
- Sudan
- Uganda
- Tanzania

Population, mln people	357	561	767
Electricity access, %	55%	58%	100%
Clean cooking access, %	23%	52%	100%
Economic demand, TWh	785	1,235	2,061
Electricity generation, TWh	57	521	2,468
Energy demand not served, %	94%	65%	0%
Installed capacity, GW	16	105	475

South African Region

- Angola
- Botswana
- DRC
- Eswatini
- Lesotho
- Malawi
- Mozambique
- Namibia
- Zambia
- Zimbabwe

Population, mln people	220	376	556
Electricity access, %	41%	92%	100%
Clean cooking access, %	23%	82%	100%
Economic demand, TWh	484	873	1,672
Electricity generation, TWh	79	554	1,734
Energy demand not served, %	84%	39%	0%
Installed capacity, GW	19	110	381

The Republic of South Africa

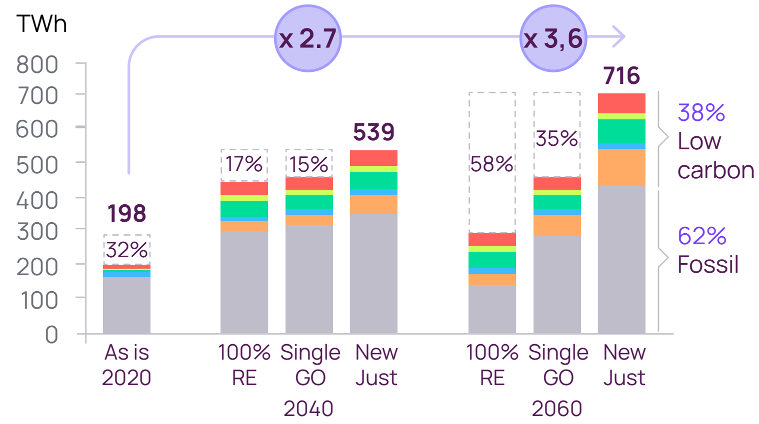
Population, mln people	59	70	75
Electricity access, %	90%	100%	100%
Clean cooking access, %	87%	100%	100%
Economic demand, TWh	218	263	302
Electricity generation, TWh	213	269	309
Energy demand not served, %	7%	0%	0%
Installed capacity, GW	59	71	80

Source: IRENA, World Bank, IEA, Kept analysis

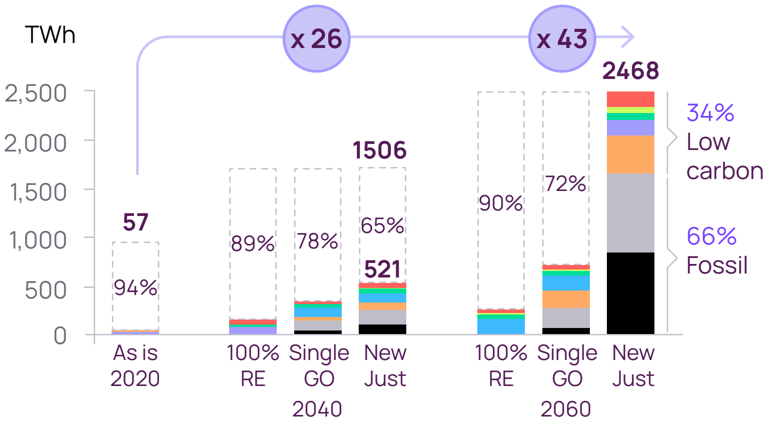
Two regions – SA and Egypt can meet their future national energy needs by adopting only national energy policies (SingleGo scenario)

Electricity generation by scenario

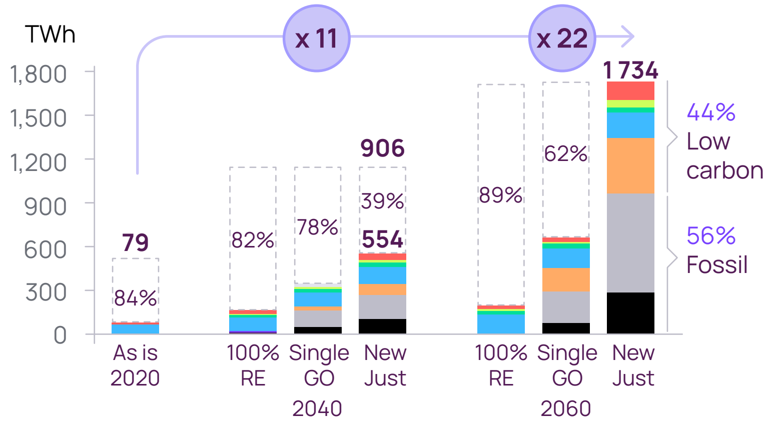
Egypt: As of 2020, the electricity generation is 198 TWh with unserved demand of 32%. The economic demand increases to 474 TWh by 2040 and 630 TWh by 2060. The key drivers of demand growth are economic development and population growth. Electricity generation can fully cover economic demand in 2040 and 2060. The main generation source will be gas (up to 62%) due to large domestic reserves. Nuclear (up to 15%) can have a significant impact in stabilizing the gas balance in the electric sector. RES production can reach up to 23% by 2060.



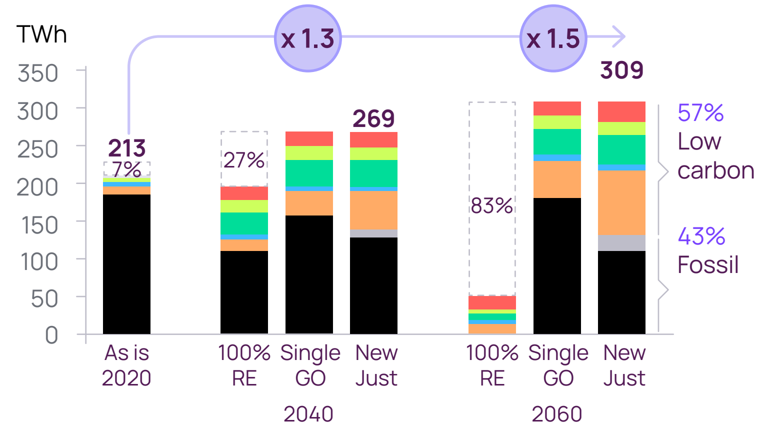
EAR: As of 2020, the electricity generation is 57 TWh with unserved demand of 94%. The economic demand increases to 1,235 TWh by 2040 and 2,061 TWh by 2060. The key drivers of demand growth are are access to electricity and population growth and, increasingly after 2040, economic development. Generation can fully cover economic demand only by 2060. The main generation will be from gas and coal (up to 66%), using the reserves of the region. Nuclear has a special place (up to 15%) and can be easily integrated into small power systems with the use of SMR. RES production can reach up to 20% by 2060.



SAR: As of 2020, the electricity generation is 79 TWh with unserved demand of 84%. The economic demand increases to 873 TWh by 2040 and 1,672 TWh by 2060. The key drivers of demand growth are access to electricity and population growth, and, after 2040, and then a significant demand growth will be driven by industrial development. Generation can fully cover demand only by 2060. The main generation will be from gas and coal (up to 56%), using the reserves of the region. Nuclear has a special place (up to 22%) and can be easily integrated into small power systems with the use of SMR. RES production can reach up to 22% by 2060.



South Africa: As of 2020 the electricity generation is 213 TWh with unserved demand of 7%. The economic demand increases to 263 TWh by 2040 and 302 TWh by 2060. The key drivers of demand growth are access to electricity, population growth and economic development. Two scenarios (Single Go and New Just) make it possible to cover the economic demand even before 2040. The main generation will be from coal and gas (up to 43%) with the modernization and life extension of coal plants. Nuclear generation accounts for up to 28% of total output. RES production can reach up to 29% by 2060.



● Coal ● Gas ● Nuclear ● Hydro ● Wind ● Solar ● Other

Electrification of the ESA region opens up one of the world’s largest markets with over 930 GW of new power generation capacities

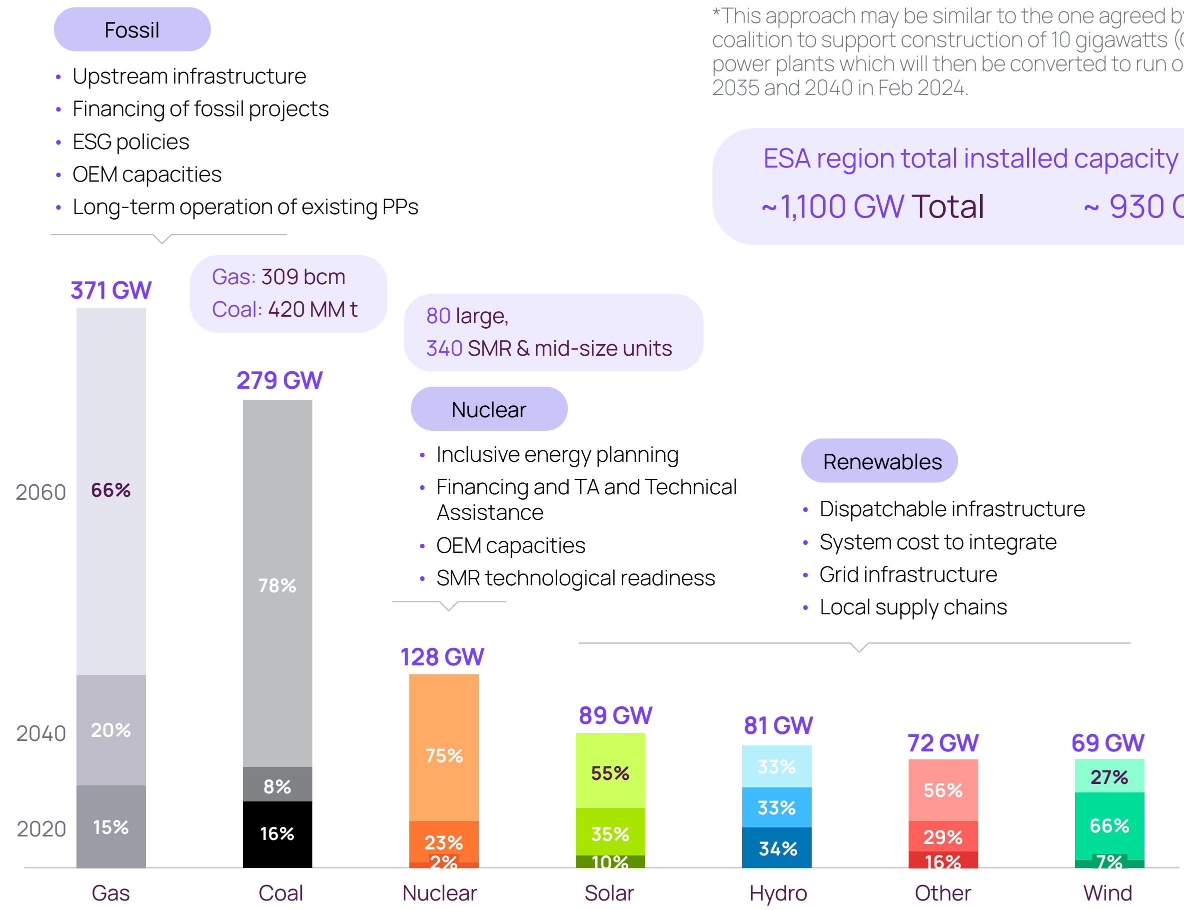
Market outlook - New Just scenario

The energy modeling shows that full electrification of the region is possible in the New Just scenario. We estimate the power generation new build, reconstruction and maintenance market to be approximately 1,100 GW in the ESA region, including:

- Gas generation - 371 GW
- Coal generation – 279 GW (incl. re-powering for 40GW)
- Renewables (solar, wind and others) – 230 GW
- Nuclear generation – 128 GW (incl. 32 GW of SMRs)
- Hydro generation – 81 GW
- Transmission and distribution network development

The implementation of the electrification program of this scale – comparable to building 5 power systems of the size of Russia – over a span of just 40 years is a significant and challenging undertaking. It requires the complex development of the entire supply chain for primary energy resource extraction, mining, OEM manufacturing, construction capacities, staff education and trainings, financing and adjacent industrialization. The sections below provide detailed technological outlook to understand the role of each type of generation, the specifics of application and sensitivity in relation to each of the four ESA’s macro regions.

Installed capacity and deployment challenges by technology in ESA, 2060 (New Just)



Fossil

- Upstream infrastructure
- Financing of fossil projects
- ESG policies
- OEM capacities
- Long-term operation of existing PPs

Gas: 309 bcm
Coal: 420 MM t

80 large,
340 SMR & mid-size units

Nuclear

- Inclusive energy planning
- Financing and TA and Technical Assistance
- OEM capacities
- SMR technological readiness

Renewables

- Dispatchable infrastructure
- System cost to integrate
- Grid infrastructure
- Local supply chains

Source: Kept analysis.

Fossil transition

The electrification and industrialization of ESA countries will require the use of all available resources. However, fossil fuels will play a major role, contributing over 60% to the energy mix. This is due to their unique ability to provide the necessary scalability of generation.

The vast gas and coal reserves in Africa have the potential to support the development of large-scale dispatchable generation on time (NPPs will provide dispatchable generation too, but amount is limited to OEM construction capacities and time). Partnering with countries in the region and developing import supply chains can effectively promote a just energy transition, even in countries with limited domestic resources. The proposed fossil generation may be pre-designed to be capable to run on hydrogen or/and use biomass co-firing in the future. So as soon as international technologies and supply chains are mature – as it is expected by some experts around mid-2040 to mid- 2050 - these plants can be converted to low carbon fuels without a risk to become stranded assets*. This deployment will be supplemented by nuclear baseload power, however limited by the production capacities, construction time of OEMs and financing.

The deployment of fossil generation will also be crucial for integrating variable renewables, such as solar and wind, as well as hydro resources with significant seasonality. These resources cannot operate without backup from dispatchable generation in the power system.

*This approach may be similar to the one agreed by Germany’s ruling coalition to support construction of 10 gigawatts (GW) of new gas-fired power plants which will then be converted to run on hydrogen between 2035 and 2040 in Feb 2024.

ESA region total installed capacity by 2060

~1,100 GW Total ~ 930 GW New

Gas can contribute to the largest share to ESA's future electricity mix, with an estimated 1,920 TWh, or 36%, by 2060 and this natural resource, as well as coal (unlike imported solar and wind technologies) is local and abundant in Africa

Gas generation outlook

Gas generation will be a key contributor to the successful electrification of the region. By 2060, the total demand for the construction of new gas-fired power plants in ESA can exceed 320 GW. The distribution of capacities of gas PPs by region is shown in the figure below. The largest capacities are distributed between the EAR and SAR, with 132 GW and 142 GW, respectively. This is due to the largest unserved economic demand, as well as large natural gas reserves in these regions. The total contribution of gas generation, including the existing power plants, can reach 36% in the energy mix, or 682 TWh and 1,920 TWh by 2040 and 2060, respectively.

The main markets for new gas generation capacity will be the EAR and SAR markets together accommodating over 85% of demand, or 280 GW of new capacity, by 2060. Egypt and South Africa could add up to 38 GW and 4 GW, respectively.

To meet the gas demand for power generation of about 309 billion cubic meters of gas per year by 2060, gas production will have to increase fourfold compared to current capacities. This would require discovery and development of new fields, scaling up of gas projects and the development of infrastructure. The development of the regional gas transportation infrastructure will contribute to the creation of import supply chains for countries lacking this resource. This will lead to the formation of regional gas markets and the development of interregional gas transportation infrastructure, involving also related industries such as manufacturing of pipes, distribution station equipment, consumer gas equipment (gas stoves, heaters and meters), construction and engineering.

The scale of gas-fired power plant construction will support the development of local supply chains for component manufacturing, including electrical and thermal components, gas and steam turbines, and all engineering design capabilities, thereby reducing construction costs and providing jobs for local communities.

In addition to power generation, gas provides households and industries with cleaner and more affordable energy, replacing charcoal and eliminating deforestation, wood, biomass and diesel.

Of particular importance is the development of gas-fired generation as the baseload capacity in the power system, especially in countries that do not have their own alternatives. As baseload generation, interconnections and transmission lines are developed, it is possible to integrate variable renewable energy sources such as wind, solar, etc. available in the region.

Gas sector development opportunities in Tanzania and Mozambique

The region's large resource discoveries over the past decade provide an opportunity for natural gas to play a greater role in ESA's energy system. According to the IEA (Africa Energy Outlook 2022), more than 30 trillion cubic meters of natural gas have been discovered in Mozambique and Tanzania.

In order to advance the energy sector, the integration of gas-fired generation into the energy mix is crucial, and this involves developing potential resources and reserves, discovering new gas fields, and scaling the gas industry. The success of gas projects will depend on an integrated strategy:

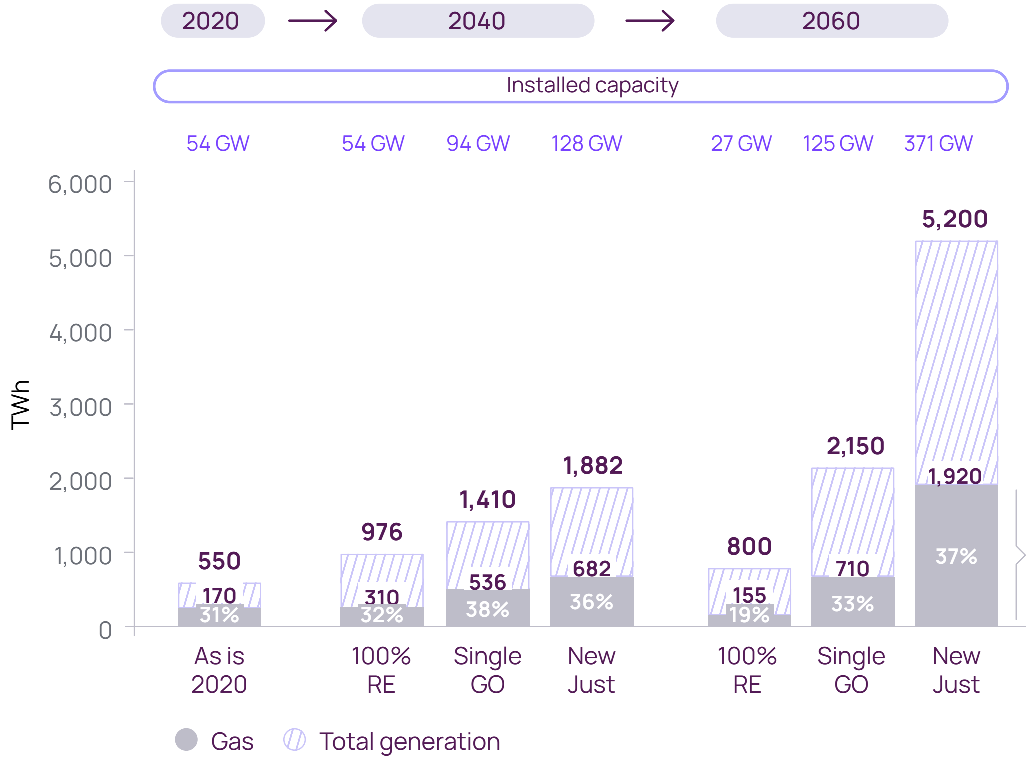
- **Balancing exports and national needs**: the great temptation for any new gas discovery in Africa - to favor the development of export-oriented LNG projects, which are easier to finance and implement than the local development of value-added industries - is the risk of missing opportunities.
- **Diversification of gas use**: increasing positive impact on economic development through multi-directional use – energy sector, industrial needs and exports – to maximize resource value for local economies.
- **Localization of supply chains**: development and transfer of technologies for the production of gas industry equipment, personnel training, local servicing.

We estimated a rule of thumb for successful gasification programs can be described as the "1/3 rule": for national gas resources to be sustainable, they should be equally divided between export, power generation, and local industrial and municipal use to maximize their value for the country's economic development.

Source: IEA, Kept analysis

The primary regions for new gas generation are the SAR and EAR markets, which will collectively host 280 GW by 2060

Electricity generation by gas power plants



Role of gas:
gas may provide the greatest contribution to the ESA future electricity mix, or 36% by 2060

Distribution of new gas power plants and fuel consumption by 2060 (New Just)

	New power plants	Consumption	Import share
	GW	New + Existing PPs, bcmpa	Fuel, %
Egypt	38	71	0
Eastern African Region	132	126	80
Southern African Region	142	108	50
South Africa	4	4	100
	320 GW	309 bcmpa	

Need for new gas discoveries:
As of 2023, ESA's actual natural gas production will hardly be enough to cover one-third of the projected demand. Therefore, new gas fields and import infrastructure must be developed to close the gap

Source: EIA, www.theglobaleconomy.com, Kept analysis

Coal generation will be the second most important source of electricity in ESA, with 1,200 TWh, or 24%, by 2060 and this natural resource, as well as gas (unlike imported solar and wind technologies) is local and abundant in Africa

Coal-fired generation outlook

Coal generation will be the second most important power source for the ESA region's electrification. Coal-fired generation, including the existing power plants, can reach 24% in the energy mix, which corresponds to 1,230 TWh in the annual electricity generation mix by 2060 (see the picture below). The total demand for the construction of new coal-fired power plants may exceed 245 GW. The distribution of the new coal-fired generation in the EAR and SAR is 165 GW and 80 GW, respectively.

The key deployment challenge for coal generation is the existing ESG policies and restrictions on CO_2 emissions by international financial institutions and some corporate players, resulting in limited availability of financing for this type of generation in Africa.

Other challenges facing coal-fired generation today – environmental (non-carbon related pollution) and technical (related to the need to become more flexible in support of renewable energy penetration) – can be successfully solved by introducing Clean Coal or High Efficiency Low Emissions (HELE)* technologies for new builds and retrofitting existing power plants. The scale of coal-fired power plant construction makes it feasible to develop a local supply chain for producing components, including electrical and thermal elements, and steam turbines, as well as all technical design possibilities, thereby reducing the cost of construction. In the future perspective gas-fired power plants can be switched to hydrogen-gas mixtures, and coal-fired plants to co-burn fossil fuels and industrial biomass should this transition will be technically possible and economically feasible.

To make the coal program a reality, it is necessary to change the approach to financing coal projects in countries where primary electrification and industrialization are taking place.

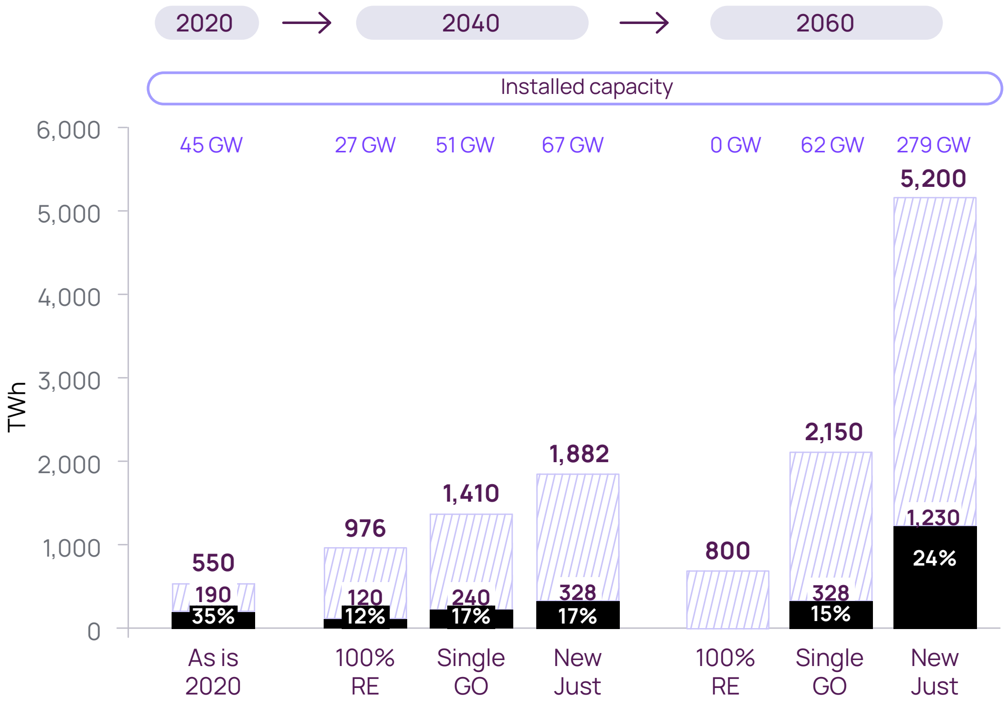
Coal power plants and fuel consumption by 2060

Region	New power plants	Consumption (New + Existing PPs)	Import Share (Fuel)
	GW	mt/year	%
Egypt	-	-	-
Eastern African Region	165	284	95
Southern African Region	80	98	70
South Africa	~40 rehab.	38	0

*Clean Coal" or "High Efficiency Low Emissions" technologies include technological solutions in two areas:

- solutions to control pollutant emissions and clean flue gases, incl. improving the quality of burned coal, NOx and desulfurization equipment, and ash filters;
- solutions to address climate change, incl. increase in the efficiency of coal generation, carbon dioxide capture and biomass co-firing.

Electricity generation by coal power plants



● Coal ▨ Total generation

245 GW
~420 mt/annum

Coal-fired generation may add up to 1,230 TWh to the ESA energy mix, with main limitations being only regulatory restrictions and finance

To provide coal-based generation, it is necessary to develop potential domestic coal resources and import resources (from other African countries)

Source: EIA, IRENA, Skolkovo, Kept analysis

Flexible coal applications in Germany to integrate renewables and cut costs may serve as good practice example for SA and other African locations

“Flexible coal” in Germany

Role of coal for energy transition

In the context of the energy transition, coal generation continues to be an integral part of Germany’s energy mix with its role changing from energy supply to capacity and flexibility supply. The graph below demonstrates the flexible operation of coal-fired power plants in Germany for a week in 2023, where coal plants balance the power grid by compensating for the variable supply of electricity from wind and solar generation. For this, high flexibility is needed in terms of having resilience to frequent start-ups, meeting major and rapid load changes, and providing frequency control functions.

The long-term operation and refurbishment of coal-fired plants aimed at increasing their flexibility helped reduce investment in construction of new gas-fired plants and the time needed to create flexible capacities (by 2–4 times). The saved investments have been used to increase the share of VRE and retrofit and upgrade grids in parallel with the adjustment of market rules for simultaneous operation of conventional and VRE generation facilities.

So, coal generation is not decommissioned, but rather carefully maintained and repurposed. This approach completely contradicts the so called “Just Energy Transition IP” initiative supported by the EU and the US to develop the markets of SA, Indonesia and others, promoting pre-mature closure of coal generation.

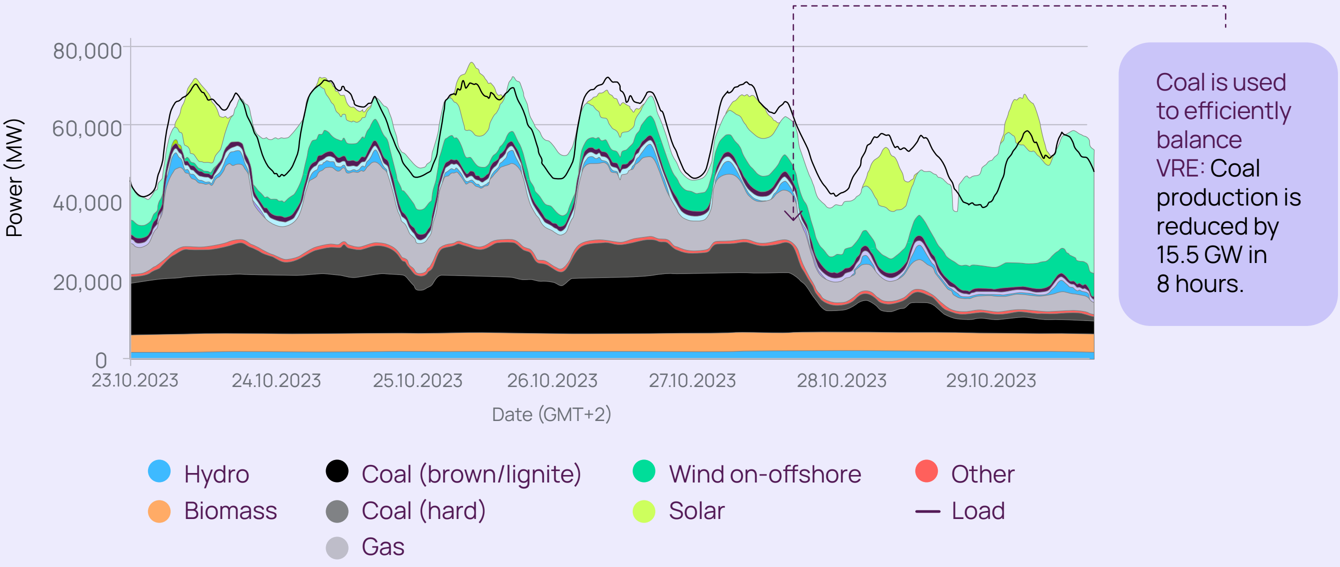
Coal financing

Top German banks are far from putting an end to financing of the coal generation, including direct lending and capital markets transactions. For example, from October 2018 to October 2020, German banks invested EUR 15 billion into the German coal generation.

Financing of the coal-based generation remains significant not only in Germany, but also across OECD countries. According to S&P Global and Urgewald, between January 2019 and November 2021, the global coal industry received USD 363 billion in loans and USD 1.2 trillion through underwriting from commercial banks. The three Japanese banks Mizuho Financial, Mitsubishi UFJ Financial and SMBC Group, along with Barclays from the UK and Citigroup from the US, make up the top 5 lenders in the “dirty dozen” rating. Notably, these five banks, along with the other ten largest lenders to the global coal industry, are simultaneously members of the Net Zero Banking Alliance.

This pragmatic approach may be used as a good practice example by African nations, especially South Africa operating a large coal generation fleet, before making any decommissioning commitments.

Power generation by plant type in Germany, week 43, 2023



Coal is used to efficiently balance VRE: Coal production is reduced by 15.5 GW in 8 hours.

*Kept adapted (only the main generating sources are presented)

Source: S&P Global Analytics, Energy-Charts.info, Kept analysis

Nuclear generation with 128 GW of new builds may contribute up to one-fifth to the future ESA energy mix

Nuclear generation outlook

By 2060, the total installed capacity of nuclear power plants may reach up to 128 GW adding up to 950 TWh or 18% to the ESA energy mix. The market will be split into segments of conventional large-scale and SMR generation.

Large-capacity units: The total market for large-capacity nuclear is estimated at 96 GW or 80 units. Particularly, it is possible to build up to 12 high-capacity power units in Egypt and 8 power units in South Africa. In Egypt, nuclear energy can play an important role in stabilizing the gas balance in the country and redirecting gas resources to other sectors of the economy. As for South Africa, nuclear energy can play an important role in replacing outdated coal generation and developing new generating capacities in the context of the decarbonization policy.

SMR & medium-sized units: the size of the market is estimated at 30 GW or 320 Small Modular Reactors (SMR) x 50-100 MW size and some 20 medium-capacity power units x 400-600 MW. These technologies are expected to play a special role as baseload generation in the power systems of land-locked countries with limited domestic fuel resources. At the same time, mass construction and scalability of low- and medium-capacity nuclear power plants make it possible to flexibly adapt to the actual demand for electricity.

Main limitations for the construction of nuclear power plants are the main OEMs' construction capacities and finance, but also the technological readiness of SMRs for mass deployment by 2040-2060. Nuclear energy is recognized as a low carbon emissions technology like hydropower, wind energy and solar energy, however it is not included into the IFIs portfolio for financing or technical assistance programs. The integration of nuclear power plants makes it possible to reduce total electricity emissions and plays a fundamental role in decarbonizing the energy sector, and integration of renewable energy sources.

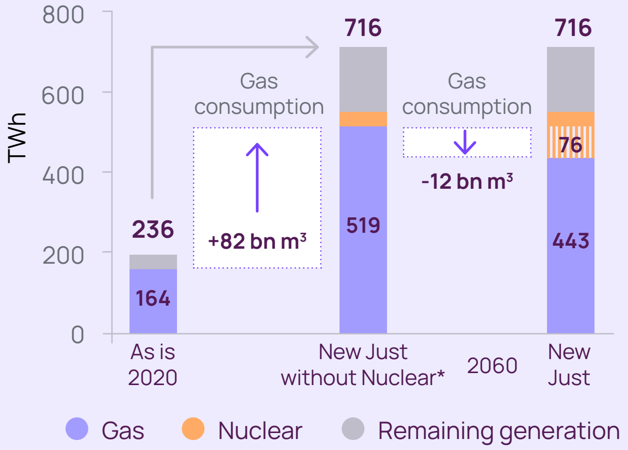
"Egyptian case": Role of nuclear for gas producing countries

The construction of nuclear power plants in gas-producing countries, such as Egypt, performs an important function of freeing up produced gas for industrial needs and the needs of public utilities, as well as for exports. At the same time, the implementation of nuclear technologies is an important element of the sustainable development strategy as it increases the reliability of the national energy supply and covers the growing demand for electricity for economic and industrial development.

Nuclear outlook for Egypt (New Just scenario):

- Construction of a 12x1,200 MW nuclear power plant will help save up to 12 billion cubic meters of gas per year;
- Lower CO$_2$ emissions (minus 30 MM tCO$_2$/year as compared to gas-fired power generation).

Electricity generation and gas consumption outlook in Egypt, 2060



*Construction of the El-Dabaa NPP is taken into account

Source: Kept analysis.

SMRs for the EAR and SAR countries

The developed types of SMR (up to 50-300 MW) and medium-capacity (400-600 MW) nuclear technologies are expected to be essential for eliminating energy poverty and meeting energy needs of the economic development with strong decarbonization effect in the EAR and SAR continental countries.

Independence from imported resources: In countries having no reserves of domestic fossil resources, nuclear energy can eliminate dependence on imported resources. Nuclear power plants have the lowest risks associated with the logistics and supply disruptions.

Dispatchable power: SMR is baseload generation that ensures the stability and reliability of the energy system and supplies electricity in accordance with all electricity quality requirements, which is crucial for the development of energy-intensive industries.

Smaller power systems: The integration of small/medium nuclear power units contributes to the most economically feasible small power systems with weak interconnections and is a solution for the development and transition stages for the integration of medium- and then high-power units as the energy system develops.

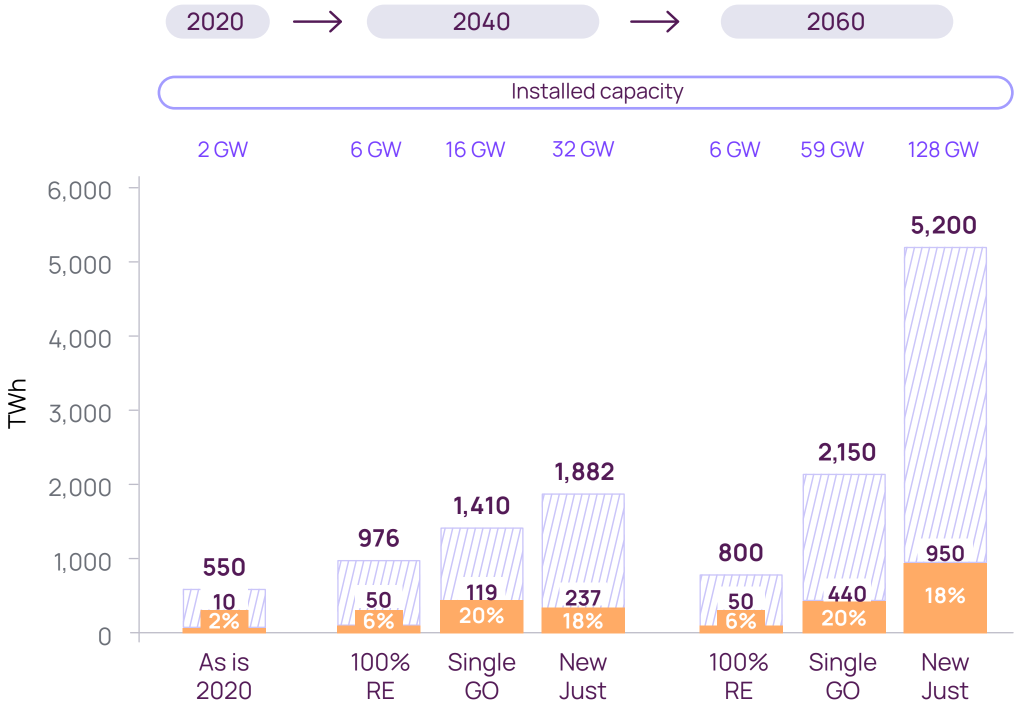
Renewable integration support: The presence of dispatchable capacity in the energy system contributes to the integration of solar and wind energy and ensures the reliability and stability of the energy system and guarantees the supply of electricity to consumers.

Multi-unit scalability: The scalability of SMR helps meet the growing demand for electricity and creates the basis for construction of energy-intensive industrial facilities with high added value.

Source: IEA, Kept analysis

Main limitations of nuclear programs include scaling up OEMs’ manufacturing capacities and nuclear finance

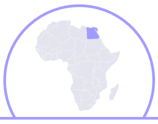
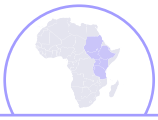
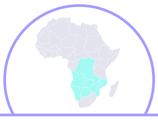
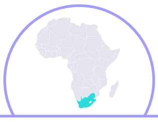
Electricity generation by nuclear power plants



● Nuclear ▨ Total generation

Nuclear generation may add up to 950 TWh to the ESA energy mix with main limitations being only OEMs’ construction capacities and finance

Distribution of new nuclear power plants by 2060 (New Just)

125 GW	SMR	Medium	Large
		Number x MW	
 **Egypt**	✕	✕	12 x 1,200
 **Eastern African Region**	160 x 55	10 x 600	30 x 1,200
 **Southern African Region**	160 x 55	10 x 600	30 x 1,200
 **South Africa**	✕	✕	8 x 1,200
	18 GW	12 GW	96 GW

SMR and medium-sized reactors are essential for the initial phase of industrialization of the EAR and SAR “landlocked countries” with limited domestic natural resources

Renewable generation may contribute up to 1,100 TWh or one-fifth to the future ESA energy mix in the New Just scenario. New Just scenario allows much higher amount of renewables than 100% RE scenario (1,100 TWh vs 600 TWh)

RES generation outlook

The modeling shows that renewables may contribute up to one-fifth or 1,100 TWh to the future ESA energy mix. As part of the initial electrification process in the region, RES generation needs to be developed together with baseload and dispatchable generation. We estimate that over 310 GW of renewable capacities, including over 81 GW of hydro and 69 GW of wind may be integrated into the power system.

The scaling-up of renewables generation is limited by two major factors: (1) limited primary resources and sites for deployment, especially valid for hydro and wind generation (2) efficient integration of intermittent energy sources. It may sound counterintuitive, but the fossil-dominated New Just scenario allows almost doubling the integration of renewable generation – 1,100 TWh compared to the 100% RE scenario focused on promoting “clean energies” only with its mere 600 TWh of renewable generation. This is primarily due to different levels of VRE generation that can be integrated into the grid - 230 GW vs 99 GW accordingly.

The modeling also shows that targeting a 100% renewables share in the ESA energy mix is technically and economically unrealistic as it is not scalable to the energy density required for full electrification of the region, though this may sound not in line with the mainstream energy planning research.

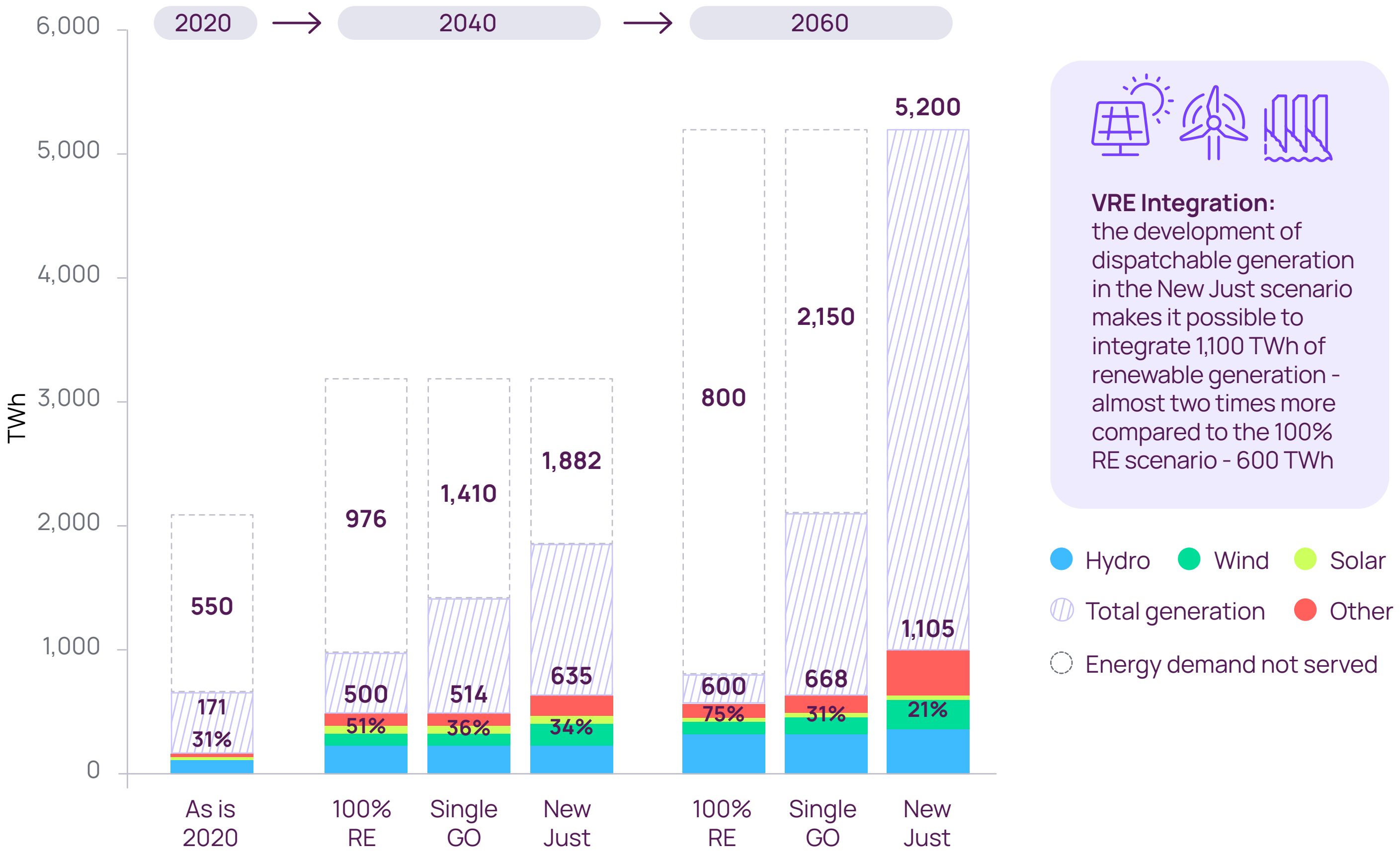
Renewables potential in ESA

IRENA’s 2021 study estimates that the technical potential for wind and solar projects in the region is 147 GW and 337 GW. The economic potential of identified sites across 335 zones is estimated at 120 and 180 GW for wind and solar. The potential estimate for other RES, such as biomass, geothermal energy, tidal power, marine current energy etc., still needs additional clarification, but is assumed to be below that for wind and solar. So, the total deployable renewable potential, besides hydro, is in the order of 1,000 TWh – far too small compared to the 5,200 TWh of economic demand in the region.

However, local renewables may play. For example, the countries located along the Great Rift Valley (Ethiopia, Kenya, DRC and Tanzania) have potential for geothermal energy. The potential of Kenya alone is about 10 GW, and that of the EAR is 16 GW. Another important resource is biomass, incl. wood, rainfed sugarcane and sorghum stalks. High theoretical capacity for the production of electricity from biomass can be noted in the DRC (more than 12 GW), Uganda and Ethiopia, as well as Angola, Egypt, Mozambique, Tanzania and Sudan. Eastern Africa has diverse potential for offshore RES, including wave power, ocean thermal energy conversion, marine floating solar power, and ocean current power.

Source: IRENA, EAPP, REGLOBAL

Electricity generation by RES power plants



VRE Integration: the development of dispatchable generation in the New Just scenario makes it possible to integrate 1,100 TWh of renewable generation - almost two times more compared to the 100% RE scenario - 600 TWh

Source: Kept Analysis

Large-scale renewables deployment in Africa is dependent on timely development of dispatchable fossil generation

Hydropower outlook

The region has rich hydro resources that are not yet fully deployed. However, even the full deployment will hardly cover one tenth of economic demand of the region by 2060.

Large hydropower potential is found in Ethiopia, the Democratic Republic of the Congo, Angola, Mozambique, Tanzania, Sudan and Zambia. At the same time, the development of hydro potential, such as the construction of large hydroelectric power plants, is a challenging task. It is important to take into account not only economic or technical aspects related to attracting investments in large-scale projects or transferring power to large power centers, but also environmental ones, because the creation of reservoirs requires flooding of land and affects the flow of the river downstream in other countries. Therefore, the decision to construct facilities under large-scale and long-term projects should be made in cooperation with the neighboring countries of the region.

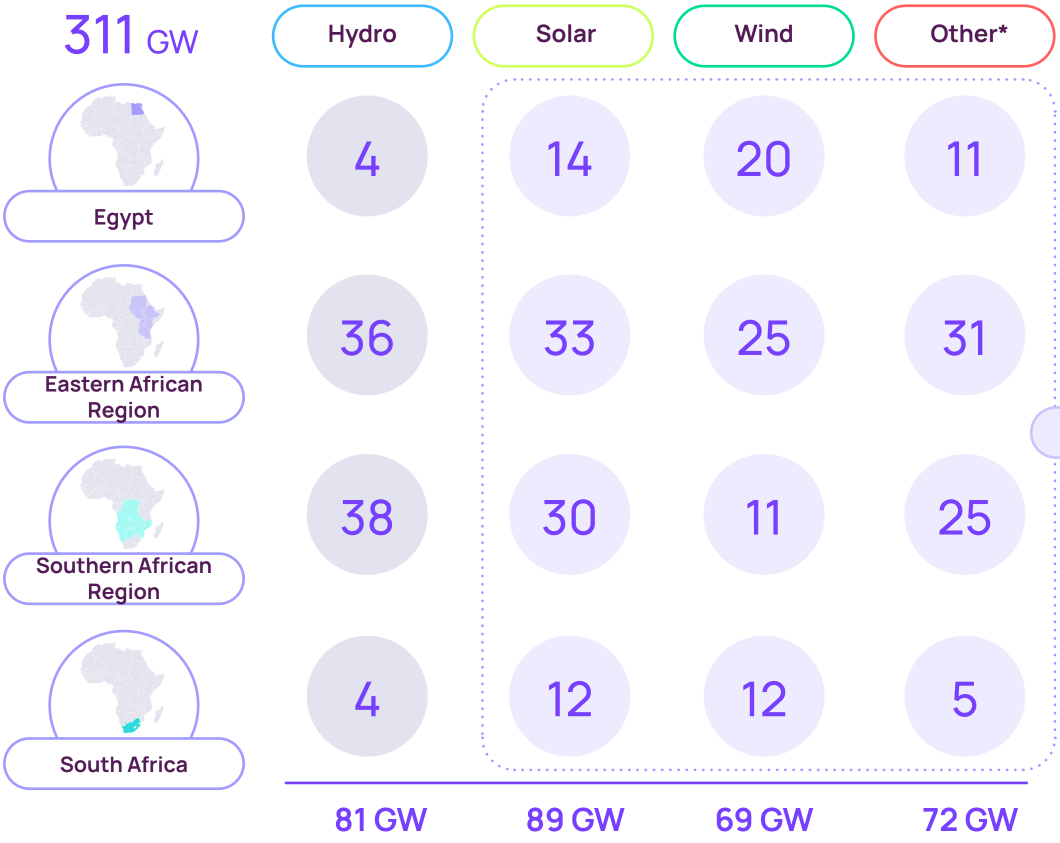
According to the master plans of the EAPP (2014) and SAPP (2017), maximum potential capacities for electricity production from new and existing hydropower technologies is 121 GW. The study assumed an increase in the capacity of hydroelectric power plants under the New Just scenario to 81 GW (construction of new power plants - 54 GW) by 2060 (see the figures below), which corresponds to 369 TWh (7% of the total generation). The main limitation of hydropower are limited hydro resources and the long lead time of construction.

The theoretical deployment of the entire potential of hydro resources - 121 GW - makes it possible to increase electricity generation to 500 TWh, which will be less than 11% of the total generation.

The seasonal characteristics of the water inflow availability (rainy and dry periods) have a direct impact on the hydrological situation of rivers and so on the availability of hydroelectric generation which changes 2-3 times during the year. So, hydro generation that is seasonally lacking has to be complemented by dispatchable generation. So, the electricity demand during dry hydrological periods can be covered by using the power reserves of thermal power plants or neighboring regions with high-capacity transmission lines.

The development of hydropower capacities, even in the context of limited potential, is important in terms of improving the performance and efficiency of the power system as a whole. The development of hydropower capacities contributes to the integration of renewable energy sources, peak load coverage, load schedule flattening, increased reliability, and the flexibility of hydroelectric power plants enables them to use their power reserves in case of emergency shutdowns of generating units at other plants of the power system.

Distribution of new RES power plants by 2060 (New Just)



311 GW	Hydro	Solar	Wind	Other*
Egypt	4	14	20	11
Eastern African Region	36	33	25	31
Southern African Region	38	30	11	25
South Africa	4	12	12	5
	81 GW	89 GW	69 GW	72 GW

* including biomass, biogas, peat, geothermal, waste-to-energy and other regional specific mostly renewable sources

VRE Integration: the development of dispatchable generation makes it possible to integrate 230 GW of RES and ensures the generation of more than 740 TWh

Source: Kept Analysis


Blyde River Canyon, South Africa

3

Climate Policy Impact

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Climate policies place an additional burden on the energy sector development in Africa

Impact of climate policies on Africa’s development

Modern ESG strategies play a pivotal role in shaping the energy sector development in Africa. A notable trend of these policies is the emphasis on exclusively green energy projects often supported by international financial institutions (IFIs), donor-funded programs, and corporate policies. While the focus on green energy is widely recognized, it poses certain challenges to the energy sector in Africa:

- **Limitation of the energy mix available to Africa**: current policies severely restrict the development of fossil and nuclear technologies by financing almost exclusively the development of renewables.
- **Insufficient system reliability**: overreliance on specific RES technologies can make the power sector vulnerable to fluctuations in weather patterns, impacting the reliability of the overall energy supply.
- **Insufficient generation to cover demand**: the transition to green energy is a gradual process, and the abandonment of conventional energy sources may leave certain regions facing energy shortages. The difference between the volume of VRE integration and the growing economic demand will hinder industrial growth and overall economic development.

Taken together, these issues lead to a lack of practical options for electrification and industrialization, increasing energy poverty and insufficient energy supply of local economies.

To solve these problems, the climate policy and ESG policies need to be adapted to recognize the importance of a diversified energy mix. For Africa, which has some of the lowest energy emissions (3% of the global total, see the figure), policymakers, IFIs, and corporations should work together to support not only green energy projects, but also to invest in development of all technologies. This comprehensive strategy ensures a sustainable energy transition consistent with environmental goals and economic development.

Emissions accounting blind spots

When discussing sustainable development for Africa, one “blind spot” aspect of emissions accounting is often ignored. This is related to the use of the so called “traditional biomass” as a substitute for lacking modern energies. While it is widely believed that increased fossil fuel use is directly correlated with higher emissions, the reality in many African countries is more complicated.

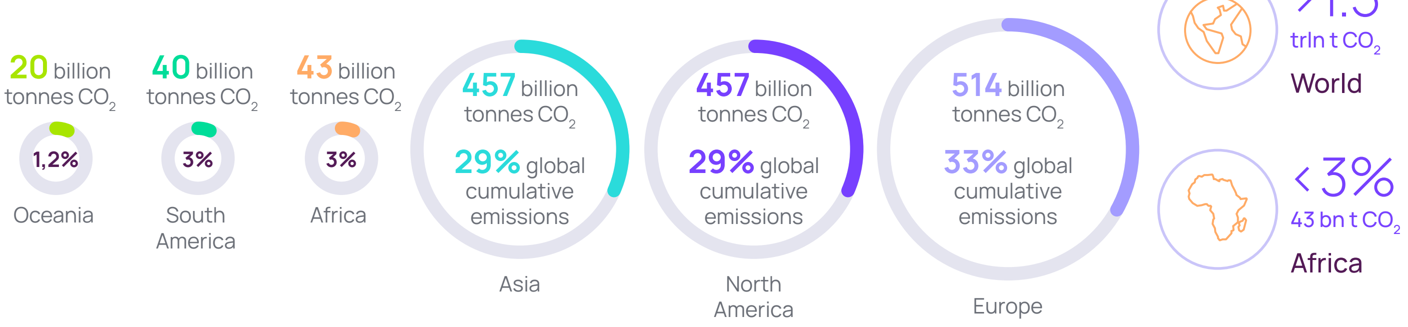
For 2020, it is estimated that more than 73% of the economic demand of the ESA region could not be met due to a lack of generation and infrastructure. This gap was filled by biomass combustion for heating and cooking purposes. This amount of charcoal and wood combustion resulted in additional emissions of 470 MM tCO_2 - 110% higher compared to emissions which would have been generated if the same amount of energy was produced by gas and coal power generation.

The use of “traditional biomass” already contributed significantly to deforestation, resulting in the annual loss of 4.4 million hectares of forests in Africa between 2015 and 2020. Currently, the continent has the highest losses in forested areas compared to any region in the world.

Traditional biomass is the preferred fuel for households due to its local availability in terms of cost and amounts needed. However, its inefficient production and utilization lead to negative impacts not only on the environment but also on the population’s health, including chronic respiratory diseases.

The significant negative impacts of biomass combustion require efforts to transition away from wood fuels to other modern forms of thermal energy and affordable electricity to meet clean cooking and home heating needs and energy technologies.

Africa’s share in global cumulative CO_2 emissions over the period from 1751 to 2017



Source: World Bank, Our World in Data, Kept analysis.

Charcoal and firewood are a major contributor to the energy sector’s “shadow emissions” in Africa

CO_2 emissions outlook

To assess the climate impact of the Eastern and Southern Africa electrification program, CO_2 emissions for the three power sector development scenarios were calculated, incl. direct emission from fuel combustion and “shadow emissions” from unsustainable burning of traditional biomass used as a substitution for the lacking access to modern energies.

The main assumption is that, as electrification and transition to centralized electricity and heat supply progresses, the use of traditional biomass for heating and cooking goes down and finally will be completely eliminated. If such transition is not managed on time, this, in contrast, will force the growing population to use even more wood and charcoal and so increase emissions.

The modeling shows that in 2020 up to 66% of emissions were “shadow emissions” related to the unsustainable use of biomass. By 2060, those cumulative emissions are likely to increase in all scenarios driven by the population growth to the level of some 1,790-1,610 MM tCO_2.

The worst performing scenario in terms of environmental harm and social wellbeing is 100% RE scenario. As the per capita electricity consumption drops from 735 to 510 kWh/year, the total amount of biomass use almost triples – due to expedited use of firewood and charcoal amid the rapid population growth. Though direct emissions drop, total emissions actually rise to 1,600 MM tCO_2, with 97% of emissions becoming “shadow emissions.”

In the Single GO scenario, emissions from the heat and electricity sector rise slightly less to 1,490 MM tCO_2, however, as more than 59% of the energy demand remains unserved, it is still impossible to avoid burning firewood and charcoal amid the rapid population growth. Biomass combustion accounts for 63% of the total (the results are shown in the figure on the right).

Approach to CO_2 emissions calculation

Electricity generation
direct emissions

+

Emissions from
biomass combustion
for household needs
("shadow emissions")

=

Total emissions

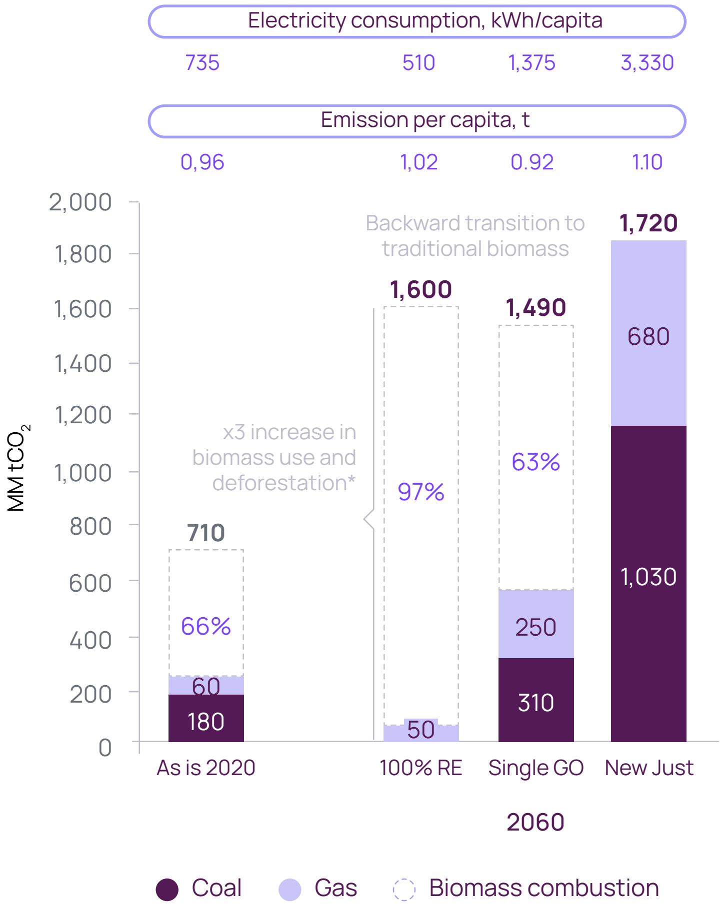
Source: World Bank, IEA, EIB, Journal of Agricultural Science and Technology, Kept analysis

In the New Just scenario where the economic demand (including the needs of not only households, but also industry, production, transport and the services sector) is fully covered by the developed electricity sector, the total emissions will be slightly higher at 1,720 MM tCO_2. At the same time, deforestation is almost completely eliminated, which has a favorable effect on the environmental situation in Eastern and Southern Africa. It is important to note, that total CO_2 emissions in New Just scenario is only 7.5% higher (1,720 vs 1,600 MMt) than in 100%RE scenario (although electricity generated is x6.5 times higher in New Just vs 100%RE scenario.

It is assumed that the real situation in the 100% RE and Single GO scenarios will be much less favorable than in the estimates made in this study as there are no complete statistical data on the use of charcoal and firewood.

The modeling also reveals that below a specific per capita consumption level – assumed to be in the range of 1,000 kWh per person – any fossil-based electrification produces a net positive effect on emissions reduction. This is explained by higher efficiency of burning fuels at modern power plants (35-55%) compared to a fireplace (5-10%).

Electricity CO_2 emissions by scenario

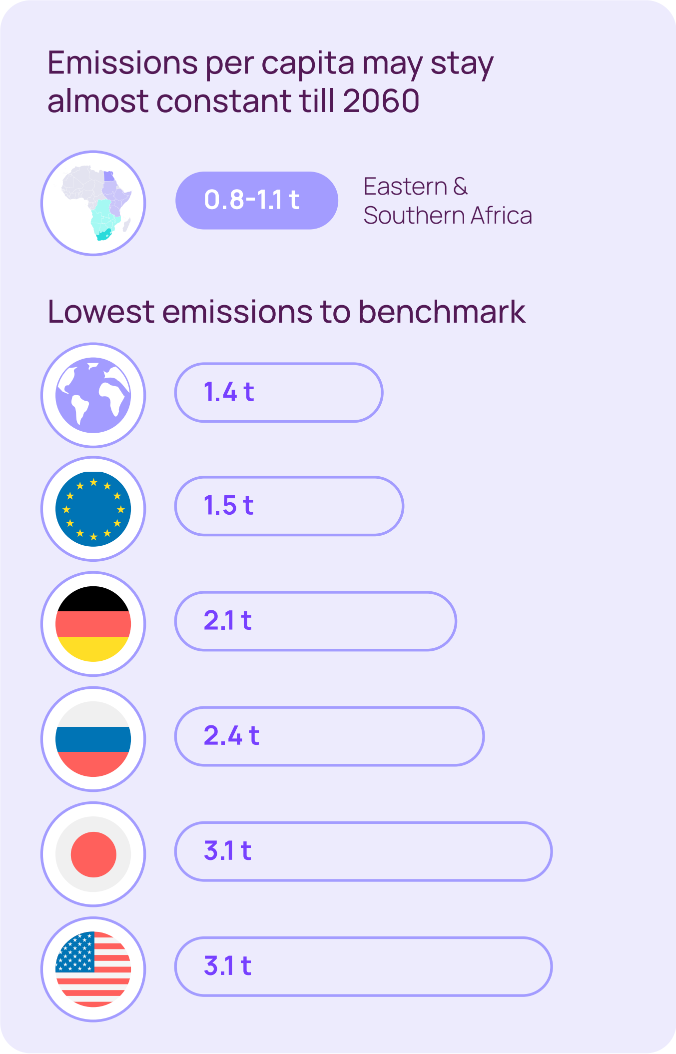


*Note: The real impact of traditional biomass use is likely to be higher due to deficiencies in statistics

Pelindaba, South Africa's nuclear plant

Even assuming a 60% fossil share in electrification, the real change in ESA's emissions will be negligible compared to business-as-usual

Electricity CO_2 emissions per capita



Then, per capita emissions in Eastern and Southern Africa forecast by 2060 were compared with per capita emissions (from the electricity sector) of developed countries and other regions (the results are shown in the figure left). Thus, per capita emissions in the ESA countries will be 0.8-1.1 tons, while in such countries as Germany, Russia, Japan and the US such emissions will amount to 2.1-3.1 tons. But it is important to note that the development of the ESA power sector that is up to 61% based on fossil fuels leads to per capita emissions remaining below the global average or, for example, the average for the EU countries.

The modeling shows that even assuming a significant fossil share in electrification, the real change in ESA emissions will be negligible compared to the current "business-as-usual" practice involving increased traditional biomass use driven by population growth. The reason is simple: burning gas and coal at a powerplant is 5 to 10 times more efficient (35-60% efficiency), compared to burning wood or charcoal in a stove or fireplace (5-10% efficiency).

Therefore, the transition to a developed power sector and access to modern energy sources (even up to 60% based on fossil fuels), electrification of economies, introduction of environmentally friendly cooking technologies are crucial to preventing the harmful effects of deforestation and environmental crises in Eastern and Southern Africa.

To allow electrification, any limits on fossil generation should be lifted below 1,000 kWh per capita

ESG policies adaptation to the African context

The energy transition in Eastern and Southern Africa could be a major boost to achievement of the 17 UN sustainable development goals.

But to enable this transition, the ESG and climate policies should be amended by international financial institutions and corporations to support not only green energy projects but also invest in development of all possible technologies, including fossil fuels and nuclear power to support significant social development and improving quality of life with no significant growth in CO_2 emissions (as in New Just Scenario).

When assessing the climate impact of new generation projects, it is important to take into account not only the changes in direct CO_2 emissions from the generating facility, but also its indirect impact on reducing biomass consumption, and, therefore, on reducing emissions from burning charcoal and firewood in low-efficiency stoves and fireplaces.

This new approach will help evaluate potential energy projects more fairly and could provide a deeper understanding of the overall feasibility of implementing a particular technology in a particular region.

In this regard, it is proposed amending current IFIs' ESG policies for financing new power generation projects in countries in the electrification phase with specific electricity consumption of less than 1,000 kWh/year per capita. No prohibitions on financing coal generation should apply until the electricity consumption reaches 1,000 kWh/capita, and for gas generation this threshold should be at 2,500 kWh/capita.

This strategy would ensure a sustainable transition to a modern power industry, in line with global climate, environmental and social development goals.

Suggested new electrification standard

"1,000 kWh for all" modern electrification standard

Building up on the idea of Modern Energy Minimum, we suggest the following implementation standard for countries passing the initial electrification phase:

1. **1,000 kWh/year** per capita as the minimal target
2. No limits on financing of fossil generation below **1,000 kWh/capita** for coal-fired PPs and **2,500 kWh/capita** for gas-fired PPs
3. **30/70% share** of domestic to commercial consumption target in power system and economy
4. **>50%** of local content in electricity costs **(Cost-to-GDP of less than 50%)**

The expected results of the new standard:

- Decrease in total emissions
- Improves the level of economic development and the quality of life
- Enables adaptation to climate change, e.g. through the provision of clean water, heating and cooling
- Supports local employment and wealth growth

In particular, this should be integrated into financing and ESG policies and KPIs for IFIs and development agencies.

Source: World Bank, Kept analysis.

Electrification and industrialization in Africa will help achieving a broad range of UN SDGs

Safeguarding the well-being of both people and the planet

The intensive development of the energy sector in general and electrification of economy in particular could be a great impetus for achievement of the 17 UN sustainable development goals (SDGs).

The construction of large infrastructure facilities, such as energy infrastructure, gives a positive boost to the development of the economy and society in the region where such a project will be implemented. The impact of the energy sector is very extensive and affects almost all aspects of the life of the population.

The industry itself provides new jobs, creates demand for a higher level of education in general and for engineering degrees in particular, facilitates the development of infrastructure and creates employment opportunities for various categories of the population: men, women and people with disabilities.

Availability of electricity and heat supply makes it possible to develop production processes with high energy intensity and value added per capital, which launches mechanisms for further development and welfare enhancement in the country. So, electrification has a huge impact, direct or indirect, on the society as a whole and on how quickly it is moving towards sustainability.

In general, from the point of view of the SDGs, any power plant construction and operation will make a significant and positive direct contribution to the achievement of the goals “Affordable and clean energy” (SDG 7), “Industry, innovation and infrastructure” (SDG 9), “Sustainable cities and communities” (SDG 11) and “Climate action” (SDG 13). The indirect impact could vary from technology to technology and is applicable to the goals “No poverty” (SDG 1), “Zero hunger” (SDG 2), “Good health and well-being” (SDG 3), “Quality education” (SDG 4), “Gender equality” (SDG 5), “Clean water and sanitation” (SDG 6), “Decent work and economic growth” (SDG 8), “Reduced inequalities” (SDG 10), “Responsible consumption and production” (SDG 12), “Life below water” SDG 14), “Life on land” (SDG 15), “Peace, justice and strong institutions” (SDG 16) and “Partnerships for the goals” (SDG 17).

Contribution of power plants to achieving SDGs

Socio-economic development

Indirect impact

Energy sector development

Direct impact

Source: IEA, IOPscience, www.globalgoals.org, Kept analysis.

No access to clean cooking is one of the most severe problems for health and social development

Goal of universal access to clean cooking

Today, about 240 million people in Southern and Eastern Africa – nearly one third of the population – still cook their meals over open fires or on basic stoves, breathing in harmful smoke released from burning coal, charcoal, firewood, agricultural and animal wastes. The usual cooking appliances found in every modern kitchen are unaffordable for most of these households.

The absence of clean cooking contributes to premature deaths. Poor indoor air quality stands as a leading cause. Overall in Africa, women and children account for 60% of early deaths related to smoke inhalation and indoor air pollution. Beyond the evident health hazards, a lack of clean cooking hinders the educational and economic prospects of many women and girls preventing them from accessing education, earning a wage, or starting a business that would offer financial independence.

The dependence on firewood and charcoal for household needs has led to a serious problem – massive deforestation. Production of firewood and charcoal leads to the annual loss of forests the size of Ireland, with the worst effects concentrated in Africa where the growing population increasingly depends on these shrinking forest resources. The dependence on firewood has led to a food crisis in certain areas where valuable fruit-bearing trees are being sacrificed for the sake of fuel, further exacerbating resource shortages.

So, the transition to clean cooking technologies is key to changing the quality of life and preserve the environment. It extends beyond the preservation of forests; it's about safeguarding livelihoods, ensuring food security, and elevating the quality of life for communities.

Electrification is key to ensuring the transition to clean cooking directly – through the use of electricity for heating and cooking, but even more so indirectly - by promoting economic development and increasing incomes to make the non-biomass solution affordable.

Production of charcoal for cooking

Cooking with traditional fuel in Africa

Aerial view of Dar es Salaam, Tanzania

4

Transition Costs

The classic least cost generation planning doesn't tell whether the electrification program is actually affordable

Re-defining the affordability lens

It is clear that capital investments will be significant for any scenario of the Energy Transition. To reach the GDP mid-income level in the ESA region by 2060, electricity generation has to increase by nine times to 5,200 TWh – to the scale comparable to five power systems of Russia. So, it is essential to focus on how to make this cost affordable.

The affordability means that countries can gradually generate enough added value within their national GDP to justify new capital investments in electrification. Therefore, energy planning should be focused on the possibility of receiving a return on investment. It means that generation of higher revenues should enable Africans to earn enough through industrialization to pay back investments.

GDP is one of the main metrics of countries' economic development. The electricity industry represents a pure cost to the economy (electricity is an intermediary product for the economy; it is also mostly consumed domestically in contrast to the oil & gas industry where exports play a significant role), but these expenses can represent a significantly different cost to GDP at the same level of the nominal cost, depending on the share of the cost remaining within the national economy as "Internal national costs". So, the affordability task within energy planning is not the same task as finding nominally the lowest cost generation mix.

Limitations of the classic least cost planning

The review of various electrification plans prepared by international institutions and utilities over the last years shows that in most cases the least cost energy approach is chosen as the main approach when developing energy plans. The target function of this approach is to minimize the cost of electricity generated over the planning horizon.

Similarly to the least cost generation planning, the Leveraged Cost of Electricity (LCOE) metric is often used for initial planning and ranking of power generation options. According to LAZARD, IRENA and other organizations' LCOE studies, VRE (wind and solar) outperform widely fossils fuels and nuclear.

The use of these least cost metrics for choosing the preferred energy mix may be quite misleading, even putting aside the issue of comparing the cost of variable and firm capacities. This approach doesn't tell much about the real affordability of large electrification programs for a particular country as it is applied in isolation from macroeconomic planning which takes into account the total value to the economy that investments bring.

Taking into account macroeconomic factors, the cost of electricity generated can represent a very different value multiplier for the economy as well as the cost to GDP depending on the use of local labor, financial, energy, production resources, which finally is critical for understanding the affordability of an electrification program.

Existing and proposed integrated energy planning concepts

Cost to GDP - new concept of energy planning

Least cost generation planning + Economic and GDP planning = Least cost to GDP energy planning

LCOE model
- CAPEX and OPEX to generate electricity (by generation type)
- generation by plants over their life cycle

Levelized cost

Input-output model
- investment in the economy
- government expenditures
- end use
- net export (export-import)

Contribution to GDP

Cost-to-GDP model
- Levelized cost
- Deduction of the localization share (technology, fuel, personnel, services, cost of financing)

Cost to GDP (RealLCOE)

New integral electricity cost metric "RealLCOE": cost share of imports within LCOE comprising imported fuel, equipment and services, adversely impacting GDP

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Changing the planning focus on Cost to GDP gives a very different power mix compared to classic least cost studies

Cost to GDP (RealLCOE) as an alternative concept of energy planning

As the next step in the energy planning theory and as an extension to the classic least cost analysis, we suggest accounting for direct macroeconomic effects of deploying particular generation technologies on particular national markets.

To do so, in this study we proposed a new energy planning concept called Cost to GDP. The method determines the cost share of imports within LCOE comprising imported fuel, equipment and services, adversely impacting GDP – called “RealLCOE.”

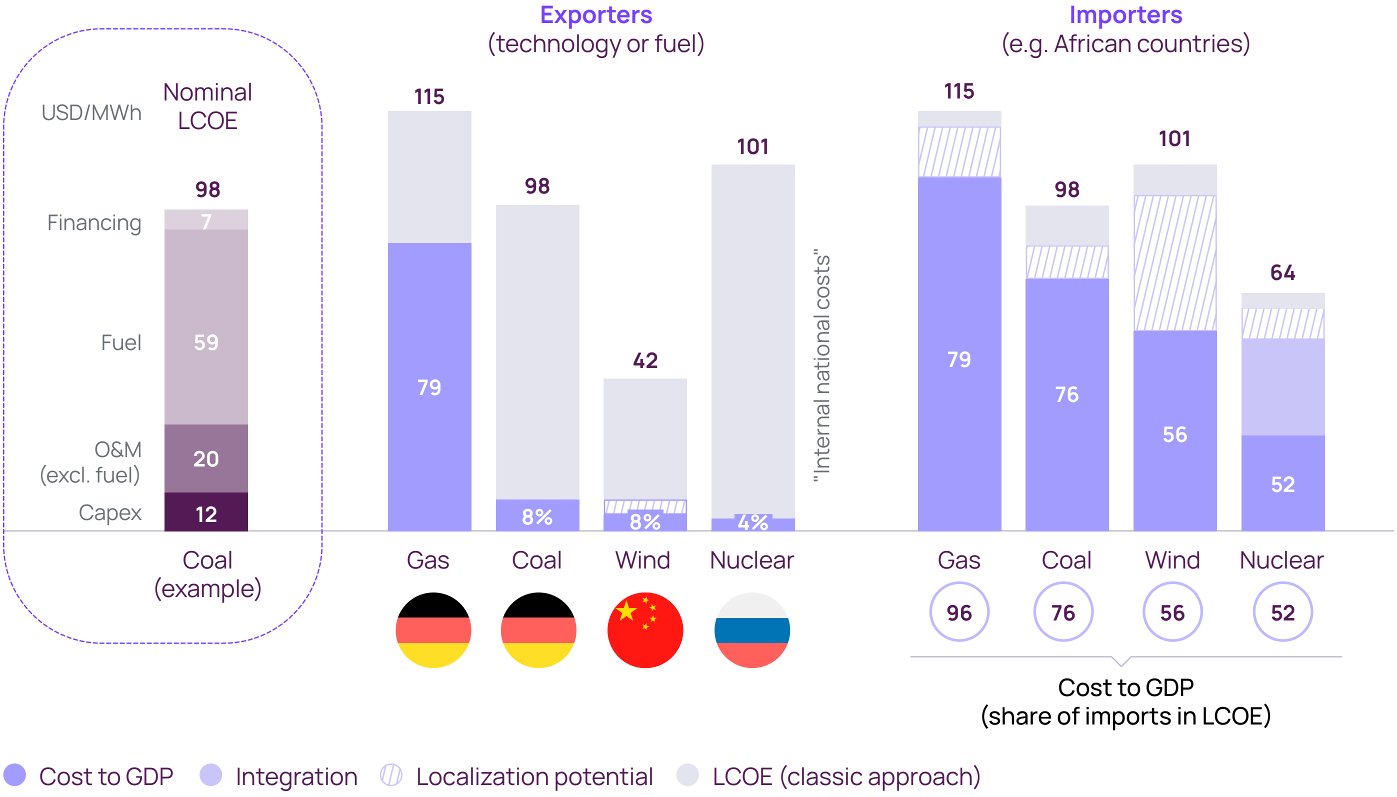
The RealLCOE approach makes it possible to choose the most affordable option to GDP by taking into account not only the absolute LCOE value, but rather the actual cost to GDP for a particular electricity generation technology in the analyzed market environment, which helps get the highest multiplicator for local economic development.

The figure below illustrates how the change in optimization criteria from least cost to least cost to GDP impacts the merit order of preferred generation technologies for a range of exporting and importing countries taken as an example.

For example, in Germany the nominal costs for a new lignite power plant may be comparable to a CCGT - 98 USD/MWh vs. 115 USD/MWh, however in “real terms” coal generation is times cheaper compared to gas - 8 USD/MWh vs. 79 USD/MWh as coal uses almost exclusively local resources of fuel, technology, O&M and financing. Using the same logic, it may seem cheaper for Russia to buy a German gas turbine, but measured by the cost to GDP impact it is more efficient to build a new nuclear power plant based on the Russian design and components (nuclear LCOE is 101 USD/MWh and RealLCOE is 4 USD/MWh for the domestic market). China outperforms everybody by localizing supply chains for renewables, so wind generation is very affordable in China even at high VRE integration costs (as high as additional 1.0-2.0 times VRE build costs) or a 50% curtailment.

Unfortunately, in developing markets in Africa the “real cost” of electricity rises significantly compared to fuel and technology exporters (even if the nominal LCOE value remains the same) as they rely almost completely on the import of fuel, technology, O&M and financing. This makes the local economy uncompetitive in the international market, unless the share of the local content of energy production significantly increases.

Cost of electricity based on LCOE and RealLCOE by type of economy



Source: IAEA, NEA, Lazard, IRENA, NREL, EIU Data, Kept analysis

Electricity Costs to GPD may be 2-5 times lower than System LCOE if the local content is managed properly

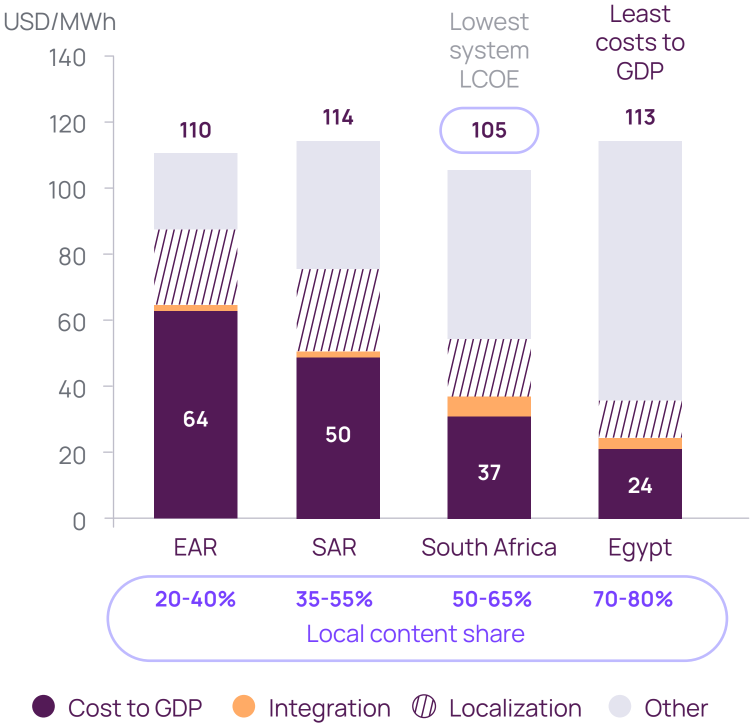
Electricity system Cost to GDP

The figure on the right shows the estimated system cost of electricity supply as well as the local content share for the projected electricity mix for regions of Africa under the New Just scenario by 2060 using the LCOE and RealLCOE (or "Cost to GDP") methodologies (Structure of generation by fuel type – refer to the previous chapter).

Nominally, the System LCOE value is within a narrow range from 105 USD/MWh for South Africa to 114 USD/MWh for SAR with a tiny difference of some 5–10%. Thus, given the long term uncertainty factors, the competitiveness of regions can be assessed as equal. In contrast, RealLCOE demonstrates up to 2-5-fold differences between the upper and lower values of the range for various scenarios. So, the system cost measure on the Cost to GDP metric is in the rang from 24 USD/MWh for Egypt to 64 USD/MWh for EAR. So, it becomes obvious that a lower cost to the economy correlates with a higher local content share.

Thus, the selection of the optimal mix of technologies should be made considering the opportunities to reduce Cost to GDP under the conditions corresponding to the specifics of each individual region and the potential of economies to develop local supply chains.

System cost by region by 2060 (New Just)



(Structure of generation by fuel type – refer to the previous chapter).

Classic least cost planning

105-114
USD/MWh
System LCOE

Affordability focused planning

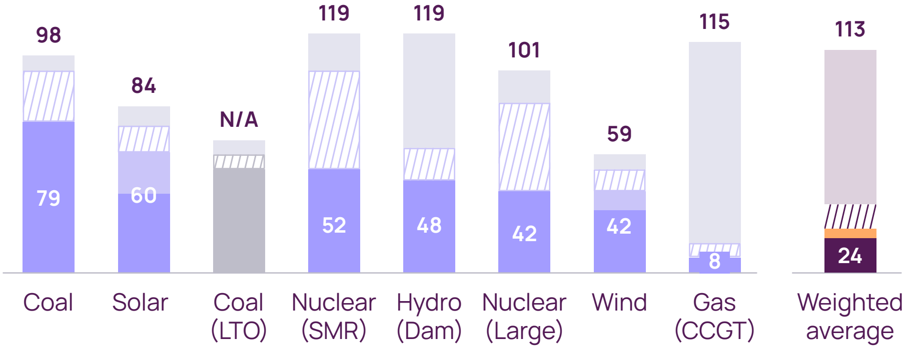
24-64
USD/MWh
Costs to GDP

Skilled Machinery Operators Working at a Factory in Africa

Cost-to-GPD merit order differs by region depending on availability of local fuels and supply chains

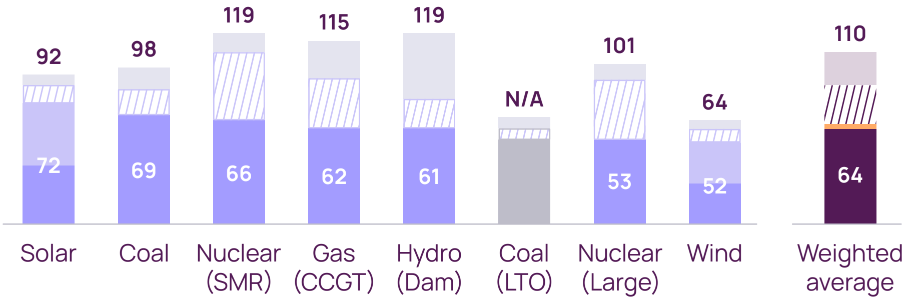
RealLCOE by technology and region (New Just)

Egypt



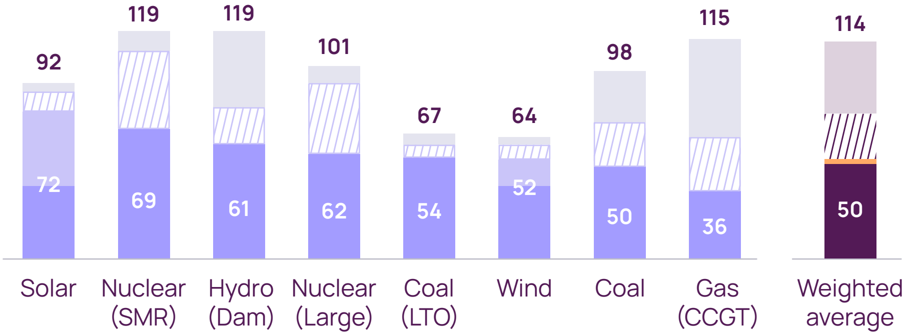
Eastern African Region

- Burundi
- Djibouti
- Ethiopia
- Kenya
- Rwanda
- South Sudan
- Sudan
- Uganda
- Tanzania

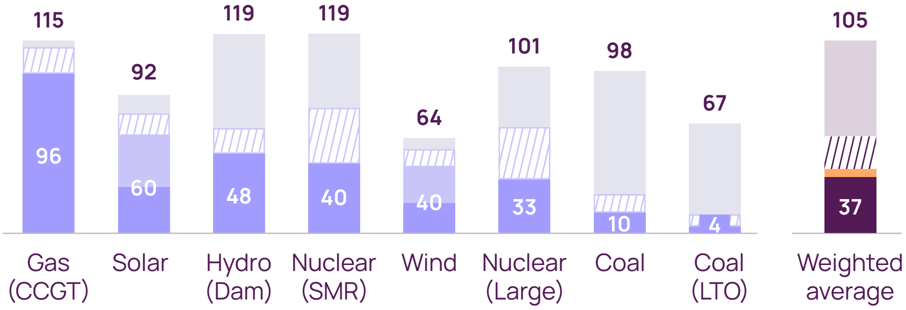


South African Region

- Angola
- Botswana
- DRC
- Eswatini
- Lesotho
- Malawi
- Mozambique
- Namibia
- Zambia
- Zimbabwe



The Republic of South Africa



● Cost to GDP ● Integration ▨ Localization potential ● Nominal

Source: IAEA, NEA, Lazard, IRENA, NREL, EIU Data, Kept analysis

Egypt and South Africa are the two most competitive regions compared on the Cost to GPD basis

System costs by region

Egypt: the most cost competitive ESA region. The system electricity cost to GDP by 2060 is projected at 24-35 USD/MWh and system LCOE is 113 USD/MWh for the New Just scenario. The cheapest generation technologies are: gas-fired (CCGT), wind and nuclear generation (RealLCOE is 8 USD/MWh, 42 USD/MWh and 42 USD/MWh respectively). System LCOE does not differ significantly in various scenarios, but the Cost to GDP value in the New Just scenario is 20% lower than in the 100% RE scenario.

	New Just	Single Go
System LCOE	113 USD/MWh	114 USD/MWh
Cost to GDP (RealLCOE):		
Worst case	35 USD/MWh	35 USD/MWh
Best case	24 USD/MWh	24 USD/MWh

EAR: the region with the highest electricity costs across ESA regions. The system electricity cost to GDP by 2060 is projected at 64-87 USD/MWh and system LCOE is 110 USD/MWh for the New Just scenario. The cheapest generation technologies are: wind, nuclear and hydro (RealLCOE is 52 USD/MWh, 53 USD/MWh and 61 USD/MWh respectively, considering that only few coal plants exist and so are available for LTO). System LCOE differs for each scenario, with the lowest value being in the New Just scenario. In terms of the Cost to GDP value, the scenarios do not differ significantly.

System LCOE	110 USD/MWh
Cost to GDP (RealLCOE):	
Worst case	87 USD/MWh
Best case	64 USD/MWh

SAR: The system electricity cost to GDP by 2060 is projected at 50-75 USD/MWh and system LCOE is 114 USD/MWh for the New Just scenario. The cheapest generation technologies are: gas, coal and wind (RealLCOE is 36 USD/MWh, 50 USD/MWh and 52 USD/MWh respectively). **System LCOE differs for each scenario, with closer value in the New Just and Single GO scenarios, but the lowest Cost to GDP value is in the New Just scenario (22% lower than in the 100% RE scenario)**.

System LCOE	114 USD/MWh
Cost to GDP (RealLCOE):	
Worst case	75 USD/MWh
Best case	50 USD/MWh

South Africa: The system electricity cost to GDP by 2060 is projected at 37-54 USD/MWh and system LCOE is 105 USD/MWh for the New Just scenario. The cheapest generation technologies are: coal LTO, coal and nuclear (RealLCOE is 4 USD/MWh, 10 USD/MWh and 33 USD/MWh respectively). **System LCOE and Cost to GDP differ for each scenario, with the lowest values being in the Single GO scenario**. The South Africa case has its own specifics and is discussed separately below.

System LCOE	105 USD/MWh	100 USD/MWh
Cost to GDP (RealLCOE):		
Worst case	54 USD/MWh	39 USD/MWh
Best case	37 USD/MWh	25 USD/MWh

Methodological note: For simplicity reasons and to more clearly articulate impact of local content on affordability the absolute value of LCOE by technology assumed to be equal across all four regions in this study

Rehabilitation of the coal generation fleet is the key to the freedom of choice for the SA future energy strategy

Future of coal in South Africa

Load shedding problem and its causes

South Africa has been experiencing a long-lasting energy crisis with regular load shedding since 2007, which is diminishing the quality of life and hindering economic development of the country. We estimate that up to 7% of electricity was not supplied as on 2020. The major reason for load shedding is the worsening availability of coal power plants (50-60% compared to design values of 85%) caused by underinvestment and low O&M quality. In order to restore the adequacy of the power system, the local utility - Eskom - initiated the Reliability Maintenance Recovery Program and the Generation Recovery Program. However, these programs in their current form do not produce the desired results.

JET IP program risks

As a remedy for the load shedding problem, the initiative group of C5* western economies offered the USD 8.5 bn Just Energy Transition Investment Plan to the government of SA. According to the plan, large coal-fired power plants in South Africa are to be decommissioned over the next three decades, except for the two newest plants Medupi and Kusile and one unit of the older Majuba plant which remain operational, and replaced by renewables, supported by batteries and few gas generation facilities.

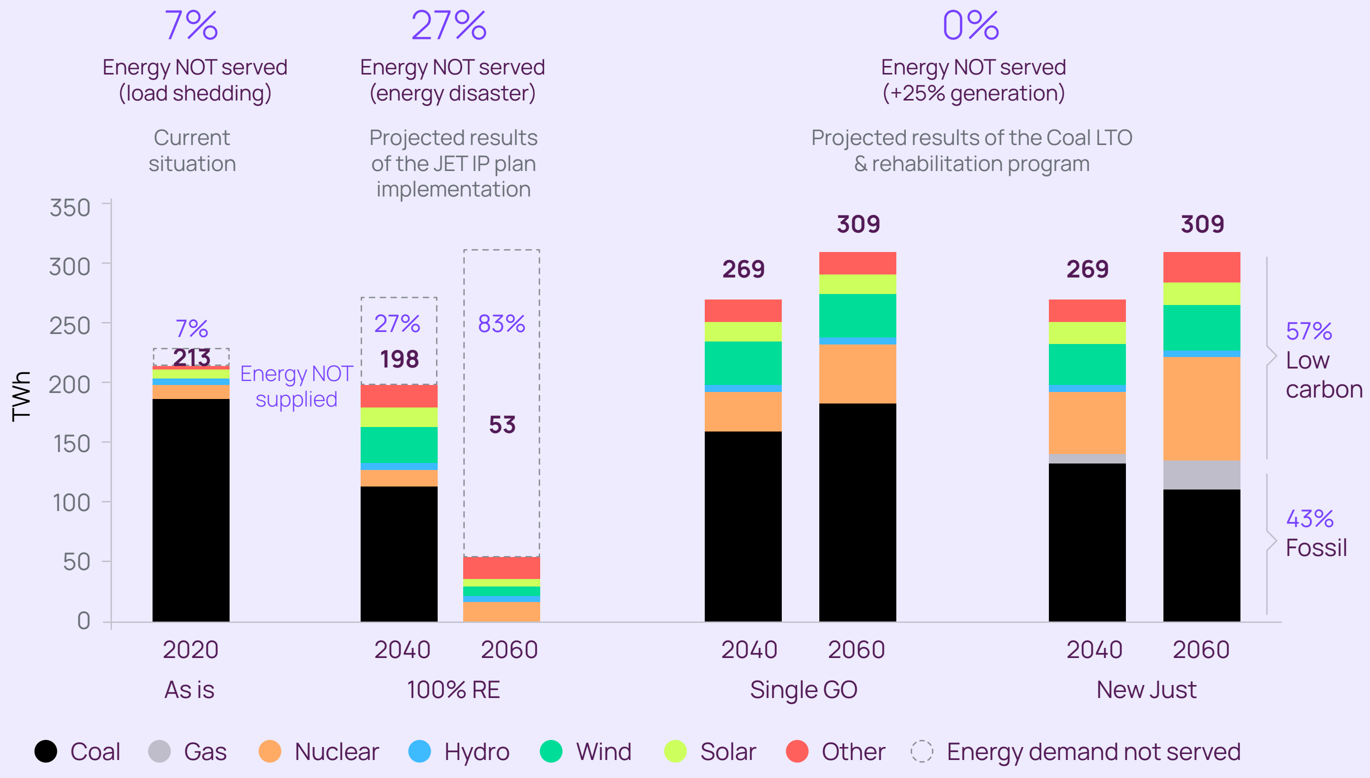
Our energy modeling shows that as a result of JET IP actions, the amount of non-supplied energy increases from 7% in 2020 to 27% and 83% by 2040 and 2060 (see the 100% RE scenario below). This means a serious deterioration of the existing situation associated with extended load shedding and blackouts in South Africa.

Coal LTO as an alternative to secure supply

Another more cost-efficient option for eliminating load shedding may be the Long Term Operation (LTO) of the existing coal fleet. The LTO program may help prolong the service life of coal-fired power plants by upgrading equipment and technical retrofitting to increase its availability and flexibility within 2-3 years (see the Single GO scenario below).

South Africa has its own largest reserves of thermal coal, which allows it to generate electricity at a lower cost. Rehabilitation of the coal generation fleet now is the key to the freedom of choice for the future energy strategy in South Africa. Indeed, the rehabilitation of coal generation is a way to save dispatchable generation, integrate a larger amount of renewable generation into the power system without compromising the reliability of power supply and have a time allowance for construction of nuclear generation facilities.

Electricity generation outlook by scenario in SA



Source: JET IP, Eskom report 2022, Kept analysis

Coal LTO may provide a timely solution to end load shedding and secure dispatchable capacities in South Africa

Programs aimed at rehabilitating and flexibilizing coal power plants are successfully implemented in Germany, China, Russia and Poland. As an example, Russia successfully solves similar problems of equipment deterioration by implementing the "Capacity Supply Agreement" program. The CSA allows creating new generation facilities or modernizing existing ones by providing a fixed capacity payment for implementing utilities over 10-15 years of the program.

Coal and cost competitiveness of the economy

The energy modeling shows that across four ESA regions South Africa is in a unique position in terms of two aspects: firstly, it can supply all required energy based on national resources within the existing international climate policy framework; secondly, it may become one of the most cost competitive markets in terms of cost to GDP being as low as 25 USD/MWh (see the Single GO scenario below).

The achievement of such low Cost to GDP values is possible due to the combination of the availability of local fuel, labor and other resources and the existence of a large coal-fired generation fleet. We project that under the Single GO scenario the share of low carbon sources may increase from current 13% to 42%.

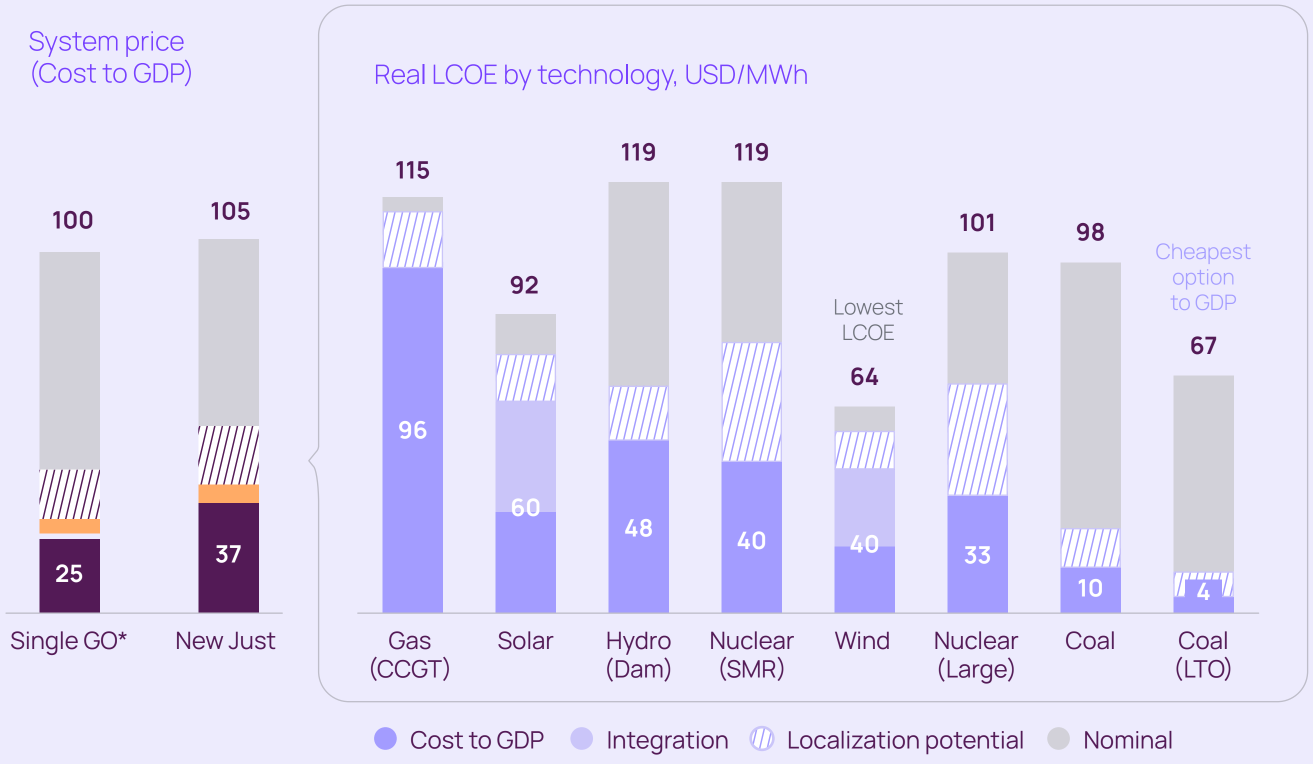
It may sound counterintuitive, but rehabilitation and life extension of existing coal-fired power generation facilities will be the key to the progress towards a lower carbon future.

The cheapest options in terms of the Cost to GDP value are Coal (LTO), Coal (new) and Nuclear (Large power plants) with RealLCOE of 4 USD/MWh, 10 USD/MWh and 33 USD/MWh respectively.

It should be noted that in the case of South Africa, System Cost to GDP is growing as you move from the Single GO scenario to the New Just scenario. This is mainly due to the introduction of more expensive solar and gas-based (CCGT) generation technologies having the highest Cost to GDP value for this region.

This shows that in South Africa the use of imported natural gas may be more efficient in the real sector of the economy compared to the power industry and may stimulate development of industries and production facilities (for example, the chemical industry, production of fertilizers and mixed fuels, etc.).

South Africa: Cost to GDP and RealLCOE by technology



Source: IAEA, NEA, Lazard, IRENA, NREL, EIU Data, Kept analysis

*Cheapest option in terms of Cost-to-GDP

Development of local supply chains is key to making the energy transition affordable

Local supply chains and affordability

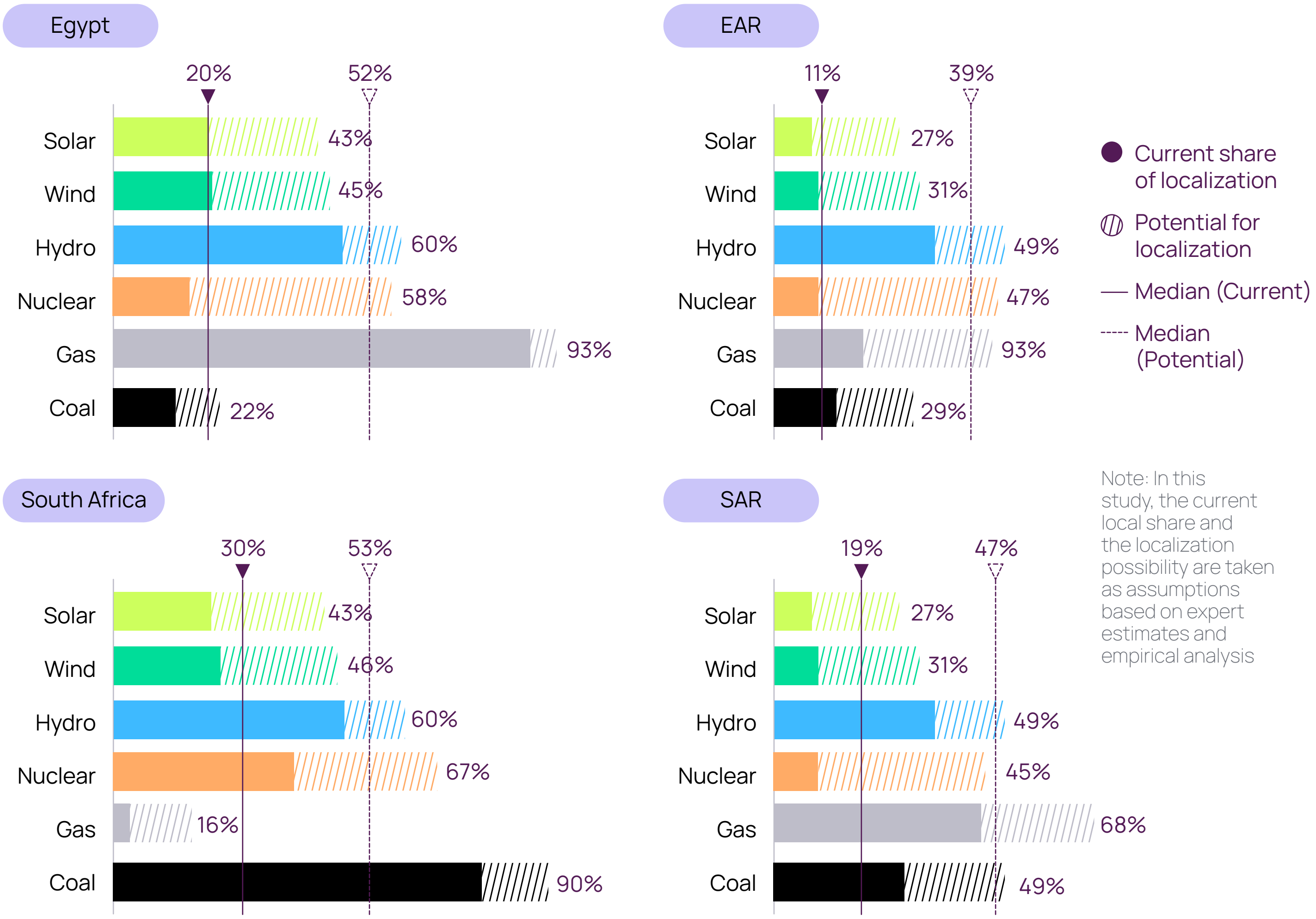
As part of our work, we analyzed four ESA regions and empirically determined the numerical value of the localization possibility by type of technology and by region (see the figure below). The localization possibility value is expressed in USD/MWh and determined by experts as the possibility of reducing the import component for each of the main cost elements forming LCOE (capital expenditures, operational expenditures (excl. fuel costs), fuel costs, cost of financing) with the help of existing or developing internal capabilities of the African regions under consideration.

The results of the analysis show that the greatest localization potential is usually formed for fossil generation – up to 90-93% in countries with a rich local resource base for coal and gas and 58-67% for nuclear generation, assuming development of the local construction industry, raw material supply and skilled workforce. Wind and solar have the lowest local content share of 27-46% due to a high share of the imported technology cost and a low share of local skilled labor in the operation phase.

The estimate of localization limits is essential for estimation of RealLCOE for a particular technology and region. The RealLCOE value may range from 7% to 84% of the nominal LCOE value, influenced by the share of costs for imported financial resources, raw and other materials, technologies, fuel and human resources.

Thus, technologies that have the most developed local supply chains (now and in the future) of raw and other materials, equipment and components, design, construction and installation, commissioning services, as well as technologies that can be operated and serviced by qualified local personnel and there are specialized secondary and higher education programs and professional retraining programs in this region will have the lowest Cost to GDP value.

Current and future localization level by type of technology and region



Note: In this study, the current local share and the localization possibility are taken as assumptions based on expert estimates and empirical analysis

Source: Statista, BP, EIA, UN, AEP, African Energy, African local statistics agencies, Kept analysis

Cairo aerial View and Nile River in Egypt

5

Just Transition Approach

International cooperation is required to make the ESA energy transition happen

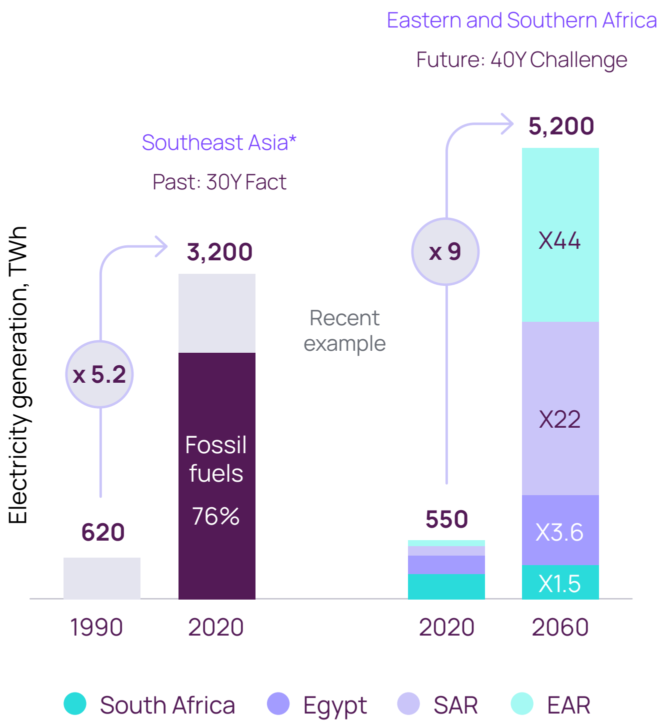
International experience of transition

The transition to the modern energy system in Eastern and Southern Africa will be, without any doubt, a challenging but manageable task. The development of a power system with cumulative capacity of some 1,100 GW – i.e. the size of five power systems of Russia – along with an in-depth transformation of national economies and societies within a period of just under 40 years may sound too ambitious, however there is a number of good examples of regions in the world that have already passed this rather difficult and complex way.

One good example of a similar scale is Southeast Asia. The electrification and industrialization process here continued for about 30 years. During this period, power generation increased from 620 TWh to more than 3,200 TWh - by more than 5 times. The development of the energy sector here was based on the use of fossil resources such as coal and gas located in this region. This allowed the development of energy intensive industries requiring high process temperatures, such as the metallurgical, machine-building, petrochemical industry, etc., which ensured a leap in the development of the economy.

Looking at this good example, we believe that the energy transition in the countries of Eastern and Southern Africa is quite manageable in 40 years. However, the currently developed programs for the implementation of the energy transition need to be adjusted taking into account specifics of the energy sectors of African regions.

Energy transition outlook



* Non-OECD Asia (excluding China)

“5Just” concept

To enable the energy transition and to meet the electrification and industrialization goals of the ESA countries, we offer an approach called the “5Just” concept. This approach is based on the following principles:

Just energy planning: “Plan to scale” considering the future market size and resource scalability. When selecting solutions for the development of energy systems at the stage of electrification and industrialization of the country, the scalability of solutions should be taken into account. All available energy sources should be used to make the transition happen.

Just technology access: All energy sources including fossil, nuclear and renewables are needed to cover demand, there should be no discrimination in favor of specific technologies. The choice of sources and technology used for each country or region may be individual and should take into account the specifics of the country in question.

Just climate & ESG policies: Give the green light for primary electrification: no limits to apply to fossil generation below 1,000 kWh per capita for coal and 2,500 kWh per capita for gas plants. This approach gives countries a chance to develop their economies before decarbonizing them.

Just financing policies: To make the transition happen, it is critically important to change the approach to financing fossil and nuclear generation. Financing policies of IFIs should be amended to include fossil and nuclear projects (not only renewable energy sources) in primary electrification plans of African countries.

Just negotiations of the parties: Governments, businesses and the society should not be shy to speak up about the real transition agenda and its specifics in Africa in international energy and climate policy negotiations. This is required to exercise the just and equitable right to use all available local energy sources to make energy poverty become history as soon as possible.

Conclusion

Currently, the energy sector in a number of countries on the African continent is at the beginning of a transformation from small, fragmented power systems with a low technological development base to more complex, centralized systems in order to make the transition to full electrification of the economy.

This transition is taking place in the unique context of global climate and socio-economic challenges. On the one hand, a complex demographic situation drives electricity demand growth. On the other hand, the global climate agenda has had a significant impact on energy planning on the African continent for several years, limiting the projects for which funding is allocated to almost exclusively renewable energy facilities. However, in the last year or two there has been a growing number of opinions and publications that reject such an unambiguous positive role of renewable energy sources in energy systems, and suggest reconsidering the current restrictions on conventional and nuclear generation projects, especially in those countries where specific electricity consumption per capita is close to or less than 1,000 kWh/person/year. One objective of this study is to help you understand the various plans, concepts, and approaches to energy planning in Eastern and Southern Africa. By doing so, you can form your own perspective on the issues raised by the African community.

Kept team has analyzed existing energy planning plans and approaches in Eastern and Southern Africa and developed its own concept the 'New Just Energy Transition' based on the principles of human-centricity, technology neutrality, and comprehensive assessment of the socio-economic, climatic, and environmental impacts of the implementation of specific projects in the electricity sector. We would especially like to note that this paper introduces for the first time the new Cost to GDP concept developed by Kept experts, which allows for a multi-factor technology assessment and selection of the most affordable and relevant technologies to develop local supply chains and strengthen the economies of those African countries that are just beginning their primary electrification journey.


Cape Town, South Africa

1

Market scale

The Eastern and Southern African region represents the world's largest untapped energy market. To achieve the GDP levels of middle-income countries, with per capita income of over USD10,000, power generation from energy systems must increase nine-fold by 2060, reaching 5,200 TWh. This is equivalent to the power generation of five Russian power systems. Such scale undoubtedly represent a huge technical challenge, but also creates opportunities for significant investment projects in the energy sector and infrastructure construction in the region.

2

Transition pathways

This scale of transformation is only possible by combining all available energy sources – coal, gas, nuclear and renewables. In the New Just scenario meeting the economic demand, about 60% of electricity will be generated by coal- and gas-fired power plants, while the remaining 40% will be almost equally distributed between nuclear power plants and renewable energy sources. The fossil generation may be pre-designed to be capable to run on hydrogen or/and use biomass co-firing in the future. So as soon as international technologies and supply chains are mature – as it is expected by some experts around mid-2040 to mid-2050 - these plants can be converted to low carbon fuels without a risk to become stranded assets. Thus, the African energy market has an extremely high potential for conventional and nuclear power, not only for renewable energy technology providers.

3

Role of energy resources

Significant development of gas and coal infrastructure is required to make the transition happen and meet the needs of the electricity sector. Nuclear power will play a crucial role in stabilizing the gas balance and utilizing fossil resources. Continental countries with low-capacity power systems and weak connections will benefit greatly from SMR technologies. Although renewable energy sources (RES) can generate up to 1,100 TWh, which is one-fifth of the energy mix, achieving 100% RES in the region's energy mix is technically and economically unfeasible. Thus, conventional and nuclear generation will play a significant role in developing power systems, creating the basis for integrating RES and promoting a balanced distribution of energy resources in the trade balance of countries producing fossil fuels.

4

Climate impact

Developing the energy sector using a combination of energy sources and achieving the 60% share of fossil fuels will not change emissions compared to "business as usual" approach. Electrification will decrease reliance on traditional biomass, eliminate household burning of firewood and charcoal, reduce household emissions, and prevent deforestation. In this regard, it is proposed to amend the current ESG policy of international financial institutions to finance new electricity generation projects in countries with specific electricity consumption of less than 1,000 kWh/year per capita for coal-fired power plants and 2,500 kWh/person for gas-fired power plants.

5

Cost of transition

To increase the availability of electricity for consumers, it is necessary to reduce the cost to GDP and develop local supply chains for technology, labor, financing and fuel. With a comprehensive approach to electrification that takes into account the potential of technologies to be localized in a particular country, the cost to GDP can be reduced to USD24–64/MWh, which is 2–5 times lower than the levelized cost of electricity. Suppliers of technologies where a high share of localization is possible should emphasize this advantage and position projects with their participation not only as an important contribution to the evolution of the electricity sector in African countries, but also as a significant impetus for the socio-economic development of the region.

6

Feasibility of energy transition

The electrification and energy transition program facing African countries is quite complex but feasible, as confirmed by similar examples in global practice (South East Asia, Middle East countries). As part of this study, the Kept team has proposed the concept of international cooperation 'Five Just Energy Transition Principles': ensuring just energy planning, technology access, ESG and financing policies, as well as equal rights to have a voice in the negotiations on climate and technology neutrality in the energy sector.

Kept is confident that this independent study will help in the interaction between our countries as part of future energy projects on the African continent. The team will continue to deepen its expertise both in African countries and in other regions of the world.

Acronyms and abbreviations

AEP	Africa Energy Portal
BRICS	The intergovernmental organization comprising Brazil, Russia, India, China, South Africa, UAE, Saudi Arabia, Iran, Egypt and Ethiopia
CAGR	Compound annual growth rate
CCGT	Combined cycle gas technology
CO_2	Carbon dioxide
CSA	Capacity supply agreement
DRC	Democratic Republic of the Congo
EAPP	Eastern African Power Pool
EAR	Eastern African Region
EIA	Energy Information Administration
ESA	Eastern and Southern Africa
ESG	Environment Social Governance
GDP	Gross domestic product
GW	Gigawatt
IEA	International Energy Agency
IFI	International Financial Institutes
IRENA	International Renewable Energy Agency
JET IP	Just Energy Transition Investment Plan
kWh	Kilowatt-hour
kWh/a	Kilowatt-hour/annum
LCOE	Levelized Cost of Electricity
LPG	Liquefied petroleum gas
LTO	Long-term operation
NPP	Nuclear power plant
OECD	Organization for Economic Co-operation and Development
OEM	Original equipment manufacturer
PP	Power plant
RES	Renewable energy sources
Real LCOE	Cost share of imports within LCOE comprising imported fuel, equipment and services, adversely impacting domestic GDP
SAPP	Southern African Power Pool
SAR	Southern African Region
SME	Small and medium-sized enterprises
SMR	Small modular reactor
TA	Technical assistance
TWh	Terawatt-hour
UK	The United Kingdom
USD	United States dollar
VRE	Variable renewable energy sources

Annexes

Economic demand and electricity consumption outlook

Economic demand outlook, TWh (overnight consumption required to reach mid-income economy level)

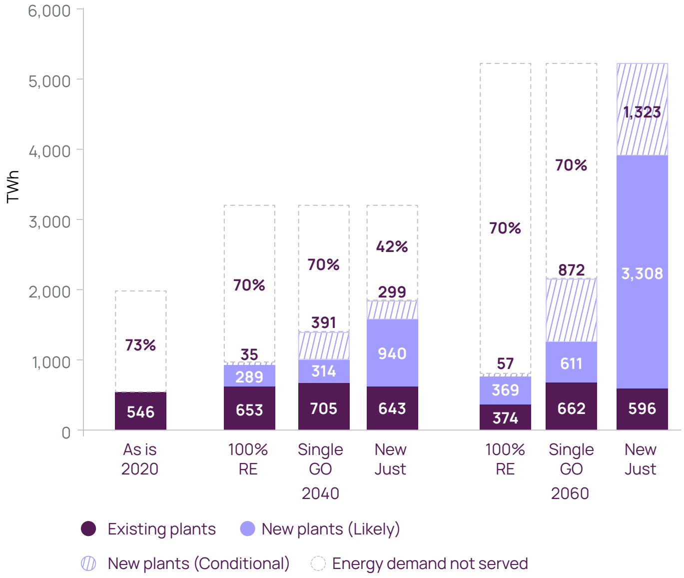
	2020	2025	2030	2035	2040	2045	2050	2055	2060
Angola	73.5	85.7	98.8	112.9	127.8	159.6	211.7	258.8	298.0
Botswana	5.6	6.1	7.7	9.5	11.0	12.2	12.9	13.6	14.1
Burundi	26.9	30.7	34.8	39.2	43.8	48.6	53.3	57.8	62.1
Democratic Republic of the Congo	204.3	240.0	280.7	325.7	374.0	425.2	478.5	533.3	667.2
Djibouti	2.4	2.6	2.7	2.9	3.5	4.3	4.9	5.4	5.6
Egypt	236.4	255.8	337.7	412.9	474.5	528.1	564.8	601.3	630.2
Ethiopia	257.8	292.5	328.5	364.6	400.5	436.7	472.6	506.4	607.2
Eswatini	2.6	2.7	2.9	3.7	4.6	5.2	5.8	6.1	6.4
Kenya	114.4	126.1	138.8	151.8	164.5	176.3	189.9	250.5	296.4
Lesotho	5.0	5.2	5.5	5.8	6.0	6.9	8.5	9.6	10.3
Malawi	42.6	48.5	54.9	61.5	68.3	75.1	88.7	115.7	138.2
Mozambique	68.6	78.8	90.0	101.8	128.8	170.0	206.1	238.4	262.2
Namibia	5.5	6.4	8.4	10.0	11.4	12.5	13.4	14.4	15.2
Rwanda	28.9	32.4	36.0	39.7	43.4	47.1	50.7	54.0	59.6
South Africa	217.6	228.2	239.2	250.0	262.9	276.0	286.8	296.7	302.2
South Sudan	23.3	25.2	27.7	30.5	33.3	36.0	38.4	40.6	42.6
Sudan	97.8	111.4	125.4	139.9	154.8	181.0	239.5	292.1	333.3
Uganda	97.7	112.8	128.4	144.4	160.6	176.8	192.8	208.1	236.2
United Republic of Tanzania	135.8	157.1	180.1	204.8	230.9	258.0	285.8	313.6	418.0
Zambia	41.6	47.8	54.3	62.3	85.2	107.5	126.3	143.7	156.5
Zimbabwe	34.5	38.2	42.2	46.3	56.3	72.9	86.1	97.0	103.9
Egypt	236.4	255.8	337.7	412.9	474.5	528.1	564.8	601.3	630.2
South Africa	217.6	228.2	239.2	250.0	262.9	276.0	286.8	296.7	302.2
EAR	784.9	890.8	1,002.4	1,117.7	1,235.3	1,364.7	1,527.9	1,728.6	2,060.9
SAR	483.8	559.4	645.3	739.5	873.4	1,047.1	1,238.1	1,430.5	1,672.0
Total	1,722.7	1,934.2	2,224.7	2,520.1	2,846.1	3,215.8	3,617.6	4,057.1	4,665.3

Electricity consumption outlook, TWh (economic demand factored by speed of consumer side electric consumption development)

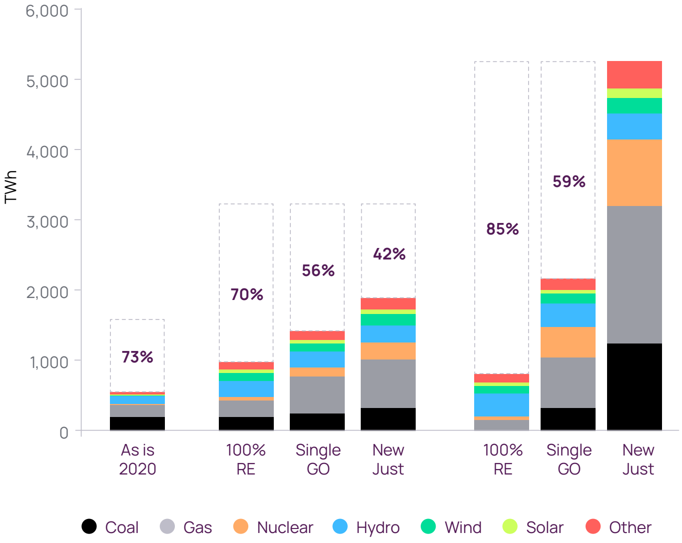
	2020	2025	2030	2035	2040	2045	2050	2055	2060
Angola	11.9	23.2	41.0	68.7	108.7	159.6	211.7	258.8	298.0
Botswana	3.7	5.6	7.7	9.5	11.0	12.2	12.9	13.6	14.1
Burundi	0.3	0.9	1.7	2.9	4.5	7.4	11.9	19.7	30.8
Democratic Republic of the Congo	8.1	17.9	35.0	63.5	109.1	186.6	302.0	467.1	667.2
Djibouti	0.6	1.1	1.7	2.5	3.5	4.3	4.9	5.4	5.6
Egypt	173.9	254.0	337.7	412.8	474.5	528.1	564.8	601.3	630.2
Ethiopia	10.2	21.7	40.7	70.5	116.3	190.9	297.2	442.1	607.2
Eswatini	1.3	1.9	2.8	3.7	4.6	5.2	5.8	6.1	6.4
Kenya	9.5	18.2	32.7	54.6	87.1	133.8	189.9	250.5	296.4
Lesotho	0.8	1.4	2.3	3.5	5.1	6.9	8.5	9.6	10.3
Malawi	4.0	7.9	14.5	24.9	40.2	61.8	88.7	115.7	138.2
Mozambique	18.3	33.2	56.5	89.1	128.8	170.0	206.1	238.4	262.2
Namibia	4.4	6.4	8.4	10.0	11.4	12.5	13.4	14.4	15.2
Rwanda	1.0	2.1	3.9	6.7	10.9	18.0	28.2	42.6	59.6
South Africa	207.9	222.0	236.4	250.0	262.9	276.0	286.8	296.7	302.2
South Sudan	0.6	1.3	2.3	4.0	6.4	10.7	16.8	25.9	37.1
Sudan	14.6	28.0	48.7	79.9	123.6	181.0	239.5	292.1	333.3
Uganda	3.4	7.5	14.2	24.9	41.5	69.1	109.4	167.5	236.2
United Republic of Tanzania	6.5	13.8	26.2	46.8	78.8	131.3	205.3	305.9	418.0
Zambia	14.3	25.2	41.2	62.3	85.2	107.5	126.3	143.7	156.5
Zimbabwe	9.1	15.9	26.2	39.7	56.3	72.9	86.1	97.0	103.9
Egypt	174	254	338	413	474	528	565	601	630
South Africa	208	222	236	250	263	276	287	297	302
EAR	47	94	172	293	473	746	1,103	1,552	2,024
SAR	76	139	236	375	560	795	1,062	1,364	1,672
Total	504	709	982	1,331	1,770	2,346	3,016	3,814	4,629

Electricity generation outlook for Eastern and Southern Africa

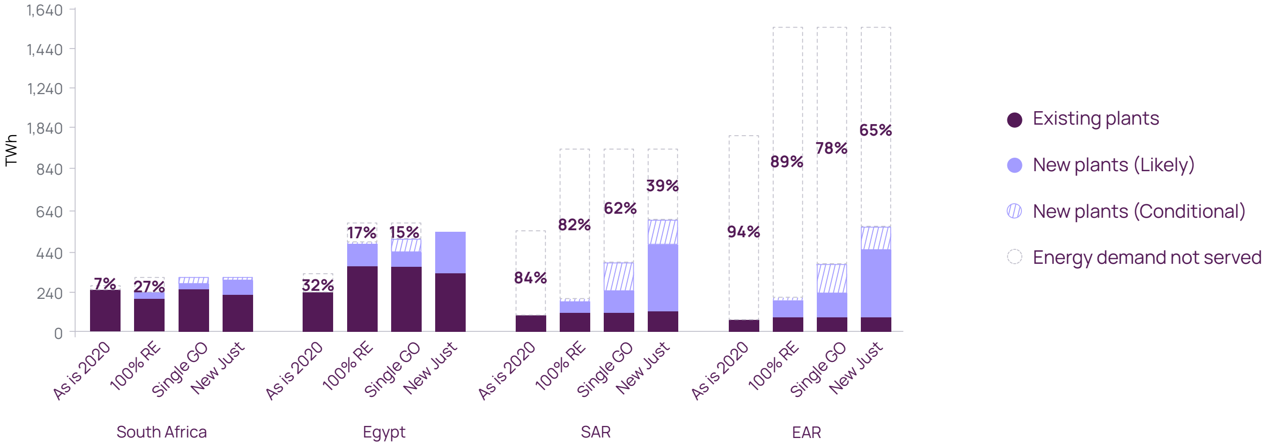
Electricity generation outlook for ESA by 2040-2060



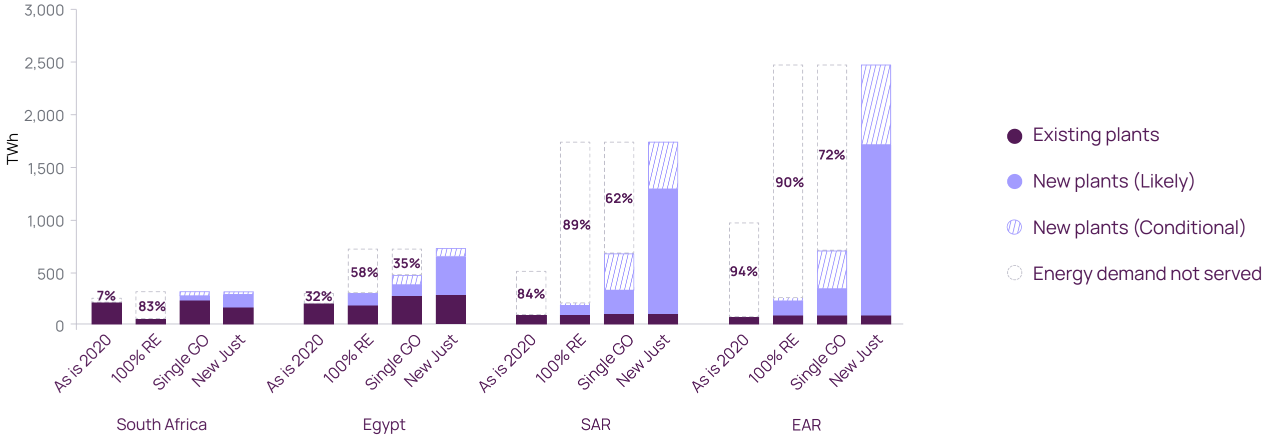
Generation mix for ESA for 2040-2060



Electricity generation outlook by regions for 2040



Electricity generation outlook by regions for 2060



Source: Kept analysis

Installed capacity outlook for Eastern and Southern Africa

Installed capacity of ESA's power plants by scenario

Resource	Installed capacity, GW						
	As is	100% RE		Single Go		New Just	
	2020	2040	2060	2040	2060	2040	2060
Eastern and Southern Africa							
Hydro	27	50	72	50	72	54	81
Wind	5	35	40	37	44	50	69
Solar	9	31	35	30	35	40	89
Coal	45	27	0	51	62	67	279
Gas	54	54	27	94	125	128	371
Nuclear	2	6	6	16	59	32	128
Other	12	22	24	24	28	32	72
Total	**153**	**226**	**204**	**302**	**425**	**404**	**1,089**
South Africa							
Hydro	3	4	4	4	4	4	4
Wind	3	9	9	11	11	11	12
Solar	6	11	11	12	12	12	12
Coal	42	25	0	37	36	33	32
Gas	0	0	0	0	0	2	4
Nuclear	2	2	2	4	7	7	12
Other	3	3	3	4	4	4	5
Total	**59**	**55**	**30**	**71**	**73**	**71**	**80**
Egypt							
Hydro	3	3	4	3	4	3	4
Wind	1	14	14	13	13	16	20
Solar	2	11	11	9	9	11	14
Coal	-	-	-	-	-	-	-
Gas	52	52	26	55	51	70	90
Nuclear	-	4	4	4	8	7	14
Other	1	7	7	7	7	9	11
Total	**59**	**93**	**67**	**92**	**92**	**117**	**154**
Southern African Region							
Hydro	13	21	29	21	29	25	38
Wind	0.005	5	7	6	10	11	11
Solar	0.4	4	6	5	7	9	30
Coal	2	1	0	8	14	18	82
Gas	2	2	1	20	37	29	144
Nuclear	0	0	0	4	22	10	51
Other	2	4	5	5	7	8	25
Total	**19**	**38**	**46**	**69**	**125**	**110**	**381**
Eastern Africa Region							
Hydro	8	22	36	22	36	22	36
Wind	1	6	10	7	11	12	25
Solar	0.4	4	7	4	7	8	33
Coal	0.015	0.09	0	6	12	16	165
Gas	1	1	0	19	37	28	133
Nuclear	0	0	0	3	22	8	51
Other	5	7	8	8	10	11	31
Total	**16**	**41**	**61**	**69**	**134**	**105**	**475**

Electricity generation outlook for Eastern and Southern Africa

Electricity generation outlook for ESA by scenario

Resource	**Electricity generation, TWh**						
	As is	100% RE		Single Go		New Just	
	2020	2040	2060	2040	2060	2040	2060
				Eastern and Southern Africa			
Hydro	120	222	325	222	325	245	369
Wind	5	113	108	119	143	163	222
Solar	13	47	42	45	52	59	133
Coal	193	120	0	240	328	328	1239
Gas	172	310	155	536	713	682	1935
Nuclear	11	46	46	119	436	237	950
Other	32	118	126	128	149	169	380
Total	**546**	**976**	**800**	**1,410**	**2,145**	**1,883**	**5,228**
				South Africa			
Hydro	6	6	6	6	6	6	6
Wind	0.3	30	8	35	35	35	38
Solar	8	17	6	17	17	17	18
Coal	186	112	0	158	180	132	111
Gas	0	0	0	0	0	9	23
Nuclear	11	14	14	32	50	50	86
Other	2	18	18	20	20	20	27
Total	**213**	**198**	**53**	**269**	**309**	**269**	**309**
				Egypt			
Hydro	15	17	19	17	19	17	19
Wind	4	47	47	41	41	52	66
Solar	4	17	17	14	14	17	21
Coal	0	0	0	0	0	0	0
Gas	164	295	148	316	291	352	443
Nuclear	0	31	31	31	63	54	107
Other	10	39	39	39	39	48	59
Total	**198**	**446**	**301**	**458**	**467**	**539**	**716**
				Southern African Region			
Hydro	62	99	135	99	135	121	180
Wind	0.2	17	22	21	32	36	36
Solar	1	6	8	7	10	13	44
Coal	7	8	0	48	79	105	288
Gas	3	9	5	112	212	163	677
Nuclear	0	0	0	31	162	72	378
Other	7	23	25	28	37	44	131
Total	**79**	**162**	**195**	**345**	**668**	**554**	**1,734**
				Eastern Africa Region			
Hydro	37	100	163	100	163	100	163
Wind	1	20	31	22	35	39	82
Solar	0.4	7	11	7	11	12	50
Coal	0.02	0.02	0	34	68	91	840
Gas	5	6	3	108	210	159	792
Nuclear	0	0	0	24	162	61	378
Other	14	38	44	42	53	57	163
Total	**57**	**171**	**251**	**337**	**702**	**521**	**2,468**

GDP (PPP) & annual per capita consumption by ESA and countries, kWh

	GDP (PPP), 2020, $/capita	2020	2025	2030	2035	2040	2045	2050	2055	2060
Angola	6,030	357	595	914	1,338	1,870	2,450	2,927	3,254	3,442
Botswana	13,545	1,451	2,023	2,585	3,007	3,278	3,458	3,510	3,583	3,636
Burundi	711	24	62	109	163	224	335	492	750	1,092
Democratic Republic of the Congo	1,044	87	164	274	429	642	966	1,388	1,927	2,494
Djibouti	4,754	588	928	1,382	1,924	2,485	2,960	3,268	3,476	3,551
Egypt	11,990	1,619	2,184	2,698	3,077	3,308	3,468	3,522	3,597	3,651
Ethiopia	2,253	87	163	272	425	639	962	1,383	1,921	2,486
Eswatini	8,290	1,075	1,575	2,147	2,683	3,076	3,318	3,486	3,559	3,612
Kenya	4,497	182	317	518	791	1,165	1,669	2,229	2,793	3,170
Lesotho	2,285	364	600	929	1,351	1,870	2,450	2,927	3,253	3,440
Malawi	1,490	208	359	579	890	1,295	1,812	2,388	2,888	3,231
Mozambique	1,233	587	928	1,382	1,927	2,487	2,962	3,270	3,478	3,553
Namibia	9,042	1,784	2,373	2,876	3,203	3,391	3,504	3,557	3,631	3,685
Rwanda	2,067	73	142	237	370	553	840	1,224	1,735	2,299
South Africa	12,816	3,535	3,600	3,657	3,714	3,771	3,842	3,901	3,980	4,039
South Sudan	-	54	110	187	289	426	652	962	1,403	1,919
Sudan	3,875	329	553	854	1,256	1,756	2,339	2,834	3,197	3,406
Uganda	2,240	76	145	243	380	568	860	1,248	1,770	2,335
United Republic of Tanzania	2,474	105	193	319	502	751	1,120	1,580	2,147	2,700
Zambia	3,184	755	1,160	1,671	2,241	2,752	3,142	3,371	3,536	3,588
Zimbabwe	1,990	578	915	1,364	1,885	2,455	2,948	3,256	3,464	3,540
Egypt	11,990	1,619	2,184	2,698	3,077	3,308	3,468	3,522	3,597	3,651
South Africa	12,816	3,535	3,600	3,657	3,714	3,771	3,842	3,901	3,980	4,039
EAPP	2,700	130	233	378	576	842	1,214	1,651	2,157	2,640
SAPP	2,407	345	546	807	1,127	1,491	1,892	2,278	2,667	3,005
Average by ESA	**4,757**	**735**	**932**	**1,152**	**1,404**	**1,693**	**2,049**	**2,425**	**2,849**	**3,330**

Cost assumptions

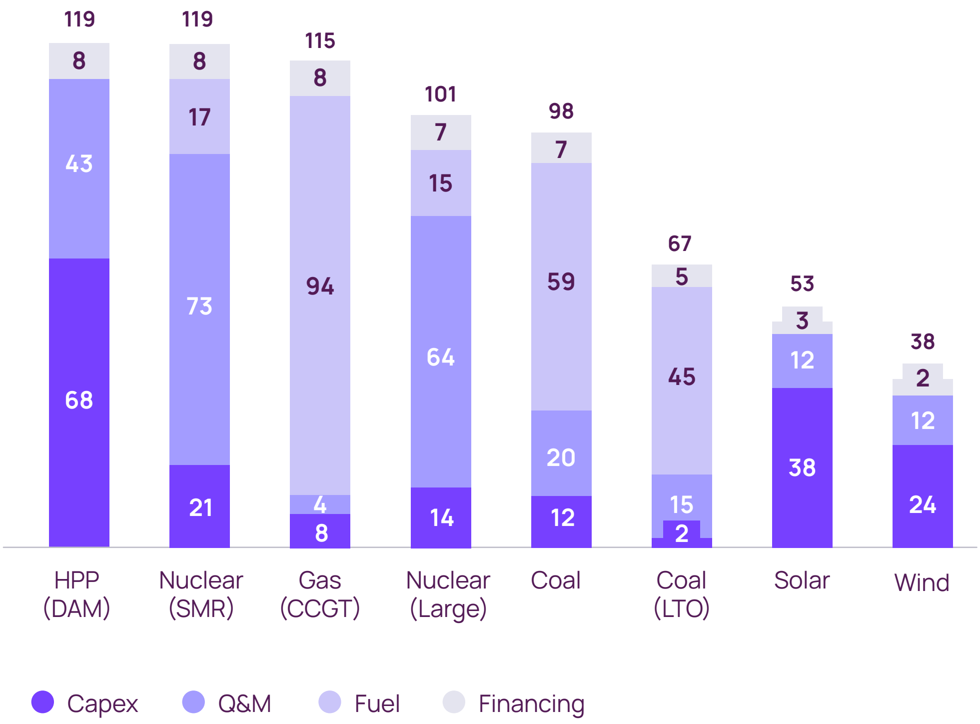
Structure and parameters of LCOE by technology (baseline costs used in this study), %

Name of parameter	**UoM**	**HPP (Dam)**	**Nuclear (SMR)**	**Gas (CCGT)**	**Nuclear (SMR)**	**Coal**	**Coal (LTO)**	**Solar**	**Wind**
Levelized Cost of Energy (Base)	$/MWh	119	119	115	101	98	67	53	38
Capex	%	57%	17%	7%	14%	12%	3%	72%	63%
O&M	%	36%	61%	4%	64%	20%	23%	23%	32%
Fuel	%	0%	15%	82%	15%	60%	67%	0%	0%
Financing	%	7%	7%	7%	7%	7%	7%	5%	5%
Capacity factor	%	50%	90%	65%	90%	55%	55%	17%	37%

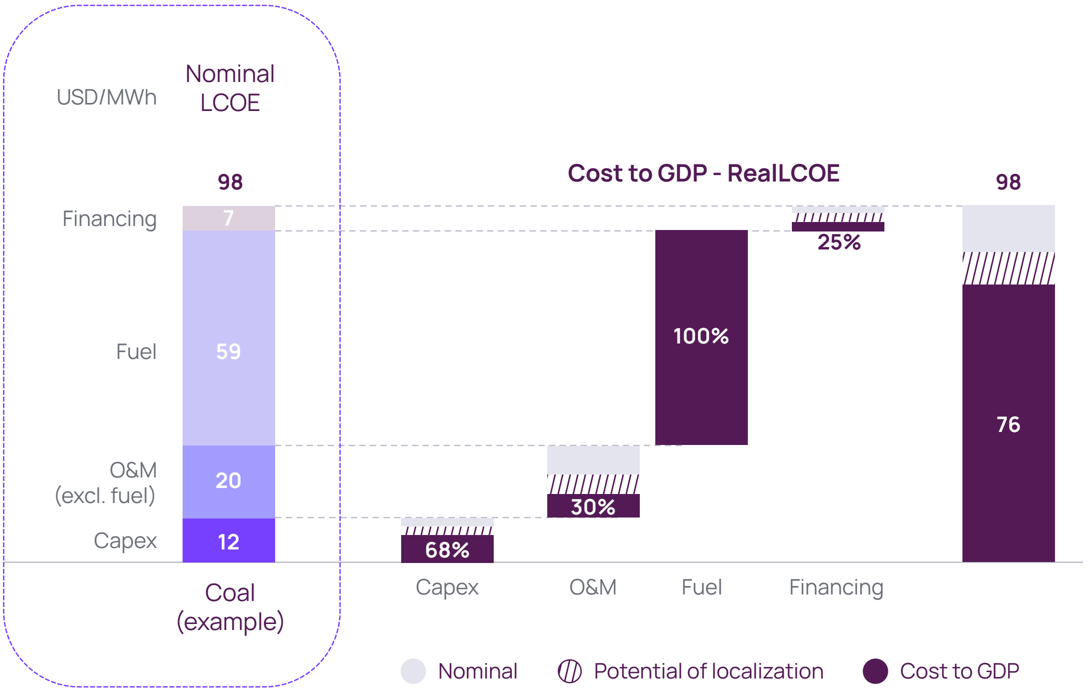
Local share and best-case scenario for localization

Region	Assumed current local share				Assumed best-case scenario for localization			
	EAR	Egypt	SAR	South Africa	EAR	Egypt	SAR	South Africa
Coal	**13%**	**13%**	**28%**	**76%**	**29%**	**22%**	**49%**	**90%**
Capex	20%	20%	20%	30%	32%	32%	32%	65%
Fix O&M	30%	40%	30%	50%	65%	70%	65%	90%
Var O&M	30%	40%	30%	50%	48%	55%	48%	63%
Fuel	5%	0%	30%	100%	15%	0%	48%	100%
Financing	20%	30%	20%	30%	60%	65%	60%	65%
Gas (CCGT)	**19%**	**88%**	**44%**	**4%**	**46%**	**93%**	**68%**	**16%**
Capex	10%	30%	10%	10%	15%	48%	15%	28%
Fix O&M	20%	40%	20%	20%	40%	88%	40%	40%
Var O&M	20%	40%	20%	20%	40%	70%	40%	40%
Fuel	20%	100%	50%	0%	48%	100%	75%	10%
Financing	20%	30%	20%	30%	60%	65%	60%	65%
Nuclear	**9%**	**16%**	**9%**	**38%**	**47%**	**58%**	**45%**	**67%**
Capex	10%	20%	10%	20%	24%	40%	19%	40%
Fix O&M	25%	40%	25%	40%	63%	88%	55%	88%
Var O&M	25%	40%	25%	40%	44%	70%	44%	70%
Fuel	0%	0%	0%	50%	50%	50%	50%	70%
Financing	0%	0%	0%	0%	50%	50%	50%	50%
Hydro (Dam)	**34%**	**48%**	**34%**	**48%**	**49%**	**60%**	**49%**	**60%**
Capex	20%	30%	20%	30%	28%	44%	28%	44%
Fix O&M	60%	80%	60%	80%	80%	85%	80%	85%
Var O&M	60%	80%	60%	80%	80%	85%	80%	85%
Fuel	100%	100%	100%	100%	100%	100%	100%	100%
Financing	20%	30%	20%	30%	60%	65%	60%	65%
Wind	**10%**	**21%**	**10%**	**22%**	**31%**	**45%**	**31%**	**46%**
Capex	5%	20%	5%	20%	15%	36%	15%	36%
Fix O&M	20%	25%	20%	30%	60%	63%	60%	65%
Var O&M	20%	25%	20%	30%	60%	63%	60%	65%
Fuel	100%	100%	100%	100%	100%	100%	100%	100%
Financing	0%	0%	0%	0%	50%	50%	50%	50%
Solar	**8%**	**20%**	**8%**	**21%**	**27%**	**43%**	**27%**	**43%**
Capex	5%	20%	5%	20%	15%	36%	15%	36%
Fix O&M	20%	25%	20%	30%	60%	63%	60%	65%
Var O&M	20%	25%	20%	30%	60%	63%	60%	65%
Fuel	100%	100%	100%	100%	100%	100%	100%	100%
Financing	0%	0%	0%	0%	50%	50%	50%	50%

Structure of LCOE by technology (baseline costs used in this study), USD/MW



LCOE structure and Cost to GDP share by component (example: Coal TPP in Egypt)



RealLCOE

As majority of fuel and technology is imported the actual Cost-to-GDP is very close to full LCOE (> 3/4 of LCOE).

CAPEX	**OPEX**	**Fuel**	**Financing**
Technology is imported, but construction work executed locally	Local operating staffing, but major O&M operations and spare part are imported	100% imported coal for power generation	Mixed project finance with significant foregnt export credit

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