SOLARIZE

MARKET REPORT AFRICA

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1. Introduction

Africa, as a continent, is almost as populated as China. However, Africa comprises 54 countries. The energy consumption on the African continent cannot be comprehended with mere numbers: they would not do justice to the variety of energy sources available. The same goes for the prospects and challenges ahead. This report boldly claims “Solarize Africa” as a call to action to finally untap the potential for photovoltaics (PV) on the continent. The report will cover ten key markets on the African continent as well as trends, opportunities and business models.

This is a report authored by Europeans about the African economic markets which were the first source of interest in the 19th century when the continent was built upon seized lands and resources carved up by European leaders. The second source of interest followed in the 20th century during the Cold War when the Eastern and the Western blocs vied for alliances, often at the cost of supporting dictators and despots. So today, the authors would like to encourage the spirit of cooperation and mutual benefit.

Climate change is already at the African continent’s doorstep, with accelerated desertification, change of agricultural conditions and loss of habitat. There is a pressing need to tackle the rising temperatures, poverty rates and the lack of access to energy sources particularly in the sub-Saharan zone. We strongly believe that PV can play a significant role to overcome these challenges.

To start with, we will discuss the long-term energy transition in Africa to put the results in perspective and to present an overview of the main challenges and opportunities on the continent. Different scenarios for the energy demand and PV distribution are discussed. The 2018 market data are provided by region and country together with short-term forecasts. We will provide an analysis of key markets before giving an overview of countries and their market potential for PV. The combination of these two exercises is revealing market trends and local enablers or barriers to the development of PV.

Specific market conditions such as subsidized electricity prices, unstable grids, fast developing suburban areas, off-grid markets including distributed storage solutions are being laid out as well. We will then dive into specific business models paving the way for the energy transition in Africa.

We will review tenders for utility-scale solar in different markets. We will then investigate key supporting policies and framework conditions for PV including self-consumption. The report also explores local manufacturing policies per country. We also discuss the impact of international organizations. The report moves beyond PV with an outlook on the deployment of electric vehicles (EV) and storage. While these are still nascent, we have gathered existing business cases and innovative approaches to overcome the barriers facing the implementation of EVs and batteries.

We hope that you are on board with us and our partners in Africa to embrace solar energy as an abundant resource – so the jobs and business opportunities it creates will be beneficial for the cooperation between our economies and people.

2. The energy transition in Africa - long term energy scenarios

The current population in Africa reaches approximately 1.3 billion people, of which only 62% have access to electricity [1]. The energy consumption per capita is amongst the lowest globally, with large disparities between the economically developed cities and rural areas. According to the International Energy Agency (IEA), 212 million people gained access to electricity from 2000 to 2015 in Sub-Saharan Africa. Despite the recent progress, the continent struggles to keep up with the growing population and, hence, meeting the energy demand. Indeed, in a special report on Energy access [1], the IEA expects further electrification in Africa: the share of the population without access to electricity would fall to 36% in 2030. However, the total amount of people without access would continue to increase.

As both population and economic activities soar, energy demand will continue to rise for both power and transport. To meet its growing electricity demand, Africa has an urgent need to raise the level of investments in the power sector. According to IRENA [2], the continent will need to double its capacity between now and 2030 to meet the demand. The IEA seconds the statement and predicts that the capacity needed will be of 497 GW in 2030 [3].

The continent can benefit from recent global progress and cost reductions in renewable power generation technologies, to leapfrog fossil fuel-based systems and move directly to a renewable-based system. The decreasing prices for solar PV and the high irradiation on the African continent demonstrate the case to develop renewable energies (RE) and solar PV. African countries are currently raising their commitments to RE with important innovations in tariffs, increased use of independent power producers (IPPs) and improving their legislations to stimulate renewable energy, decentralized off-grid solutions such as mini-grids and solar home systems.

Despite significant progress, technical and financial barriers are holding back the expansion of renewables. The African energy sector suffers from a number of structural problems, such as the presence of fossil-fuel subsidies, weak financial strength of utilities, outdated and unstable grids and an unstable policy environment, which all translate into a high level of risks for investors in the sector and makes it difficult for potential investors to access needed infrastructure finances. This is even more relevant for investments in solar PV installations as these are characterized by higher upfront costs than fossil fuel power plants.

Given the challenges cited above, most of the scenarios developed to predict the long-term energy trends in Africa are quite conservative when it comes to integrating renewable energy sources. Even more ambitious renewable energy scenarios are often not in line with the objective of 100% renewable energy towards 2050 and therefore not consistent with the Paris climate goals (examples: IEA Energy Outlook, IRENA Prospect for the African Power Sector, Mac Kinsey Energy 2050).

In the figure below, we compare the share of solar PV in the electricity production in the IEA sustainable development scenario and of the 100% renewable energy study from the Lappeenranta University of Technology (LUT) [4].

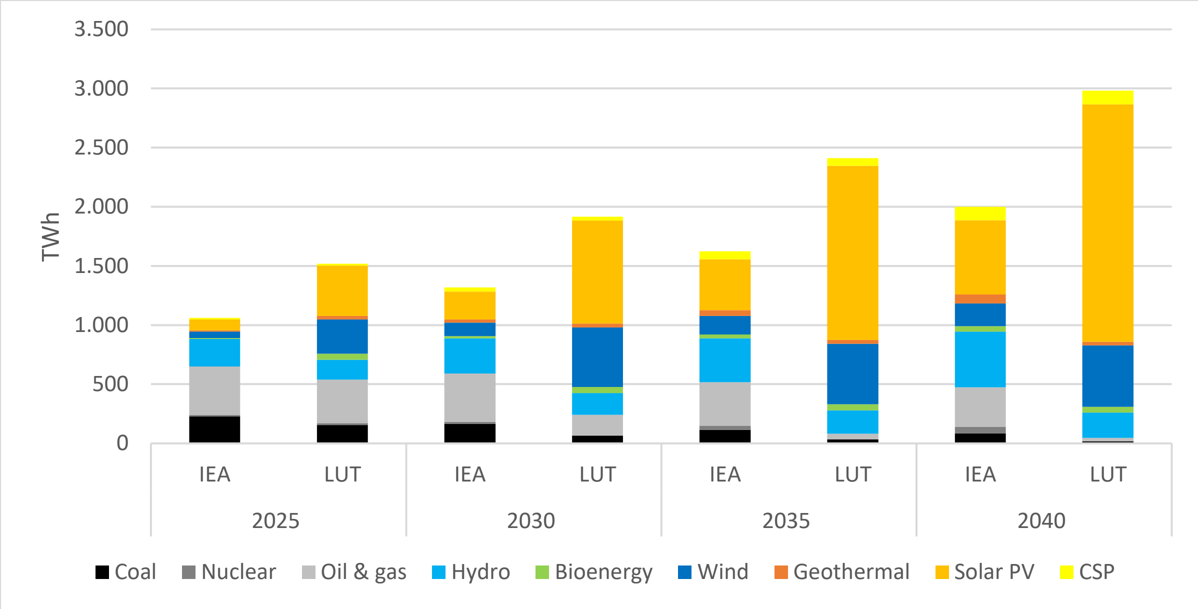


Figure 1: Comparison of scenarios of future electricity generation from different technologies in Africa. Sources: IEA & LUT

The two main differences that can be observed in the two scenarios above are the difference in the total electricity generation and the difference in the PV share in the total electricity generation. The difference in the total electricity generation can be explained by the shift towards electrification of the energy system in the scenario of LUT. This electrification of the energy system is essential to fully decarbonize the energy consumption and for the deployment of electric vehicles (EVs) as well. The higher share of PV in the LUT scenario can be explained by both economic and environmental factors. Indeed, the massive penetration of PV and other renewable energy sources is not only required to achieve the Paris Climate Agreement but is also more cost-efficient [4].

In the past, ambitious scenarios were characterized by a higher energy and system costs. However, the trend is now reversing as renewable energy sources are becoming the cheapest production assets, and even more in the long term [4]. Therefore, the share of renewables on the African continent could grow faster than expected, especially if some new innovative business models and new ways to facilitate access to finance make their way through.

3. Market status and forecasts

3.1 2018 market numbers per region and country

Despite the growth of the market to around 1.2 GW in 2018, the share of the PV market in Africa remains relatively small compared to other regions of the world. The total solar PV installed capacity at the end of 2018 in Africa reached 5,110 MW[1] [5]. This represents a mere 0.7% of the world solar PV capacity. One of the main reasons for this delay is the difficulty for many countries to attract the needed private investments, together with political uncertainty and in several cases instability. Indeed, solar PV installations are capital intensive which means they have higher upfront costs than thermal plants. Even if the fuel costs are higher in the long term, thermal plants are still being installed massively in Africa [6]. To mitigate this financial challenge, several solar PV projects are developed in partnership with international organizations. This is further discussed in point 5.4.

Market numbers in Africa are in most cases good, estimations based on a variety of sources. Few countries follow installations with a level of confidence which can be found in most OECD countries for instance. Data are based on imported statistics, local sources and specialized expertise.

The first countries to adopt solar PV on the continent in 2006 were Burkina Faso, Egypt, Libya, Mali, Morocco, Namibia, Niger, Reunion Island (France), Senegal, Uganda and Zambia. These first installations where often linked to rural electrification programs. Off-grid hybrid PV and diesel back-up systems also quickly made their way to Africa, especially in remote areas. Although most of the African countries already had some level of installations in 2010, the PV market really took off in 2014 with the first tender in South-Africa and other countries in the following years. Nowadays, solar PV is present under multiple forms in Africa, from rooftop to utility scale, but also for some various applications such as street lightning, water pumping, powering hospitals or fridges, etc. Medium scale installation of ground mounted PVs are probably the least represented of the segments.

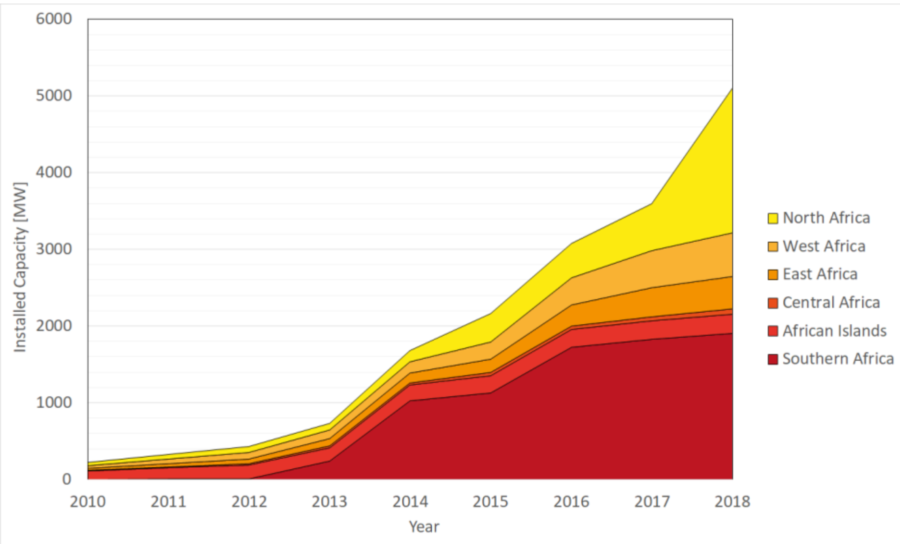


Figure 2: Evolution of the total installed PV capacity per region in Africa. Source: Becquerel Institute et al.

[1] All the solar capacity numbers are reported in direct current (DC).

Next to PV, Concentrated Solar Power (CSP) reaches 975 MW in Africa, approximately one fifth of the total capacity installed in the world. CSP has been developed mainly in Morocco (530 MW) and South-Africa (400 MW), but the first CSP plant in Africa was built in Algeria in 2010 (25 MW). Egypt also installed some CSP (20 MW) and announced more in his renewable energy plan. CSP heat can be directly used for industrial heating processes or combined with storage to deliver electricity and heat when most needed. Though very promising, CSP did not follow the steep reduction cost of solar PV which explains its slow development as shown in the figure below. Even though recent development efforts have reduced the costs of this technology, CSPs competitiveness is far below PV and it remains unsure whether CSP will once benefit from a significant market push to continue lowering its costs.

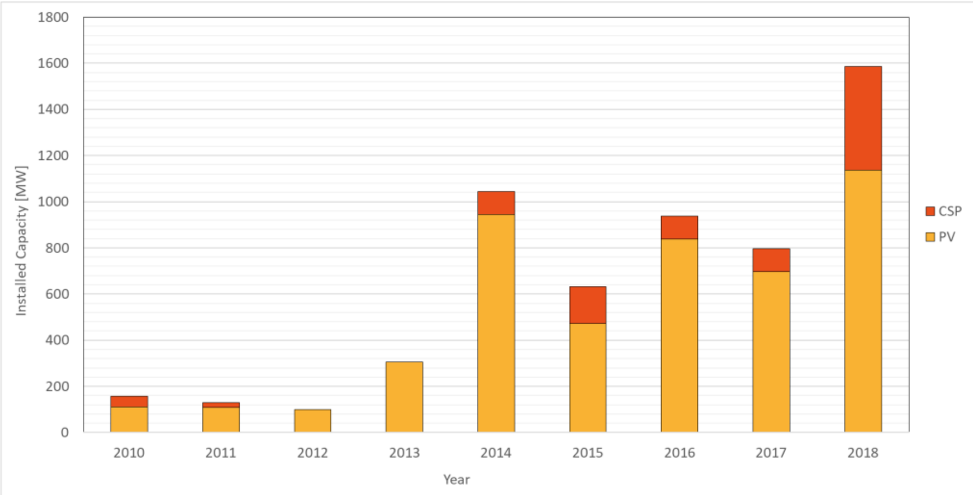


Figure 3: Evolution of the yearly installed PV and CSP capacity in Africa. Source: Becquerel Institute et al.

The deployment of solar PV is mainly driven by Egypt (660 MW), Morocco (606 MW) and Algeria (519 MW) in Northern Africa and by Lesotho (79 MW) and South-Africa (1,815 MW) in Southern Africa. Not surprisingly those are the countries which combine official renewable energy targets, PV policies and support measures. In the other regions, the most active markets were La Réunion island (190 MW), Senegal (134 MW), Kenya (93 MW), Mauritania (86 MW), Namibia (79 MW) and Ghana (64 MW).

Total PV installed capacity Top 10 of the African countries	
South Africa	1,815 MW
Egypt	660 MW
Morocco	606 MW
Algeria	519 MW
La Réunion	190 MW
Senegal	134 MW
Kenya	93 MW
Mauritania	86 MW
Namibia	79 MW
Ghana	64 MW

Figure 4: Total PV installed capacity - Top 10 in Africa. Source: Becquerel Institute et al.

3.2 Analysis of key markets

The diversity of human, social, economic and policy environments in Africa would imply to look at each country in detail to understand their complete solar development potential. The ten countries selected below represent key examples of countries with either a significant potential for PV development or an already existing and dynamic PV market. They also represent an interesting set of economic and policy environments. More could have been added to this report and could be studied more in depth in further editions.

Algeria

With the Sahara Desert representing 75% of its territory, Algeria has the highest solar potential in the region and one of the highest in the world. Measurements of solar radiation reported an average annual global solar radiation of 6.6 kWh/m².

Energy occupies a predominant place in the economy with oil and gas covering 98% of its export incomes. However, about 10 years ago, the Government started considering renewable energy sources to satisfy the local energy consumption.

In 2011 Algeria defined a "Renewable Energy and Energy Efficiency Development Plan 2011-2030" setting an ambitious target of 22 GW renewable energy installations by 2030, of which 10 GW are destined for exportation. Solar energy (PV) is expected to contribute significantly to this target, with a total capacity that should reach 13.6 GW in 2030 [7].

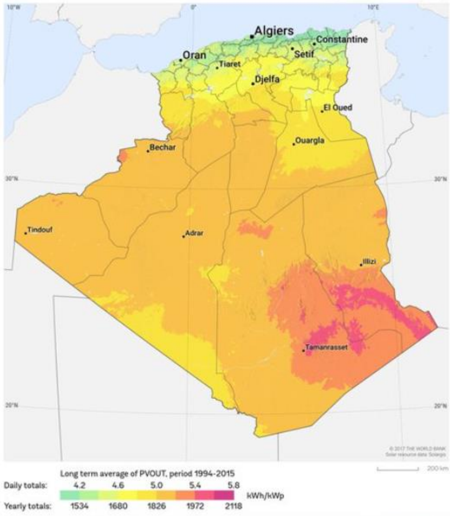


Figure 5: Photovoltaic power potential Algeria. Source: Solargis

In 2010, Algeria installed one of the world's first hybrid power stations, which combines 25 MW of CSP with a 130 MW combined cycle gas turbine plant. The development of solar PV consistently took off with the increased FiT in 2015, when 48 MW were installed, followed by 180 MW in 2016 and 181 MW in 2017. In 2018, 119 MW were installed, for a total PV installed capacity of 519 MW.

A governmental program ended in 2010 which provided solar electricity for 302,795 isolated and off-grid households in the south of the country [8].

Regulatory framework

Since 2014, Algeria incentivizes the installations of small-scale PV plants mainly through FiT: ground-mounted PV parks above 1 MW were eligible for FiT for a limited number of hours per year [9]. The renewable energy programs should be funded by a levy of 0.5% on oil tax revenues. However, these have been decreasing in the last years. Therefore, the FiT has been repealed in 2018.

In November 2018, the government released a new series of tenders for electricity production from renewable sources. A total capacity of 150 MW was available for solar projects with a capacity range of 10-50 MW. Selected plants got a PPA with a duration ranging from 20 to 25 years. Another 50 MW were tendered for off-grid hybrid gas/diesel and solar projects in the non-interconnected areas in the south of Algeria.

Potential for PV development

Algeria has several features which makes it attractive for the development of PV. There is a well-developed local PV panels industry which is still growing, the desert offers plenty of opportunities and the country shares some interconnection with Morocco (1,400 MW) and Tunisia (900 MW). However, the political climate in the upcoming years is uncertain as Algeria's president was forced to abandon his bid for a 5th term amid persistent protests [10]. The country needs to find a consistent and sustainable way to finance the energy transition to gain investors’ confidence. Also, in order to enable the growth of distributed PV, the nation should reduce subsidies on conventional electricity retail prices [11]. Over the next five years, there is potential for up to 4.8 GW of PV installation if the country wants to achieve its target.

Angola

Angola is a large country with a central plateau and a long coastline in southwestern Africa. Luanda is its capital and is home to a quarter of the 27 million inhabitants. More than 60% of the population has no access to electricity, especially in rural areas [12]. The projected current energy mix consists of primarily hydro power (58%) followed by diesel (30%) and natural gas (12%) [13].

In 2014 the Angolan Ministry of Energy and Water (MINEA) has identified a potential of 55 GW solar, 3 GW of wind and 18 GW of hydro power. The annual solar radiation is very high and ranges between 1,350 and 2,100 kWh/m^2/year. Nevertheless, only a solar capacity of 13 MW is currently installed countrywide, mostly in small solar home systems and some commercial applications [12].

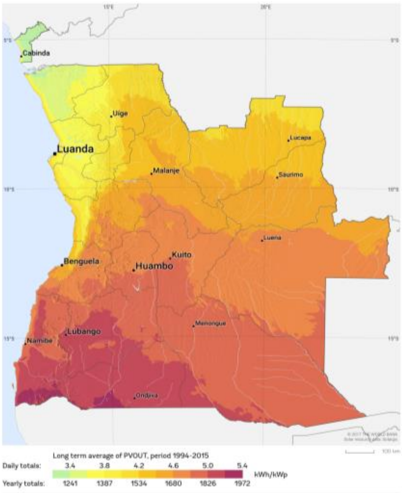


Figure 6: Photovoltaic power potential Angola. Source: Solargis

The recent national strategy *Angola Energia 2025* [14] shows a vision for the energy sector of Angola until 2025. Due to an abundant resource paired with relatively little demand, the country has several feasible options for power generation: large hydropower, solar PV, solar thermal, biomass, wind and mini-hydropower. To achieve the governmental target of a 50% electrification rate by 2022 and 60% electrification rate by 2025, the total generation capacity has to quadruple from 4,700 MW in 2019 to an intermediate target of 7,500 MW by 2022 (of which 500 MW should come from renewables) and approximately 9,500 MW in 2025 (of which 800 MW should be renewable energy). The main reasons for this increase in demand are the rising residential consumption, industrialization and growth of the services sector.

Regulatory framework

The Angolan government recognized that renewable energy can play an important role in further electrification. The Regulatory policies to support Renewable Energy sources include Feed-in-Tariffs, net-metering, tendering (hydro) and fiscal incentives [12]. The Angolan government has originally planned to install 100 MW of solar power projects, including 22 MW focused on rural electrification (mini-grids/off-grid systems) and 78 MW grid-connected PV. Recently an increase in solar capacity to 200 MW by 2025 has been proposed by the Ministry of Energy and Water [15]. In addition, Angola Energia 2025 has a target of 500 “solar villages” to implement by 2025. A concrete roadmap with the proposed locations for the implementation of these villages as well as solar systems in other remote places already exists [14]. Generally, the plan is to create small local grids in townships with more than 3,000 people.

This solution provides a suitable electricity service to communal infrastructures, such as schools, health units, administration and public lighting of main streets. Private local initiatives are supposed to develop these local networks.

Potential for PV development

The Angolan government plans to significantly increase the power generation capacities. But the planned share of renewable energy sources (excluding hydropower) is only about 8 to 10% by 2025, not a very ambitious goal given the country resources. Solar energy could play a more significant role here thanks to its low costs and the wide range of possible applications. In rural regions, solar energy can ensure the supply of electricity in combination with batteries and/or diesel generators. The Angolan Action Plan of the Energy and Water sector (2018-2022) sees a potential of 100,000 imported and/or distributed individual solar systems [16]. Furthermore, Angola has expressed interest in joining the World Bank's Scaling Solar Program. This could significantly increase solar development in the coming years [12]. In the next five years a potential of about 150 MW of PV installations countrywide can be seen. In addition to large grid-connected systems, off-grid systems in rural areas are particularly needed.

Egypt

Egypt has immense potential in the solar energy realm. In the northern country, the average annual radiation is between 1,900 and 2,600 kWh/m², and in the South, it can reach 3,200 kWh/m². These constitute ideal prerequisites for the use of photovoltaic applications to generate electricity. The government has undertaken a plan to increase the share of renewable energy sources to 20% in 2022 [17]. Currently, around 90% of the energy generation is covered by fossil fuels.

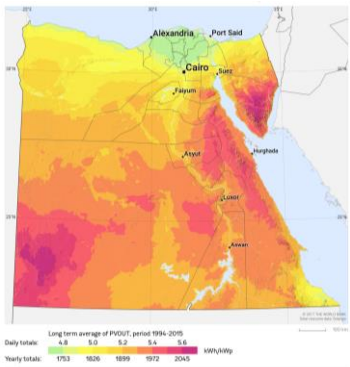


Figure 7: Photovoltaic power potential Egypt. Source: Solargis

Egyptian cities suffer from significant air-pollution problems. In order to reduce CO_2 emissions, renewable energy sources are to become the primary fuel for the generation of electricity in the future. By the end of 2018, the PV capacity installed in Egypt was estimated at around 660 MW, with the newly installed capacity during the year reaching 500 MW; among the sources was the Benban Solar Park. The Ministry of Electricity and Renewable Energy sees a solar power potential of more than 50 GW [18].

This set of conditions renders photovoltaic applications economically attractive, and they already represent an interesting and economic option in many sectors, with both on-grid and off-grid solutions being feasible. In addition to small-scale applications in private households, PV projects in the tourism secto; agricultural and industrial sectors hold significant promise. The noticeable increase in energy efficiency would also help reduce Egypt's high energy consumption, with a resulting positive effect on climate protection. The export of renewable energy to neighboring Arab countries or even to Europe is also a conceivable option.

Regulatory framework

All of Egypt's population has access to energy. However, energy prices and consumption have soared at the same time. The state has been cutting energy subsidies for years, which will improve competition in the long run, but higher prices have already an impact. Since the entire country is electrified, renewable energy sources (RES) can be integrated into the existing grid with relative ease. The government's New & Renewable Energy Strategy aims to increase the share of generated energy from RES to 20% out of the total generated energy in Egypt by 2022.

The Egyptian government incentivizes the installation of PV plants mainly by FiT and quotas. There are different feed-in tariffs for PV projects, according to the size of the PV plant. Net metering regulations for feeding electricity from small systems into the low-voltage grid were already defined by the Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) in 2013. The guidelines were revised and published at the end of February 2017. Net metering is intended for systems below 500 kW but can also be used in individual cases for larger systems (> 500 kW). The government offers further support for RES, for example with long-term PPAs, governmental guarantees or reduced custom duties.

Potential for PV Development

According to IRENA, Egypt has the potential to reach 44 GW of installed solar PV power by 2030 [19]. In total, there is huge potential in the country's residential, commercial and industrial sectors. Over the next five years, cumulative installed PV capacity of 3 GW is expected. It should not be a problem to include the energy into the existing grid. A large amount of PV capacity will be realized through the Benban Solar Park. 1.8 GW and should be connected to the grid during the year 2019. More should be installed and connected in the coming years.

Egypt's Renewable Energy plan aims to install 3.5 GW by 2027, including 2.8 GW of solar PV and 700 MW of CSP [20]. It seems obvious that the PV target could be reached.

Ethiopia

Ethiopia's population of +100-million is the second largest of Africa but one of the least prosperous lands on earth. Ethiopia, nonetheless, has excellent potential for the deployment of solar energy. Solar irradiation ranges between 1,800 and 2,200 kWh/m² per year, but the PV installed capacity is only 14 MW countrywide. The electrification rate is currently around 40%. The government's target is to increase this rate to 100% by 2030.

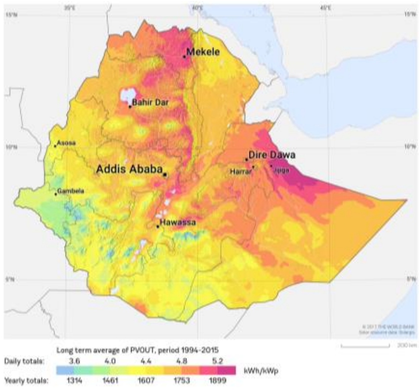


Figure 8: Photovoltaic power potential Ethiopia. Source: Solargis

Ethiopia has a large potential for solar generation capacity. According to a study by the Ethio Resource Group (ERG), there is a potential of approximately 10 million off-grid households generating energy by PV systems (technical potential) [21]. Currently, hydropower is the main source of energy in Ethiopia and covers approximately 86% of the installed capacity of 4.4 GW [22].

Regulatory framework

The Ethiopian government is striving to supply electricity to almost 100% of the country's households by 2030. Despite the fact that there is currently little political support for renewable energy sources, a declared governmental statement aim at providing the entire electricity supply with renewable energies by 2050 [23]. Renewable energy sources are promoted through Power Purchase Agreements, by the development of RES-based off-grid systems as well as by introducing more efficient on-grid management policies.

the Ethiopian Ministry of Water, Irrigation and Electricity (MoWIE) has published a National Electrification Program (NEP) - Implementation Roadmap (IRM) to achieve universal electricity access nationwide by 2025. The public share of financing for this grid and off-grid program is about 1.5 billion USD. Solar systems play an important role in this context, especially for the development of rural areas [24].

Studies have concluded that the electrification of remote villages by means of PV installations is significantly more cost effective than the expansion of the grid or through provision using diesel generators. Nonetheless, the Rural Electrification Fund (REF), existing since 2003, only supports small-scale renewable energy projects and decentralized power grids ("mini-grids") in rural areas to a limited extent [25]. For example, an application mentioned is to use small-scale solar for household illumination and charging mobile phones.

Potential for PV Development

Renewable energy, especially PV systems, is certain to play an increasingly important role in Ethiopia's energy development endeavors. Today, however, solar energy's potential contribution is underestimated. In the on-grid sector, low energy prices constrain solar installations. Concomitantly, important applications in the off-grid sector are currently limited to small-scale solar devices for household lights and charging mobiles. In total, there is an impressive potential for renewables, especially in off-grid solutions in the efforts toward electrifying the rural areas. In many regions where there is no access to the grid, PV systems and captive diesel PV hybrid systems are cost-effective and safe solutions. The integration of a storage facility to improve the power supply often makes sense. There is significant potential for on-grid as well as off-grid solar infrastructure. Over the next five years, a potential installation of 1,250 MW PV seems realistic.

Ghana

With 29 million inhabitants, Ghana is one of the continent's smallest states. It is among the lower-middle income countries but boasts one of the most accessible markets in the sub-Saharan region. Ghana has a relatively open economy, with few import restrictions. Thanks to its political stability, legal security and low crime rate, Ghana is an interesting investment target for international companies.

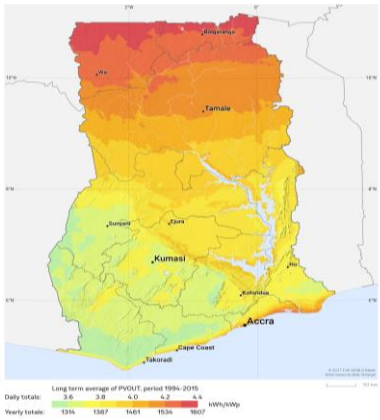


Figure 9: Photovoltaic power potential Ghana. Source: Solargis

Countrywide, there is a large solar potential, with an annual sunshine duration ranging between 1,800 und 3,000 hours. Nevertheless, the installed PV capacity only reached 65 MW by the end of 2018. The Nzema Solar Power Station, with 155 MW, is still under construction. When finished, it will only cover about 2% of Ghanaian energy consumption.

About 70% of the population has access to electricity, with marked North-South and urban-rural differences. Many areas in the northern countryside have none whatsoever. According the Ministry of Energy's plan [26], electricity for the entire population should be available by 2020. In the northern rural areas, off-grid provision should be part of the solution.

Regulatory framework

A governmental energy policy stipulates that around 10% of the electricity has to come from renewable sources by 2020. The percentage should reach 100% in 2050. The government realizes that power sources should be diversified. The country is vulnerable to droughts due to Ghana's heavy dependence on hydropower. Feed-in tariffs and net metering are important support schemes to reach the goals.

As part of the renewable energy targets, the government has set a series of targets for solar technologies. Until 2030, around 1 million solar lanterns, 450 MW utility scale PV, 200 MW distributed PV; 20 MW standalone PV, 46,000 ha irrigation by PV and 135,000 solar water heaters should be installed [26].

There are many RE programs to promote and/or determine targets. These include the Renewable Energy Act 2011, the Off-Grid Electrification Program, the Renewable Energy Master Plan, and the Scaling Up Renewable Energy Program (SREP).

Potential for PV Development

Renewable technologies, especially solar systems, play an important role in electrifying Ghana's rural areas. Various concepts encompass solar-based mini-grids; solar home systems (SHS) in rural or isolated areas; solar lanterns and community lightning systems; solar water pumps, as well as solar electrification in off-grid public facilities (i.e. schools or hospitals). Smaller roof systems up to 1 MW could be interesting for commercial and industrial companies with high electricity consumption, i.e. for industries or mining. In many cases, the integration of a storage facility to improve the power supply would be relevant.

Across the country, there is a large potential for off-grid and on-grid solutions based on solar applications. Thanks to declining prices for solar systems, high energy prices, and a stable political environment, foreign investments in the Ghanaian power sector are very promising. Over the next five years, 360 MW PV installations seem highly possible.

Morocco

Morocco has very high levels of solar resources, about 3,000 hours per year of sunshine and up to 5.8 kWh/m² in the desert. The desert is especially suited for the development of large-scale solar projects.

In 2015, Morocco increased its official target to 52% renewables in the mix by 2030, which translates into a target of 4.5 GW solar [27].

The PV installed capacity grew steadily from 13 MW to 25 MW between 2008 and 2017. In 2017 and 2018 the total installed capacity reached 606 MW due to the construction of several utility-scale plants, mostly around Noor (combination of solar PV and CSP plants).

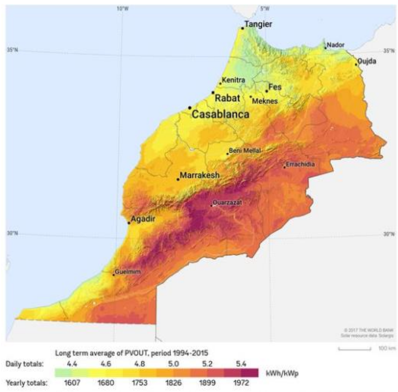


Figure 10: Photovoltaic power potential Morocco. Source: Solargis

Morocco also invested in a rural electrification program and installed more than 70,000 solar kits for households between 1998 and 2017 [27]. Hence, the electrification rate is very high and 99% of the population has access to electricity.

Regulatory framework

Morocco is essentially working through tenders linked to specific projects. There is no incentive measure for distributed PV installations and the discussions are still ongoing about their implementation. Injection of solar electricity on the low and medium voltage grid is allowed since 2016 and net-metering should be applied [28]. However, there is no official tariff for the electricity surpluses injected into the grid, which reduces the security of investment. It is the grid operator ONEE which decides the price for the injected electricity, the grid connection and grid utilization fees.

Solar is also a good alternative to diesel for powering water pumping installations in rural areas. The government announced that a budget would be available in 2021 for solar installations in agriculture [29].

Potential for PV development

As electricity demand in Morocco is growing by 5% per year, the opportunities for investment in new production facilities are increasing. The country wants to invest more in renewable energy sources and energy efficiency measures to curb energy imports.

The monarchy is looking to increase the interconnection with neighboring countries and Europe [27]. Morocco already has two energy interconnectors in Spain and the two nations have signed a memorandum of understanding to build a third power link. A feasibility study for an interconnection between Morocco and Portugal was launched in 2016. In addition to Spain and Portugal, Morocco has two interconnections with Algeria. The country is also looking for opportunities to connect with Mauritania [27].

The Noor Solar Plan will result in a combined solar capacity of about 2,000 MW together with storage in the form of heated molten salt [29]. In the first three phases of the plan, Morocco invested in CSP: 160 MW in 2016, 200 MW in 2018 and 150 MW still to be build. However the next phases should be dedicated to solar PV. The Moroccan Agency for Sustainable Energy (MASEN) will launch new tenders to complete the project. The state utility in charge of water and electricity (ONEE) is also planning the development of 500 MW of PV capacity by 2020. Over the next five years, there is potential for up to 3.2 GW of PV installation.

Namibia

The opportunities for solar energy in Namibia are almost unlimited thanks to the good natural solar conditions. The annual solar irradiation ranges between 1,600 and 2,100 kWh per square meter and is one of the highest worldwide. About 300 sunny days and more than 3,000 sun hours per year make solar energy extremely attractive in Namibia.

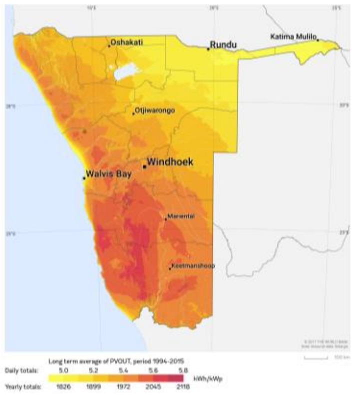


Figure 11: Photovoltaic power potential Namibia. Source: Solargis

This potential is set to be better exploited in the future. The government has specified a Renewable Power Target of 70% by 2030. Furthermore, the country's electricity generation has to be covered by renewable sources, including solar energy. This will create numerous investment and business opportunities for foreign companies. So far, a PV capacity of around 79 MW is installed nationwide. Excluding hydro power, the share of RE in the electricity market reaches 2 to 3%.

Regulatory Framework

Namibia has a total installed electrical generation capacity of around 550 MW, but only about 460 – 470 MW is available. Therefore, there is a strong dependence on electricity imports. More than 60% of the total energy consumption consists of electricity imports from Zimbabwe, Zambia, South Africa and Mozambique (South African Power Pool). The Namibian Energy Ministry developed a National Integrated Resource Plan (NIRP), a 20-year development plan for Namibia's Electricity Supply Industry (ESI) for the period 2016 to 2035. This plan contains projections of future electricity demand which identifies a mix of the cheapest electricity generation options to meet the country's electricity needs in a reliable and efficient way. In the reference case, Namibia’s energy peak demand will rise to 930MW in 2025 and reach more than 1,300 MW by 2035 [30]. Namibia’s national power utility (NamPower) recently signed Power Purchase Agreements (PPAs) with 19 Independent Power Producers (IPPs) to realize around 176 MW of RE generation capacity by 2020 [31].

Renewable energy sources are also promoted by net-metering (self-consumption systems up to 500 kW) and by the REFiT-Program (systems between 500 kW and 5 MW) and tenders for large grid connected RE systems superior to 5 MW.

Large-scale PV systems feeding into the grid will continue to be operated by private producers in the future. The current regulations provide for a feed-in tariff (REFiT) for systems of up to 5 MW. The Namibian government limits the licenses, and thus controls the number of REFiT projects. There are fourteen 5 MW REFiT projects in Namibia. Eleven of them are already in operation (55 MW). [32] In total, all projects inject up to 70 MW of renewable energy into the grid. The largest solar power plant, with a generation capacity of 32 MW (near Mariental), will be finished soon [31].

Potential for PV Development

Altogether, there are around 22,000 industrial and commercial electricity consumers in Namibia. A conservative estimate based on large industrial consumers assumes that there are at least 5,000 potential customers for PV self-consumption systems. Small Renewable Energy Systems, especially PV systems for private households, will not play a market-relevant role for foreign companies [33]. Over the next five years, a potential of 100 MW PV installations seems realistic.

Nigeria

Nigeria has excellent natural conditions for the use of solar energy. The average annual solar radiation is between 2,000 and 2,200 kWh/m² in the North and about 1,600 kWh/m² in the South. The country's potential for solar generation capacity is around 427 GW (CSP + PV). Further estimates assume a theoretical solar thermal generation capacity of 42,700 MW in central and northern Nigeria [34]. Nigeria today has more than 180 million inhabitants and an electricity-generation capacity of no more than 13 GW. Less than 60% of the population has access to electricity. Half of this capacity is available on a regular basis and around 80% of the country's power plants are gas fired.

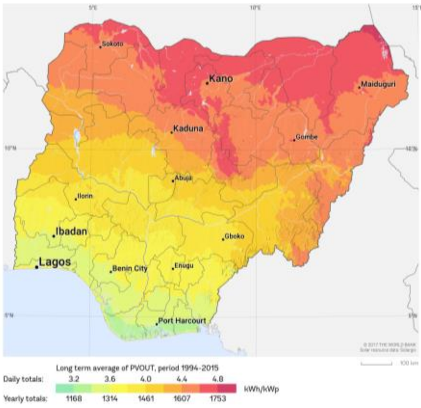


Figure 12: Photovoltaic power potential Nigeria. Source: Solargis

It is assumed that electricity demand will continue to rise due to the rapidly growing population and economy. The current electricity supply is characterized by frequent interruptions. The very inefficient power supply wastes considerable resources. Renewable energy sources, especially PV energy, offer immense savings potential and excellent opportunities for investors.

Regulatory framework

By 2030, the Nigerian government intends to cover around 30% of the country's energy needs with renewables. By then, the cumulative installed capacity is expected to have reached 30 GW. The Nigerian government's National Renewable Energy Action Plan (NREAP) [35] created the framework for the use of renewable energy sources. The installed PV capacity is expected to reach around 5 GW in 2030 and solar thermal around 1 GW. Around 20 MW of installed PV capacity, mainly via off-grid solutions [36], were foreseen before the end of 2017 and more was expected in 2018 and 2019.

By 2030, the government's plan anticipates the share of the rural population served by renewable energies and hybrid mini-grids to reach 10%. Furthermore, an installed capacity of more than 5 GW in mini-grids powered purely by renewables capacity (off-grid) is planned [35].

The Rural Electrification Agency of Nigeria (REA) estimates that the Nigerian mini-grid and solar home systems market can easily reach a level of more than 9 billion dollars a year [37]. The 2030 targets for solar water heaters for sanitary hot water and preheating of industrial process water are also very ambitious and promise enormous installation potential for solar solutions. Many on-grid PV systems have already been approved in Nigeria, but relatively few are in operation due to regulatory and technical circumstances.

Promotion of renewable energy sources: In order to achieve the government's goals, fundings and financing opportunities have been created. These include a fixed feed-in tariff (REFiT, 20 years; solar power up to 5 MW), power-purchase agreements, tax advantages for the importation of solar products, and mini-grid regulation [38].

Potential for PV Development

Renewable energy sources, especially PV systems, are an important pillar to solve Nigeria’s energy problems. There is certainly some potential, particularly for off-grid solutions. In many rural areas, where there is often no access to electricity, PV systems and captive diesel-PV hybrid systems are a cost effective and safe solution to reach governmental renewable energy goals. In many cases, the integration of a storage facility makes sense or is necessary. The situation presents an interesting opportunity for international project developers [34].

The World Bank’s “Nigeria Electrification Project” aims to increase access to electricity services for households, public educational institutions, and underserved micro, small, and medium-sized enterprises (MSMEs), with a focus on RE/solar (off-grid projects). This electrification program expects to provide electricity for 2.5 million people and 70,000 MSMEs [39]. With the support of the project, the REA of Nigeria plans to install 10,000 mini-grids all over the country. However, since the generation capacity of these grids is a mere 100 kW, only about 30% of the expected demand in the country will be covered [36].

Additionally, commercial and industrial electricity consumers, agriculture and private households can benefit from PV applications. One of the main incentives is to reduce the costs of diesel-powered electricity generation. Over the next five years, there is potential for up to 3.5 GW of PV installation.

South-Africa

Most areas in South Africa have on average more than 2,500 hours of sunshine per year. Average solar-radiation levels range between 4.5 and 6.5 kWh/m² in one day.

In line with the national commitment to transition to a low carbon economy, South-Africa promulgated the Integrated Resource Plan in May 2011. This plan sets a more ambitious target of 17,800 MW of renewable energy to be achieved by 2030 [40], of which 5,670 MW come from solar power. The implementation of the plan has been effective, as the installation rate of solar PV has been accelerating since 2013, to reach 1,815 MW in 2018.

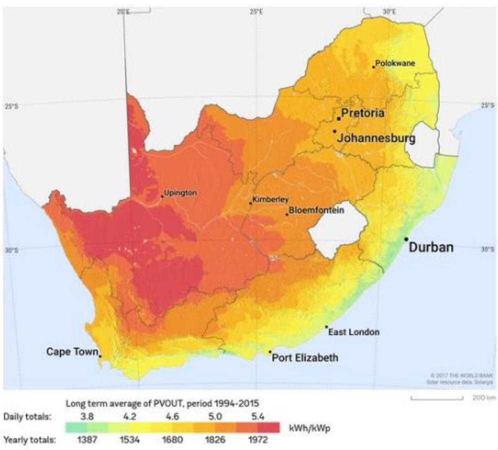


Figure 13: Photovoltaic power potential South Africa. Source: Solargis

The development is mainly driven by utility-scale installations in the framework of official tenders. According to official sources, there was approximately 285 MW of small-scale distributed generations installed in South Africa in 2017.

The costs of solar PV installations have decreased while the retail electricity prices, on the other hand, have increased at similar rates. Therefore, the financial case for investment of distributed solar installations improved.

86% of the population has access to electricity and the government wants to achieve 100% by 2019.

Regulatory framework

Four solar tenders were already organized under the South Africa's Renewable Energy Independent Power Producer Procurement Program (REIPPPP) which started in 2011 [41]. RES power installations are being financed through PPA's with Eskom, the national company for electricity generation, transmission, trading and distribution.

Seven municipalities have National Energy Regulator of South Africa (NERSA) approved FiTs.

As of 1 January 2016, the government introduced a tax incentive for the installation of photovoltaic solar energy generation systems. Depending on the size defined in MW, the section 12 B of the Income Tax Act No. 58 of 1962 stipulates that the size of the tax shield available through accelerated depreciation of the commercial tax paying entity. Photovoltaic solar systems greater than 1 MW are depreciated with the scheduled 50%, 30%, and 20% in the first 3 years respectively [42].

Potential for PV development

In the upcoming years, the growth is likely to be pursued as the target for solar energy of 5,670 MW has not been realized yet [43]. The current market and policy conditions will remain as the country has reaffirmed and even boost his ambitions in the latest energy blueprint.

There are currently 34 municipalities in South Africa who have an approved registration process designed for the grid connection of small-scale distributed PV installations. If the business case for small-scale solar installations further improves, the adoption of solar PV in this segment might continue to grow as well. Over the next five years, there is potential for up to 3 GW of PV installation.

Tanzania

Tanzania is one of the largest East African countries, with a population of around 56 million. The country is characterized by relatively high political stability. Furthermore, Tanzania is one of Africa's safest countries for investments. Countrywide, the installed capacity is 1.5 GW, around 40% of which is covered by hydro and more than 55% by fossil fuels. By the end of 2017, estimated solar PV capacity reached approximately 11 MW. The current rate of access to electricity is around 30%. In rural areas, which usually have no access to public grid or off-grid solutions like diesel-powered electricity generation are the most common source. As a result, Tanzania energy prices are very high, and power outages are frequent. The county's mining industry consumes 30% of all energy.

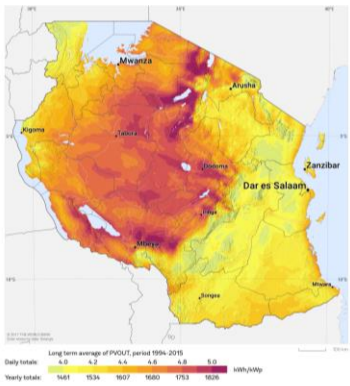


Figure 14: Photovoltaic power potential Tanzania. Source: Solargis

Positive GDP growth rate over the last decade stimulated growing demand for electricity. The government expects an installed capacity of more than 10 GW by 2035.

One goal is to reduce dependency on fossil fuels and hydropower, the latter due to frequent droughts. Renewable sources like solar and wind are perfect alternatives. Solar radiation ranges between 2,800 and 3,500 hours per year. The potential for grid-connected solar PV is estimated at 800 MW [12].

Regulatory framework

The government's target is to achieve a 100% national electrification rate by 2030 and 100% renewable power in 2050 [23]. However, because the country has its own fossil fuel resources, the government plans to install new plants fired by oil and gas. Currently, solar energy does not play an important role. In order to achieve governmental goals for a countrywide electrification, solar energy will have to be integrated both on- and off-grid.

Tanzania is developing FiTs and capacity auctions under the guidance of the GET FiT initiative [12]. Additionally, the government aims to stimulate RE installations by lowering the VAT, as well as import duties on PV equipment.

On-grid projects with a total capacity of about 150 MW are in the planning stage; some have been financed, but not yet commissioned [12]. A one MW utility-scale PV power plant has already been installed, but uncertainty and a lack of confidence in long-term payments from utilities restrict installations in this segment. Additionally, there are significant inflation-related currency risks. As mentioned before, a governmental proposal to stimulate installations relies on a reduction of the country's VAT and import duties on PV equipment.

Potential for PV Development

Target sectors are mining, farming, industry (metal, glass, paper, etc.), tourism, public facilities, and households. A market of interest lies in rural areas due to the widespread lack of electrification. The off-grid market, e.g. solar home systems (10 – 200 W) shows huge potential for PV installations. Mini-grids of up to 5 MW that would have hundreds of customers are also a potentially attractive field of business. Other promising areas for investment are the mining industry and the manufacturing sector, where PV systems suitable for self-consumption combined with diesel generators can reduce energy costs. Furthermore, batteries can lead to a shift in the consumption of solar power. The attractiveness of PV systems should increase due to falling prices, which, in turn, should lead to a rethink on the part of the government.

The Power System Master Plan (PSPM) 2007-2031 envisaged the construction of 120 MW of PV capacity by 2018 and several private companies have expressed interest in developing 50 – 100 MW solar plants [44]. Furthermore, the Rural Energy Agency (REA) and other donors have supported several solar PV expansion programs. Over the next five years, there is potential for up to 200 MW of PV installations.

Potentially interesting technologies are technologies for self-consumption, mini-grids, and island systems. Off-grid PV solutions can be used in villages, schools, and hospitals, as well as in the commercial sector and households, for street lighting, and for basic electricity needs. A further attractive idea is to install solar power plants as additions to all new rural hydro projects. This would help mitigate seasonal shortcomings due to droughts.

3.3 Key markets and regional PV development forecast

Forecasting PV development is a difficult task in all countries and even more in a continent as diverse as Africa. This chapter presents three scenarios for PV development with a critical perspective.

The three scenarios are built as follow:

- The **Policy-Driven scenario** is based on official roadmaps and announcements made by policy-makers in key African countries. Several countries in Africa have different energy plans and targets which include set goals for installed PV capacity by different years. For the countries that have a set goal of installed PV capacity by a certain year, a value of installed PV capacity per capita has been derived from that goal and the UN´s world urbanization prospects. In each region, an average PV capacity per capita has been calculated based on the countries that have official goals or roadmaps in that region. This average PV capacity per capita has then been used to calculate an installed PV capacity for the countries with no goals within a region to complement the countries that has a set PV target.
- The **Business as Usual scenario**: this low scenario envisages some market development driven by existing policies (or the lack of policies), in a realistic and conservative way. It assumes the existing constraints for PV development in Africa won't be lifted simply and immediately and that existing constraints in many countries that delayed the development of the energy sector will remain in place. On the medium term, it assumes that the targets from the policy-driven scenario described above will be reached progressively.
- The **Solarize Africa scenario** assumes that Africa will experience the same kind of PV development as the rest of the world. With declining PV prices, the question of policies becomes less important in Africa and the natural competitiveness of the technology will open largely the doors to PV in all segments. The scenario is based on a methodology developed by Becquerel Institute, Chris Werner and Alexandre Gerlach [45] and considers that in an environment without specific financial incentives, a competitive technology can be developed according to logistic curves until it reaches market saturation. Market saturation has been evaluated in this case according to IEA energy consumption scenarios for Africa. This comprises the shift to electricity for industrial applications, transport and heating (when applicable), while it is assumed that a complete electrification of the continent will be achieved in 2050. Rising consumption levels to comparable ones in other world regions with similar patterns. In the case of markets with specific incentives such as Egypt and South Africa for example which are developed already, the scenarios until 2025 and 2030 have been adapted to avoid a burst in the coming years followed by a decline of the market afterwards.

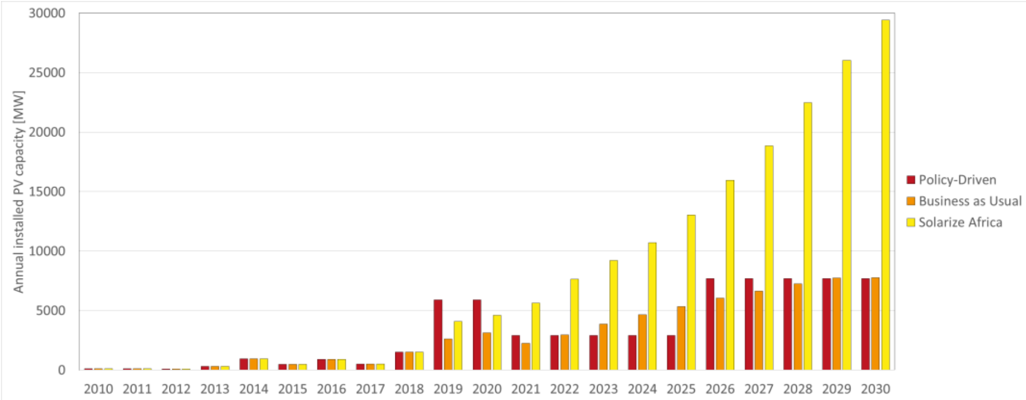
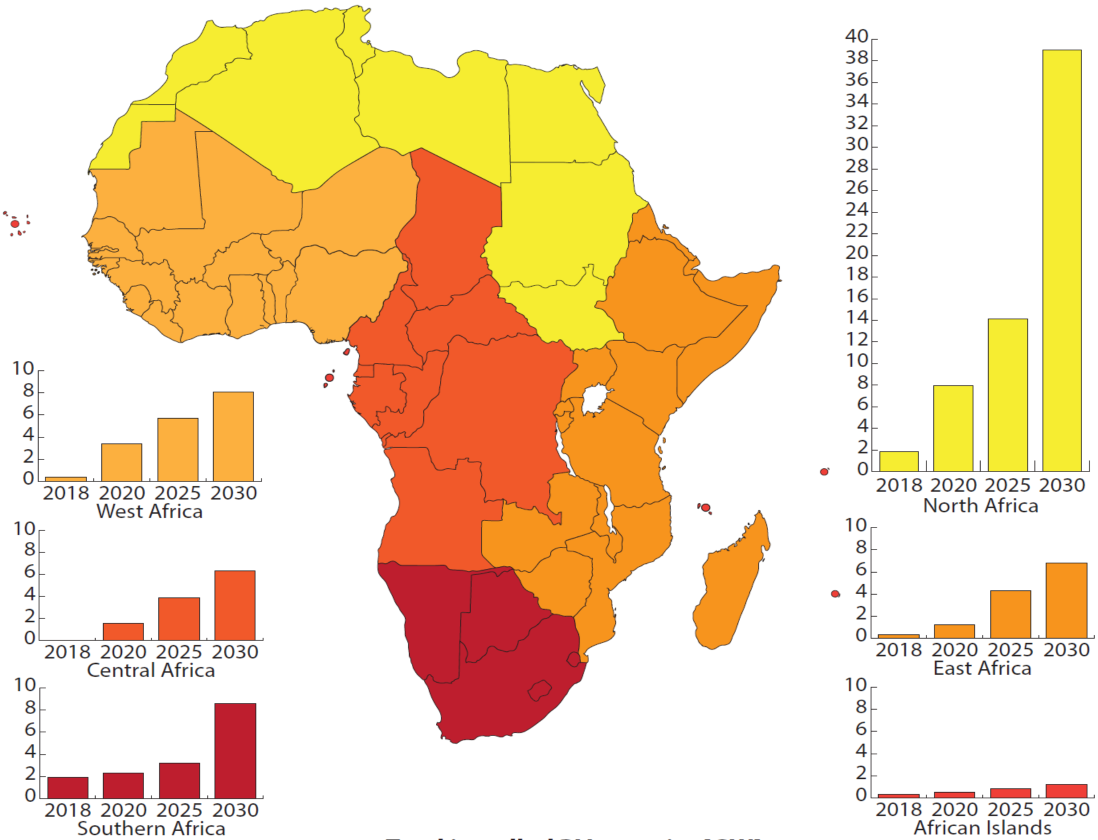


Figure 15: Business as usual, policy driven and Solarize Africa scenarios for PV development in Africa. Source: Becquerel Institute.

The three scenarios design a totally different evolution of the PV market in African countries in the coming decade. The key element is the start of growth from 2018 onwards which is expected in any case to develop in the coming years. The policy-driven scenario indicates, with the necessary caution, the lack of coherency of public policies at the scale of the continent, while the two other scenarios offer perspectives based on the analysis of potential future African realities.

It is interesting to start with the policy-driven scenario, which represents somehow the development of solar PV in Africa according to the willingness of policy-makers.



Total installed PV capacity [GW]

	2018	2020	2025	2030
Central Africa	0.1	1.6	3.9	6.3
East Africa	0.4	1.2	4.3	6.8
African Islands	0.2	0.5	0.8	1.2
North Africa	1.9	8.0	14.2	39.0
Southern Africa	1.9	2.3	3.2	8.6
West Africa	0.6	3.4	5.7	8.1
Total	**5.1**	**16.9**	**32.0**	**70.0**

The graph and the table show total installed PV capacity per region in 2018 in GW according to numbers from IRENA, alongwith a prognosis basedon official national goals and roadmaps for PV deployment. Several of these goals and roadmaps are by the authors considered as conservative compared to the potential in these countries. So there is a good chance that this prognosis will be surpassed.

Figure 16: Policy driven scenarios of installed PV capacity in Africa based on national goals and roadmaps. Source: Becquerel Institute

Some of the national goals and roadmaps have been set a few years ago. As a result, some roadmaps have underestimated the full potential of future PV installations. Price development, until today and in the future, has not been fully considered. This leads to goals and targets that can be considered as quite conservative. From the authors' perspective, this is usually the case for some countries in East Africa and Southern Africa regions. There is a good chance that long-term installation numbers (i.e. 6.8 and 8.6 GW respectively by 2030) in the policy driven scenario will be overshot in these regions.

Another potential source of uncertainty in the policy driven scenario is that some national goals set a couple of years ago have overestimated the near future developments. This is particularly true for the region of North and West Africa where a few of national targets will most likely not be reached.. Fewer projects and installations have been implemented in comparison to what was expected a couple of years ago.

In these cases, this relates more to policy difficulties and investment uncertainties which are delaying the market uptake. The 3.4 GW of solar installations in West Africa and 8.0 GW in North Africa will therefore unlikely be achieved in 2020, which means that to the overall 16.9 GW target in the whole continent by 2020 will not be reached.

In the policy driven scenario for the whole of African continent and in most regions, the yearly installation rate is quite high: 6.1 GW per year until 2020. It will slow down to an average of 3.0 GW per year until 2025. Then it will accelerate again with an average of 7.6 GW per year. As mentioned above, these fluctuations are partly due to the flaws of the national goals and roadmaps: governments have a tendency to define policies with clear marketing deadlines, such as 2020 or 2030. Often governments that set 2020 targets are not the same that defined the 2030 targets, leading to incoherencies. However, there is anyway a possibility to see an accelerated-decreased-accelerated market development until 2030 for the African PV market. In some countries, it is still unsure whether the electricity infrastructure will cope with an accelerated PV development. A weak electricity infrastructure has the consequence that in many places, a rather limited PV capacity can be installed before the local electricity grid could be developed further. To increase the PV capacity, investments in - and roll out of infrastructure are needed. Building electricity grid lines, substations, etc. can in many cases take longer than installing PV systems. It would be unlikely that several African countries will experience such an instable PV market until 2030.

Business-as-Usual

After having pinpointed the difficulties to develop PV in Africa from public policies one must consider that there is a possibility to see the market taking the negative perspective, combining incoherent policies with the lack of infrastructure, political instability and more constraints that could delay the massive development of PV in Africa. Not all regions could take this direction, and we might see a more dynamic North and South with a struggling center. This business-as-usual scenario has the lowest chances and will have to be updated in the coming years. Countries at war or unstable are the ones that will most probably follow this scenario in the coming years, while opportunities will continue to develop PV based on international funding and private investments. In this scenario, the market could reach 2 to 3 GW in the coming years, driven by the existing installations ongoing in North Africa for instance. It could continue growing slowly to achieve more than 7 GW a year at the horizon 2030, after a dip following 2020. Since this scenario combines negative outlooks for all regions, its general probability of occurrence is relatively low and should be considered as a bottom line which most probably won’t be achieved.

Solarize Africa

While ambitious scenarios have been set in some countries, this scenario expects short term installations to be delayed in most countries due to a combination of policy and economic challenges. This is quite visible in Morocco for instance where the decisions to tender hundreds of MW have been several times delayed. But the increased competitiveness of PV implies that such developments are just temporarily delayed and will find their way to real installations. The low system prices already available in many countries are unlocking markets and projects are popping up all over the continent. This scenario supposes that most barriers are rapidly lifted, and that PV can develop according to its potential and needs. This would result in a 4 to 6 GW annual market in the coming years, with a regular market increase, reaching more than 10 GW a year from 2024 and up to 29 GW a year in 2030. There are also reasons to believe that the market could develop faster and reach these levels expected in 2030 earlier but this would require significant policy developments which are not often visible yet. We believe that this scenario is the most probable after 2021-2022 and will lead to significant installation levels.

This scenario also assumes a reasonably fast transition to electric mobility in densely populated cities and the massive use of PV with battery storage in suburban areas which will simplify grid developments and reduce their costs. In most places, solar will come in support or replace progressively diesel generators, using more and more storage units than in the last 5 years. PV for agriculture could also become a trend with the possibility to protect crops and enhance agriculture production in places where conditions have hardened. Finally, floating PV could thrive next to hydropower plants and the possibility to use existing grid connections to facilitate PV development. In a nutshell, we expect this scenario to rapidly become the most probable with opportunities for faster and wider development around 2025.

The business-as-usual scenario would imply 65 GW of PV installations in Africa at the horizon 2030, a level slightly below the 70 GW of the policy-driven scenario. In the Solarize Africa scenario, this could be as much as 173 GW which could be installed, a level comparable to what China has reached at the end of 2018.

3.4 Ranking of countries according to attractiveness for PV

The experience of two decades of PV market development shows that PV never develops by chance. Its development comes from a combination of drivers, which ultimately translates into policy decisions and private or public investments. Africa doesn't escape that reality. The methodology used below was initially developed for the "Unlocking the Potential of PV in Sunbelt Countries" report published in 2011 [46]. It was further developed since then but continues to position countries according to the attractiveness of PV in the country and the attractiveness of the country for PV investments. The combination of both can lead to a conclusion where a PV market could likely develop well. To sum up, political and economic stability play a key role while the competitiveness of PV increases the chances to see a rapid and sustainable development.

The attractiveness of a country is defined by its economic development and stability, a business friendly environment, the regulatory quality and reliability and the political stability to name a few. While the attractiveness of a country for the PV market is likely determined by its renewable energy policies, level of energy access, electric power consumption per capita etc., each of these elements is quantified using international indicators, weighted to provide a unique value per country.

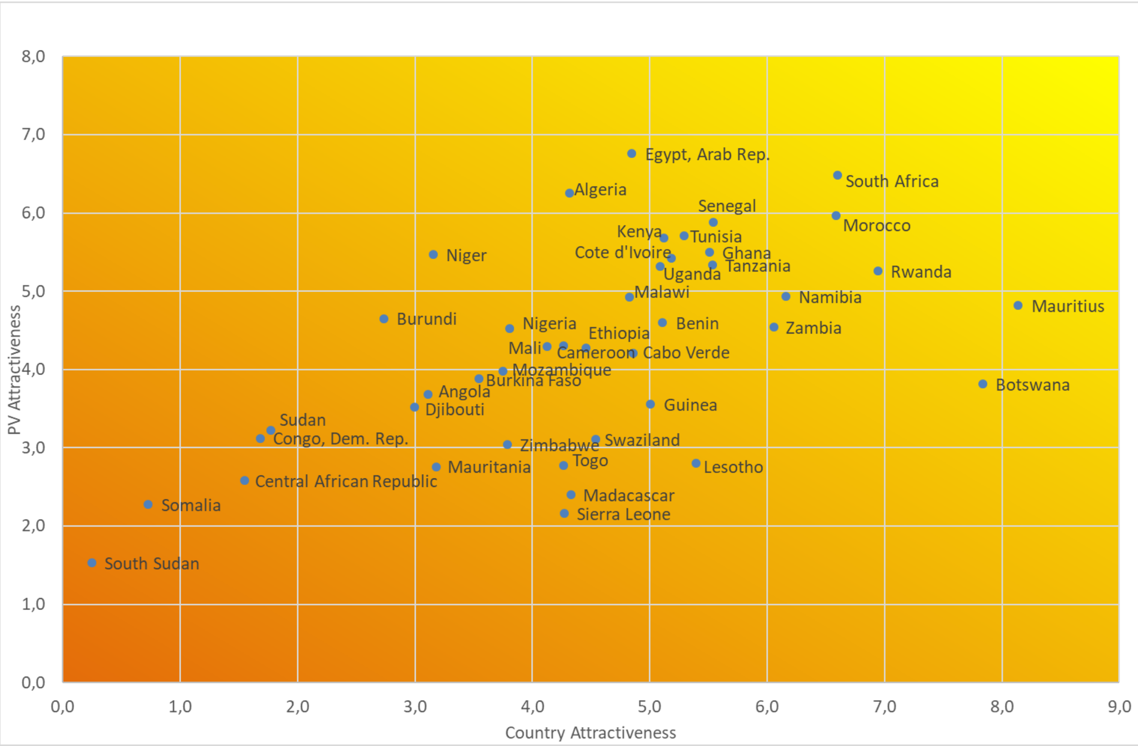


Figure 17: African countries scoring for PV attractiveness. Source: Becquerel Institute

Country attractiveness

Countries which are more stable, both politically and economically, such as Botswana, Mauritius, Morocco, Rwanda and South-Africa seem also the most attractive for PV. This is inevitable as transparent and reliable frameworks are a prerequisite for any kind of investment. Most of these countries also already implemented some renewable energy policies and targets.

Other countries such as Ghana, Ivory Coast, Kenya, Tanzania and Uganda have also implemented renewable energy policies. However, making business is not especially being facilitated for foreigners and investors in these countries which cost them slightly but they are still quite attractive.

Countries which recently experienced political instabilities are the least attractive for PV. The situation in South Sudan is an unfortunate example. Indeed, shortly after its independence in 2011, South Sudan fell into civil war and endures since then one of the worst humanitarian crises in modern times. However, even in this context PV might be a solution to improve the living conditions for the country's population and to deliver short-term cost savings in a nation where electricity generation is one of the highest recurring costs in humanitarian budgets [47]. Solar installations are already in place in South Sudan for some specific projects or applications. For example, PV is used to preserve the cold chain in the transport of vaccines or to provide electricity for drinking water pumping installations or lighting in remote areas or hospitals.

PV attractiveness

The whole continent has very high solar irradiation rates, yet, there are some local differences. Coastal areas and densely forested areas, for instance, are on average less insolated and less suited for large-scale PV installations. While desert regions, on the other hand, are optimal for solar irradiation and large-scale PV development, it is not surprising that countries such as Algeria, Egypt, Morocco and South Africa are amongst the most attractive countries for the PV market. However, the irradiation was not considered to evaluate the attractiveness of a country for PV. In fact, the factors making these countries attractive for PV are, on the one hand very good energy access and high electricity consumption per capita. And on the other hand, renewable energy policies that lead to some PV installations.

Namibia and Zambia are both attractive countries when it comes to the ease of doing business; they are nevertheless not the most attractive for the PV market. The main reason is the lack of flexible generation capacity and the low electric consumption, especially in Zambia. Botswana has an even lower share of flexible generation capacity but the higher electricity consumption per capita compensates.

Although Tunisia is very attractive for the PV market in many aspects (interconnection, land use, PV regulation), the country is not amongst the most attractive for the PV market. Essentially because the population and the electric consumption growth are a bit lower compared to the countries mentioned above and those parameters are important in our model for the attractiveness of a country for PV. The possibility of interconnecting Tunisia with Europe via Malta could probably significantly increase the attractiveness of the nation for the PV market.

3.5 Specific market conditions

Dependence on fossil-fuel and subsidized electricity price

Most African countries still rely massively on thermal energy to produce electricity from fossil fuel and continue to develop traditional, non-renewable energy sources, such as coal to satisfy rapidly increasing demand for electricity. And this trend continues even though solar PV, and other renewable energy sources, have become competitive with fossil fuel technologies, which are often imported and expensive.

Despite growing international momentum towards climate change mitigation, various African countries continue to subsidize fossil fuels, with the risk of locking these countries into high emission trajectories for the next few decades [48]. In addition to encouraging wasteful consumption and hindering investment in energy efficiency, fossil fuel subsidies are also economically inefficient as they impose a significant burden on government budgets and decrease the competitiveness of key industries, including the renewable energy sector [49]. In general, fossil fuel subsidies are still used by various sub-Saharan African countries to compensate for electricity tariffs that are not fully cost-reflective.

However, the introduction of cost-reflective tariffs is politically challenging, and often meets strong resistance from politically influential groups as well as the populations. The common argument against energy price increases is the affordability of energy services for the poor people – even if poor consumers are typically not the ones that benefit most from the subsidies [50].

The countries that provided fossil fuel subsidies in excess of USD 1 billion in 2015were Angola, Ivory Coast, Mozambique, Nigeria, South Africa, Tanzania, Zambia, and Zimbabwe. The estimated costs associated with fossil fuel subsidies rose to USD 75 billion in 2015 for the whole region [49].

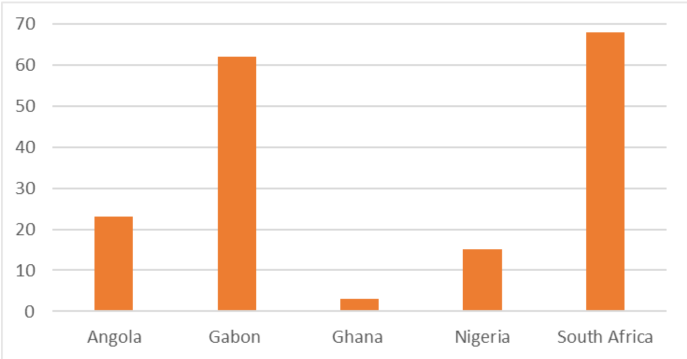


Figure 18: Normalized fossil fuel subsidies for select sub-Saharan African countries (2016, USD per capita). Source: IEA fossil fuel database; and World Development Indicators

Need for grid upgrade and strengthening

Even when African countries try to increase electricity production, in most markets we analyzed there is still a significant part of the population who have no access to the grid face regular blackouts and brownouts due to capacity shortages and infrastructure failures. As shown in figure 19 below, power outages are part of daily life in SSA, even in South Africa. In many countries back-up diesel generators are used to face these situations, increasing the cost of electricity up to three times more than it would be if grids were reliable [51].

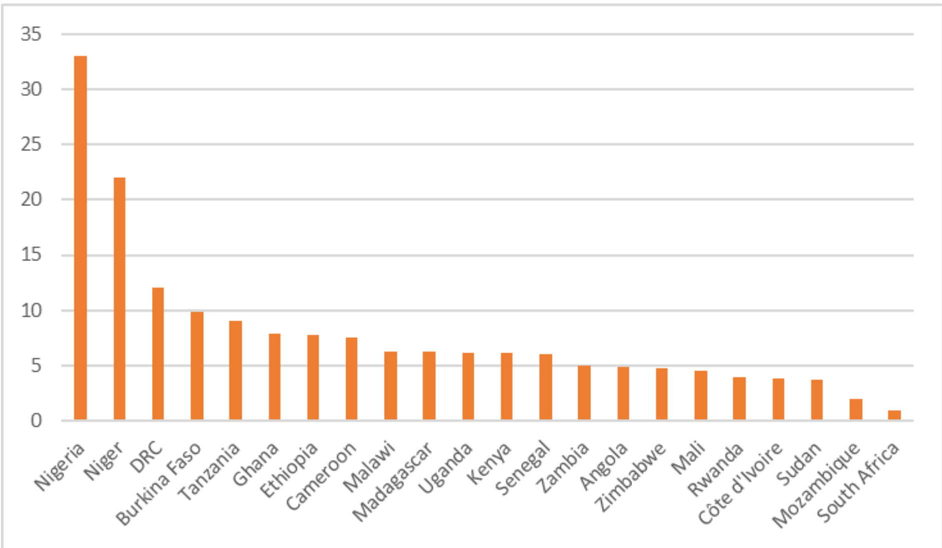


Figure 19: Number of electrical outages in a typical month. Source: World Bank, Bloomberg NEF

Inadequate infrastructure remains a core challenge for African power utilities, especially in sub-Saharan Africa where efforts to expand electricity supply to meet the growing demand struggles with low capacity utilization, inefficient grid operations and high distribution and transmission losses [50].

One reason for this is the lack of investment and financial creditworthiness of power utilities to maintain operations, as well as to invest in upgrading infrastructures [52]. Additionally, with the declining cost of solar and wind technologies, which are even challenging base load coal generation, utilities face the challenge of integration of intermittent renewable energy such as solar and wind.

To attract foreign investors to develop renewable energy, Africa will require improvements and upgrades of outdated grid infrastructure to connect new power plants (conventional and renewable), improve power supply reliability and to reduce electricity losses. In fact, a key issue for investors is not only to know whether solar is competitive today, but also whether electricity supply from the grid will improve (and therefore become cheaper compared to diesel generators).

3.6 Off-grid market including distributed storage solutions

Distributed generation to contribute to universal energy access

While Northern Africa is near universal access to electricity, Sub-Saharan Africa (SSA) is the least electrified region in the world and the electrification is proceeding at a slower pace than in other world's regions. SSA electrification rate has increased from 23% to 43% between 2000 and 2017 [53], but in absolute terms the number of people lacking access to electricity has increased since demographic growth outpaced electrification efforts. To date, 602 million people still lack access to modern electricity in SSA, roughly 80 million more than in 2000.

The dominant pathway for providing electricity access to date has been through grid extensions, which have been the source of the vast majority (97%) of new electricity connections since 2000. However, considering that nearly 80% of those lacking access to electricity across SSA are in rural areas [54], it becomes clear that reaching universal access to electricity by 2030, as outlined in the Sustainable Development Goals (SDGs), will not be achieved only through grid extension. Solar can dramatically improve energy access in SSA, thanks to the high irradiation in the continent as well as the decline in the technology costs. This is particularly true for rural and dispersed communities not served by a main grid and where it may take years for one to arrive.

Electricity access is now at the forefront of the development agenda and emerging and developing countries are supporting the deployment of distributed renewable energy sources to increase electricity access in rural areas where distributed generation is often the most cost-effective option. Many governments in SSA offer subsidies for the installation of off-grid systems as rural households in many cases have no financial capacity to pay for RE applications themselves. Decentralized systems can also be attractive in areas with grid access but unreliable power supply [53]. Among off-grid systems we distinguish:

- **Mini-grids**, also termed as isolated grids, involve small-scale electricity generation with a capacity between 10 kW – 10 MW. This grid uses one or more renewable energy sources (solar, hydro, wind, biomass) to generate electricity and serves a limited number of consumers in isolation from national electricity transmission network. Back-up power can be batteries and/or diesel generators. Batteries balance out fluctuations between electricity supply and demand. But currently batteries are still very expensive.
- **Stand-alone systems**, i.e. solar home systems or pico systems, that are not connected to a central power distribution system and supply power for individual appliances, households or small (production) business. Batteries are also used to extend the duration of energy use.

Although SHS or pico-solar appliances represent the bulk of distributed solar, thanks to the significantly lower system prices, the role for mini-grids is expected to increase, especially when electricity access initiatives aim to provide electricity for productive and commercial activities. However, to attract investments, mini-grids need a supportive enabling environment, including a clear national grid extension plan, regulations on how to integrate mini-grids if/when the main grid arrives, and clear rules for setting tariffs [53].

Innovative business models supported by digital technologies, together with the widening connectivity and data collection, are already contributing to fostering the access to electricity through solar in SSA. Delivery of utility services on a pay-as-you-go basis integrated with mobile payments is an example of innovative business model. Despite the potential, many start-ups and investors find barriers in countries' regulatory frameworks. For this reason, there is a pressing need to elaborate policy recommendations tailor-made for individual African countries and to give a bigger weight to these innovative solutions when designing national electrification strategies [55].

Distributed generation for Commercial & Industrial buildings

Developers are increasingly interested to invest in distributed solar installations for Commercial and Industrial (C&I) buildings. According to the BNEF report [56], the (still small) C&I solar market in Ghana, Nigeria and Kenya is set to grow by 162% in 2019. In fact, selling solar directly to C&I end-consumers could bypass some of the challenges linked to the grid connected solar market. Since solar is becoming cheaper than the electricity tariffs that the C&I customers would buy from the grid, it provides direct savings for the C&I customers. This is already the case for some countries such as Ghana, Senegal and Kenya [56]. The frequent power outages and instability of the transmission grids make solar and decentralized solar installations even more attractive for C&I customers who have no other choice than to turn to diesel generators for back-up power or alternately loose sales or manufacturing output [56]. Because in many countries excess power cannot be sold back to the grid, in absence of net-metering or FiT schemes, the solar system has to be designed to maximize self-consumption. Unless the solar system is just used for self-consumption of C&I customers, there are some regulatory barriers that may cause delays and uncertainties for investors. Distributed solar installations coupled with diesel generators are becoming an interesting alternative especially for the mining industries [57] which are often located far for the main grid. Other segments that are receiving increased attention by investors are: manufacturing and large retail spaces, public building and social infrastructures such as hospitals, schools, churches and administration offices [56].

4. Specific business models paving the way for energy transition in Africa

4.1 Pay-as-you-go M-KOPA

Digitalization is currently playing a big role in fostering the access to electricity in Sub-Saharan Africa. Since the early 2010s, companies have been adapting traditional business models for the installation of Solar Home Systems (SHS) to the specific African context where the rural populations have limited means to pay for its electricity. The « **Pay As You Go (PAYG) Model** gives the possibility for small customers to pay small amount each month through « **Mobile money** » transfers to pay for the solar system. If the customer stops paying, the system switches off and works again as soon as the customer pays the remaining credit.

M-KOPA Solar is a Kenyan company, one of the world leading providers of PAYG energy for off-grid customers. M-KOPA (M= mobile, KOPA= to borrow) combines mobile payments with GSM sensors to enable consumer financing of solar power systems. Created in 2011 by the same founder of M-PESA, one of the largest mobile banking systems in SSA, their offer includes an 8 W solar panel, providing energy for 3 LED light bulbs, a portable rechargeable torch, a home charging USB with five standard connections, a rechargeable radio and a 20 W SHS which has a 16” digital television. For an up-front payment of USD 30 and USD 60 respectively, and daily instalments of USD 0.50 and USD 1 respectively [58]. Prices are similar in neighboring Uganda and Tanzania. The payment frequency and size are up to the customer’s choice, but the entire value has to be paid within the payment period agreed (from 380 to 570 days). Many retailers are encouraged to look for new customers since they receive small sales commissions [59].

One of the key drivers of this model is the increased penetration of mobile use among the poorest in sub-Saharan African countries [55]. African phone companies offer payment services linked to a mobile phone account, without the need to open a bank account. Kenya, Namibia and South Africa are the leaders, but mobile money usage penetration is very high in countries such as Gabon, Ghana, Uganda, Zimbabwe, Rwanda and Tanzania. Countries like Guinea, Senegal, Togo, Burkina Faso, Benin, Gabon, Madagascar, Zimbabwe and Congo are also witnessing a soaring increase suggesting a bright future for this technology.

4.2 City electrification in DR Congo

The city of Manono in DR Congo hosts around 50.000 inhabitants and was powered by some diesel generators only until a project to electrify the city was implemented. The project was realized by Group Forrest (Congo energy Forrest) and the PV specialist ENERDEAL. The project consisted in creating a complete 21 km long MV/LV backbone fed with solar PV electricity. The project can be considered as a complete PV-driven electrification, together with the realization of trenches, posing cables, MV cabinets and meters. In order to ensure the full redundancy, two banks of batteries in air-conditioned containers have been installed, with a rather low DOD level (70%) ensuring 15 years of operations (or 5000 cycles). Black start capability with PV only is foreseen and batteries regeneration cycles without diesel generators have been achieved. Diesel generators are used in backup and to allow managing the spinning reserve for instance.

The project brought electricity to a complete city, including street lighting, with 1 MW of PV, which could be expanded.

The logistics also indicate how complex such projects can be and more expensive than the usual utility-scale PV since planes delivered the PV panels. It offers opportunities for further development of PV to electrify places from the main centers with clean energy, cities and harbors at a competitive price.

Figure 20: Congo Energy Forrest – ENERDEAL PV plant in Manono, DR Congo. Source: Enerdeal

4.3 Solar supporting diesel generators

Africa is the leading place to power places far from the grid using diesel generators. Entire villages, companies or sites are powered only by electricity produced by such diesel generators. Until recently, solar PV was considered as an add-on to these generators, with the ability to reduce their fuel consumption by 20 to 50% depending on conditions. Below such levels, the generators cannot stay idle and additional constraints appear. But the business model remained the same, especially with high oil prices and the additional cost of transporting (in some places far from large cities, the cost of fuel can go up to 5 USD per liter). On a regular basis, this takes large quantities of fuel to ensure a regular production of electricity. In the last years, the drop of battery prices has opened new opportunities to hybridize the GENSET with solar PV and batteries. In that case, the business models would encourage producing electricity with PV, store it in the batteries and keep the generator in reserve in case of a lack of production from PV during several days. This business model is for instance promoted in Madagascar by the Belgian cooperation and other places.

Such development implies a high level of commitment for the maintenance since the lifetime of batteries will dramatically depend on it. In that respect, it might develop in the coming years under different business models where the question of the operations will take a higher turn than in the simple solar-diesel hybridization.

By solving the question of the delivery of fuel in time, solar and batteries also offer new opportunities for development to communities, which were not always considered in the past, while the extension of the grid to these communities can be envisaged in a faster way.

Finally, the question of the hybridization of diesel generators might rapidly become a question of partial replacement if the solar PV plus batteries option becomes reliable. In several cases, the question of replacing the investment in an upgrade of the diesel generator by an investment in additional storage capacities could lead to a progressive decrease of the market for diesel generators and a market increase of smart connected solutions for PV and adequate batteries.

4.4 Crowdfunding to finance solar mini-grids in Nigeria

Since 2018, six pilot solar mini-grids are giving 15,000 people access to reliable electricity in Nigeria. Those people no longer rely on diesel generators to light homes and run small businesses such as grain mills, cocoa drying and welding operations, carpentry workshops, and small restaurants and hotels [60]. The solar mini-grids were partly funded through the European Union, the German government (GIZ) and the USAID-funded Renewable Energy and Energy Efficiency Project (REEEP) in collaboration with the Nigeria's state government.

The funds available for the mini-grid component are USD 150 million. The Component consists of two funding windows: a minimum subsidy tender to electrify selected communities that have high economic growth potential; and a performance-based grant program for the development of mini-grids on a spontaneous basis. The grant amount is set at USD 350 per connection.

One of the main barriers to realize this project was the financial aspect. Surprisingly, the project partners found two original solutions which could be applied elsewhere:

- First, they worked with a so-called split asset model. Instead of trying to convince banks and other financial institutions to invest in a mini-grid project, REEEP separated the distribution and generation components.
- Secondly, they decided to collaborate with the German crowdfunding platform Bettervest with the aim of entering the Nigerian market.

The financial model developed for this project allowed to lower the risk faced by its investors. Therefore, such financial models have the potential to improve access to finance in countries with higher investment risks.

4.5 The Desertec Concept

Producing electricity with renewables in the desert to power Europe is an idea that flourished already some years ago. The initial DESERTEC concept was developed by the Trans-Mediterranean Renewable Energy Cooperation (TREC), a voluntary organization founded in 2003 by the Club of Rome and the National Energy Research Center Jordan [61]. Desertec promotes the large-scale production of solar and wind power in the desertic regions of the world with a transfer through high-voltage direct current transmission to consumption centers.

The first focus application involved a Euro-Mediterranean electricity network to integrate abundant sources of renewable energy in the European Union, Middle East and Northern Africa. To accelerate the implementation, an industrial initiative called "Desertec Industrial Initiative" or Dii was created in 2009 to facilitate contacts between relevant stakeholders [62]. As a partner in a new partnership between Europe and MENA, Morocco seemed especially well-suited since a grid connection from Morocco via Gibraltar to Spain already exists. However, despite the efforts of the Dii, the project was incompatible with current levels of grid interconnectivity between the Maghreb and Europe, and within Europe itself [63].

Another factor which explains the apparent low rate of success is the initial focus on CSP, which unfortunately didn't break through. African countries also need to first meet their own growing demand before exporting to Europe. Therefore, Dii continues its work behind the scenes to enhance cross-border trade and regional cooperation with a stronger focus on the MENA region.

Other initiatives are emerging, such as the Africa Clean Energy Corridor (ACEC), which is a regional initiative to accelerate the development of renewable energy potential and cross-border trade of renewable power within the Eastern and Southern Africa [64]. In 2017, the Tunisian based company TuNur launched a request to export 4,5 GW of solar energy to Europe [65]. It will link Tunisia and Malta by 2020. In a second phase, further links to the center of Italy and southern France are planned.

While the idea was premature, the decrease of PV production costs, together with the emergence of solar fuels prototype projects, could provide new opportunities for such projects. This could lead to massive PV developments without any grid connection, easing the development and reducing the costs while providing energy for Europe.

5. Policies

Following the cost reductions and technology developments of renewable energy sources, many countries introduce policies and adjust their markets and regulatory frameworks to accelerate investments, innovation and the introduction of efficient and environmentally sound technology options. But renewable energy policies are just one component of broader energy sector policies, such as fossil fuel subsidies or carbon pricing mechanisms [66].

Solar systems have relatively high upfront investment costs compared to other renewable energy sources. The introduction of ad-hoc policies promoting the use of solar energy is crucial to ensure the deployment of this technology in Africa both for on-grid and off-grid. Furthermore, one of the main barriers for the entry of foreign investors into African countries is the limited availability of governmental regulations to promote and protect investors. Finally, as renewable energy technologies and markets have matured, policy makers face new challenges related to the integration of variable renewable energy such as solar and wind into power systems, this implies adjusting existing policy mechanisms and possibly developing new ones [66].

Most African countries have introduced national support instruments for the development of renewables. Key policies for on-grid and distributed generation encompass:

- **Renewable energy targets and national commitments**, which are still one of the main means for policy-makers to express political will to renewable energy deployment and give a signal to the market. These targets are increasingly linked to climate targets.
- **Financial and fiscal incentives** in the form of tax incentives, rebates, grants, performance-based incentives, concessional loans and guarantees, and measures to mitigate risks, which are used to catalyze private investments, reduce the high upfront costs or the production costs of renewable energy projects.
- **Regulatory and pricing policies** such as FiT, auctions, and net metering.

Renewable energy targets exist in almost all African countries. Tax reductions are a common instrument, existing in almost 30 countries in Africa. Twenty countries support renewables via direct public investments, loans or grants. Capital subsidies or rebates are employed in 13 countries [67].

5.1 Analysis of key supporting policies for distributed PV

Feed-in tariffs (FiTs) and **feed-in premiums (FiPs)**: have been instrumental in encouraging renewable energy projects worldwide, since they provide a stable income to generators and help increase the bankability of projects [68]. In 2017, FiTs and FiPs had been adopted by ten African countries, among which Egypt and Uganda have their FiT scheme already completed. In general, FiTs still contribute to scale up renewables, particularly to provide support for smaller-scale projects and specific technologies [68]. As an example, in 2017, Zambia launched its 200 MW FiT strategy for small and medium scale renewable energy systems up to 20 MW to improve rate of access in rural area [66].

Some FiT-schemes in Africa tend to be poorly working because of unfavorable institutional design, insufficient level of FiT rates or obstacles in the process of implementation [69]. Deficiencies in the design of those schemes and in their implementation can be due to conflicting policy targets like affordable power prices and grid stability but also to an unclear allocation of property rights that can lead to time-consuming negotiations over Power Purchase Agreements.

Self-consumption policies. Several countries in Africa are not able to meet energy demand, especially during peak hours because of insufficient power generation and the status of the distribution networks [68]. Self-consumption reduces power flows through the grid, thus decreasing energy losses, especially in the distribution network where most energy system losses occur. It can also enable reductions in peak demand, thus potentially postponing the need for grid reinforcements and upgrades.

Some countries have introduced or are currently introducing compensation schemes such as net-metering in their policy frameworks, i.e. South Africa, Cabo Verde, Egypt, Ghana, Kenya, Lesotho, Morocco, Namibia, Senegal, Tanzania, and Zimbabwe. The policy is running in Egypt, South Africa and Namibia. Reality shows that many countries are facing difficulties in its application. Reasons vary from the lack of policy will to create a regulatory framework for its implementation e.g. Ghana to ratify and enforce the law e.g. Kenya and Senegal or the fear of distribution companies to incur in revenue losses if the compensation scheme is implemented, Cabo Verde for example [70]. Nevertheless, few countries are introducing incentives to promote self-consumption, for commercial customers. An example is given by Ghana through the Solar Rooftop program.

To be successful, self-consumption policies need to be attractive: utilities revenue losses are taken into consideration, there is a strong political will to increase RE through binding targets and efficient and user-friendly registration procedures are enforced for people willing to join the program.

5.2 Overview of tenders for utility-scale solar in Africa

Although many countries are still introducing Feed-in policies, auctions are expanding rapidly worldwide as key policy support for utility scale RES [68]. This is also true for new African emerging markets. Auctions or tenders are already used in Algeria, Botswana, Egypt, Ethiopia, Madagascar, Malawi, Morocco, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Tunisia and Zambia [68].

However, when it comes to utility scale tenders, the largest African operating solar power plants are all located in South Africa followed by Northern Africa [71]. SSA counts only around 10 grid connected PV power plants that exceed 20MW and four of them are in Senegal [6].

	Operational (MW)	Non-operational (MW)
South Africa	1,333	1,127
Sub-Saharan Africa less South Africa	330	1,842
North Africa	385	1,820

Figure 21: Africa Large-Scale Solar Tracker. Source: Renewables in Africa. February 2019

The utility-scale solar market is struggling to grow in Africa. Limited institutional capacity, administrative delays, non-bankable PPAs and difficulties in securing transmission grid connections and land rights are hindering the project development and increase the uncertainty in the market [56]. In addition, the effort of the development agencies or equivalent institutions to subsidy solar projects in immature markets helping to train local stakeholders including national electricity companies, to convince local decision-makers that solar energy is a reliable answer, and support planning efforts, may involuntary bring distortions into the market [6]. In fact, subsidized projects may directly compete with existing ones, driven by private actors, as it has been the case in some countries in Western Africa. Or, alternatively where there is no direct competition with other existing projects, a subsidized project may create an artificial price signal that does not reflect the actual costs of project implementation, thus hampering non-subsidized projects [6].

In general, auctions have contributed to the recent reduction of renewable energy prices and, if thoughtfully implemented, they can lead the market to real price discovery. Often, they are coupled with support instruments to increase social economic benefit, i.e. local content requirements in Morocco and South Africa, or to facilitate access to finances, i.e. financial guarantees backing contracts to increase investor confidence in Zambia [68].

5.4 Focus on local manufacturing policies: examples of Morocco and South Africa

The energy transition requires a significant investment that represents an economic opportunity for the African countries. In this context the importance of having a well-articulated and coherent local content policy becomes relevant.

In many emerging markets, Local Content Requirements (LCR) are important to foster local manufacturing, implement local supply chains and innovative industries.

South Africa is an interesting example of a market developing rather fast, with local initiatives to promote the industry. Through its Industrial Policy Action Plan (IPAP), the Government identifies local content as a strategic industrial policy instrument. The revised Preferential Procurement Policy Framework Act (PPPFA) regulations which came into effect on 7 December 2011 empower the DTI to designate industries, sectors and sub-sectors for local production at a specified level of local content.

Within the framework of the Renewable Energy Independent Power Producer Procurement Program (REIPPPP), the Department of Trade and Industry (DTI) developed a table of socio economic output to be met or exceeded in order to become a “preferred bidder” in the tender. Each renewable energy project required a minimum of 40% participation by a South African entity, a minimum ownership by black South Africans of 12% (with the target set at 20%) and a minimum ownership of a local community of 2.5% where the community lived within a 50 km radius near the project.

Morocco is another example of how local market development, together with regulations favoring the local industry indirectly, combined with local industry financing, could support local manufacturing. MASEN is responsible for managing the solar auction scheme to install 2,000 MW across five sites by 2020 and it operates a two-phase auction process: a pre-qualification phase and an evaluation phase. In the evaluation phase, the selection is based on price. MASEN also sets a condition on local requirement: 30% of the plant’s capital cost (local equipment manufacturing, operation and maintenance, R&D) must come from the local industry. MASEN is responsible for promoting the development of R&D, education and training to support this local requirement as a means of improving economic conditions and creating jobs in country.

5.5 International organizations implication

Under the impulse of the UN’s Sustainable Energy for All (SE4ALL) initiative and its three central objectives of ensuring universal access to modern energy services, doubling the global rate of improvement in energy efficiency, and doubling the share of renewable energy in the global energy mix. All major bilateral and multilateral donors are committed to the promotion of renewable energy which is an important element of their international climate and development policies [67].

Donor organizations’ support can take many forms—from Development Finance Institutions (DFIs) that provide concessional loans, to bilateral foreign aid agencies that can offer grants, direct subsidies and technical assistance for policy support and institution building, project preparation and implementation / capacity development and training, to non-governmental organizations (NGOs) and private charities that can have diverse goals and objectives. Donors' active implication is crucial to ensure the technical, technological transfer and financial support towards renewable energy projects and programs in Africa, both large and small in scale, on-grid and off-grid [72] .

The three major multilateral donors in the energy sector in Africa are the World Bank, the EU and the African Development Bank. While the three of them participate and manage various multi-country programs, the bulk of multilateral lending is disbursed via loans and grants to individual national governments [73]. The Global Environment Facility (GEF) and the Green Climate Fund (GCF) are two other important sources of funding in the renewable energy sector.

Among major bilateral donors that offer different forms of technical and financial assistance to African countries, we can mention: for France, the Agence Française de Développement (AFD), for Germany, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the German development bank, Kreditanstalt fuer Wiederaufbau (KfW), the Japanese International Cooperation Agency (JICA) and the Japanese Bank for International Cooperation, the Swedish International Development Cooperation Agency, the Danish International Development Agency, the UK's Department for International Development and the Canadian International Development Agency.

Next to the traditional bilateral and multilateral development cooperation, both bilateral and multilateral donor agencies have launched a significant number of new initiatives at the regional and sub-regional level to support the energy sector and renewable energy in Africa over the past years. Following the Africa-EU Energy Partnership (AEEP) mapping report [73], we can distinguish them in:

- *High level Initiatives*, supporting political dialogue between African countries and major donor agencies such as the **SE4All initiative**, the **Africa Clean Energy Corridor**, the **Africa-EU Energy Partnership (AEEP)**, the **African Renewable Energy Initiative (AREI)**, the **Program for Infrastructure Development in Africa (PIDA)**, **International Solar Alliance (ISA)**, etc.
- *High level initiatives with an operative program*, such as **Power Africa**, **World Bank Energy Sector Management Assistance Program ESMAP, etc.**
- *Operative programs and delivery mechanisms* providing different forms of technical assistance and financial support for the development of renewable energy sources, such as the **Africa Renewable Energy Fund** (AREF), **Scaling Up Renewable Energy** in Low Income Countries Program (SREP), **Energizing Development** (EnDev), **Clean Technology Fund** (CTF), the **Mediterranean Solar Plan, Lighting Africa programme, GET.pro** (former EUEI PDF), **GET.invest** (former RECP)**, European Union's Technical Assistance Facility** (TAF), The **EU- Africa Infrastructure Trust Fund's**, **IRENA/ADFD Project Facility, GET FiT Uganda, Renewable Energy Solutions for Africa (**RES4Africa**),** etc. There is a number of instruments that have been developed with the primary purpose of attracting the private sector through de-risking investment in renewable energy projects [67]. We can mention among others, the EU's **ElectriFI**, the **Sustainable Energy Fund for Africa** (SEFA), **Green Africa Power** and the **IFC's Climate Change Investment Program for Africa** (CIPA).

As shown in the figure below, almost all the existing high-level initiatives and operative programs support renewable energy, although not exclusively.

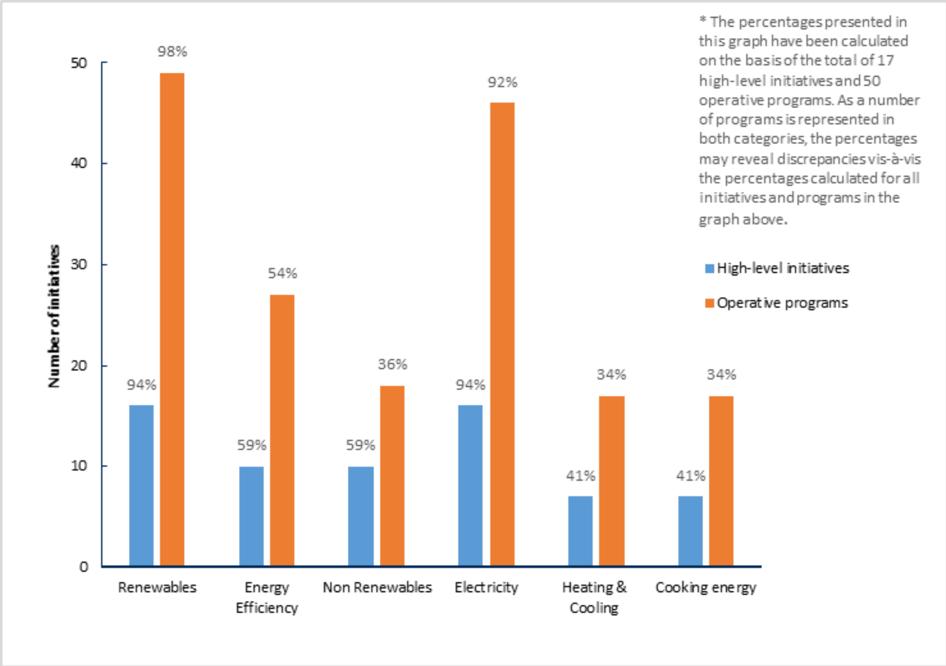


Figure 22: Sectors covered by selected initiatives and programs. Source: [74]

6. Outlook on electric vehicles and storage deployment

Grid energy storage during times when solar energy exceeds demand can be returned to the grid when production falls below consumption. Grid energy storage is a crucial alternative to peaking thermal units to ensure supply to the grid connected customers. Storage is also crucial in off-grid and mini-grids systems as presented in the section 3.6. Electric vehicles (EV) batteries can also be used to accommodate the fluctuating availability of solar and wind energy. Therefore, EVs represent a solution to leverage the abundant renewable energy resources in Africa and to improve the air quality of Africa's congested cities.

In this section, we discuss the respective contributions that storage and electric vehicles can bring to support the grid and energy management, and to which extend they are already present on the continent.

Transport

The demand for electric vehicles is progressing around the world. The African market is behind but growing, especially in urban areas. Rising fuel costs could increasingly become a driver to adopt electric mobility. However, the charging infrastructure is often non-existent except for a few countries such as Egypt, Morocco or South-Africa.

Egypt has been working on a plan to increase the share of EV towards 2040, new legislations on customs, tax and solar energy stations are coming. The importation of used electric cars has already been exceptionally allowed, provided that they are no more than three years old.

No countries incentivize the purchase of EVs yet, except for Morocco, that exempted electric and hybrid vehicles from customs duties since 2017. The country wants to invest in renewable energy and EV deployment. From 2019, the government will gradually renew its car fleet with electric cars aiming at achieving 30% EV towards 2021. The government fleet is composed of 115,000 vehicles, the investment cost for the EV should be compensated by the fuel savings according to the official sources.

In 2018, Elon Musk, co-founder and CEO at Tesla, announced that he has plans to launch Tesla's electric cars in South Africa by the end of 2019. There are already 2 EV models on the South-African market. However, these are not a very popular choice because of load shedding and the EVs price. EV tend to be more expensive. In some cases the difference in price of car may outweigh the savings on fuel. Solar home systems could solve both issues by providing cheap and reliable power.

Electric cars have also made their entry in Kenya with a Finnish taxi company known as Nopia Ride. All Nopia vehicles are 100% electric. For the drivers, the company claims that it offers 30-50% higher revenues than traditional gasoline cars. The company is co-guaranteeing the vehicles together with the drivers and this has given financial institutions confidence to extend financing.

A team of young engineers of Makerere University in Uganda developed an EV prototype, Kiira, initially a two-seater vehicle that runs on rechargeable lithium batteries. The team has gained the Ugandan government support and brought the car to the market. The prototype became Africa's first electric vehicle. Its makers say that in motorway conditions, the Kiira EV can attain a speed of 100km/h and is engineered to achieve an inter-charge distance of 80km according to the designers. In parallel, the team developed an electric bus and a hybrid 5-seater front-wheel drive. Other EV prototypes have been built, some specially adapted for Africa's rural roads and cheaper than the average EVs. Unfortunately, most of them didn't make it to the market. However, further increases in fuel prices might unlock the production and large-scale deployment of EV in Africa.

Storage

As the penetration of solar PV increases in the system, flexibility and storage become crucial to the further renewable energy deployment. As of 2018, the largest form of grid energy storage in Africa is dammed hydroelectricity, with both conventional hydroelectric generation (272,078 MW) as well as pumped storage (3,196 MW) [75].

Pumped water systems have high dispatch ability, meaning they can come on-line very quickly, typically within 15 seconds, which makes these systems very efficient at soaking up variability in electrical demand from consumers. On a slightly larger time scale, excess energy from renewable sources can be stored and therefore increase kinetic water volume which can be released later.

Hydroelectric dams with large reservoirs can also be operated to provide peak generation at times of peak demand. Water is stored in the reservoir during periods of low demand and released through the plant when the demand is higher. The net effect is the same as pumped storage, but without the pumping loss. Depending on the reservoir capacity the plant can provide daily, weekly, or seasonal load.

Thermal energy storage is achieved with widely differing technologies. Even though it might be less efficient for storage of excess energy from PV directly, it is worth mentioning as it already appears to be economical and it contributes to the system balance [76]. Indeed, heat storing infrastructure can decouple heat and power production and help to meet peak demands. Heat storage in tanks and rock caverns or in hot rocks, concrete or pebbles is being investigated in combination with wind energy in Germany. Molten salt can be employed as a thermal energy storage method to retain thermal energy. This technology has been chosen for the phases I and III of the Noor project in Morocco to store the solar energy from the CSP installation up to respectively 3 and 8 hours.

As the costs and the performance of batteries are improving rapidly, these could grow significantly in the coming years. The question is whether the falling costs will be sufficient to create new economic opportunities in Africa. The competitively of batteries is directly related to their cost. However, the business case for delivering ancillary services such as frequency response or capacity reserve depends on the price network operators. In the end consumers, are willing to pay for grid stability and power reliability. Power supply in many African countries is expensive and often not reliable.

Storage will be crucial to accelerate renewable energy deployment, both in mini-grids and in the transmission and distribution grids. Batteries will play a pivot role in mini-grids and has the potential to increase energy access and living standards in remote areas. However, the African transmission and distribution grids face other challenges to improve the grid management. Indeed, as the basic structure of the electric power grid has remained unchanged for more than a hundred years, existing power generation infrastructure is outdated and not able to keep pace with the growing power demand.

To integrate more renewables and to unlock the potential of batteries to support the grid, smart grids must be implemented. Thanks to digitalization, distributed communication and computing technology, smart grid enables active participation by consumers and optimizes asset utilization and efficiency.

7. Conclusion

With a mere 5,110 MW of solar PV capacity installed, Africa, despite its large potential, is well behind other regions in the world in terms of solar PV installations. In order to unleash the deployment of solar PV in the African markets, adapted infrastructures and access to financing are required. Indeed, a challenge that needs to be addressed in most markets is the aging or lacking grid infrastructure. Important investments in the grid infrastructure are required in several markets to improve grid management and grid monitoring. This would prove essential to achieve better grid integration of the production assets and optimization of adequacy between production, demand, and storage. Many countries we analyzed have a low electrification rate: where to build or strengthen grid infrastructure and where it is more cost-effective to use off-grid solutions. Solar mini-grids and solar home systems truly have the potential to increase access to cheap, clean and reliable energy, especially in remote areas allowing households and productive use facilities.

Most of the governments analyzed in this report have implemented support measures for the deployment of solar PV and international organizations are often providing resources for large scale and for smaller systems such as mini grids. However, electrification cannot rely solely on government programs or aid alone. A business model should truly drive the development. So called “pay-as-you-go” models or leasing could leverage the deployment of small PV installations for households that otherwise would not be able to meet the upfront costs of solar PV which are higher than for fuel-based power installations. These business models, combining mobile payment with decentralized generation is an area where several markets in Africa are ahead of the more mature solar markets in Europe and elsewhere. Much like the prolific use of mobile phones, this might be a disruptor and market driver which might have a strong market impact in the near future.

When looking at the potential attractiveness of the individual markets, we found that irradiation is not a factor in making countries attractive for PV. It is rather good energy access, high per capita consumption and favorable framework conditions. The environment to do business can differ for foreign companies which can drag the development of the sector. Botswana, Mauritius, Morocco, Rwanda and South Africa are currently among the markets with the highest potential for PV. Ghana, Kenya and others follow them close. Most markets in this report are worth a look for investors. Political instability, however, remains a major roadblock for some, not only in the PV sector.

Three scenarios were designed to discuss the evolution of the PV market in African countries in the coming decade: a policy driven, a business as usual and a more ambitious scenario. Despite the challenges cited above, we expect the low prices of solar PV production to unlock many new market segments on the African continent with an increased development rate and scope after 2025. Hence, the solarize Africa scenario is likely the most probable, except for the countries that are at war or experience disruptive political or economic instabilities.

To summarize, increased electrification through renewable generation is required if the continent is to meet this growing demand in a sustainable and affordable way. The market is in different stages of development and the interest in PV is growing everywhere on the continent. In the utility sector, tenders have already accelerated PV deployment and this trend is set to continue, allowing the continent to finally reap the fruits of this abundant and renewable resource.

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Acronyms and abbreviations

ACEC – Africa Clean Energy Corridor

C&I – Commercial and Industrial

CSP – Concentrated Solar Power

DC – Direct Current

DFIs – Development Finance Institutions

EV – Electric Vehicle

FiT – Feed in Tarif

GW – Gigawatt

IEA – International Energy Agency

IPP – Independent Power Producer

IRENA – International Renewable Energy Agency

MASEN - Moroccan Agency for Sustainable Energy

MENA – Middle East & North Africa

MSME - Micro, Small, and Medium-sized Enterprises

MW – Megawatt

LCR – Local Content Requirements

LUT – Lappeenranta University of Technology

PAYG – Pay-as-you-go

PPA – Power Purchase Agreement

PV – Photovoltaic

RES – Renewable Energy Source

SSA – sub-Saharan Africa

SHS – Solar Home system

USD – US Dollar

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