Chapter 1
The Challenge of Energy Access in Africa

Abstract There are multiple dimensions to the problem of energy access in Sub-Saharan Africa, where large shares of population lack a reliable supply of electricity and affordable modern cooking fuels: from insufficient power generation capacity, to difficulties in managing energy infrastructure and attract investments in the sector, to challenges in serving low-income users. Booming populations, urbanization, and ambitions of economic development will all demand more energy. This chapter illustrates the main challenges ahead towards the sustainable development objective of achieving universal access to electricity and clean cooking in the region.

1.1 Today's Landscape

1.1.1 Energy Demand, People and Sectors

Energy—or, more precisely, access to energy—represents one of Africa's greatest obstacles to social and economic development. Few indicators are sufficient to draw a picture of a continent where the energy sector is dramatically underdeveloped, at a time when growing populations and prospects of economic growth would require more energy.

Energy use per capita in SSA[1] is equivalent to one-third of the world's average and one fourth of Middle East and North Africa's (MENA) (Fig. 1.1). Only South Africa's per capita energy use exceeds the world average, and all across SSA there are large disparities in per capita consumption between urban and rural areas, with those in cities typically enjoying better access to modern forms of energy than the others.

[1] Throughout the book, "SSA" will be used to refer to the Sub-Saharan region excluding the Republic of South Africa; we will refer to the "subcontinent" to indicate the whole region.

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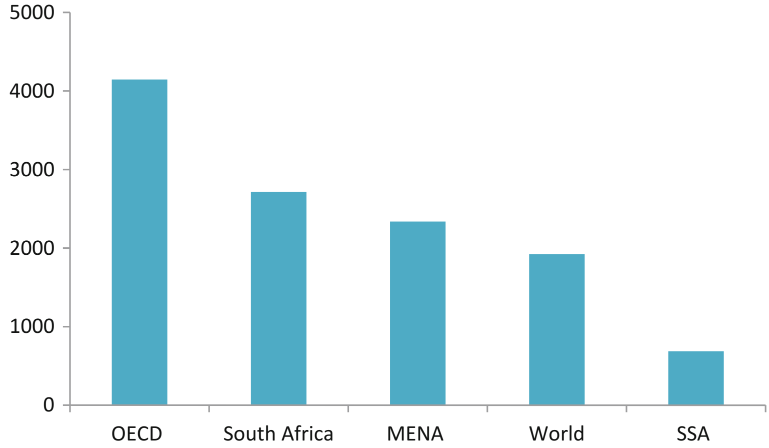

Fig. 1.1 Energy use (kg of oil equivalent) per capita (2014). *Source* World Bank, World Development Indicators, accessed in November 2017

When it comes to electricity,[2] the average person living in SSA consumes as little as 200 kWh/year, against 1,442 kWh in North African countries and 4,148 kWh in South Africa (Table 1.1). The situation is even worse in rural areas, where people can consume as little as 50 kWh/year, a quantity that allows to charge one mobile phone and use minimal lighting for a limited amount of hours a day (International Energy Agency 2014). In perspective, the average citizen consumes in one year considerably less electricity than what a fridge does over the same period of time in the US (Fig. 1.2).

Looking at the whole energy system, it is in the residential sector that lies the core of primary energy consumption. This means two things. Firstly, that more productive sectors like industry and transport consume little amounts of energy (not only if compared to OECD countries, but also to other developing regions). Secondly, that energy consumption is driven by traditional uses: it is solid biomass for cooking that constitutes the bulk (80%) of residential consumption. A global perspective can help visualising the entity of the problem: there are 25 countries in the world today where 90% of the population uses solid biomass for cooking, and 20 of them are located in SSA (International Energy Agency 2017).

The transport sector consumes only 11% of the total primary energy, and productive uses a mere 21% altogether (productive uses include industry, services, and agriculture in order of magnitude of consumption) (International Energy Agency 2014). This reflects a deep infrastructural gap: the penetration of railways, paved roads, and even ports is very low, as is the diffusion of energy (power, hydrocarbons) distribution systems. The implications of this infrastructural under-development include low human mobility and low accessibility of goods (including among others, fuels

[2]"Power" will be frequently used as a synonym of "electricity" throughout the book.

Table 1.1 Power consumption per capita in selected African countries

Country or Region	Consumption per capita (kWh/capita)
North Africa	1,442
SSA	200
Angola	346
Democratic Republic of Congo	94
Ethiopia	85
Ghana	320
Kenya	168
Mozambique	507
Nigeria	144
Tanzania	98
Zimbabwe	510
South Africa	4,148
World—High income countries	9,086
World—Low and middle income countries	1,933

Source IEA, World Energy Statistics, 2017 and World Bank, World Development Indicator database, accessed in November 2017

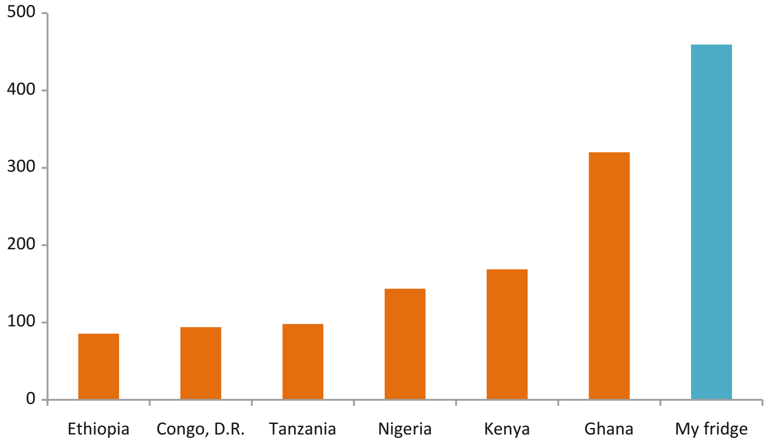

Fig. 1.2 My fridge uses *five* times more energy than the average Ethiopian citizen (kWh) (2015). *Source* author's update of a graphic from (Moss 2013) "My fridge uses nine times more energy than the average Ethiopian citizen" with data from IEA, World Energy Statistics, 2017

and energy equipment), which in turn explains the low levels of productive energy use and the high reliance on biomass.

In SSA the share of electricity in total energy consumption is as low as 4% (against the 19% of North Africa). Mostly, electricity is consumed to power two key industrial activities: mining and refining, and the rest is more or less equally distributed between services and the residential sector.

To a certain extent, small businesses like carpentry or tailoring can get by with little or no electricity, but of course scaling them up becomes impossible without a reliable source of power. In other words, without electricity it is impossible to set up an industrial activity. As electrification tends to develop around the supply of centres of demand that can function as anchor loads for the benefit of surrounding communities, the small consumption of productive sectors is clearly a missed opportunity for broader electrification.

1.1.2 Mapping Access to Modern Energy

From the perspective of modern energy access (Box 1.1) the African continent can be roughly divided into three areas (Fig. 1.3), the most critical situation of access to electricity being in SSA where only 43% of the regional population have access to it. SSA's electrification problem is the most dramatic in rural areas, where electrification rates average at 25%, against 99% in North African countries and 83% in South Africa (Table 1.2).

Box 1.1 Defining and Measuring Energy Access
While there is no universally accepted definition of "energy access", this concept can be generally defined as the *ability of the end user to utilize energy supply that is usable for the desired energy services* (Energy Sector Management Assistance Program, World Bank 2015). The easiest way of measuring access is estimating the number of households that have access to electrical supply on the one hand, and those that use solid biomass and traditional means of cooking on the other, on the basis of available sources such as international statistics, governmental agencies and multilateral development banks. This is, for instance, the approach of the International Energy Agency that—for the purpose of modelling—defines "modern energy access" as the situation of *a household having reliable and affordable access to clean cooking facilities and to a minimum level of electricity consumption which is increasing over time*. This definition does not include "community" access, meaning public services (e.g. street lighting, hospitals) and productive uses (e.g. industry and agriculture).

In order to come up with a sophisticated indicator of energy access it is necessary expand the concept of household access to electricity and clean cooking to consider (1) the quality of supply (availability, affordability, adequacy, convenience, reliability) and (2) non-residential sectors of consumption. It is on this basis that the World Bank and other agencies proposed a "multi-tier framework" to measure energy access (Energy Sector Management Assistance Program, World Bank and International Energy Agency 2013). Such framework aims at providing a much clearer picture of access to modern energy by including an indication of both its quantity and quality of supply.

The downside is that populating such framework with real data is a challenging and resource intensive exercise (to give an example, the World Bank is the only source that carries out standardized surveys to enterprises in developing countries on the quality of supply (World Bank)), however progress is being made both in terms of methodologies and data gathering. Digital technologies in particular can allow for the collection of real-time, highly disaggregated data on electricity use on large scales. The manipulation of big data through advanced analytics can produce useful insights on consumption patterns, key for business developers (Onyeji-Nwogu et al. 2017; Ekekwe 2017). In the future, this type of innovation in collecting and manipulating digital data can therefore play a central role in the process of advancing modern energy access.

The number of people in SSA living without access to electricity is also on the rise, as ongoing electrification efforts are generally outpaced by rapid population growth. This trend is here to stay given that SSA population is projected to more than

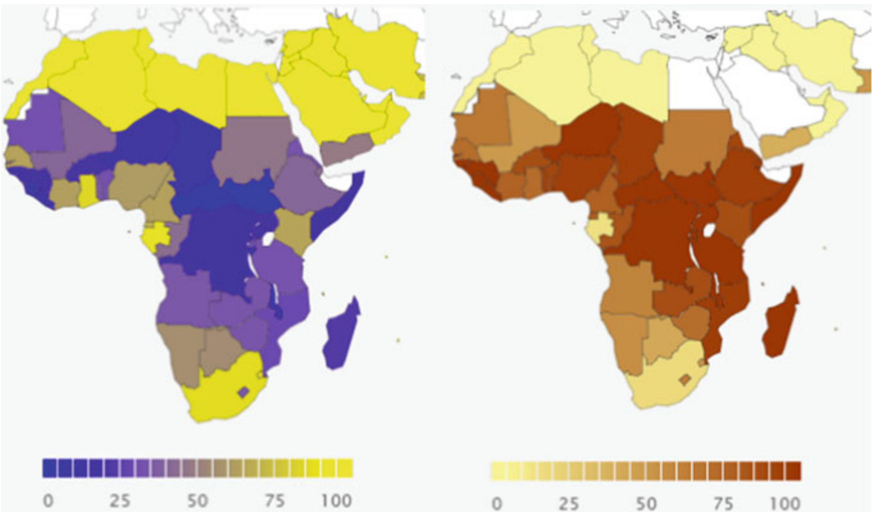

Fig. 1.3 Share of population with access to electricity (left, 2015) and share of population without access to clean cooking (right, 2015). *Source* IEA, 2017, Map © Natural Earth. Energy Access database, accessed in March 2018

Table 1.2 Electrification rates in the three African regions, with a zoom on selected countries (2016)

	National electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)
North Africa	100	100	99
SSA	43	71	25
Angola	35	69	6
Burkina Faso	20	58	1
Burundi	10	35	6
Central African Republic	3	5	1
Democratic Republic of Congo	15	35	0
Ethiopia	45	85	29
Guinea	20	46	1
Kenya	65	78	60
Mozambique	29	57	15
Namibia	56	78	34
Nigeria	61	86	34
Rwanda	30	72	12
South Africa	86	87	83

Source IEA, Energy Access database, accessed in November 2017

double by 2050 (UN Department of Economic and Social Affairs 2017). The strong commitment of some countries to electrification, however, is starting to payback: 2014 was the first year that saw a reduction in the total number of Africans without access to electricity. Up until 2014 major improvements had been made in Nigeria, Ethiopia, South Africa, Ghana, Cameroon and Mozambique. Afterwards, Ethiopia and Ghana kept on leading electrification efforts together with Ivory Coast, Kenya, Sudan and Tanzania (International Energy Agency 2017). Some countries made an incredible progress in a very short time, like Kenya: only in 2013, the percentage of people with access to power was 27%, and only three years later it reached 65%, also through the electrification of rural areas (Table 1.2). At the same time, however, some countries like Central African Republic or Burundi remain stuck with an incredibly low power coverage: they have seen no progress, or just too little vis-à-vis population growth.

In practice, electrification rates follow to a good extent economic growth, so while Central Africa and East Africa had similar electrification rates at the beginning of the century (around 10%), today we see that the latter region has left the former far behind. Indeed, no country in Central Africa saw a comparable growth to that of Ethiopia or Kenya.

Country differences in terms of access to modern cooking are relatively less pronounced. In most countries of SSA over 50% of the population relies on solid biomass, and in half of them the share exceeds 90%, with the five most populous countries in the region (Nigeria, Ethiopia, Democratic Republic of Congo, Tanzania and Kenya) bearing the heaviest burden in terms of total biomass consumption.

It can be observed how the three zones of energy access of Fig. 1.3 overlap with three zones that had different historical developments also due to fossil fuels endowment. South Africa could count on massive reserves of coal on which it still largely relies, while the region of North Africa is overall rich in oil and gas. Over time, several countries in SSA entered the ranks of top global producers of fossil fuels too (notably Nigeria and Angola) but their production has been mostly developed for export, with little improvements in terms of universal access to energy and the development of domestic energy markets (Chap. 3). To give a sense of this disparity: South Africa with a population of 57 million has 48 GW of power capacity installed, Egypt with a population of 100 million has an installed capacity of 39 GW, while Nigeria with a population of 195 million is still at 13 GW (Climatescope 2017).

1.1.3 Primary Energy and the Role of Traditional Biomass

Given the lack of alternatives, many in SSA still rely on traditional forms of energy. When looking at the primary energy supply (PES) mix of African regions, it is immediately clear that bioenergy dominates (60–80%) on any other source in SSA (Fig. 1.4). This is in contrast with South Africa and North Africa, where the biggest part of the energy supply (90–99%) comes from fossil fuels—notably from coal in South Africa and from oil and gas in North Africa. After bioenergy, oil is the second most utilized source of energy; then come hydropower and natural gas, the latter concentrated in West Africa. The presence of modern renewables (e.g. solar, wind, geothermal) is still quite limited.

Of course, the regional distribution of energy supply changes considerably in relation to bioenergy. If we exclude it from the account—as it is often done in energy statistics—the cumulative share of North Africa and South Africa in the total primary energy supply of the continent jumps from less than half to three fourth, while the rest of the continent (West, East, Central, and Southern) ends up with one fourth all together (Fig. 1.5).

It should be noted that in the African context "bioenergy" does not refer to modern uses of biomass (e.g. biomass-to-power), instead it refers almost entirely to traditional uses, most notably for cooking purposes (solid biomass fuelled cookstoves, (Chap. 4). Fuelwood, charcoal, and dung are the preferred sources of biomass, particularly where the availability of alternatives is limited or there is a problem of affordability (Lambe et al. 2015).

The massive human, environmental, and in turn economic costs of this underdevelopment are becoming clearer by the day. Indoor air pollution caused by the inefficient use of solid biomass for cooking kills around 600 thousand people every

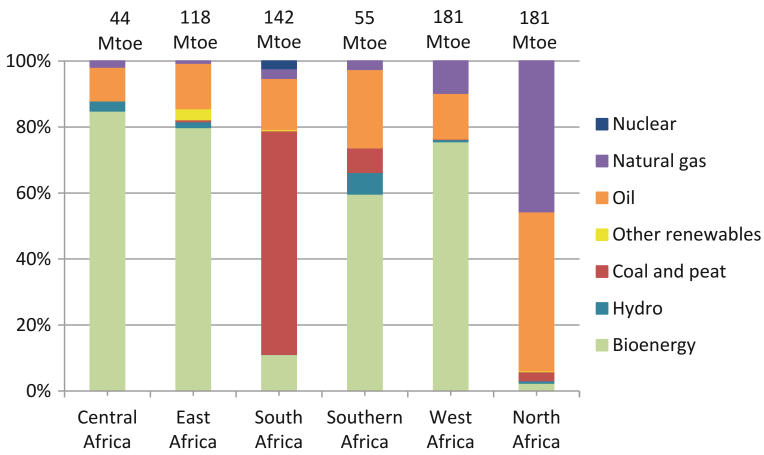

Fig. 1.4 Primary energy supply by region and source, 2015. *Source* Authors' elaboration on OECD database, accessed in November 2017. Note that the averages were calculated on the country data available (i.e. the aggregated value of "other countries" was not taken into account)

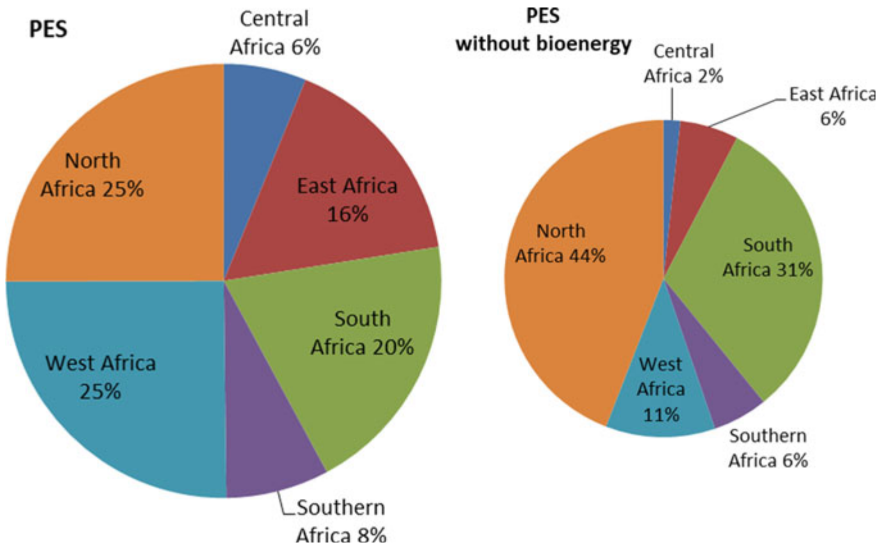

Fig. 1.5 Primary energy supply (PES) by region—including and excluding bioenergy, 2015. *Source* authors' elaboration on OECD database, accessed in November 2017

year, and as population increases this number follows (Africa Progress Panel 2015). Women and young children are the most affected by air pollution because they spend the longest time next to the stove while food is being cooked. Also, women and girls are often those in charge of household management and this includes the collection of water and energy. All in all, they can spend several hours a day fetching water and fuelwood and preparing food, tasks that keep them out of school or employment, and ultimately contribute to hinder women empowerment, and socio-economic development that it would bring.

Of course, apart from the lack of alternatives, free or very cheap fuel is simply more appealing to low income users: fuelwood can be directly harvested or bought for a cheap price in local markets, while agricultural waste is produced at home, or in farm. Typically, even in the event that the price of charcoal and firewood increases, other alternatives remain more expensive.

This problem concerns not only rural populations: worryingly, biomass holds a significant share in cities as well, where other fuels are more accessible. Charcoal is in many cases a more convenient choice than fuelwood for urban households because it is more accessible far from forests: it has a higher energy content, and it is easier to transport and commercialise. In fact, around 80% of urban households in SSA use charcoal (Lambe et al. 2015). It should be noted that charcoal is often a product of fuelwood, and its production process can be highly inefficient. In this context, the penetration of fossil fuel based cooking (with e.g. liquefied petroleum gas (LPG) or kerosene) is limited, and their use is largely concentrated in a few countries: Nigeria, Kenya and South Africa (International Energy Agency 2014).

1.1.4 Quality of Power Supply

The problem of low and intermittent access to electricity is an issue all over SSA. While there is clearly an infrastructural problem, especially in rural areas, of inadequate generation capacity and limited reach of transmission and distribution lines, in many cases even where infrastructure is in place, power supply is either insufficient or unreliable. This is due to several factors like droughts affecting hydropower production, poor maintenance of infrastructure, lack of reliable fuel supply and insufficient transmission and distribution capacity. To give a sense of the magnitude of these problems:

- In SSA power is reported to be unavailable for about 540 h per year on average (International Energy Agency 2014);
- The average efficiency of coal fired power plants in SSA is 34%, (prevalence of sub-critical plants) while that of natural gas fired power plants is 38% (prevalence of open-cycle turbines) (International Energy Agency 2014);
- Losses in power transmission and distribution (including technical losses and thievery) stand at 12% in average across SSA. The problem is tangible in some countries including Nigeria (16%) and Ghana (23%), extremely serious in others such as

Congo (45%), and Togo (73%: the highest in the world). For comparison, average losses are 6% in the OECD area (World Bank).

As already mentioned, the average household consumes little electricity and in general those who have access to the grid may receive electricity only at certain times and in little amounts. It is common that connections are informal or illegal, as many cannot afford to pay for electricity, resulting in missed revenues on the side of power suppliers. Without reliable buyers, the business of producing electricity is not a remunerative one, and of course the final user is the one who sees electricity bills increase, reaching among the highest prices of power per kWh in the world.

Society sees the impact of unreliable supply in everyday life. Unreliable supply not only affects private households, but also public spaces and buildings such as schools and hospitals. Today only 40% of health facilities have access to electricity, and just 28% enjoy a reliable service (International Energy Agency 2017). The impact of an unreliable supply limits the possibility to ensure continuity in medical operations, the storage of vaccines, and in general most activities that are essential in modern hospitals; when public lighting goes off, roads turn to darkness and unsafe; as long the use of computers is limited, the work in public offices remains inefficient; and so on.

Poor supply (low accessibility, high costs, shortages etc.) is a major constraint for industrial activities and businesses in general, as unequivocally confirmed by a survey of the World Bank (Table 1.3). In these conditions most firms have to rely on back-up generators, usually fuelled with diesel. The use of generators can significantly add to the costs of businesses and, unless fuel is subsidised, an increase in international oil prices can make it very expensive. It is clear that a situation of frequent and prolonged power outages can result in major losses and entrepreneurs can be simply held back from embarking in industrial activities.

The agricultural sector uses little amounts of energy as well. Since energy is a key input at all stages of the food value chain—from production (e.g. irrigation, use of fertilizers), processing, storage, and transport—low consumptions generally means low productivity levels (Food and Agriculture Organization 1995). The fact that agriculture generally consumes lower amounts of energy than other productive sectors should not lead to the conclusion that the situation in Africa is simply a reflection of a global trend. Given the weight of subsistence agriculture, a bad agricultural season can knock down entire economies and quickly trigger humanitarian crises. In this picture, low energy consumption in agriculture means low resilience of the sector to weather stress and high vulnerability of entire populations to climate change. The case of Ethiopia is representative: it was a drought in 2016 that put the brakes to an exceptionally fast economic growth rate (International Monetary Fund 2016). This was not an isolated event in Ethiopia, nor in other countries where the economy is still closely linked to rain-fed agriculture (Ali 2012).

Table 1.3 Quality of electrical supply in selected countries (latest available data 2007–2017)

Country	Percent of firms experiencing electrical outages	Average losses due to electrical outages (% of annual sales)	Percent of firms owning or sharing a generator	Percent of firms identifying electricity as a major constraint	How reliable is electricity supply on a scale of 1–7?[a]
Angola	87.7	12.6	79.0	35.7	NA
Democratic Republic of Congo	89.3	7.8	59.5	52.2	2.10
Ethiopia	80.0	6.9	49.1	33.3	3.20
Ghana	89.1	15.8	52.1	61.2	3.10
Kenya	89.4	7.0	57.4	22.2	4.10
Mozambique	51.8	2.4	12.6	24.8	3.00
Nigeria	77.6	15.6	70.7	48.4	1.40
Tanzania	85.8	15.1	43.0	45.8	3.10
Zimbabwe	76.5	6.1	62.3	22.1	3.10
South Africa	44.9	1.6	18.4	20.8	3.90
MENA	57.3	6.6	41	38.6	3.62
World	58.8	4.6	34.1	31	4.71
OECD high income	27.5	0.9	11.4	20.4	NA

Source World Bank, Enterprise Survey, accessed in November 2017 and World Economic Forum, Global Competitiveness Index 2017–2018 (last column)
[a]In terms of lack of interruptions and lack of voltage fluctuations. 1 is highly unreliable and 7 is highly reliable

1.2 Tomorrow's Open Questions

1.2.1 Future Energy Demand

Energy demand is on a steep rise, one of the clearest drivers being population growth. Actually, it would be more appropriate to talk about population boom, especially in East and West Africa. Demographers have been long observing a continued, sometimes accelerated growth with no sign of a reversal in fertility rates. According to UN projections, following these trends by 2100 African population could reach 4.7 billion, which will make up about 40% of the forecasted global population of 11 billion (UN Department of Economic and Social Affairs 2017). Today, Africa is "still" at 1.2 billion (or 16% of global population) but it grows so fast (and urban planning and infrastructure so slow in comparison) that challenges like overcrowding, traffic congestion, pollution, and localised resource depletion are already worrying. In this context, however, the IMF points out that the economic benefits of a very young labour force and urbanization—which should not be underestimated—are yet to be seen (Leke and Barton 2016).

Booming populations and urbanization, industrialization, and expansion of the middle class, will require more energy, however the first two may not necessarily trigger the others, meaning that with no reduction of poverty levels, population may keep on growing and aggregating without a significant increase in actual energy consumption per capita. For what concerns energy, poverty is a major obstacle to the uptake of electricity (at least as long as this remains expensive) and a driver for fuelwood consumption (at least for as long as this remains cheap, or widely available for free). Similarly, low GDPs imply low consumption levels (concentrated in residential sector, for basic activities such as cooking), while higher GDPs mean higher electricity demands with industry, services, transport, and even agriculture playing a more important role as sectors of consumption.

With this in mind, it is clear that future energy demand will largely depend on how countries will perform in terms of economic development. Current trends suggest that some countries will develop more, and faster, than others, and in turn that their energy transition can only happen at different speeds. As of 2017 there is still only one high-income country in the whole continent: the island state of Seychelles (World Bank), but some countries are currently experiencing among the fastest economic growths in the world. In fact, six out of the ten fastest growing economies expected for 2018 are in SSA: Ghana (the highest GDP growth rate globally: 8.3%), Ethiopia (8.2%), Ivory Coast (7.2%), Djibouti (7%), Senegal (6.9%), and Tanzania (6.8%) (World Bank 2018). The landscape is too various to point at common pathways but there are a few facts that stand true for many countries in the continent.

First, agriculture remains a key economic sector for most economies, accounting for around 20% of regional GDP (ranging below 3% in Botswana and South Africa to more than 50% in Chad), a very high share when compared to the global 6%. The sector employs more than 60% of the total labour force and provides livelihoods to many small scale producers in rural areas (African Development Bank et al. 2017). The crop sector dominates the total agricultural production value and, as already mentioned, the sector remains un-modernised and dependent on rain-fed crops making the impact of droughts and climate change, extremely damaging. Examples of how electricity can improve agricultural activities are many and range from the more traditional uses for irrigation and cold storage to the more sophisticated digital applications for real time weather forecasting and resource use monitoring.

Second, mining is the single largest industrial activity in the subcontinent, contributing significantly to fiscal revenues and GDPs. For instance in Burkina Faso, the Democratic Republic of Congo, Guinea, Mauritania, Mozambique, and Zambia the sector accounts for more than half of total exports. Mining is generally associated with weak direct employment compared to its contribution to GDP and fiscal revenues and yet at least in principle it has the potential for large local impacts that can foster change in local economies (Chuhan-Pole et al. 2017). Reflecting the weight of this sector, electricity demand for mining represents half of the total electricity demand in the region as a whole, while in countries such as Liberia, Guinea, Mozambique, and Sierra Leone it consumes as much as three times the amount of electricity used by the other sectors together (International Energy Agency 2014).

Third, economic growth is being driven more and more by sectors with low energy intensity like the textile industry but also, most notably, agriculture and services (International Energy Agency 2014). Within this group, banking and telecommunication are showing particular vigour, which is expected to bring significant advancement, if not disruption, not only in the energy industry but also in other key sectors, notably agriculture (Bright 2016). In particular, digitalization and the innovative application of "fintech" solutions (to payments, loans, financial advice, and so on), are giving an important boost to local entrepreneurship.

Overall, the IEA estimates that following current demographic and economic trends as well as national energy plans, by 2030 the total primary energy demand in SSA will grow by 30%. Over half of this energy will be demanded in the form of traditional biomass, as the number of people without access to clean cooking will remain huge (900 million). This will be followed by oil, to satisfy transport and cooking needs (in the form of LPG and kerosene), and modern renewables. Natural gas demand will be largely concentrated in the countries that have domestic reserves. Demand of coal will triple across the subcontinent but its consumption will decline in South Africa due to stock depletion and fuel substitution (with renewables) (International Energy Agency 2017).

According to the IEA, compared to the recent past there will be at least two extremely important positive changes in SSA energy sector. First, new investments in the electricity sector to satisfy local demands will largely exceed those in the extractive industry for the export of fossil fuels. Second, renewables and PV in particular will lead the growth in power generation capacity satisfying the largest share of additional energy demand in the period 2016–2030. Investments in renewables will be driven more and more by their cost competitiveness, particularly in a scenario of high oil prices.

Of course, while it is typically assumed that SSA will not experience an industrial boom comparable to that of India or China, it is nevertheless possible to picture the impact of massive industrialization on primary energy demand. In this type of scenario, by 2035 Africa's energy demand could be offsetting the reduction in energy consumption of post-industrial China and start driving global growth (British Petroleum 2017).

1.2.2 More Power, for All

Given the central role of electric power in modern society, its cleanness and versatility for a variety of uses, achieving universal access to electricity quickly and cost-effectively can be considered the single most important energy-related objective for African policy makers. The socio-economic benefits of universal access to electricity largely outweigh the costs of achieving it (Fig. 1.6). Moreover, particularly in SSA,

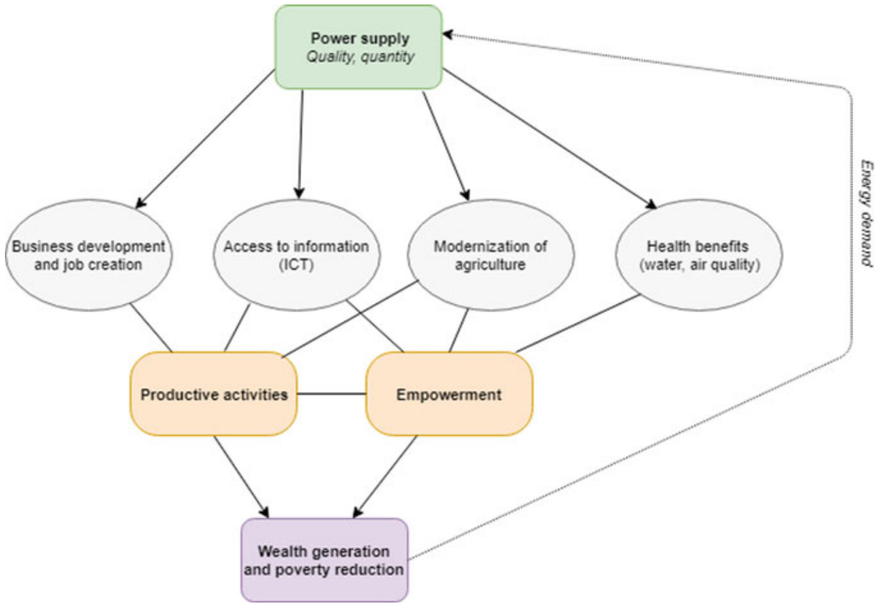

Fig. 1.6 Benefits of electrification. *Source* author's elaboration

the greenhouse gas emissions brought by the increased in power generation would be at least partially offset by the reduction in the traditional use of biomass.

Considering current policies in place, 1 billion people should gain access to electricity in Africa by 2040, but there is a high chance that electrification efforts will be outpaced by population growth. In this case, the number of people without access in 2030 could remain unchanged, if not increase (around 600 million). Taking a global perspective, by then Africa will account for 75% of the world population without access (from 50% today) and the continent will be the last one to be "left behind" in the global electrification process (International Energy Agency 2017).

The race against time to power the African continent will unfold in different ways due to an uneven distribution of resources, however a massive stock of renewables encourages a vision of a low-carbon development for the overall continent (International Energy Agency 2014; International Renewable Energy Agency 2015). It is estimated that the 90% of hydropower potential in the continent is still untapped and a good part of it is concentrated in Central Africa, followed closely by Southern and East Africa. Wind on the other hand is mostly available in the East, West and Southern regions. Geothermal potential is concentrated in the East and South, with Kenya leading the way of technology development. Solar energy, finally, is massive across the whole continent. Indeed, it is expected that solar will play a key role in the energization of most countries, also due to the increasing viability of solar-based mini-grids.

Notably, the uptake of renewable energy is happening less and less because of top down policies driven by sustainability objectives. In fact, the deployment of renewable technologies today is increasingly driven by their cost competitiveness. It seems important to underline how big of a shift this is for the energy sector and what unique opportunity this may be, especially for fossil fuel scarce developing countries. This does not mean that fossil fuels will not play a role, but it looks like they will not dominate the scene alone either (as it happened in the first stages of energy development of all other continents before). Put in a different way, those countries who have fossil fuel resources will most probably want to exploit them and if there is a sufficiently large domestic and/or export market this will make economic sense. However, those countries who will need to import them may still find it expensive or impractical (due to poor infrastructure), but the falling costs of renewables may finally offer a valid alternative.

1.2.3 Grids, Mini-Grids, or Stand-Alone Systems?

With scattered populations and a huge infrastructural gap, electrification will spread as a sort of patchwork. National grids will reach out only as far as it is technically and economically viable, so that remote demand will need to be met otherwise. Essentially, this means building mini-grids that link isolated demand (a mine, a village, an irrigation scheme) with a local source of electricity production (e.g. solar, small hydro) and a back-up generator or a battery that can jump in as needed. New technological progress and the development of ad-hoc business models are making these systems more and more viable, and yet without an anchor load building a mini-grid may just not make economic sense, therefore even a widespread deployment of mini-grids will still leave many off-grid. For them, electrification can be only provided by stand-alone systems, to make at least limited power available to satisfy basic services, such as phone charging and lighting.

Grids, mini-grids and stand-alone systems have very different underpinning economic models even though, technically, at least grids and mini-grids look similar (Fig. 1.7). A grid brings power from a number of centres of production (power plants) to many users through a capillary system of transmission and distribution lines, hence it basically differs from a mini-grid in terms of the amount of power that it carries to users. However, building grids requires huge financial effort (and risk) so that this business is ultimately in the hands of governments and public companies, while mini-grids can be built by private companies, local entrepreneurs, or even cooperatives of users, as long as there is a clear return on investment and an enabling business environment to support them. Stand-alone systems, finally, are typically distributed by private companies to single users. The business model that is proving to be most successful so far in Africa is that of PV modules that users rent and gradually come to own, through Pay As You Go payment schemes.

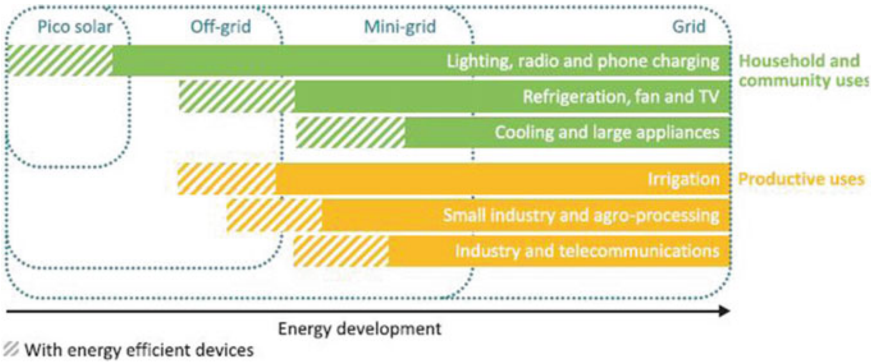

Fig. 1.7 Means of electrification and their possible uses. *Source* © OECD/IEA 2017 World Access Outlook (World Energy Outlook Special Report), IEA Publishing

Now, given the urgency of the problem and the entity of financial gaps, some questions arise. When is it more convenient to build mini-grids and when to extend grids? Where does it make sense to provide stand-alone modules? And even: what is the cost-optimal pathway to reach universal access to electricity (Chap. 5)? These questions point at a need to plan electrification sensibly taking into account real distances, locations of demands, and potential anchor loads (also keeping in mind that future interconnections could end up linking mini-grids that were initially built in isolation).

The relative shares of investment in grids, mini-grids, and stand-alone systems can vary significantly by country, but most policy makers in SSA plan for universal electrification largely in terms of national grid expansion. This should change, as a greater effort to deploy mini-grids and stand-alone solutions will be instrumental and necessary to achieve universal access by 2030. And this will not be an easy task. For instance, diesel prices still determine the viability of mini-grid solutions by affecting the cost of back-up generators (and will keep on doing so as long as storage solutions will be too expensive) (Mentis et al. 2017). Governmental support will be crucial to boost the sector, particularly when it comes to supporting private investors (TFE Consulting 2017).

Clearly, an increased focus on decentralisation should not end up downplaying the role of centralised production and regional interconnections. Big cities and related industrial areas will likely remain the largest share of electricity consumption and for many countries regional interconnections could significantly accelerate universal electrification. At the same time, existing complementarities between different countries' resource bases (particularly wind, hydropower, and natural gas) make regional interconnections a sensible option that also allows for deployment of large scale renewable projects.

At this point it seems important to recall that the challenges of energy access are so various and intertwined, that reaching users does not necessarily guarantee a good quality of supply, nor even it ensures accessibility by the side of low-income users

(Hogarth and Granoff 2015). The latter in particular is the problem of the so-called "under-grids", who cannot afford to pay for electricity hence can use it only when it is subsidised. Ultimately, the viability of grid extension, mini-grid construction and stand-alone system delivery will depend largely on the ability to design appropriate business models. Remarkably, these will need to make electricity affordable for the poorest, exploiting the ability to pay of the most reliable customers, most notably the mining industry (Ghosh Banerjee et al. 2014). In general, future grids (and mini-grids) in SSA will not only need to be "smart", but also "just", meaning that social inclusion needs to be a cornerstone of grid design in the region in order for it to be truly successful (Welsch et al. 2013).

1.2.4 The Changing Role of Fossil Fuels

Importantly for climate change concerns, Africa may be the first continent to develop without coal. While this is a resource that still features in the plans of several countries, and the increasingly prominent role of China in the continent's energy landscape has long anticipated a coal boom (led by China's strong coal industry), recent developments do not reflect such a clear trend. Among fossil fuels, natural gas appears to be a major competitor (Chap. 3), one reason being that natural gas reserves are better distributed across the continent (i.e. Nigeria, Mozambique, Angola, Algeria are all important natural gas producers, whereas the coal industry is virtually concentrated in South Africa). Also, it is a cleaner option than coal—not only in terms of greenhouse gas emissions but also in terms of air pollution. While this has been of relatively little concern for many countries on a development path, the perspective of policy makers may well be changing following increasing evidence that pollution is the first cause of death globally and air pollution sits at the top of the list, even before water contamination (Landrigan et al. 2018).

Oil and gas have a rather significant role to play for the energization of the continent. Unlike coal, their role in the energy system goes beyond power production, and their possible substitution in some key sectors of consumption is still at an early stage. First and foremost, the transport sector still heavily relies on oil (gasoline and diesel) and to some extent natural gas, and while electric cars are starting to emerge as an alternative, at least in developed countries, the use of electricity for subsectors of heavier transport (e.g. cargo ships and aeroplanes) remains impractical with the current storage technology. The demand for natural gas, on the other hand, is also driven by non-energy sectors, most importantly the production of fertilizers of which the agricultural sector in Africa is thirstier by the day given quickly decreasing soil productivity (though it should be noted that the massive use of chemical fertilizers may actually end up worsening the problem of soil degradation).

Another key sector where fossil fuels have a role to play is cooking. Actually, considering the magnitude of the problems of indoor pollution and forest degradation

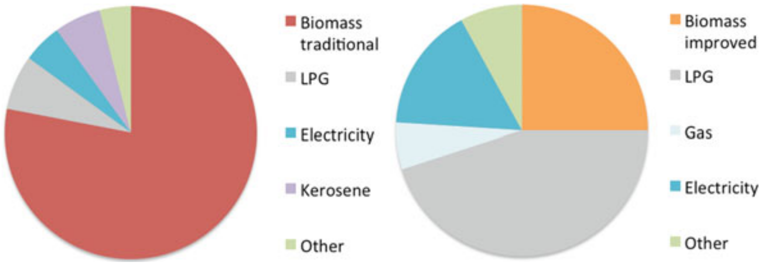

Fig. 1.8 Cooking fuels today (left) and in 2030 in the IEA Energy for All Scenario (right) in SSA. *Source* authors' elaboration on © OECD/IEA 2017 World Access Outlook (World Energy Outlook Special Report), IEA Publishing. *Note* IEA's "Energy for All Scenario" assumes that by 2030 all countries will achieve universal access to clean cooking; "Other" include coal and biogas

in SSA, their uptake as substitutes of fuelwood could be a sensible option. So far, it is largely due to LPG and kerosene that most of the progress has been registered in the sector, not only in Africa but all over the developing world.

1.2.5 The Future of Cooking

More than for electrification, policies aimed at modernizing access to clean cooking have proved so far largely insufficient, and the challenge of achieving universal access to clean cooking still receives less attention than that of electrification. One of the reasons for this is that there has been no real market breakthrough of innovative stand-alone technologies (e.g. solar or biogas cookers) yet, and the alternatives to traditional cooking today are more or less the same we had decades ago, most importantly petroleum based fuels and electricity. In other words, the main challenge of clean cooking remains that of improving the logistics, and increasing the affordability and cultural acceptance of, alternative solutions to rudimentary cookstoves.

Figure 1.8 shows SSA's cooking fuel mix today, compared to a 2030 scenario where everyone has gained access to clean cooking (IEA's "Energy for All Scenario"). This picture is quite far from what is expected to be the outcome of current policies (IEA's "New Policy Scenario"), which are going to leave 900 million people, or 56% of the population, without viable alternatives to solid biomass (International Energy Agency 2017).

Without major improvements to current trends and policy commitments, progress will likely be seen in urban areas only and will not be matched by an overall reduction in the demand of solid biomass, whereas achieving universal access to clean cooking will require a whole new level of commitment (also in financial terms, see Chap. 5).

Providing an alternative to solid biomass for everyone will mean stimulating the use of all available alternatives. As anticipated, fossil fuels and in particular LPG have an important role to play—the IEA estimates that about 90% of those who will shift away from solid biomass by 2030, will move to LPG—however difficulties of distribution will likely remain a major barrier to their wider uptake (Van Leeuwen et al. 2017) (Chap. 3). The effect of electrification can also have a major impact on the way people cook: today, for instance, electricity is already widely used in urban areas in South Africa, and assuming sufficient affordability, it can become a key fuel in the future cooking fuel mix of other countries too.

Modern forms of bioenergy, including the product of biomass residues treatment (e.g. biogas, pellets) and liquid biofuels (i.e. bioethanol and biodiesel) are potentially very promising options, although their theoretical potential is often restricted by a number of factors such as high costs, complexity of fuel production, storage, and transport, or even competition with food production (Chap. 4). Pushing these solutions will require an explicit effort to establish whole new value chains for products coming from agriculture, forestry, and waste management.

Notably, even in this scenario of universal access to clean cooking, efficient and advanced[3] cookstoves ("biomass improved" in the picture) will have a major role to play in SSA. They will likely remain the only feasible upgrading from the status quo for many—especially in rural areas—and, in terms of fuel, charcoal will play an increasingly important role compared to fuelwood and other solid biomass (e.g. agricultural residues). It should be noted that the use of fuelwood is difficult to eradicate even where alternatives are available: it is possible, and indeed common, to own more than one type of stove and fuel ("fuel-stacking") and using one or another depending on fuel availability, price, or even to satisfy food taste preferences.

The benefits of achieving universal access to clean cooking would be immense and would include improvement of health conditions, local job creation, gender empowerment, and reduced forest degradation (and in turn improved climate mitigation at global level).

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[3]In the sense of efficiency of combustion and cleanliness, in particular when it comes to indoor pollution.

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