REmap 2030
A Renewable Energy Roadmap

IRENA
International Renewable Energy Agency

AFRICA 2030: ROADMAP FOR A RENEWABLE ENERGY FUTURE

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ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

This report, a summary of findings and other supporting material are available for download through **www.irena.org/remap**

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Africa faces an enormous energy challenge. Its growing population and economic progress has sent energy demand soaring. This calls for a rapid increase in supply on the continent, to which all forms of energy must contribute in the decades ahead. Africa therefore has a unique opportunity to pursue sustainable energy development as a basis for long-term prosperity.

Africa is richly endowed with fossil-based and renewable energy sources. However, a continued reliance on oil and gas along with traditional biomass combustion for energy will bring considerable social, economic and environmental constraints. Tackling today's energy challenge on the continent, therefore, requires a firm commitment to the accelerated use of modern renewable energy sources.

Countries like Egypt, Ethiopia, Kenya, Morocco and South Africa are leading this effort, while some of Africa's smaller countries including Cabo Verde, Djibouti, Rwanda and Swaziland have also set ambitious renewable energy targets. Others are following suit, and renewable energy is on the rise across the continent.

Africa 2030, IRENA's comprehensive roadmap for the continent's energy transition, illuminates a viable path to prosperity through renewable energy development. Part of an ongoing global REmap 2030 analysis, Africa 2030 is built on a country-by-country assessment of supply, demand, renewable energy potential and technology prospects. It highlights possible roles for various renewable energy technologies across the five regions of Africa until 2030.

Africa can deploy modern renewables to eliminate power shortages, bring electricity and development opportunities to rural villages that have never enjoyed those benefits, spur on industrial growth, create entrepreneurs, and support increased prosperity across the continent. Modern renewables can also facilitate a cost-effective transformation to a cleaner and more secure power sector.

Some technology solutions are relatively easy to implement but require an enabling environment, with appropriate policies, regulation, governance and access to financial markets. As a promising sign of things to come, several African countries have already succeeded in making steps necessary to scale up renewables, such as adoption of support policies, investment promotion and regional collaboration.

Africa 2030 builds on a large body of background studies developed in close co operation with African experts. **With momentum building in support of renewable energy, IRENA is committed to further collaboration with governments, multilateral organisations and existing national, regional and global initiatives. By making the right decisions today, African countries can usher in a sustainable energy landscape for generations to come.**

Adnan Z. Amin

Director-General

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EXECUTIVE SUMMARY

Kenya, Photograph: IRENA/R. Ferroukhi

Africa's economy is growing at unprecedented speed. One of the core challenges as African countries continue to grow and develop is energy: meeting rising demand for power, transport and other uses in a way that is economically sustainable and safeguards livelihoods. Economic growth, changing lifestyles and the need for reliable modern energy access is expected to require energy supply to be at least doubled by 2030. For electricity it might even have to triple. Africa is richly endowed with renewable energy sources, and the time is right for sound planning to ensure the right energy mix. Decisions made today will shape the continent's energy use of decades to come.

The world is increasingly embracing modern renewable energy technologies. For many years they have been supported because of environmental and energy security concerns but in a rising number of situations they are now seen as the most economic option. The use of modern renewables is growing in Africa, and fostering this growth is imperative. African countries are in a unique position: they have the potential to leapfrog the traditional centralised-utility model for energy provision.

Africa 2030 is part of IRENA's global REmap 2030 analysis, which outlines a roadmap to double the share of renewables in the world's energy mix within the next 15 years. It is based on a country-by-country assessment of energy supply, demand, renewable-energy potential, and practical technology choices for households, industry, transport and the power sector. The results are shown for five African regions.

Africa 2030 analysis identified modern renewable technology options across sectors, across countries, collectively contributing to meet 22% of Africa's total final energy consumption (TFEC) by 2030, which is more than a four-fold increase from 5% in 2013. Four key modern renewable energy technologies with highest deployment potentials for Africa are modern biomass for cooking; hydropower; wind; and solar power.

The power sector presents significant opportunity to be transformed through the increased deployment of renewable energy technologies. The share of renewables in the generation mix could grow to 50% by 2030 if the REmap Options in this report are implemented. Hydropower and wind could each reach around 100 gigawatt (GW) capacity, followed by solar at about 70 GW. For the power sector this would be an overall tenfold renewable energy capacity increase from 2013 levels. It would result in a reduction of 310 megatonnes of carbon dioxide (Mt CO_2) in emissions by 2030 when compared to the baseline scenario.

In all regions of Africa except the North, hydropower will continue to play an important role. North, Eastern and Southern Africa can all derive renewable power from other sources, such as wind energy, while concentrating solar power (CSP) will matter specifically in North Africa. Additional renewable power capacity is expected from geothermal sources in East Africa, while solar photovoltaics (PV) will be important in the North and Southern regions.

This transformation would require on average USD 70 billion per year of investment between 2015 and 2030. Within that total, about USD 45 billion would be for generation capacity. The balance of USD 25 billion would be for transmission and distribution infrastructure. With the REmap Options implemented, two thirds of the total investments for generation capacity – USD 32 billion – come from renewables options. Realising this opportunity will create significant new business activity in Africa.

Whilst the power sector is the most visible candidate for an energy transformation, opportunities in the heating and transport sectors are also significant. A complete overhaul of Africa's energy supply will require increased renewable energy penetration across the three sectors, and would provide enormous socio-economic benefits. One of the main ones would be the reduced reliance on the traditional use of biomass – typically foraged wood in inefficient cookstoves. Modernising biomass use is not only beneficial for the economy but it will also improve human health and release women and children from foraging to find enough supply of firewood. REmap identified options that reduce the use of traditional cookstoves by more than 60% by 2030 (compared to 2013). That would result in significantly reduced health impacts of indoor air pollution, which would translate to the reduced external costs of between USD 20 billion and USD 30 billion in 2030. The benefits of such action would far exceed the cost.

Whilst the resource base varies for renewables in Africa, all of its countries do have significant renewables potential. Their biomass, geothermal, hydropower, solar or wind resources are among the best in the world. The abundance and high quality of renewable-energy resources render renewables economically competitive, in particular as the costs of renewable technologies are rapidly decreasing. Recent renewable-energy project deals concluded in Africa will deliver power at some of the lowest costs worldwide.

Modern renewables also offer great potential in empowering local communities. These resources can be harnessed locally at a small scale, contributing to rural development and electrification without the cost of extending national grids to remote places. Local projects also offer economic opportunities to locals. However accomplishing this requires clear policy signals, an enabling framework of laws, regulations and institutional set-up as well as viable business schemes to ensure accelerated renewables deployment.

Thus far, many African leaders have seen the opportunity that renewables present for their nations, and national energy plans and announced targets reflect this vision. As power sectors and institutional frameworks mature, regulatory policies such as auctions and net metering are likely to be introduced. Policies are needed to entice private capital include public-private partnerships, to share costs and risks, and to build capacity in local financial sectors to increase access to loans and other forms of financing.

Regional cooperation is crucial in bringing about the efficiencies and economies of scale by deploying renewable energy technologies in a coordinated manner. Such an approach is particularly effective in large-scale deployment of shared renewable resources for power generation. Adopting an integrated approach to trans-boundary issues such as trade, regulatory frameworks and policies, regional infrastructure and other cross border issues would allow the countries to benefit from accessing regional renewable resources at affordable prices.

Creating an overall enabling environment for renewables in Africa requires finding the right mix of policies and incentives and multi-stakeholder collaboration at country and regional levels. The rewards accruing to countries that meet the challenge will be immense. Modern renewables can eliminate power shortages, bring electricity and development opportunities to rural villages, spur industrial growth, create entrepreneurs, and support the ongoing lifestyle changes across the continent. At the same time, leveraging renewables would facilitate a cost-effective transformation to a more secure and sustainable power sector. IRENA, through a number of cooperation instruments, will continue to work with African countries to support their efforts to appraise the full potential of modern renewable energies and their benefits.

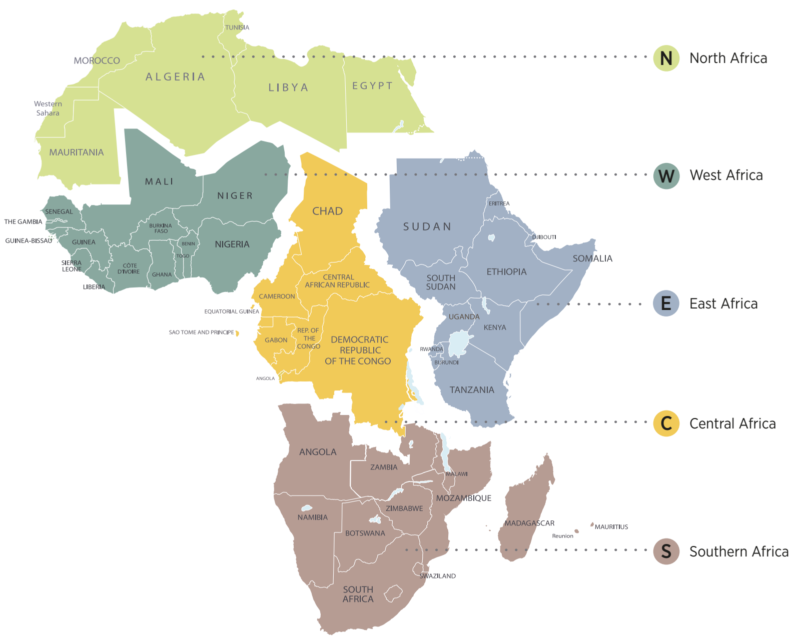
AFRICA ENERGY LANDSCAPE

Mauritania, Photograph: IRENA/C. Ruiz Sanchez

Africa has seen rapid economic growth this century, with a corresponding increase in the demand for energy. Keeping pace with rising energy needs is at the top of the agenda for policy makers, to enable economic growth and extend access to modern energy to those lacking it now. These are not easy challenges. Supply lags demand, and in as many as 30 countries in Africa recurrent electricity outages and load shedding are the norm. About 600 million people in Africa do not have access to electricity, and approximately 730 million people rely on traditional uses of biomass (IEA, 2014a).

As Figure 1 shows, different regions face different challenges. Gross Domestic Product (GDP) per capita is generally three to five times higher in North Africa, where less than 2% of the population is without access to electricity. In contrast, about half of people in West Africa and three quarters in East Africa and most of Southern Africa lack access to electricity (although only 15% in South Africa lack electricity access). North Africa on average consumes eight times more electricity per capita than the rest of the continent, excluding South Africa.

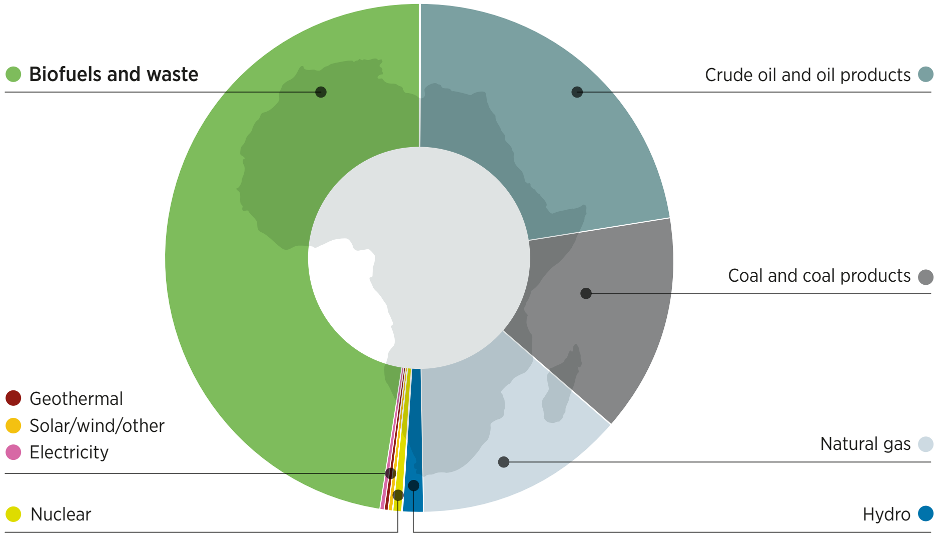
Figure 1 | **Africa's energy landscape: Present***



Region	Population (million people)	GDP billion/yr (current international $)	Access to electricity (% population)	Electricity (KWh per capita)
North Africa	175	1936	98%	1574
West Africa	327	1310	47%	188
East Africa	303	646	23%	91
Central Africa	115	227	25%	167
Southern Africa	177	1100	43%	2061

**Note: statistics refer to 2013, except for access to electricity which refers to 2012.*

Figure 2
Breakdown of total primary energy supply of Africa, 2013



Source: IEA (2015)

Africa's current energy needs are met through a mix of biomass and fossil fuels (Figure 2). Biomass accounts for approximately half of Africa's total primary energy supply. Coal and natural gas account for about 14% each, and oil approximately 22%. Hydropower represents about 1% of the total primary energy supply in Africa.

The total primary energy supply of Africa has been increasing at an annual rate of about 3%, the highest among all continents. The energy mix has been more or less constant for the last 30 years. Extensive fossil-fuel reserves, including recent natural gas discoveries, could tempt some countries to disregard the benefits of a more balanced energy mix.

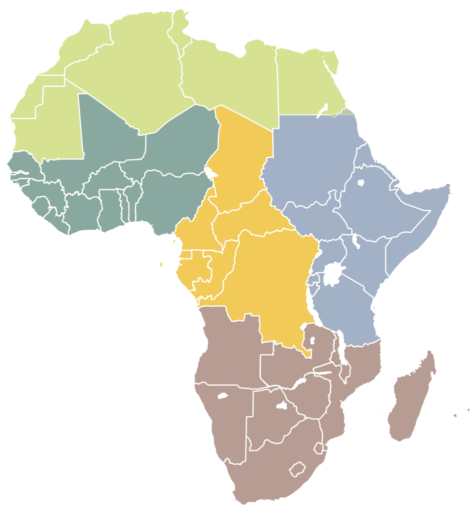
Madagascar, Anton_Ivanov, © shutterstock

At the same time, massive global deployment of renewable energy has led to significant cost reductions and performance improvements. Some African countries are already reaping benefits from proven renewable energy technologies. Along with helping to meet energy needs in a cost-effective, secure and environmentally sustainable manner, renewable energy can strengthen socio-economic development. Africa has massive renewable potentials in all forms.

Renewables can play a transformative role in the African energy mix. Abundant fossil fuels and renewable sources in many countries on the continent mean policy makers have a choice. But for a diversified, sustainable energy mix, it is more important than ever to ensure that renewables play as large a role as possible. This analysis elaborates on the costs and benefits, as well as discussing regional approaches for putting those findings into practice in the coming 15 years. *Africa 2030* builds on a large body of IRENA background studies conducted in close cooperation with country representatives and regional organisations. Renewable solutions for Africa are at the centre of IRENA's work as witnessed by four prospective studies: *Scenarios and Strategies for Africa* (IRENA, 2011a); *Prospects for the African Power Sector* (IRENA, 2011b); *Africa's Renewable Future: the Path to Sustainable Growth* (IRENA, 2013a); *Africa Power Sector: Planning and Prospects for Renewable Energy – Synthesis Report* (IRENA, 2015a). *Africa 2030* is a part of IRENA's global renewable energy roadmapping exercise, REmap 2030 (IRENA, 2014a).

The chapters that follow identify nearly 10 exajoules (EJ) of options in 2030 for sustainable development using modern renewable energy resources and technologies, known in this report as "REmap Options". Together these could account for 22% of the continent's TFEC in 2030, up from 5% in 2013. About 50% of the final energy provided by these options would be biomass-based heat applications, while 40% come from the power sector.

South Africa, © shutterstock



Regional definition used in this report

N North Africa
Algeria, Egypt, Libya, Mauritania, Morocco, Tunisia

W West Africa
Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo

C Central Africa
Cameroon, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Sao Tome and Principe

E East Africa
Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan, Tanzania, Uganda

S Southern Africa
Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Zambia, Zimbabwe

PART ONE
TECHNOLOGIES TO HARNESS AFRICA'S ABUNDANT RENEWABLE RESOURCES

The African continent is endowed with large renewable energy potential, varying in type across diverse geographic areas. Solar resources are abundant everywhere, while biomass and hydropower potential are more plentiful in the wet, forested central and southern regions. Wind resources are of the highest quality in the north, the east, and the southern regions, while geothermal energy is concentrated along the Great Rift Valley. These resources, and the settings in which they exist, can point to country-specific renewable energy solutions to fit each state's strengths and needs. Part 1 of this report describes the renewable energy resources available in Africa along with the technologies to harness that energy potential. The resources considered include hydropower, solar energy, wind energy, geothermal energy and various types of biomass. Biomass falls into three categories: woodfuel; agricultural and industrial residues; and energy crops. Africa's extensive coastline also suggests long-term ocean energy potential, but this is unlikely to be a significant source by 2030.

The possible applications for all these resources include power generation, heating and cooling for both industrial and domestic applications, lighting, transport and direct uses of mechanical energy.

- Abundant fossil and renewable energy resources are available across Africa. With rapid economic growth, changing lifestyles and the need for reliable modern energy access, the continent's energy demand is set to double by 2030.
- Renewable energy is growing rapidly around the world, driven by economics, environmental concerns and the need for energy security. The use of modern renewable energy technologies is also on the rise across Africa, where countries are uniquely positioned to leapfrog the traditional centralised energy supply model.
- Renewable energy technologies can be deployed locally, at small scale, opening up new forms of financing and productive uses, as well as broadening electricity access.
- The costs of renewable technologies are decreasing rapidly; recent project deals for renewables in Africa have been among the most competitive in the world.
- While the resource base varies, all African countries possess significant renewable energy potential. The continent's biomass, geothermal, hydropower, solar and wind energy resources are among the best in the world. Clear policy signals and an enabling framework can produce accelerated renewable energy deployment.

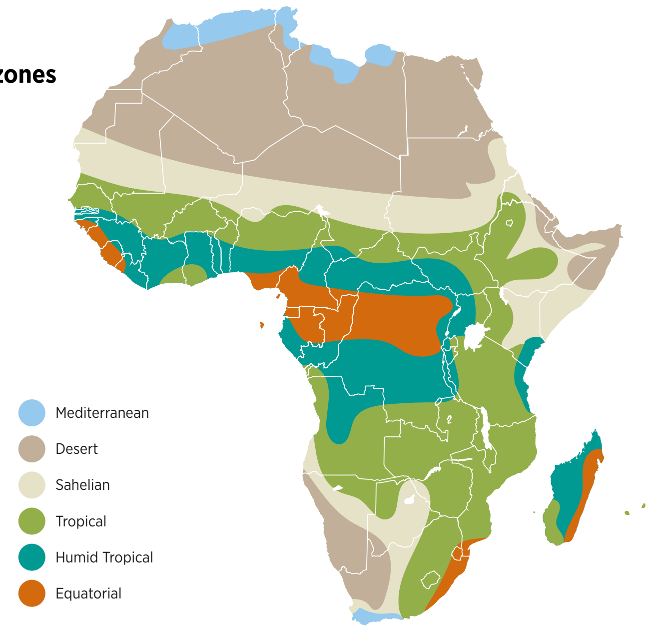




1.1 SOLAR

Africa has an exceptional solar resource that can be harnessed for electricity generation and for thermal applications. The desert regions of North Africa and some parts of Southern and East Africa enjoy particularly long sunny days with a high intensity of irradiation. Sahelian and Tropical conditions also feature strong solar irradiation. Solar energy can be utilised at various scales, making it suitable from the household and community levels to industrial and national scale operations.

Figure 3
African climate zones



POWER APPLICATIONS

Two types of technologies exist for power generation: solar photovoltaic (PV) and CSP. The former can be universally used, in applications ranging from household systems to utility-scale, while the latter is typically a technology that performs optimally in utility scale projects situated in the desert regions. Overall, Africa's solar power generation potential exceeds future demand by orders of magnitude. Even the smallest countries on the continent have at least a few gigawatts of potential for either technology.

UTILITY SCALE – SOLAR PV AND CSP

Africa's solar PV capacity has grown exponentially in recent years, but from a low base. Cumulative installed capacity at the end of 2014 was 1 334 megawatt (MW), more than ten times larger than in 2009 (127 MW). South Africa is leading this rapid growth, adding nearly 780 MW between 2013 and 2014[1]. Kenya has also seen sizable investments in solar PV, with 60 MW installed by 2014 (IRENA, 2015b). This accelerated growth will continue, as more than 14 GW of solar PV and 6 GW of CSP are either announced or in the pipeline (GlobalData, 2015). For example, a single company, SkyPower, has bilateral agreements in place to install 7 GW of solar PV capacity in the coming five years in Egypt, Kenya and Nigeria.

[1] *The African statistics include data for the French oversea territory of Reunion, whose capacity by 2014 is 167 MW, second following South Africa.*

Of 350 African solar PV projects data in the GlobalData (2015), a majority have production capacity of between 10 MW and 100 MW, with capacity factors from as low as 11% to as high as 33%. This range corresponds to utility-scale solar PV applications, though in some countries much smaller systems, in the range of 1 MW to 10 MW, are also used at a utility scale. Much bigger systems, up to 500 MW, are already under construction, for example in Namibia.

Mirroring the rapid reduction of PV module costs worldwide, which fell by 75% from 2009 to 2015, the levelised costs of electricity (LCOE) of best practices for African utility-scale projects in the continent has also rapidly fallen. According to IRENA's Costing Alliance Database (IRENA, 2015c), LCOE for African solar PV utility projects in 2013 and 2014 ranged between USD 0.13 and USD 0.26 per kilowatt-hour (/kWh).[2] The lowest cost for utility-scale PV in South Africa is below USD 0.075 per kWh, which is among the most competitive PV projects worldwide. This gap between the best practice and cost range in Africa suggests further cost reduction potential.

Deployment of CSP in Africa is in the earliest phase, as is the case worldwide. Four African countries, Algeria, Egypt, Morocco and South Africa, have deployed a total of six CSP projects as of March 2015. Their installed capacity amounts to just over 180 MW (IRENA, 2015b). Projects totalling 6.4 GW are underway, including some in Botswana, Namibia, Sudan, Tunisia (GlobalData, 2015). CSP is attractive because its efficiency increases with irradiation level, which is not the case for solar PV where efficiency declines with rising collector temperatures. Given that the irradiation level corresponds also with the demand for air conditioning, solar CSP would reduce the need for peak capacity. This feature is attractive in desert countries where solar irradiation is particularly strong. CSP systems offer the opportunity to store solar energy as heat, for use to generate electricity during periods of low or no sunshine. CSP systems with thermal storage have higher investment costs, but they allow higher capacity factor and dispatchability.

CSP projects are capital intensive. Project investment costs for the six commissioned CSP plants vary between 5 800 USD/kW (no storage) and 10 150 USD/kW (with 7 hours of storage). This range is higher than the typical range of USD 1 820/kW to USD 4 880/kW for solar PV projects. The gap is narrowing however, and cutting-edge CSP technologies are being deployed in Africa: the Redstone CSP project in South Africa, developed by ACWA power and SolarReserve (100 MW with 12 hours of storage) was contracted for USD 0.124 per kWh. This project will come online in 2018 and is well below the range of LCOE for recent CSP projects worldwide, between USD 0.20/kWh and USD 0.36/kWh (IRENA, 2015d).

DISTRIBUTED SOLAR PV

Smaller scale PV systems can be used with or without connection to a power grid. Off-grid PV markets have seen particularly dynamic development in a wide range of African countries.

Small-scale distributed solar PV systems can provide power to houses and buildings for essential services such as lighting and charging electric appliances. They are already providing alternatives in rural settings to electricity from distribution lines connected to national transmission lines. Extending a national or regional grid to remote villages has often been an expensive solution to rural electrification. Solar PV (with or without battery storage) can also help significantly reduce fuel costs in existing mini-grids. Even where a connection to the existing network is available, if an uninterrupted supply is required, such as in health-care settings, solar PV systems with battery storage can be an economic solution.

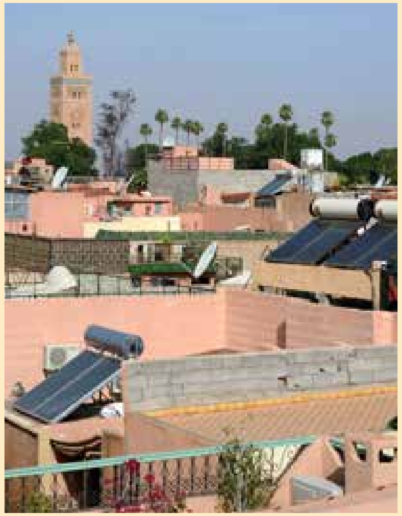
Mauritius, Photograph: IRENA/E. Taibi

2) Unless otherwise noted, all prices are in constant 2013 USD.

Burkina Faso, Photograph: IRENA/H. Lucas

Mimadeo, © shutterstock

Marrakesh, KMW Photography, © shutterstock



There are already sizeable markets for solar PV home systems in countries like Kenya and Tanzania, which are estimated at around 4 MW and 6-8 MW respectively. This may appear modest, but with solar PV home systems often sized as low as 20 watts (W), these gains represent tens or even hundreds of thousands of individual systems installed annually. At such a small scale these systems are closer to consumer electronics than energy systems, and prices vary widely depending on margins. IRENA's latest analysis of investment costs for more than 200 versions of these systems in Africa (IRENA, forthcoming) revealed a range between USD 2.2/W and USD 17/W (Figure 4). System size influences the cost. For example, the best practice investment cost for solar home systems below 1 kW in size (around USD 4/W) is almost twice as high as for systems above 1 kW. Wide cost differentials between average and best-practice investment point to significant potential for cost reductions.

Small-scale stand-alone PV systems are also used for mini-grid service in rural communities as well as for other community services, such as street lighting, solar kiosks, mobile-phone charging stations, telecom towers and pumping water. These energy services have historically been using diesel fuel, but solar PV systems offer a cost-effective alternative. Mini-grid based rural electrification has been implemented in many African countries, and diesel based mini-girds are being upgraded with PV-diesel hybrid systems.

Solar PV is especially suited for water pumping, as the operation can be adjusted to the availability of solar electricity. Sizeable markets for solar water pumping include nearly 300 MW of installed capacity in Algeria. In Egypt 9% of PV applications are for water pumping. The two phases of the Regional Solar Programme (RSP), implemented by the Permanent Interstate Committee for Drought Control in the Sahel, have resulted in the deployment of solar pumping stations systems in nine countries, providing improved access to water and electricity for 2 million people. Telecom towers are also considered a provider of steady demand, on the back of which investment cases can be made for mini-grid systems at the community level. In 2013, Africa had around eight million solar systems installed to power public lighting (IRENA, 2015e).

Solar PV systems are also increasingly deployed for industrial applications. In the mining sector there is a trend towards hybrid diesel and PV systems to lower the cost of electricity supply in remote locations without grid access, and to allow for backup supply in case of grid blackouts (Gifford, 2015). An example is Sibanye Gold in South Africa, which is installing 150 MW of PV.

HEAT APPLICATIONS

SOLAR WATER HEATING – DOMESTIC APPLICATIONS

In addition to generating electricity, a number of modern technology applications have been deployed to provide heat for domestic and industrial heating needs. Two major domestic heating needs in Africa are cooking and hot water. For cooking, there have been many projects aimed at deploying solar cookers and they have met with mixed success. The initial cost of a solar cooker is often above the means of the rural communities and eating at the time when the solar irradiance is at its best is not always convenient or traditional. On the other hand, domestic water heating using solar power has been encouraged in many parts of Africa, and the market is growing fast in selected countries including South Africa, Tunisia, and Morocco. By the end of 2013, over 1 gigawatt-thermal (GW_{th}) of solar thermal capacity was installed in South Africa, followed by Tunisia at 0.5 GW_{th}, and Morocco at 0.4 GW_{th} (IEA Solar Heating and Cooling Programme, 2015). In North Africa the primary use is residential applications.

Issues affecting the uptake of domestic solar water heaters include the high up-front installation costs compared with gas and electric boilers, the complex process and associated costs to integrate solar thermal systems into existing housing, competition with heat pumps, and in some cases the competition with PV panels for rooftop space (IRENA and IEA-ETSAP, 2015a). Moreover in parts of Africa electricity and fossil fuel subsidies have acted as inhibitors to large-scale deployment.

SOLAR HEATING AND COOLING – INDUSTRIAL APPLICATIONS

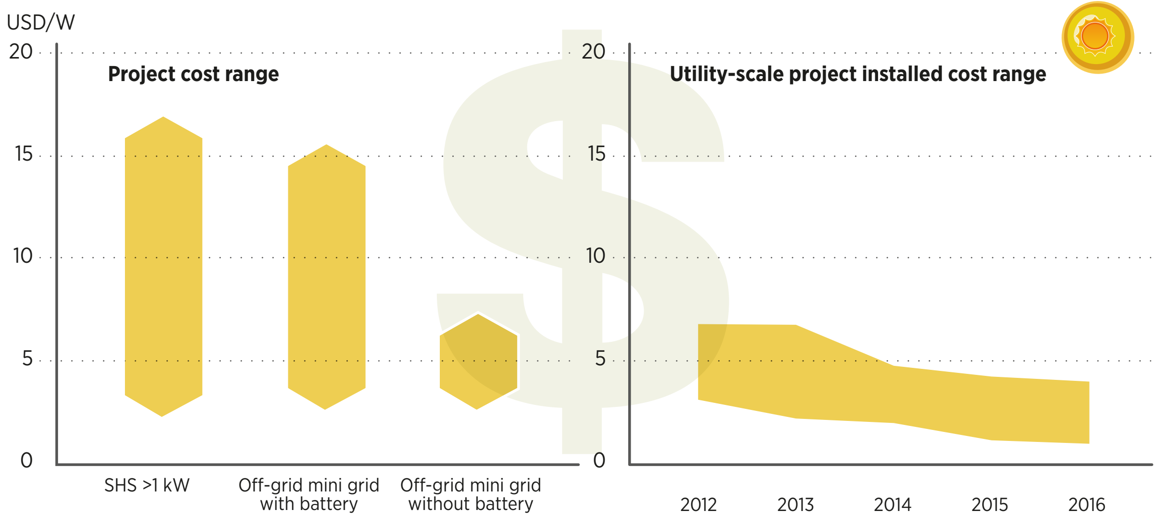
For industrial facilities, solar heaters can be used to produce process heat, primarily in low- to medium-temperature ranges. Uses include the drying of goods, heating of water, and steam generation. Compared to other parts of the world, a higher share of Africa's manufacturing sector consists of activities that are not energy-intensive. Examples include processing food or wood, and producing textiles. Up to 70% of demand for heat for these activities calls for low-temperature heat, and solar heaters are sufficient to provide it. The current use of solar heating for industrial applications is negligible in Africa. Modern solar drying technologies have been piloted mainly to increase value added to products when compared with the traditional way of drying products by sunlight. This is achieved by conducting the drying process in a controlled environment, which yields higher-quality products protected from dust, variable temperatures and insects or animals. Although the application potential of this technology may be considered a small market, it could offer significant benefits to this niche of economic activity.

It is also possible to utilise solar energy for cooling. These installations are of particular relevance for remote medical clinics as well as industries, such as the dairy industry, that require cooling to enable product storage.

WATER DESALINATION WITH SOLAR PV AND SOLAR CSP

Solar energy has been used for water desalination in North Africa, a region facing increasing stress on freshwater resources. Current global capacity for renewable-energy desalination accounts for less than 1% of total desalination capacity. Of that small amount, 43% of renewable capacity uses solar PV and 27% solar thermal (European Union, 2008). In North Africa the total volume of desalinated water is estimated to account for less than 1% of total regional water demand. Yet the amount of energy used for desalination in Algeria, for example, is as high as 10% of the total electricity consumed in 2010. With desalination increasingly important – it could be relied on to meet as much as 50% of new water demand – the implications for future energy demand are significant (World Bank, 2012). The combination of solar technologies and desalination technologies also provides a flexible demand option for non-dispatchable solar technologies.

Figure 4 **Solar PV cost ranges in Africa by market segment and size***



** Note: costs include equipment as well as installation, planning, civil works, infrastructure, construction etc.*

Source: IRENA (forthcoming)

1.2 WIND

Wind is converted into useful energy utilising wind turbines, for use either to drive electrical generators or to directly power pumps and other machinery.

The theoretical potential for wind in Africa exceeds demand by orders of magnitude, and about 15% of the potential is characterised as a high-quality resource. This enormous capacity is not evenly distributed: East, North and Southern Africa have particularly excellent wind resources. Countries with especially high wind quality include all those in North Africa; Niger in West Africa; Chad in Central Africa; Djibouti, Ethiopia, Kenya, Sudan, Somalia, Uganda in East Africa; and in Southern Africa Lesotho, Malawi, South Africa, Tanzania and Zambia.

South Africa, Grobler du Preez, © shutterstock

POWER GENERATION

By the end of 2013, total installed wind capacity in Africa was 1 463 MW. In 2014, 999 MW of new capacity was installed, bringing the total to 2 462 MW at the end of 2014 (IRENA, 2015b). Locations are indicated in Table 1. Even with the remarkable growth rate in South Africa during 2014, Morocco still had the largest installed wind capacity in Africa. East Africa is also seeing growth, with the 300 MW Turkana project under construction. Additionally, 140 African wind farms are in various stages of preparation, totalling 21 GW of new capacity expected to become operational between 2014 and 2020 (GlobalData, 2015). In Egypt, the government's goal is to have 7 GW of wind power installed by 2020. Morocco has set a target of 2 GW by 2020, and South Africa plans to install 8.4 GW of wind power by 2030 (IRENA, 2015f). Scenarios prepared by the Global Energy Wind Council (GWEC) predict that installed wind power capacity in Africa will rise to between 75 GW and 86 GW by 2030 (GWEC, 2014).

The typical range of African wind power projects is smaller than 150 MW. However, projects in the pipeline are increasingly of a larger scale, with projects between 300 MW and 700 MW under consideration.

In general, on-shore wind is now one of the lowest-cost sources of electricity available, and in Africa the LCOE range is between USD 0.046 to USD 0.145/kWh for projects installed in 2013 and

2014. The corresponding weighted average is USD 0.055/kWh (IRENA, 2015d). A recent tender in Egypt resulted in bids as low as USD 0.041/kWh, a new record for Africa. However, many projects in Africa will require considerable additional investments to bring power from the best wind locations to biggest demand centres, which can raise supply costs by USD 0.05 to USD 0.20 per kWh. Investment costs for recent projects in Kenya, Morocco and South Africa ranged between USD 1600/kW and USD 3000/kW, with the average being USD 2210/kW. This is similar to some average international prices observed in 2013 and 2014 in the United States and Europe. In China and India, the average total installed cost was significantly lower, at USD 1300/kW. Costs in Africa are expected to drop further with increased availability of locally manufactured components such as towers and blades.

Table 1 **Wind generation installations during 2014**

Country	End 2013	New 2014	Total (End 2014)
Morocco	487	300	787
South Africa	10	560	570
Egypt	550	60	610
Tunisia	200	55	255
Ethiopia	171	0	171
Cabo Verde	24	0	24
Other	21	10	31
Total	**1463**	**999**	**2462**

Source: IRENA (2015b)

WIND WATER PUMPING

The use of wind for off-grid applications, and particularly for water pumping in the agricultural sector, is widespread in Africa and particularly in Southern Africa, where over 300000 units are in operation. The technology is simple and the systems are robust, with low maintenance requirements. Given the variable nature of wind, water storage capacity is often incorporated in these projects to ensure a continuous supply. A cost comparison between wind pumping and diesel pumping in Sudan found that using wind is 30% less expensive than diesel (Omer, 2008). However, most of the ongoing renewable-energy water pumping initiatives focus on solar water pumping, rather than wind water pumping (IRENA, 2015g).

South Africa, michaeljung, © shutterstock

1.3 HYDROPOWER

Africa has abundant hydropower resources. It is estimated that around 92% of technically feasible potential has not yet been developed (IRENA and IEA-ETSAP, 2015b) (Table 2). Central Africa has about 40% of the continent's hydro resources, followed by East and Central Africa, each having about 28% and 23% respectively (Hydropower and Dams, 2014). At the end of 2014 there was 28 GW of hydro capacity installed in Africa (IRENA, 2015b). This makes hydropower by far the most important renewable power-generation option deployed today. Of the resources available, the Congo River has the largest discharge of African rivers, followed by the Zambezi, the Niger and the Nile.

Hydropower resources can be utilised in a number of ways, depending on the size of the resource. Large-scale hydro resources are often utilised in combination with a storage dam and are suitable for the production of grid electricity. Small hydro plants, (1 MW to 10 MW capacity) may or may not incorporate dams, while mini- (100 kW to 1 MW), micro- (5 – 100 kW) and pico-hydro (less than 5 kW) are suited to run-of-river (no storage dam) installations for the provision of distributed electricity to areas remote from the electricity grid.

Hydropower is dependent on a reliable supply of water, and periods of drought have a detrimental effect on the availability of hydropower stations. The droughts in Kenya at the turn of the decade resulted in extensive power outages due to a shortage of hydro generating capacity. Thus, when planning the utilisation of this resource, the seasonality and annual variability of hydro resources must be factored in.

LARGE-SCALE HYDRO

Hydropower plant projects with a combined new capacity of 17 GW are currently under construction in Africa (Hydropower and Dams, 2014). Given that large hydro projects often have outputs far in excess of the national demand for electricity, it is necessary to develop these as regional projects. Two projects of note are the Grand Inga project and the Great Millennium Renaissance Dam.

The Grand Inga project on the Congo River envisages the installation of 40 GW of hydro generating capacity, which would make it the largest hydro facility in the world. It is to be developed in 8 phases. The current phase of development, Inga 3, has a total potential of 7.8 GW, and of that total 4.8 GW of capacity is under development, to be commissioned by 2023 (World Bank, 2014a). A significant share of electricity is destined for exports, which will go as far as South Africa. Transmission lines totalling 1 850 kilometers (km) are to be developed to support Inga 3 exports of electricity.

The Great Millennium Renaissance Dam, situated on the Nile River in Ethiopia is currently under construction and will add a further 6 GW to the grid. Ethiopia has ambitious plans for hydropower expansion including electricity delivery to neighbouring countries.

Hydropower is well suited to meet large-scale industrial demand, which provides a reliable revenue stream for future hydro power developments. In the past, hydropower plants have been designed with energy-intensive aluminium smelters as planned offtakers, including in Ghana and in Mozambique. In the latter, the aluminium industry is now a significant economic activity. For the Grand Inga project, 1 GW in capacity is to be allocated to local industrial projects, according to current plans.

Hydropower currently offers the most economical solution for large-scale renewable electricity generation, as the technology is mature and the resources are very large in comparison with Africa's current energy demand. It is less expensive than most technologies of any type for power production – costs in Africa can be as low as USD 0.03/kWh, and the average is approximately USD 0.10/kWh. The weighted average installed cost for large-scale hydro in Africa is USD 1400/kW (IRENA, 2015d). Since hydropower is a mature technology, there are limited options for cost reductions.

The construction of dams associated with large hydro projects can present some problems. Popular or activist opposition can arise from the displacement of individuals and whole towns, the submersion of heritage sites and sensitive ecosystems and environmental impacts. Neighbouring states may object to altered flows in shared bodies of water, in particular those downstream. However, working with various stakeholders can provide valuable additional benefits such as flood control and irrigation reservoirs.

SMALL HYDROPOWER

Small hydro is suitable for connection to existing grids or for the provision of electricity in remote areas. Given their smaller size, any dams associated with these plants will have a significantly smaller environmental impact. Africa already has a total capacity of 525 MW from hydro plants with individual capacities of less than 10 MW, with 209 MW in Eastern Africa alone (IRENA, 2015b). Mini- and micro-hydro offer cost-effective solutions to distributed power generation requirements, particularly when the supply is at the village or household level. For these installations, water may be diverted from a rudimentary dam to power a small water turbine.

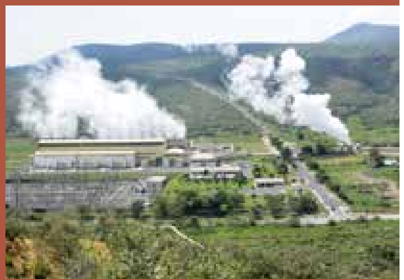
Where available, the implementation of small hydro plants is a cost-effective off-grid solution for rural areas. Capacity factors are high and generation costs can be relatively low, with an average LCOE of about USD 0.05/kWh. The weighted average installation costs for small-scale hydro in Africa is USD 3 800/kW (IRENA, 2015d).

Mulanje Micro Hydro Scheme for electricity generation for households, schools and clinics
Photograph: Drew Corbyn, Practical Action

Table 2 **Hydropower generation and technical potential** *Source: Hydropower and Dams (2014)*

Region	Hydro generation in 2013 or most recent/average (GWh/yr)	Technically feasible hydropower potential (GWh/yr)	Ratio between hydro generation and technically feasible hydropower potential
North Africa	16 728	59 693	28%
West Africa	19 445	101 492	19%
Central Africa	14 614	570 730	3%
East Africa	26 215	334 600	8%
Southern Africa	44 896	415 857	11%
Total	**122 538**	**1 584 670**	**8%**

1.4 GEOTHERMAL ENERGY



Geothermal energy is a resource of considerable importance in East and Southern Africa. It is estimated that the continent has a potential of 15 GW, all of it found along the Rift Valley, which runs from Mozambique to Djibouti (Geothermal Energy Association, 2015). As of 2014 there was 606 MW of geothermal capacity installed in Africa, of which 579 MW was in Kenya (IRENA, 2015b). Kenya's capacity more than doubled in 2014, an indication of the rapid rate of implementation of this technology in the country. Kenya has production experience and additional projects with a combined capacity of nearly 3 GW have already been identified. Some are also under development in Ethiopia and Tanzania and aim to increase the generating capacity of these countries by 640 MW by 2018. Djibouti is aiming for projects to come on-stream in 2020.

In December 2014, for the first time, power generation from geothermal sources in Kenya accounted for more than half of Kenya's electricity output. Kenya is the main hub of the African continent in terms of geothermal technology capacity building and is considering to host the Centre of Excellence for Geothermal Development in Africa.

Olkaria geothermal complex and power station.

All photos taken during the visit organized for the Global Geothermal Alliance Stakeholder Meeting in Nairobi, Kenya (June, 2015, IRENA)

Geothermal plants are capital intensive and hence development costs have risen along with increasing engineering, procurement and construction costs. Capital costs for recent projects in East Africa have ranged from USD 2 700/kW to USD 7 600/kW, with a weighted average of USD 4 700/kW (IRENA, 2015d). The price tag for projects planned for the period 2015 to 2020 is expected to drop from current levels, but overall these high upfront costs, along with associated uncertainties, are the key barriers to the development of geothermal power plants. In many instances geothermal projects also require long-distance transmission lines. Suitable risk-mitigation and transmission-network development approaches are important for the development of these resources.

Geothermal heat could also be applied directly to industrial processes that require low-temperature heat. These processes dominate a large share of Africa's manufacturing industry, and geothermal heat is a low-cost and secure substitute for fossil fuels. For example, in Kenya, geothermal direct heat is being successfully used in the flower industry. However, it is more likely that industrial demands will be met by electricity generated from geothermal resources, and then only in East Africa.

1.5 WOODFUEL

South Sudan, John Wollwerth, © shutterstock

Ghana, Sopotnicki, © shutterstock

Woodfuel is the single most important primary energy source across the African continent. With almost 15 EJ, it accounted for nearly half of total primary energy supply in 2013 (IEA, 2015). Woodfuel is primarily used for cooking and heating in the residential sector, though sizable amounts are also used by small and medium size industries for metal processing, food processing and brick making. Wood is used either directly as firewood or in the form of charcoal. It is estimated that about one fifth of harvested woodfuel is converted to charcoal.

Continuous trends of deforestation in many African countries over the past two decades, on the one side, and a growing energy demand on the other, point to an unsustainable level of forest harvesting. This is especially evident around densely populated peri-urban and urban areas. Governments are taking initiatives to slow down the speed of deforestation, but considering that 90% of final energy used by households comes from woodfuel, it is clear that a transition to sustainable bioenergy supply requires more effort.

Firewood is often the cheapest option for rural populations to satisfy their basic energy needs and it is also a source of income for those involved in the charcoal supply chain. In urban areas, charcoal is available on the market, and thus more accessible and often more preferred than firewood. Electricity, kerosene and liquefied petroleum gas (LPG) are alternative cooking fuels in these settings. Yet, without subsidies they are often more expensive and therefore not affordable for the urban poor.

In general woodfuel-based products are commonly produced and used in traditional ways, characterised by low efficiency and adverse impacts on human health and living conditions. It is estimated that nearly 600 000 people died of indoor air pollution in Africa in 2012 (WHO, 2015), and women and children spend a few hours per day collecting firewood, deprived of time otherwise used for more productive activities.

More efficient end-use of traditional biofuels is a key part of the transition towards sustainable bioenergy supply. This should be coupled with sustainable forest management and efficient biofuel conversion technologies.

In addition to sustainable management of natural and planted forest, fast growing woodfuel plantations also provide feed-stock for modern bioenergy production. IRENA estimates the wood supply potential from surplus forest (beyond what is needed for non-energy purposes) in Africa at around 1.85 EJ/yr. About 35% of this potential is situated in East Africa and a further 31% in West Africa (IRENA, 2014b). There are already 11 wood based power plants, with a total installed capacity of almost 30 MW, operating in Ghana, Congo, Ethiopia, Tanzania, Namibia and Swaziland, and a number of new plants are planned or under construction (Platts McGraw Hill Financial, 2015). There are also examples of co-firing wood-chips with coal.

CHARCOAL

Charcoal is a popular fuel because of its high energy content, clean burning characteristics, and easy storage. It is the main fuel of the urban poor, and will probably remain so in the forthcoming period during the transition to modern fuels. Even though the use of charcoal seems insignificant compared with the use of firewood (1 EJ compared with 12 EJ in the final consumption), its relative importance has been rising. Over the past 40 years, charcoal annual production has grown at an average annual rate of 6.3% (FAO, 2015). Attempts to impose requirements for sustainable feedstock sourcing, and to formalise and/or control charcoal market have not always been successful. The reasons for that include poor enforcement, complex ownership rights and prevailing socio-economic conditions, in particular given the earning potential that charcoal affords rural households.

Charcoal is currently produced largely in traditional earth kilns with efficiencies of between 10% and 20%, while improved metal, brick and retort kilns offer efficiencies between 25% and 40% (UN-HABITAT, 1993). Even though the investment in higher efficiency kilns would be recovered through increased throughputs, the producers often have limited opportunities to access capital. Accessible funds supported with strong legislative framework on sustainable forest management will be needed to convince the producers of the long-term value to change to more efficient kilns.

EFFICIENT COOKING STOVES

Cooking in Africa is still widely done by placing a pot on top of three stones in a fire, particularly in rural areas. This traditional biomass use, however, is very inefficient and creates health hazards from inhalation of smoke and particulate matter.

Numerous projects have been undertaken to promote the use of efficient cookstoves. Besides the significant efficiency improvement (up to 50% in a modern and efficient cookstove) and the consequent reduction in fuel requirements, the smoke from these stoves can be vented outside, reducing the risk of adverse impacts on health. In addition the risk of burns associated with open fires can be removed. Countries such as Somalia and Kenya have well-established cookstove programmes, and today similar programmes are implemented in most of Southern, Central and East Africa as well as some in West Africa. The penetration of efficient cookstoves is encouraging, having reached 36% in Kenya and 50% in Rwanda. As carbon-offset projects, 2 million efficient stoves have already been installed in Africa (Global Alliance for Clean Cookstoves, 2014a).

Even though the prices of efficient cookstoves range from USD 5 to USD 10, there is still a barrier to the uptake of efficient stoves in that poor households are the main users of biomass cookstoves and these low prices are still beyond the means of many. Costs can be further reduced by design and manufacture changes, or through subsidies. Alternatively, micro-financing schemes can help those unable to make a large lump sum payment. Some other issues that can result in the failure of cookstove projects include a failure of the stove to meet the cooking requirements for particular dishes, the non-availability of suitable fuels, and religious beliefs in which the traditional cookstove plays an important role in religious lore and practices (Global Alliance for Clean Cookstoves, 2014b).

Efficient cookstoves sold in Uganda, Photograph: GVEP International

1.6 BIOMASS RESIDUES

Richard Jary, © shutterstock

Biomass residues are generated at various stages of agricultural and forestry production. They include:

- Wood logging residue, *i.e.* parts of trees that are left in the forest after removal of industrial roundwood and woodfuel
- Crop harvesting residues generated in the fields, such as wheat straw, maize stover, cassava stalk, etc.
- Residues generated on animal farms, which may include manure and a mixture of manure and bedding materials
- Agro processing residues generated at the agri-food processing plants, for example rice husk, sugarcane bagasse, etc.
- Wood processing residues generated in sawmills, furniture production facilities, or similar, which include bark, sawmill dust, and cuttings
- Biodegradable waste, including organic fraction of municipal waste, construction and demolition debris, etc.

The total supply potential of crop harvesting and agro processing residue in Africa is estimated at around 4.2 EJ in 2030. The West Africa region has 40% of this resource. Total supply potential of wood residues (including both logging and processing residue) and wastes and animal residues are estimated at around 1.1 EJ and 1.5 EJ per year, respectively. The North Africa region has 40% of the wood residue and waste resource, and the Central region has the lowest wood residue potential (IRENA, 2014b).

Collection and transportation of residues tend to constitute a significant part of the overall costs. Thus, it is most cost-effective to convert feedstocks into fuels or final energy forms as close as possible to the point of consumption. In the case of waste and residues that may have negative environmental impacts, bioenergy technologies provide a cost-effective solution for their treatment in addition to energy production (IRENA, 2014b).

CROP-HARVESTING RESIDUE: BRIQUETTES AND PELLETS

Crop-harvesting residue can be used as feedstock for briquettes and pellets. Briquettes have been successfully marketed as an alternative to wood and charcoal in countries such as Egypt, Sudan, Rwanda, Namibia and Kenya. Their greater density means reduced transport costs, a longer burning time and, depending on the type of biomass and processing method, less emissions. However, many briquetting projects have failed in the past due to poor project planning, marketing, low quality products and lack of availability of appropriate stoves. For example, it has been found that in some cases it was essential to locate points of supply and points of sale in proximity to each other, as small-scale producers and buyers may not have access to transport. In the future, creating a briquette industry and market will require addressing these issues and also benefit from creating economies of scale that can reduce prices, for example from the creation of feedstock collection points, where sufficient volume can be collected (ERC, 2012).

AGRO- AND WOOD-PROCESSING RESIDUE: ELECTRICITY GENERATION AND INDUSTRIAL APPLICATIONS

Sugarcane bagasse is widely used to generate the electricity and heat needed on-site. As elsewhere in the world, the African sugar industry has in the past made efforts to adjust the efficiency of combustion to utilise as much as possible bagasse and avoid its disposal. In regions where legal and technical conditions allow, such as Mauritius and South Africa, the industry is also moving toward selling any excess to the grid, which would eliminate the need to adjust combustion efficiency. Bagasse is particularly important in countries that produce large volumes of sugar cane, such as South Africa, Egypt, Sudan, Kenya, Swaziland and Zimbabwe (FAO, 2015).

Besides bagasse, there are several other biomass by-products that are typically generated in Africa which have energy value. For example, wood processing and logging residues in Africa could provide sufficient feedstock for up to 20 GW of power generation capacity (IRENA, 2015a). Generated electricity can be exported, or if dedicated clients are available, the residues could otherwise be processed and sold to them for purposes other than power generation.

In addition to power generation, biomass residues are suitable for a range of industrial applications, providing process heat, as well as heating and cooling of industrial facilities. Food processing is one of the most developed industrial activities in Africa, with typical products including sugar, dairy, baking, beer brewing, fish smoking, tea, coffee, and cocoa, among others. These industries sometimes use traditional methods of production, which are often inefficient. The use of modern renewable energy would modernise processes and provide opportunities to add more value to their products.

BIOGAS FROM RESIDUES

Biogas is primarily a mixture of methane and carbon dioxide, produced by the anaerobic digestion of biodegradable organic materials. Various feedstocks can be used for biogas production, including manure, food processing residues, waste water treatment sludge and energy crops. Biogas can be used for cooking and lighting, which is often the case in developing countries with biogas generated in small sized digesters, as well as for power and heat generation in industry facilities and on commercial animal farms.

Landfill gas is another gaseous fuel generated from the organic fraction of municipal waste. Landfill gas projects are becoming increasingly common in Africa. For example, in South Africa, the Durban municipality has implemented a landfill gas-to-electricity project with an installed power generation capacity of 7.5 MW (IEA, 2014b).

A number of interesting biogas-generation projects have been initiated in Kenya, such as producing off-grid electricity from biogas generated by manure and sisal, utilising slaughterhouse waste to produce biogas for electricity production, and another producing 20 kW of electricity from vegetable waste (IRENA, unpublished).

Biogas is commonly used in rural areas of China and India, mainly for cooking. The estimated potential for biogas in Africa is significant, with 18.5 million households having sufficient dung and water, primarily in rural areas. A number of programmes are in place in Africa to increase the use of biogas in domestic applications. The Africa Biogas Partnership programme has already installed 46 000 digesters (Africa Biogas Partnership Programme, 2015) and intends to extend the programme to reach another 100 000 households by 2017, in Kenya, Ethiopia, Tanzania, Uganda and Burkina Faso (Africa Biogas Partnership Programme, 2014). Cameroon and Rwanda have initiated national programmes for the implementation of biogas.

Biogas digesters are typically designed to serve more than a single household and are thus a solution for urban peripheral and rural communities. However, costs are high, and subsidies are typically applied to encourage their use. In Kenya, for example, a EUR 240 per plant flat subsidy is provided, while in Cameroon 30% of the digester cost is subsidised. Without subsidies or innovative financing methods the availability of biogas facilities to the poor will be limited.

In industrial settings, dairy operations and other food-processing plants, technically all energy requirements could be met by converting manure to biogas. Several pilot and demonstration projects have been put in place in various African countries.

Ghana, Photograph: S. Sackey

1.7 ENERGY CROPS FOR LIQUID BIOFUELS

Mauritius © Robert Mandel

The feedstock used for production of first generation liquid biofuels includes starch and sugar crops in the case of ethanol and oil crops in the case of biodiesel. The most common crops used for the production of liquid biofuels in Africa are sugarcane and molasses for ethanol, and oil palm, jatropha and to some degree soybean and sunflower for the production of straight vegetable oil and biodiesel. Advanced technologies also allow for production of ethanol and biodiesel from woody (lignocellulosic) biomass. Liquid biofuels can be used in the transport sector, pure or blended with fossil fuels, as well as in the industry, agriculture and residential sectors as engine, cooking or lighting fuels.

In many African countries there is a significant gap between the current and potentially attainable crop yields. Through sustainably improved productivity of agricultural production, sufficient crops would be produced to ensure food security while providing feedstock for production of liquid biofuels. Due to the lack of verifiable information and data on the current land use, agriculture production practices and foreseen food and feed needs, estimates for energy crops potential for the whole continent are highly uncertain, ranging from 0 PJ yearly to 13.9 EJ/yr, depending on assumptions (IRENA, 2014b). Southern and East Africa show the most promise for ethanol production, and Southern Africa has by far the greatest potential for plant oil crops.

IRENA estimates that the energy content of that potentially available for conversion into liquid biofuel by 2030 at about 4.8 EJ/yr. 3.6 EJ of this potential corresponds to crop for ethanol production. 65% of ethanol potential is found in Southern Africa and 20% is in East Africa, followed by Central Africa. West and North Africa contribute a negligible amount (IRENA, 2014b). Oil palm, the fruits of which are important feedstock for biodiesel, is produced widely in plantations in West and Central Africa and particularly in Nigeria, Ghana and Benin. For biodiesel, 41% of potential is found in Southern Africa and 22% each in Central and Eastern Africa, while West Africa accounts for 15% of the potential.

The total installed costs for biodiesel plants are generally lower than those associated with ethanol production. A study of North African and Middle East countries found the installed costs to be USD 0.25/litre/year of production capacity (IRENA, 2013b).

Uganda, Pecold, © shutterstock

TRANSPORT

The total demand for liquid fuels in the African road-transport sector today is around 108 billion litres. Half of this is gasoline and the other half is diesel (IEA, 2015). Theoretical supply potential of ethanol and biodiesel for the whole continent exceeds this demand.

Ethanol has been used as a blending agent in gasoline at levels of between 5% and 15% in a number of Southern African countries in the past including Kenya, Malawi and Zimbabwe (Lerner, 2010). However, the practice has continued only in Malawi. Other African countries that have set national renewable-energy and/or liquid biofuels targets for their transport sectors include Benin, Burkina Faso, Cote d'Ivoire, The Gambia, Ghana, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo and Uganda (IRENA, 2015f).

Railway, maritime and river transport can be important consumers of liquid biofuels, not only biodiesel and ethanol but also straight vegetable oil and biogas. However, the role of renewables in the shipping industry is expected to remain limited in the near to medium term. A number of commercial airlines have used biofuels on selected flights since 2011, but the availability of biofuels in sufficient quantities has limited the application of this fuel.

COOKING APPLICATIONS

Ethanol and ethanol gels are emerging as cooking fuel options in Africa. In Mozambique, the first supply chain to distribute ethanol and efficient ethanol stoves is in place. About 1 million litres of gel fuel are produced in South Africa annually (BFAP, 2008).

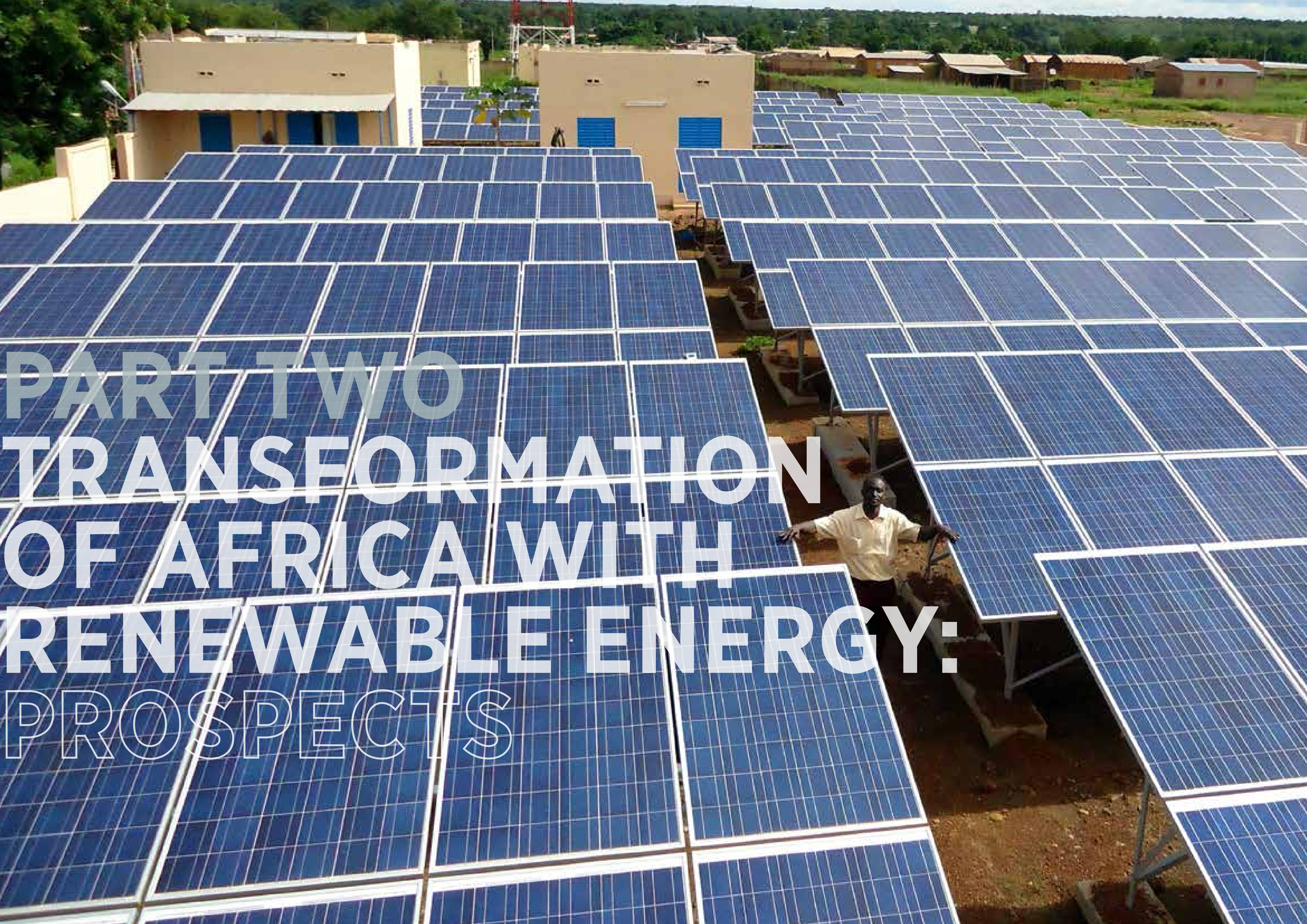
As a domestic fuel, ethanol gel has the advantages of safety over liquid ethanol and kerosene. Ethanol gel is manufactured by mixing ethanol with cellulose to produce a clean-burning fuel that does not spill. It is also denatured to prevent accidental ingestion. There are several ethanol gel stoves available, incorporating single or double burners and which accommodate custom pots. The level of heat can be controlled and the stoves operate silently.

Ethanol stoves can utilise ethanol with a water content as high as 50%. This solution, given its low concentration of ethanol, can be easily produced locally. The efficiency of such cookstove is mostly in the range of 55-65% (Lloyd and Visagie, 2007).

Cooking with ethanol is generally cheaper than cooking with ethanol gel. Ethanol has been found to be competitive against charcoal and wood in Ethiopia, Malawi, Mozambique, Senegal and South Africa in 2004, while ethanol gel was approximately three times the price of ethanol/water blends.

Pilot study in Ethiopia to test the feasibility of ethanol fuel and the clean cookstoves as a household energy source
Photograph: www.projectgaia.com

PART TWO TRANSFORMATION OF AFRICA WITH RENEWABLE ENERGY: PROSPECTS



Energy is at the core of two very important issues in Africa: ensuring a steady, reliable and sustainable supply for all people in all settings, and facilitating and extending the economic growth that has created opportunities and raised hopes across the continent in the past decade. To address these issues, African countries will have to harness their own vast energy resources. For this, modern renewable technologies have an important role to play. Renewable technologies promote more inclusive economic and social development than fossil fuel-based options, because they are suitable small-scale solutions that can run independently from central control.

Global renewable energy solutions are available and economical. Solutions which are specific to Africa's energy challenges are also emerging. These solutions will allow Africa to leapfrog to achieve minimum cost, environmentally friendly energy sector development, which ultimately contributes to sustainable development goals.

Part 2 presents an analysis of REmap Options for the African continent. It is built on a country-by-country assessment of energy supply, demand, renewable-energy potential and technological considerations, and highlights the potential for renewables technology to transform the energy mix across Africa's five regions by 2030. REmap Options include a wide range of modern renewable technologies that could play a larger role in meeting as much as 22% of energy needs by 2030. In absolute terms, this would be a thirteen-fold increase in modern renewables usage from 2013.[3] The analysis further explains benefits renewables could provide in specific areas, such as industry, lifestyle and the environment.

3) Throughout the report, 2013 – the latest year that most energy statistics are available – was used as a base year of the analysis.

Photo: 4 MW Hybrid Solar PV diesel mini-grid project for 30 rural villages (selected for funding in the IRENA/ADFD Project Facility), Mali
Photograph: Agence Malienne pour le Développement de l'Energie Domestique et de l'Electrification rurale (AMADER), Mali

- Africa 2030, part of IRENA's global REmap 2030 analysis, identifies modern renewable technology options spanning different sectors and countries. Collectively, these "REmap Options" could supply 22% of Africa's total final energy consumption by 2030, compared to 5% in 2013.
- Key modern renewable energy technologies across Africa include modern biomass solutions for cooking, along with hydroelectricity and wind power. Solar installations can also play a critical role in providing electricity access for remote off-grid locations and for grid connected applications.
- Half of all energy use in Africa today involves traditional biomass consumption, which entails health risks due to smoke inhalation and social disparities in wood collection. Modernising biomass is not only beneficial for the economy. It will also improve human health, create social benefits and reduce environmental damage.
- The population relying on traditional cookstoves could decline by more than 60% between now and 2030 with the shift to modern cooking solutions. This transition can save USD 20 billion – USD 30 billion annually by 2030 due to health benefits resulting from indoor air quality improvements.
- Electricity demand in Africa is projected to triple by 2030, offering huge potential for renewable energy deployment. The power sector requires investments of USD 70 billion per year on average between now and 2030. This can be split into about USD 45 billion per year for generation capacity and USD 25 billion for transmission and distribution. Renewables could account for two thirds of the total investments in generation capacity, or up to USD 32 billion per year. Realising this opportunity will create significant business activity in Africa.
- In the power sector, the share of renewables could grow to 50% by 2030. This would result in around 310 Mt CO_2 emissions reduction compared to the Baseline scenario in 2030. Hydropower and wind capacity could reach 100 GW each, followed by a solar capacity of about 70 GW.

2.1 REMAP 2030 FOR AFRICA

REmap 2030's Africa analysis found tremendous potential to diversify energy sources and meet growing demand using modern renewable technologies. The analysis considered individual countries' demand profiles, resource endowments, and potential. Conclusions are specific to the continent as well as its five regions. REmap analysis found that renewable energy accounted for nearly 13 EJ of Africa's TFEC of 23 EJ in 2013, but of that total just 1.1 EJ came from modern types of renewables (Figure 6). The vast majority was firewood and charcoal used in traditional cookstoves and in industrial devices (See Box 1 for how this report defines modern and traditional use). Of the modern renewable sources in use in 2013, more than half came from modern biomass for cooking. Renewable electricity generation accounted for over 30%, mostly from hydropower.

Though opportunities to adopt modern renewables are spread unevenly across the continent, even countries with very small energy demand have a role to play in the transition to renewables. This analysis identifies modern renewable technology options that could be further deployed in Africa by 2030, referred to in this report as "REmap Options". If all are implemented by 2030 the use of modern renewable energy would jump from 1.1 EJ to about 9.6 EJ. This is equivalent to 22% of TFEC by 2030, up from 5% in 2013. This is a significant contrast with the development in the share of all renewables (including both modern and traditional renewables) in TFEC; it decreases from 56% to 31%.

REmap Options for 2030 are summarised for the continent in Table 3, together with the estimated modern renewable energy technologies deployment in 2013. More detailed regional summaries are in the annex. Detailed discussion is found in the subsequent sections of this report.

With modernising economies and rising standards of living in Africa in the next 15 years, electricity demand is expected to grow more than threefold. Meeting demand will require a wave of new capacity, and planning at this point is an opportunity to help Africa build a more resilient, green and sustainable power sector in the process. Almost half of all modern renewable energy use could come from the power sector. The fuel mix for power generation varies by region and type. Hydro generated 14% of the total electricity supply for Africa in 2013, and was the predominant source of generation in the central and eastern regions. While it will continue to be an important and growing resource, the steady rise in demand is a chance for other renewable energy resources to play a larger role, and contribute to diversification of the source for power generation. Under the Remap Options, wind, solar PV and CSP would gain significant shares and their total potential would exceed hydro by 2030. If all the identified REmap Options for power generation would be realised by 2030, they would make up half of total electricity generation including 20% for hydropower.

Table 3 **Renewable energy use in 2013 and REmap Options for 2030***

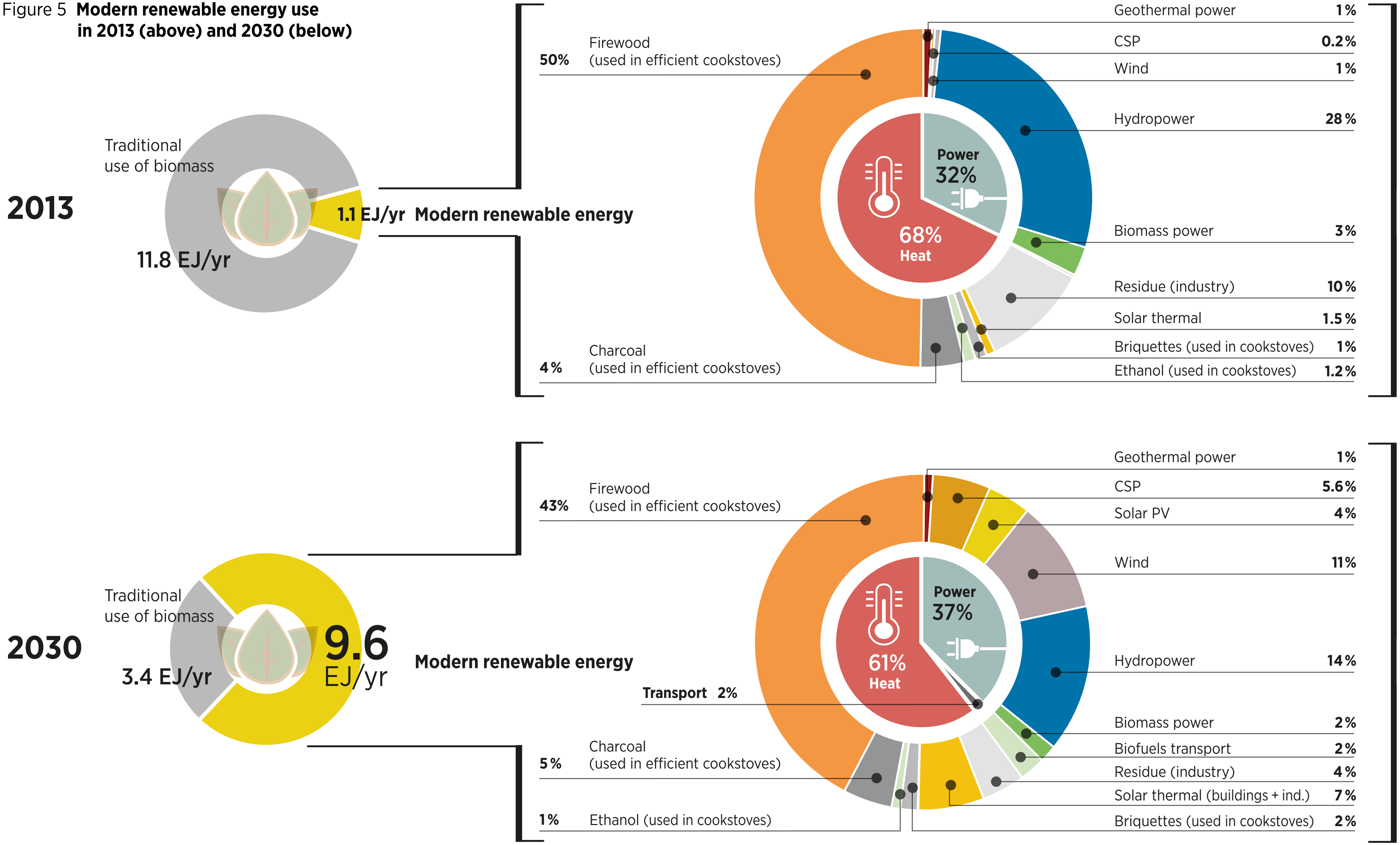
	2013 (in PJ/yr)	2030 (in PJ/yr)	2030 *(in physical units)*
INDUSTRY SECTOR			
Firewood for boiler	721	608	*220 000 average systems*
Solar thermal	3	244	*90 million m² area*
Biodiesel	0	7	*200 million litres*
Bagasse CHP (heat for own use in sugar sector)	43	104	*4 600 MW_{th}*
Biogas digester (heat for own use in dairy sector)	1	4	*1 100 average systems*
Boiler with industrial residue (heat for own use in coffee, pulp and sawn wood sectors)	74	276	*20 000 average systems*
Industry residue based power	18	63	*17 TWh*
Other renewable energy fuelled power (on-grid/off-grid)	155	1 557	*430 TWh*
Share of renewables	29%	30%	
Share of modern renewables	**8%**	**23%**	
BUILDING SECTOR			
Firewood used in traditional cookstove	10 270	3 115	*50 million stoves*
Firewood used in efficient cookstove	571	3 851	*180 million stoves*
Charcoal used in traditional cookstove	846	330	*5 million stoves*
Charcoal used in efficient cookstove	47	408	*19 million stoves*
Briquettes used in cookstove	15	152	*3 million stoves*
Ethanol used in cookstove	13	82	*2 million stoves*
Solar water heating	7	326	*120 million m² area*
Biogas digester	0	0.1	*8 million households*
Renewable energy fuelled power (on-grid/off-grid)	199	1 701	*470 TWh*
Share of renewables	80%	54%	
Share of modern renewables	**5%**	**33%**	
TRANSPORT SECTOR			
Biodiesel	0	93	*2 800 million litres*
Ethanol	0	123	*5 800 million litres*
Share of modern renewables	**0%**	**2%**	
POWER TRANSFORMATION SECTOR (GENERATION IN TWh)			
Hydropower	97	402	*101 GW*
Solar PV	0	70	*31 GW*
CSP	1	160	*38 GW*
Wind	2	304	*101 GW*
Geothermal	2	21	*3 GW*
Distributed solar PV	0	46	*24 GW*
Biomass	5	37	*8 GW*
Biomass industrial residues (own production)	5	17	*4 GW*
Share of renewables except hydropower	2%	30%	
Share of all renewables	**17%**	**49%**	
TOTAL FINAL ENERGY CONSUMPTION			
Share of renewables	56%	32%	
Share of modern renewables	**5%**	**22%**	

** All the options (except for the power sector) are evaluated as fuel inputs equivalent at the TFEC level.*

Tanzania, Photograph: Francesco Fuso Nerini

Source: IRENA

Figure 5 **Modern renewable energy use in 2013 (above) and 2030 (below)**



Box 1 **Renewable energy analysis requires better biomass statistics**

IRENA's definition of renewable energy explicitly includes the notion of sustainability: "Renewable energy includes all forms of energy produced from renewable sources in a sustainable manner". The sustainability matters particularly for biomass sources, as some biomass is sustainably sourced while others are not. Current statistical practices, however, do not allow us to quantify what portion of biomass use is sustainable. As a practical convention, traditional uses of biomass – use of biomass in inefficient equipment – is associated with unsustainable biomass. A common example in Africa is the uncontrolled self-harvesting of biomass for domestic cooking.

Because it is difficult to assess how much biomass is used with traditional equipment, the practice used by the International Energy Agency (IEA) is to assume that all biomass used in households in the non-OECD countries counts as traditional use. All biomass use in industry is considered modern. The Global Tracking Framework (GTF), which measures progress towards the United Nations Sustainable Energy for All (SE4ALL) goals, follows this IEA practice, while noting the caveat that residential uses may not necessarily be unsustainable.

For this REmap Africa analysis, fuels used in the building sector in efficient cookstoves are considered modern, and therefore sustainable. In analysing the industrial sector, this analysis classified the use of all existing direct uses of firewood to be traditional. However, these approaches, by definition, cannot be precise – only with better biomass statistics could we come to a more precise understanding of the potential of biomass in transitioning to a sustainable energy system for Africa.

The building and industry sectors have particularly high potential for modern renewable-energy technology, supplanting traditional biomass for heating. Modern renewables would meet total energy demand of heating for these sectors by 35% and 23% respectively, increasing from 5% and 8% in 2013. Solar thermal in industry and buildings accounts for about 7% of all the REmap Options identified for 2030. Except in North Africa, both sectors utilise significant amounts of woodfuel, the majority of which is considered a traditional use of biomass. This transformation of traditional woodfuel use for industrial process heating and cooking in households to modern forms of renewable energy is significant. REmap Options include efficient cookstoves with various feedstock which are key drivers for the household sector. They could account for nearly three quarters of the total cookstove stock in Africa by 2030. The population relying on traditional cookstoves could decline by more than 60% in the same period. The increased adoption of modern cookstoves could save USD 20 to 30 billion annually through the reduction of health problems caused by poor indoor air quality by 2030.

Liquid biofuels from indigenous energy crops also have significant potential. REmap analysis suggests that total demand for liquid biofuels for the transport sector can increase from the currently negligible level to about 220 PJ (8.5 billion litres) in 2030. Although the growth is immense, it only represents 2% of the transport sector's total energy demand.

Côte d' Ivoire, Photograph: UNEP

2.2 RENEWABLE ENERGY TO FUEL INDUSTRIAL GROWTH

The African economy is growing at an unprecedented speed. Despite the global recession triggered by the 2008 financial crisis, growth has averaged 5% for over a decade, making Africa the fastest growing continent in the world (African Development Bank Group, 2014). *Africa Energy Outlook 2040*, developed as a part of Programme for Infrastructure Development in Africa (PIDA) (NEPAD, African Union and AfDB, 2011) forecasts the economic growth between 2015 and 2030 to be even higher, at 7% per year on average, with varying rates across five African regions. Renewable energy has the potential to transform Africa's industrial sector, supporting sustainable growth through the provision of reliable and affordable energy, as well as transforming the economic competitiveness of small and medium-sized enterprises.

South Africa, Martin Maritz, © shuttertsock

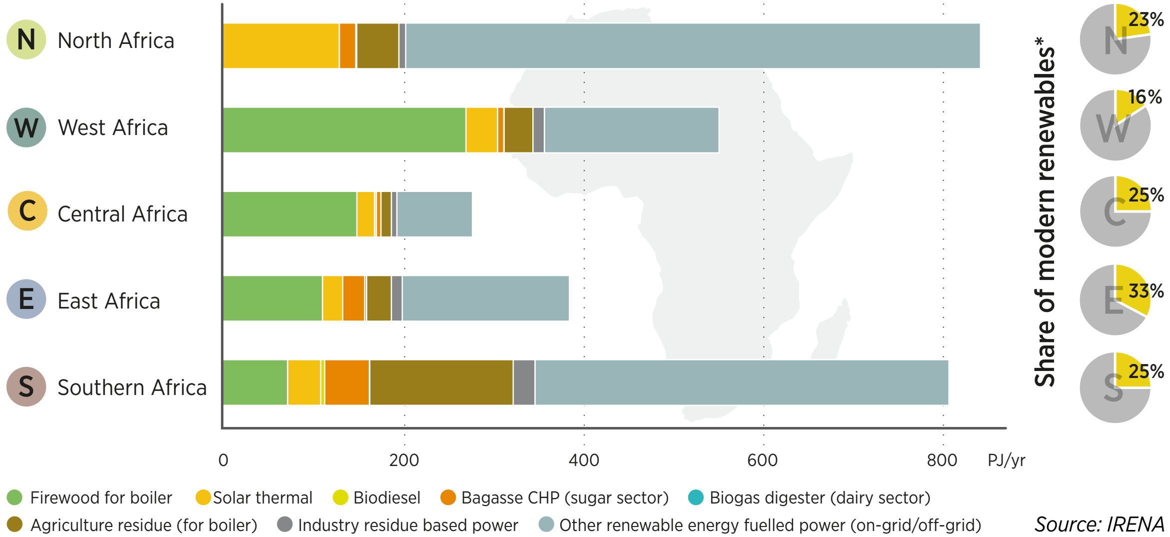
Reliable and affordable energy is an important factor for industries. However, unreliable power supply has been one of the obstacles in accelerating economic transformation. More than 30 African countries experience regular outages and load shedding, with opportunity costs amounting to as much as 2% of their GDP. Power shortages are substantial, pushing industrial plants to resort to expensive diesel generators as a secondary source. One in two plants in sub-Saharan Africa considers electricity supply a major constraint.

The mining industry, which has been an important driving factor for Africa's growth, accounted for 6% of the continent's electricity demand in 2013. In smaller countries, individual mining projects may dwarf most local countries' electricity demand from all other sources. In West Africa, the Western African Power Pool's Master Plan assessed electricity demand for mining projects in Guinea, Guinea-Bissau and Sierra Leone at three times the sum of all other demand in the three countries. Many mining companies are still opting to supply their own electricity with diesel generators because of unreliable energy supply from national power grids. Mining represents more than 20% of installed diesel generator capacity, making the sector the second-largest user after the power sector itself, which accounts for 36% (World Bank, 2015). One positive trend is that miners are increasingly adopting renewable power, and can be relied on to provide steady demand and justify investments for hydropower. The cost advantages of hydro over diesel generators are already established – on-site hydro is USD 0.04/kWh versus USD 0.29/kWh for on-site diesel – and more mining companies are looking to renewable technologies as a way to reduce fuel costs.

Currently industry in Africa, in comparison with other regions of the world, is more focused on activities that are not energy-intensive. These include wood and food processing and textiles production. Industries in Africa rely on a mix of fossil fuel and biomass. About 70% of thermal energy demand comes from coal, oil and natural gas, whereas 30% is a mixture of biomass and waste products. The biomass breakdown is not known in detail, but IRENA analysed a portion of residue use, notably from black liquor and bagasse. Only 8% is from modern biomass, either purchased or produced as a by-product of industrial processes. These by-products come from the processing of sugar, dairy products, coffee, tea, and wood. The residues can be used to generate on-site heat and electricity. By 2030, waste-generated process heat could meet about 120 PJ of energy needs in industry. The use of bagasse (waste from sugar cane processing) for process-heat generation is already a common practice. Co-generation of heat and electricity using these residues would offer on-site electricity supply potential of about 17 terawatt-hours (TWh), or 4 GW, for internal use or sale to others.

Overcoming lack of quantity and quality of power supply, and achieving a transformation of the economy would imply that industrial energy demand would triple from 3.5 EJ in 2013 to 9.6 EJ in 2030 despite significant efficiency improvement. Electricity demand would grow by 270%, surpassing the rate of total industrial energy demand growth. Through the development of its abundant renewable energy resources, Africa has the ability to attract new industries and build a truly green economy. REmap Options shows that 23% of the industry demand can be met by modern renewable energy technologies (Figure 6). The regional breakdown of renewable energy use and the shares for renewable energy in the final energy consumption are shown in Figure 7.

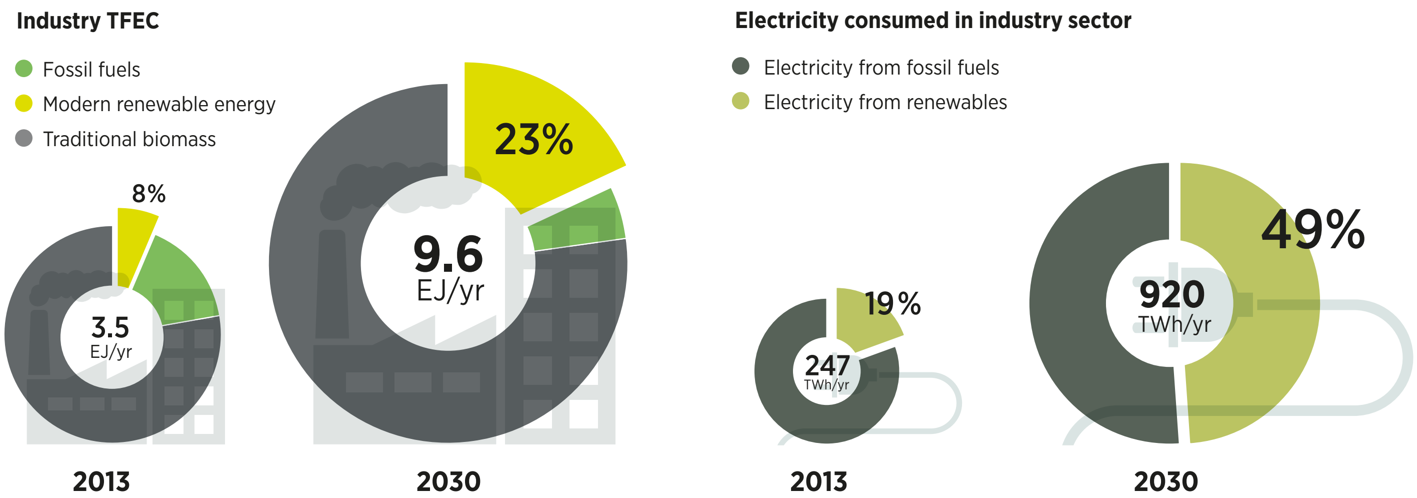
Figure 7 **Final renewable energy use in the industry sector in 2013 and the share of modern renewable energy use in each region**



** Note: Use of traditional firewood in the industry sector is not counted as modern renewable energy.*

Source: IRENA

Figure 6 **Total final energy consumption (left) and electricity demand (right) in the industry sector**



Source: IRENA

2.3 RENEWABLE ENERGY FOR POWER SECTOR TRANSFORMATION

Africa is scaling up its electricity supply to overcome supply shortages in the short term, and meet the demand to fuel economic growth. In the longer term, the aim is also to ensure modern energy access to the entire population. In doing so, Africa's power sector needs to diversify the sources of power to enhance the security of supply. Africa has sufficient fossil resources but if it continues relying on them, it will not allow a transition to a low-carbon power supply system. Hydro resources are also large, but excessive reliance on it also raises a supply security concern, because climate change increases the risk of droughts.

Electricity demand projections in various African regions highlight the magnitude of the task at hand. Demand is projected to increase by as much as fivefold in West and North Africa, and double in Southern Africa by 2030 (IRENA, 2015a) – the lowest growth-rate expectation among the continent's five regions. As of 2013, for the continent as a whole, there was 160 GW of installed power-generation capacity. Of that total, about 100 GW comes from ageing plants expected to be technically retired within the next 15 years. Demand projections suggest that installed generation capacity in Africa's power system should reach 610 GW in 2030. That means there is an opportunity now for comprehensive planning in order to find the optimal structures in countries as well as in regions. The 2030 figures include 318 GW seen as necessary in North Africa, 63 GW in West Africa, 25 GW in Central Africa, 55 GW in Eastern Africa, and 150 GW in Southern Africa, for the scenario with high economic growth and high demand for electricity. Meeting this demand will require an annual average of USD 45 billion in investment until 2030. An additional USD 25 billion in transmission and distribution lines would be required annually.

Currently the pipeline of power-generation projects in Africa is expected to bring 81 GW in new capacity. Of that total more than a third will use renewable energy, mostly hydro. Almost two thirds of those planned projects are in the East and Southern regions. (Platts McGraw Hill Financial, 2015). A separate source reports 11 GW of solar PV, 6 GW of CSP, and 18 GW of wind projects have been either announced or are in the pipeline (GlobalData, 2015).

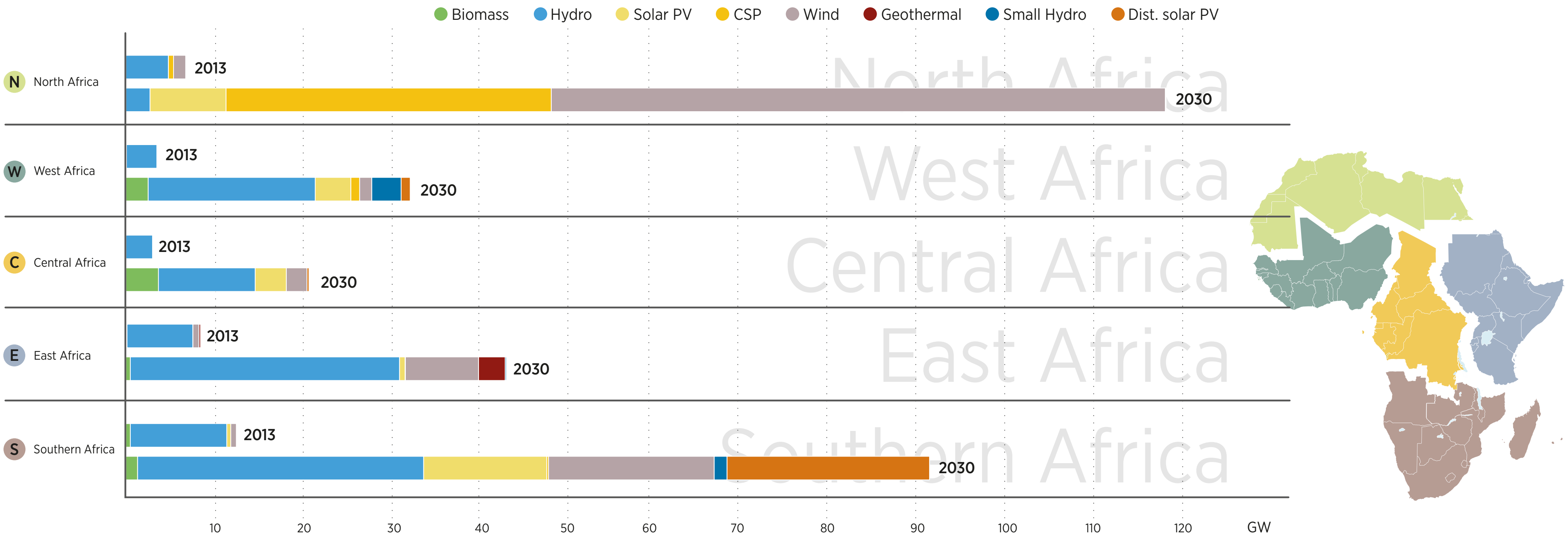
Of total investment needs to supply 610 GW by 2030, REmap Options would account for 310 GW. Renewable power generation would surpass 1000 TWh and comprise about half of total generation, an increase from 17% as of 2013. Figure 8 provides an overview of generation capacity developments in the five regions from 2013 to 2030. Of 310 GW, hydro represents 101 GW, 63 GW of which is in the East Africa and Southern Africa

left: Kenya, © John Wollwerth
right: © Protasov AN

regions. Large-scale deployment of wind resources, reaching 100 GW of capacity by 2030, could further help diversify systems that are reliant on fossil fuels. The highest potential for wind is in North Africa, at 70 GW. CSP would add additional capacity of 38 GW, almost exclusively in North Africa, while 30 GW of solar PV would be deployed across all regions except East Africa where hydro and wind power are the most-cost effective solutions. About 33 GW of all REmap Options are decentralised solutions, mostly solar rooftop PV in Southern Africa.

Full deployment of the REmap Options described above would open up potential investment opportunities in the renewable energy market of up to USD 32 billion per year. Cumulative investment needs between 2015 and 2030 in the entire power sector, including both renewables and non-renewables, is presented in Table 4 for each region. Investment costs for renewable energy technologies tend to be higher than for non-renewables. These up-front costs, including additional transmission costs, would be compensated fully by savings over the life of the projects because there is no

Figure 8 **Capacity development of REmap Options in 2030**



Source: IRENA

need to use fossil-fuel products on a regular basis to run the plants. For energy importers, this cuts the import bill. For energy exporters, it creates earnings opportunities from export revenue.

Regional electricity exports from hydro projects are common and can be envisaged for other renewables-based generation facilities as well. A large-scale renewable deployment offers economic and technical advantages in regional power-sector development. For example, IRENA's detailed analysis of the Southern African power pool market indicated that electricity exports from the Grand Inga project in the Democratic Republic of the Congo could reduce average regional power generation costs in the Southern African Power Pool (SAPP) by nearly 10% in 2030, and save an estimated USD 2 billion in annual costs of power system operation and development (IRENA, 2013c).

Lesotho, Daleen Loest, © shutterstock

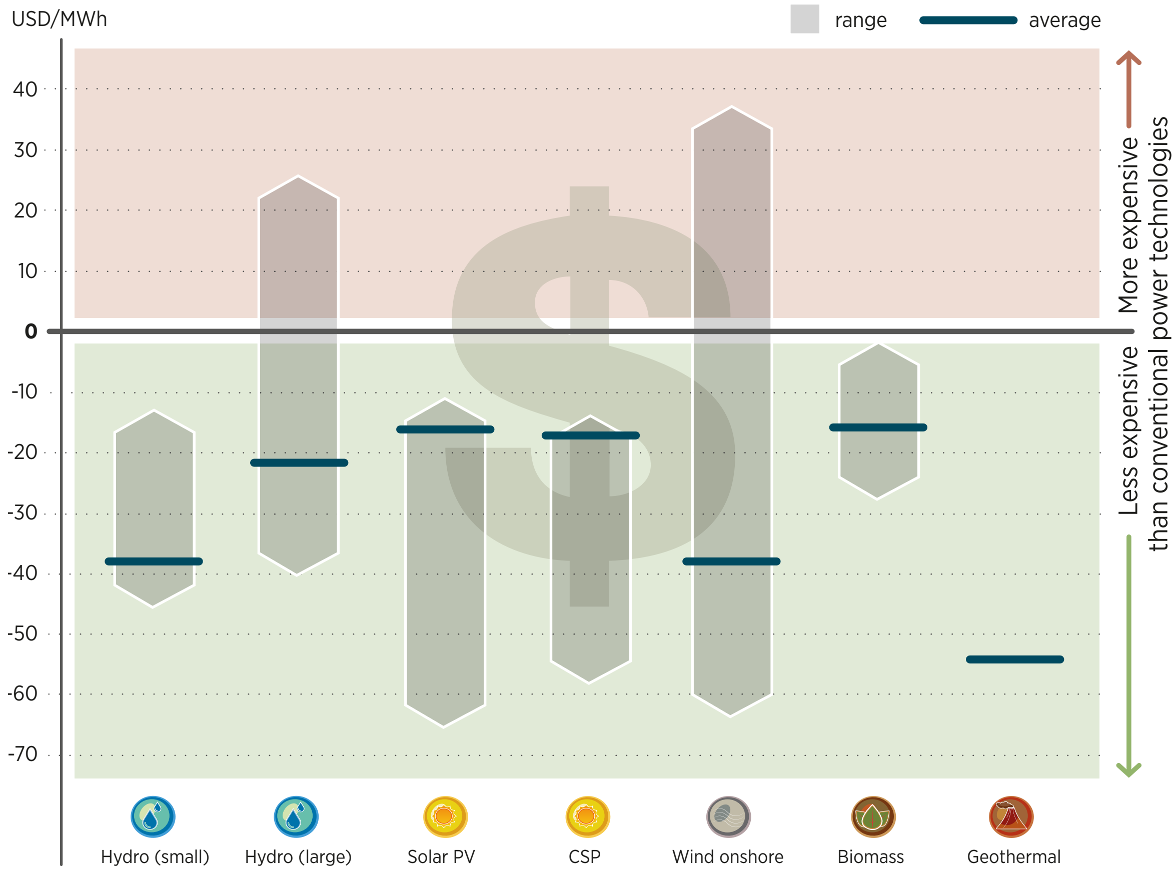
Table 4 **Cumulative investment needs between 2015 and 2030**

Region	**Investment billion USD** (2015 – 2030)			
	All generation	**Large hydro**	**Other renewables**	**T&D**
N North Africa	342	2	218	186
W West Africa	89	36	31	52
C Central Africa	32	13	17	14
E East Africa	72	36	21	49
S Southern Africa	145	18	94	74
Total	**681**	**106**	**381**	**375**

Figure 9 shows the range of "substitution costs" for REmap Options in the power sector. These costs are the differences in levelised costs of electricity to deliver a given amount of power if using a renewable REmap Option or if using a mix of fossil fuels and nuclear energy depending on the region. Negative substitution cost indicates a given REmap Option would deliver an equal amount of power at a lower cost than the fossil fuel-based equivalent in that region. The overall average with all the REmap Options implemented was a savings of approximately USD 3 cents per kWh.

Implementing these REmap Options would reduce the carbon intensity of Africa's power sector by two thirds by 2030. Although electricity supply would triple by 2030, carbon emissions would rise by only 20% – an increase from 550 Mt CO_2 in 2013 to 660 Mt CO_2 in 2030. In comparison, IRENA's analysis indicates that if REmap Options were not implemented, carbon emissions in 2030 would jump to 970 Mt CO_2.

Figure 9 **Average regional substitution cost of REmap Options in 2030**

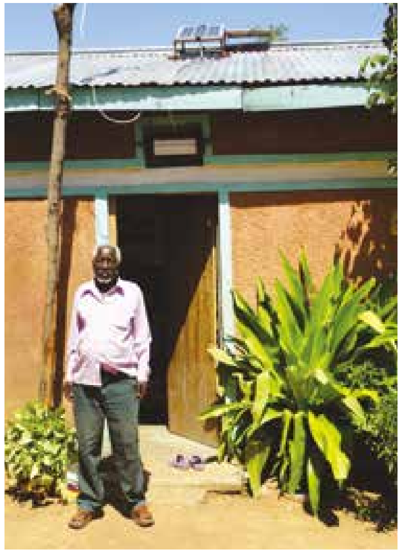


Source: IRENA

2.4 RENEWABLE ENERGY TO SUPPORT LIFESTYLE CHANGES

Africa's long-term development aspirations, as well as the economic growth achieved to date, are creating lifestyle changes and consumer purchases that result in more demand for energy. Household demand growth will come mainly in the electricity sector, to power household appliances such as lights, refrigerators, stoves, washing machines, and air conditioners, and also in the transport sector with increased owner-ship of cars and other vehicles. Changing lifestyle will not only increase the demand but also impact choice of fuel among the population. Modern renewable energy will provide a prominent alternative to support the African population, which is striving for better living standards, more comfort, and fewer health hazards and avoiding extreme inconveniences.

Perhaps more than any other option, the use of modern biomass in cooking and space heating instead of traditional biomass can accomplish this. Clean cookstoves and other modern alternatives to traditional biomass use reduces demand for energy because their efficiency in converting biomass to heat is two to three times higher. The uptake of modern cookstoves today is estimated at about 30 million units in Africa. Given that access to self-harvested firewood may become increasingly restricted due to deforestation and more stringent government regulation, implementing REmap Options in Africa would mean the uptake of 170 million more cookstoves. Even though some hard-to-reach populations would lag behind in adoption, modern cookstoves would become the primary tool for cooking across the continent by 2030. Total demand for firewood would decrease from 14.6 EJ to 9.6 EJ (including wood converted to charcoal) as a result in the same period. The availability



Tanzania, Photograph: GVEP International

Burkina Faso, Photograph: GIZ

of renewable alternatives to firewood largely depends on the resource endowment of the country.

With REmap Options in place, the large increase in energy needs would not translate to a major boost in demand. This is because efficiency gains will mean more energy being extracted from the existing supply. IRENA's analysis suggests that energy demand in the building sector (residential and commercial sectors) would expand from 14.8 EJ to 17.5 EJ (Figure 10). Within that total, which accounts for all types of energy, demand for electricity is expected to triple, from about 1.2 EJ to 3.6 EJ (340 TWh to 1000 TWh). Summaries of REmap Options for each region and their respective contributions to TFEC are provided in Figure 11.

Charcoal, an important cooking fuel for urban poor people, would remain important as urbanisation continues. Despite charcoal manufacturing and trade being illegal in many countries, it remains a popular product because it is convenient and is an income opportunity for many rural households. Briquettes from agro crop residues can be a modern renewable alternative to charcoal, providing equivalent convenience of use and income-earning opportunities. Despite urbanisation, charcoal demand would gradually decrease from about 890 PJ to 740 PJ by 2030, partly due to efficiency improvements from using modern cook-stoves, and partly because of the shift to briquettes from agro-crop residue. Demand for such briquettes for urban cooking would

Figure 10 **Share of modern renewable energy use in building and transport sectors**

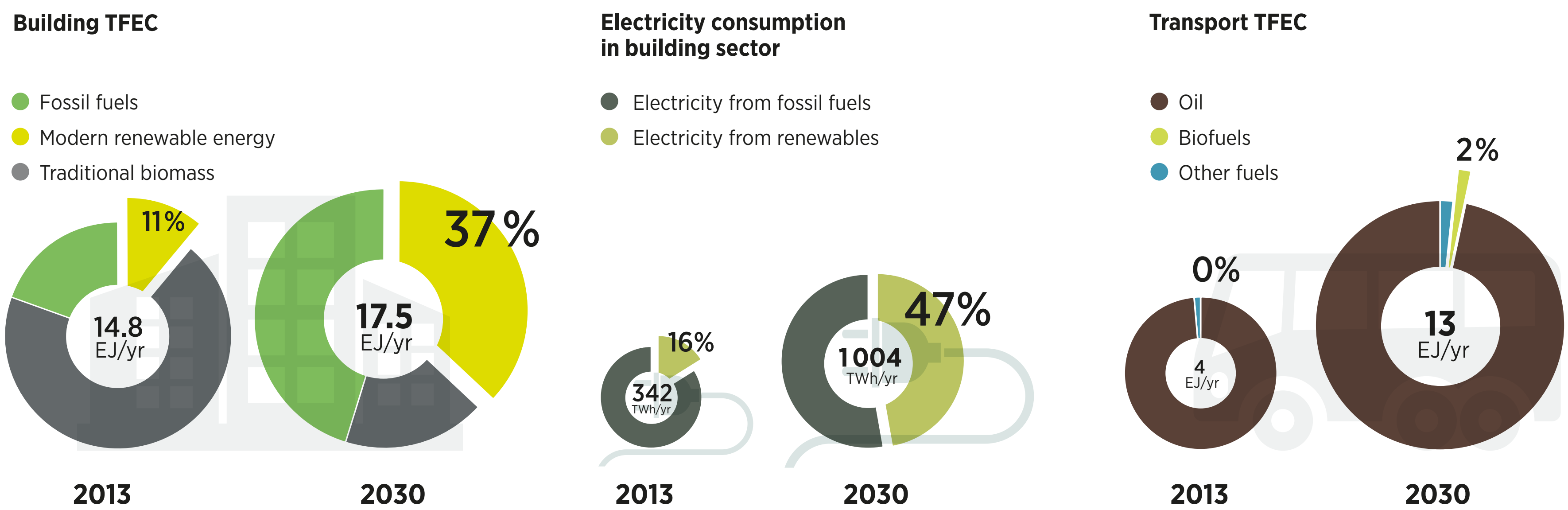
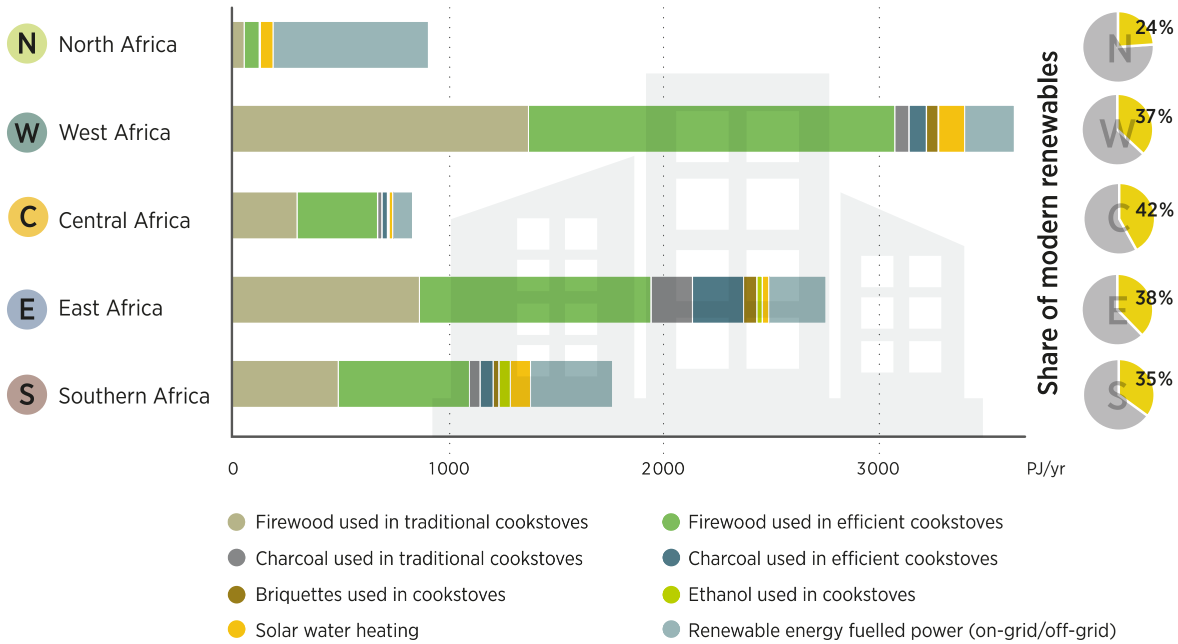


Figure 11 **REmap Options for the building sector by 2030, contribution to TFEC**



reach 150 PJ compared to an estimated 15 PJ for today's use. The potential is highest in East and West Africa.

Ethanol is a promising renewable fuel now deployed in some countries. It is used as fuel for cooking, either in its liquid form or as a gel. Ethanol gel offers a niche market to replace paraffin (kerosene). Ethanol and ethanol gel could meet about 80 PJ of cooking demand by 2030. Potential is highest in Southern and East Africa.

Until today, the use of modern water-heating appliances in Africa is limited, but demand for hot water is expected to grow. Solar water heaters offer a solution for the urban population, and could meet over 320 PJ of energy demand across Africa by 2030. This would represent 120 million m^2 in collector area, equivalent to 30 to 60 million households in Africa owning such systems.

Another important market in transition is transportation. Car ownership is expected to rise substantially, and demand for motor fuel could quadruple between 2013 and 2030. Several countries in Africa are starting to mandate the blending of liquid biofuels into petroleum-based fuels such as petrol (gasoline) and diesel. Regionally-produced ethanol and biodiesel would provide positive impacts in parts of Africa where the potential for sustainable local production of biofuel is high. If all REmap Options are implemented by 2030, ethanol and biodiesel demand for the transportation sector would grow to 2.8 billion and 5.8 billion litres respectively. Across the continent, biofuel use in the transportation sector would represent only 2% of the total, although regional usage rates could vary widely. Central Africa could have the highest share of biofuel (6%), and the Eastern and Southern regions would reach 4% and 3% respectively (see REmap Options table by region in the Annex).

2.5 RENEWABLE ENERGY FOR RURAL COMMUNITY DEVELOPMENT

Access to modern energy sources such as electricity is low in most rural areas of Africa. The use of small-scale renewables systems to meet demand may not make a major difference in the overall energy mix in Africa, but social benefits and new economic opportunities could be enormous.

The fact that renewable-energy technologies can be widely distributed is a source of autonomy for local areas and villages. They can increasingly plan for and meet their energy needs on their own, as localisation gives isolated communities a chance to participate in the process. They can serve as workers, and local businesses can play a role in supply and procurement, for example in engineering and construction of mini-grid and off-grid projects. These do not require connection to a centralised or national electricity transmission and distribution network, which is why they are a good fit for isolated communities far from existing transmission lines. Given that approximately 40% of Africans reside in rural areas, the continent has a great potential to benefit from inclusive approaches to energy development. Access to modern energy through off-grid solutions presents tremendous opportunities in the health, education, agriculture, water, and telecommunications sectors. In the latter, solar power is replacing grid or generator power for network towers. Stable access to such services provides a basis for income generating activities.

Today, rural electricity demand represents about 10% of the total electricity demand on the continent. Due to increased access to electricity enabled by a combination of grid extension and decentralised solutions, and off-set by urbanisation, the share may stay almost the same, while in absolute term it is expected to increase from 68 TWh to 180 TWh per year between 2013 and 2030.

IRENA's preliminary analysis for West Africa and Southern Africa shows significant potential for decentralised solutions for rural electrification (IRENA, 2013c; IRENA, 2013d). For West Africa, mini-hydro options could provide up to 70% of rural electricity. In Southern Africa, mini-hydro and solar rooftop systems using batteries would meet half of rural demand, with the rest coming from the grid.

Mini-grids can run purely on renewables, but battery storage is needed if variable renewables are used. Tremendous opportunities exist for hybrid systems that use both renewable and non-renewable sources. Such systems can be implemented as either greenfield investments or by retrofitting existing diesel-powered mini-grids to use renewables. There is also potential for cost savings: although the economics are site specific and rely on a diversity of project characteristics, on average decentralised renewable-energy solutions are competitive on costs when grid expansion investment needs are accounted for.

Beyond electricity, rural energy needs are met primarily using traditional biomass, or by the direct use of renewable energy, such as sunlight (for drying clothes and foods) and burning animal dung. For small communities, biogas digesters using animal and human manure could provide cooking solutions while also providing supplementary benefits to sewage treatment. By 2030, more than 8 million rural households could benefit from biogas digesters.

Photograph: Solar Sister

Malevic, © shutterstock

2.6 SPURRING TECHNOLOGY INNOVATION AND DIFFUSION: BIOMASS TRANSFORMATION

Renewable-energy solutions must be designed for local contexts, and that means technology innovations tailored to those varied settings. Biomass is particularly important in this context, as 80% of African population relies on it. The biomass-transformation sector – converting various indigenous sources of biomass into energy sources suited to end users – presents both a great need and an opportunity for entrepreneurs. Environmental benefits from modern renewable-energy solutions would also be significant. Efficient energy uses would lower demand for firewood, reducing the burden on forests. Combined with sustainable forestry management, the use of plantations could mean an opportunity to produce wood pellets for use in domestic power production or for export. REmap Options identified that wood pellets for electricity generation would amount to 8 GW of installed capacity in 2030 and would require about 10 million tonnes of feedstock. If the firewood saved from unsustainable foraging could be turned into wood pellets, it could also create an export market of more than USD 30 billion per year for Africa.

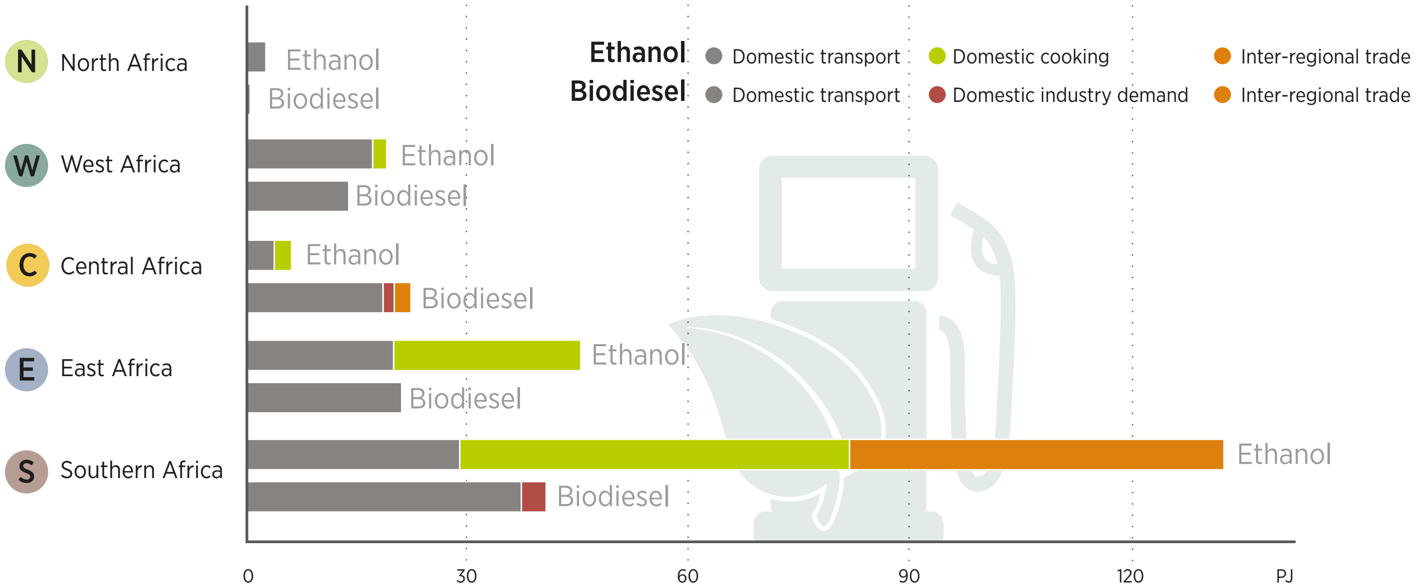
For both energy and food crops, the two most important factors impacting supply are land availability and agricultural yields. Fully realising the potential for energy crops in Africa will be challenging: productivity has been low in many cases, agricultural land is

Ethiopia, erichon, © shutterstock

Pellets compressed made from residue, © Hadrian fragmented and underdeveloped, and getting harvested crops to users would be a challenge in many settings. Overcoming these problems requires innovation and improved yields. REmap Options using liquid biofuels from energy crops account for yield potential as well as the deployment speed of ethanol and biodiesel production. REmap Options would create demand for locally produced ethanol and biodiesel of about 9.8 billion litres and 3 billion litres respectively by 2030, corresponding to the energy contents of 200 PJ and 100 PJ respectively. The total production potential for these fuels is assessed at 2 EJ and 1.3 EJ with further potential for growth beyond 2030.

Figure 12 shows how ethanol and biodiesel produced in each of Africa's regions would be distributed according to REmap Options. It is worth noting that a portion is presented as intra-regional trade. This refers to liquid biofuel traded within each region to meet primarily transportation demand in other countries, as some countries have enough potential to meet domestic need and have supply remaining for export. They include Cameroon, Central African Republic and Tanzania for biodiesel, and Zambia for ethanol.

Figure 12 **Ethanol and biodiesel use in 2030**



Mauritius, Photograph: Pack-Shot

PART THREE
WAY FORWARD TO ACHIEVING REMAP 2030 PROSPECTS IN AFRICA

Earlier parts of this report have described the current status of renewable energy deployment, as well as the potential and the costs and benefits of different renewable energy technology options for Africa by 2030. Implementing "REmap Options" depends on a sound policy framework to attract investments.

While this roadmap covers the entire continent, the necessary actions and policies would naturally differ from country to country, reflecting Africa's wide variety of economic profiles and development levels, energy resource endowments and needs, levels of energy access, and institutional, technical and human resource capacities. Such diversity influences the policy parameters of countries. While lucrative renewable electricity exports may be a key driver for fossil-fuel producers such as Algeria, developing local industries can be a major consideration for other countries, such as Morocco and South Africa. At the other end of the spectrum, countries grappling with energy poverty and depending on traditional biomass use to meet basic needs, mainly in Sub-Saharan Africa, also need to improve energy access to enable sustainable development and create better livelihoods. Broadly, however, most African countries seek to diversify their energy mix, enhance the security of supply and maximise socio-economic and environmental benefits.

Part 3 of this report considers how African policy makers can move forward to achieve the prospects outlined by the REmap 2030 and Africa 2030 roadmaps. Strategic planning for renewable energy deployment involves national-level targets, regional cooperation, and a variety of socio-economic objectives. The continent's policy landscape covers applications for the power system, heating and transport, along with initiatives to increase energy access. Sub-Saharan Africa accounts for 13% of the world's people, but only 4% of its energy demand. The region is home to more than 600 million people who lack access to electricity (IEA, 2014a). Appropriate policy choices and the right mix of mechanisms can create an enabling environment to accelerate the energy transition across the continent through renewable energy development.

Photo: South Africa, Alzbeta, © shutterstock

- African countries have demonstrated a commitment to renewables to expand power-generation capacity, increase rural electrification and alleviate poverty, as reflected in national energy plans and announced targets. Several countries have adopted renewable energy policies, mainly involving fiscal incentives, public investments, loans and grants. Regulatory policies, such as auctions and net metering, are increasingly being introduced, demonstrating the growing maturity of African markets.
- Scaling up renewables requires governments, policy makers and regulators to establish the frameworks to catalyse private investments. Deployment policies are most effective if accompanied by a broad range of cross-cutting policy instruments to maximise socio-economic benefits.
- Investment promotion measures are needed to attract both domestic and foreign investors. In parallel there is a need to raise awareness among local financial institutions about the grid-connected and off-grid renewable energy market. Public financing can be most effective if used to reduce risk perceptions. Public-private partnerships can also help to share investment costs and risks.
- Regional cooperation facilitates large-scale renewable energy deployment and helps create economies of scale. By working together, African countries can increase their renewable energy supply, manage shared natural resources more effectively and coordinate on cross-border trade, regulations, policies and infrastructure development.
- Off-grid renewable energy solutions are essential to improve access to modern energy services and contribute to poverty reduction, particularly in sub-Saharan Africa. The off-grid market needs dedicated policy and regulatory frameworks in order to incentivise the private sector, foster innovative business and financing models and create enabling conditions for deployment.
- While the shift to sustainable energy has been most visible in the power sector, opportunities in the heating and transport sectors should not be ignored. A complete transformation requires scaling up renewables for all types of energy use.

3.1 STRATEGIC PLANNING

As shown in Part 1 and 2, Africa's abundant renewable resources can be harnessed to meet rising energy demand, as well as to bring access to the nearly two thirds of the population now lacking modern energy services. To pursue sustainable development, renewables need to be further integrated into national and regional energy plans. This section provides a brief overview of country-level plans and targets, as well as regional initiatives.

NATIONAL ENERGY PLANS

As African countries move to develop their renewable energy potential, they are pursuing a range of policy instruments. These are mostly embedded in National Energy Plans (NEPs) that can include various targets for how much renewables should contribute to the energy mix. Most African nations have introduced NEPs to meet growing energy demand with affordable, sustainable energy services that enable socio-economic development.

African NEPs mostly promote renewables as part of efforts to increase power generation capacity, expand energy access and eradicate poverty (see Box 2).

In some countries, the NEP provides aspirational guidance for the development of the energy sector. For example in Ghana, the Energy Commission's 2006 Strategic National Energy Plan (SNEP) set out to enable the development of a sound market that would provide sufficient, viable and efficient energy services for economic development. The plan identified key renewable energy sources. Unfortunately, it was not formally adopted (IRENA, 2015l). Turning the NEP into a binding policy document is one of the challenges for the development of the sector in several countries.

Africa has witnessed rapid adoption of renewable energy targets over the past decade. To date, 41 countries (out of 54) have introduced at least one type of renewable energy target for specific technologies or for specific sectors as well as dedicated off-grid policies for rural electrification and sustainable cooking. Most targets are numerical, taking the form of non-binding, aspirational goals embedded in energy planning tools or at a broad policy level. Table 5 shows the most recent information on targets (IRENA, 2015f).

The implementation of national plans faces economic and political challenges. In addition, many African countries are land-locked and some are characterised by small energy sectors spanning large geographic areas with poor infrastructure (World Bank, n.d.). Regional cooperation helps to overcome many of these barriers as discussed in the next section.

Box 2 **National Energy Plans**

NEPs generally aim to achieve one or more of these objectives:

- *Develop a strategy for diversification of the energy mix, ensuring energy security by using all existing resources;*
- *Improve energy access by establishing rural electrification programmes, extending the national grid and improving the quality of electricity supply for the households that are connected;*
- *Develop human capacity throughout the energy delivery chain;*
- *Encourage energy efficiency and an energy-saving culture through effective incentives for utilities and clients;*
- *Develop an effective institutional framework for the power sector to attract private participation and investment.*

Table 5 **Renewable energy targets of African countries**

	Share of total energy	Share of electricity	Planned capacity	Target year	Notes
Algeria	40			2030	5% by 2017
Benin				2025	50% of rural electricity
Burundi	2.1			2020	4 MW biomass, 212 MW hydropower, 40 MW PV and 10 MW wind
Cabo Verde		50		2020	
Côte d' Ivoire	5, 15, 20			2015, 2020, 2030	
Djibouti	30			2017	(solar PV off-grid)
Egypt	14			2020	(hydropower: 2.8 GW by 2020; PV: 220 MW by 2020, 700 MW by 2027; CSP: 1.1 GW by 2020, 2.8 GW by 2027; wind: 7.2 GW by 2020)
Eritrea		50		n.d.	From wind power
Ethiopia			6 810 MW	2013	760 MW of wind, 5 600 MW of hydropower, and 450 MW of geothermal capacity addition
Gabon	80			2020	
Ghana		10		2020	
Guinea		8		2025	6% of PV and 2% of wind
Guinea-Bissau	2			2015	From solar PV
Kenya			5 000 MW geothermal	2030	Double installed renewable energy capacity by 2012 and 5 000 MW of geothermal capacity by 2030
Lesotho		35		2020	Share of rural electricity
Libya	10			2020	
Madagascar	54			2020	
Malawi	7			2020	
Mali	15			2020	
Mauritania	20			2020	15% by 2015 (excl. biomass)
Mauritius		35		2025	
Morocco		42		2020	20% by 2012
Mozambique			6 000 MW and others	na	6 000 MW of wind, solar and hydro capacity (2 000 MW each) and installation of 82 000 solar PV systems, 1 000 biodigesters, 3 000 wind pumping systems, 5 000 renewable-based productive systems and 100 000 solar heaters in rural areas
Namibia			40 MW	2011	Excluding hydro power
Niger	10			2020	
Nigeria		20		2030	18% by 2025
Rwanda		90		2012	
Senegal	15			2025	
Seychelles		15		2030	
South Africa		13		2020	
Swaziland				2014	20% of all public buildings installed with solar water heaters
Tunisia		25		2030	11% by 2016
Uganda		61		2017	
Zimbabwe		10		2015	10% share of biofuels in liquid fuels

African solar-powered school, © E+CO

Sources: IRENA (2015f) and REN21 (2015)

African Union's headquarters building in Addis Ababa, Nick Fox, © shutterstock.com

REGIONAL ENERGY PLANS

Devising regional plans for renewable energy deployment and applying regional cooperation and integration can help take advantage of efficiencies and economies of scale by increasing renewable energy supply capacity; managing shared natural resources; and adopting an integrated approach of trans-boundary issues such as trade, regulatory frameworks and policies, regional infrastructure and other cross border issues. The African Union/New Partnership for Africa's Development (AU/NEPAD) African Action Plan aims to facilitate policy development and co-ordination at continental and regional levels (IEA, 2014a). Successive ministerial declarations attest to a strong political commitment among African decision-makers, articulated through regional and national institutions and plans:

- In February 2009 in Addis Ababa, the AU heads of state and government resolved to develop renewable energy resources to provide clean, reliable, affordable and environmentally friendly energy.
- The 2010 Maputo Declaration reaffirmed this commitment, establishing the Conference of Energy Ministers of Africa (CEMA).
- In 2011, representatives of 46 African countries including 25 energy ministers adopted the Abu Dhabi Communiqué on Renewable Energy for Accelerating Africa's Development.
- In March 2014 in Abuja, the Conference of African Ministers of Finance, Planning and Economic Development adopted a resolution requesting for the mobilisation of financial and technical resources to promote renewables and committing to ensure transformative industrialisation in Africa through the development of a cutting-edge renewable energy sector.

Financing for investment opportunities in small and fragmented markets stands to gain from a regional approach. Large-scale hydropower projects have relied on cross-border cooperation in the African power sector. Mali, Mauritania and Senegal share the 200 MW Manantali hydropower plant on the Bafing River and a high voltage network of 1300 km transmission lines (African Development Bank Group, 2012). While the Grand Inga project in the Democratic Republic of Congo has the potential to generate 40 GW, far beyond the needs of the Economic Community of Central African States (ECCAS), its first phase (4.8 GW) was realised with South Africa's commitment to purchase a large share of power. Such an approach also benefits from efficiently functioning regional power pools for Central, Eastern, Southern and West Africa and their respective master plans.

To further promote interconnection, countries have agreed to continue strengthening the role of power pools in harmonizing regional market developments. This requires coordination on regional planning, harmonisation of standards and procedures, knowledge sharing and other technical and institutional matters. Standardised or model tariff methodologies and Power Purchase Agreements (PPAs), technical standards, licences and approval guidelines can minimise transaction costs and help speed up project development and financing (IRENA, 2015e).

IRENA also fosters regional collaboration. The Africa Clean Energy Corridor calls for coordinated planning to develop cost-effective renewable power solutions. Initially spanning the Eastern Africa Power Pool (EAPP) and SAPP region, the initiative is to be expanded to include West Africa. Another IRENA-led initiative, the Global Geothermal Alliance, promotes the development of geothermal capacity for power and direct heat (Global Geothermal Alliance, 2014).

While some national or regional targets remain merely aspirational or indicative, others have resulted in specific policies and measures to scale up renewable energy.

3.2 OVERVIEW OF THE POLICY LANDSCAPE AND FINANCING MECHANISMS

Countries have adopted a wide variety of policy mechanisms to promote renewable energy deployment. As Table 6 shows, the prevailing policies in Africa are fiscal incentives, including tax reductions, public investments, loans and grants. Tax reductions – the most widespread incentive – require no additional budget allocation, fewer administrative procedures and minimal regulatory supervision compared to other support policies. As power sectors and institutional frameworks mature, regulatory policies such as auctions and net metering are becoming more prevalent.

Various policies and financial mechanisms have proven effective in Africa to promote renewable power, heating and transport solutions, both with modern services and in areas lacking energy access.

SUPPORT FOR RENEWABLES IN THE POWER SECTOR

Several countries have adopted feed-in-tariffs (FiT). Algeria was among the early adopters in 2003, but its FiT was only implemented in 2014. The new tariff – for ground-mounted solar parks of more than 1 MW – will be valid for 20 years but will be paid only for a limited number of hours per year. Other countries with FiT schemes include Ghana and Kenya (Box 3).

Another early adopter was South Africa, with its Renewable Energy Feed-in Tariff (REFiT) programme in 2009. However, the country switched to an auction scheme in 2011, under the Renewable Energy Independent Power Producer Procurement (REIPPP) programme. The policy change aimed in part to reduce support costs, since auctions can be effective in bringing out real prices (IRENA, 2013f). Morocco and Egypt have also implemented

Box 3 **Feed-in-tariffs in Kenya**

In 2008, ***KENYA*** *started the implementation of a FiT system and mandated grid operators to guarantee priority purchase, transmission and distribution for producers of electricity from wind, biomass and hydropower. In 2010, these feed-in tariffs were revised to include geothermal, solar and biogas sources, to cut transaction costs, and to improve market stability for private investors. PPAs were extended to 20 years, from the initial 15. Solar tariffs came under scrutiny in 2014, with complaints that stipulated rates only yielded nominal returns for investors (Willis, 2014). The FiT for biogas appeared more successful, although rate negotiations continued. In August 2015, Africa's first biogas plant, TROPICAL Power Kenya, with 2.2 MW capacity, started feeding power into the national grid for USD 0.1/kWh (about a quarter of the cost of diesel-fired generation). The company sought an increase to USD 0.16/kWh, in order to develop more plants (Doya, 2015).*

Photograph: Tropical Power

Table 6 **Support policies that have been used in Africa**

	REGULATORY POLICIES							FISCAL INCENTIVES AND PUBLIC FINANCING				
	Feed-in-tariff (incl. premium payment)	Electric utility quota obligation/RPS	Net metering	Tradable renewable energy certificate	Auctions	Heat Obligation/ Mandate	Obligation/ Mandate	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO_2, VAT, or other taxes	Production payment	Public investment, loans, or grants
Algeria	●				●				●			
Angola							●					●
Botswana								●		●		
Libya										●		
Mauritius	●				●			●				
South Africa		●	●		●		●	●		●		●
Tunisia			●					●		●		●
Cameroon										●		
Cabo Verde			●		●					●	●	
Côte d'Ivoire										●		
Egypt			●		●			●		●		
Ghana	●	●		●		●	●	●		●		●
Lesotho			●		●							●
Morocco					●							●
Senegal		●				●				●		
Benin										●		
Burkina Faso					●				●	●	●	
Ethiopia							●			●		●
Gambia										●		
Guinea										●		
Kenya	●				●	●				●	●	●
Madagascar										●		
Malawi							●			●		
Mali							●			●		●
Mozambique							●					●
Niger										●		
Rwanda	●									●		●
Sudan							●					
Tanzania	●				*		●			●		
Togo										●		
Uganda	●							●		●		●
Zambia							●	●		●		
Zimbabwe							●					

Source: adapted from REN21 (2015)

*Note: *More recently, Tanzania also announced that it will be launching an auction (ESI Africa, 2015).*

successful auctions and record low prices resulted from Egypt's 2014 wind auction (IRENA, 2015f).

Although auctions tend to favour large players, they can be designed to encourage participation by small or new power producers. Under Uganda's GET FiT programme, for example, producers also receive premium payments based on a scoring system that uses a mix of non-price factors (Box 4). The portfolio now accounts for around 17 projects, with several of them on the verge of financial close and construction start (GET FiT Uganda, 2014). Auctions can also address development goals. In South Africa, for instance, the REIPPP programme created more than 20 000 solar jobs by explicitly including socio-economic impacts in the evaluation criteria for bids.

Box 4 **Non-Price Competition in Uganda's Small Power Producer Auctions**

In ***UGANDA's*** *auctions for biomass, hydro and bagasse power plants, developers compete on factors other than price: financial and economic performance (35 points), environmental and social performance (30 points) and technical and organisational performance (35 points). Participants receiving less than 70 points out of 100 overall, or less than half of the points in any of the three categories, are eliminated. Since premium payments are already established based on the LCOE for each technology, there is no price competition.*

Source: IRENA (2015f)

Although both tariff-based mechanisms are used increasingly in Africa's middle-income countries, they require substantial administrative and human resources, a robust regulatory system and clear lines of policy action. In low-income countries, tax reductions and other fiscal incentives remain the prevailing instruments. Some countries provide incentives in the form of exemptions from value-added tax (VAT) and import-duty to bring down upfront costs.

In Kenya and Tanzania, products for efficient solar lighting are VAT- and tariff-exempted. In Mauritius, fiscal incentives spurred the development of sugar-based co-generation (Box 5). The sugar industry currently contributes with over half of the electricity supply on the island using bagasse during the six months of cane harvesting season.

Box 5 **Mauritius Fiscal Incentives**

To reduce reliance on imported oil, the government cut taxes on co-generation and offered other fiscal incentives to encourage farmers to provide bagasse for electricity generation. The Bagasse Energy Development Programme was launched and the sugar export duty was abolished to incentivise production. Foreign exchange controls were removed a year later, accelerating the centralisation of the sugar cane industry. Other incentives offered include income tax exemption on revenue derived from the sale of power, and bagasse energy pricing (UNCTAD, 2012). Regulations promoting co-generation have also facilitated and encouraged producers to sell electricity to the grid under favourable tariffs and terms reflected in a transparent and long-term PPA.

Mauritius, Thomas Amler, © shutterstock

Namibia, Michael Wick, © shutterstock

In addition to deployment policies that support a stable enabling environment, mechanisms are needed to enhance access to affordable financing for the sector. Many African countries face the difficulties of weak financial systems, reflecting low domestic savings rates and tax revenues. This limits the available pool of domestic finance, deteriorates the country credit ratings and deters international investors (IEA, 2014a). Various investment promotion mechanisms would help to overcome existing financing barriers.

Such mechanisms will be vital to achieve the investment levels needed for REmap Options: overall investment in renewable power generation of USD 32 billion per year is needed in the period between 2015 and 2030 for the power sector alone. Recent investments in the African power sector have only amounted to about USD 10 billion per year, concentrated in few countries. In 2014, USD 5.5 billion were invested in South Africa, 1.3 billion in Kenya and USD 400 million in Algeria while Egypt, Nigeria and Tanzania attracted USD 200 million each. Mauritius and Burkina Faso reached USD 100 million each, with other countries receiving less than USD 100 million each (FS-UNEP, 2015). Most investment comes from Development Financial Institutions (DFIs), including multi- and bilateral development banks. DFIs, which offer the bulk of financing and a range of de-risking instruments, will continue to play an important role in supporting the African renewable energy sector. However, DFI financing remains underutilised due to a relative lack of experience with renewable energy projects among local financing institutions.

IRENA's Project Navigator and Sustainable Energy Marketplace tools and the Regulatory Empowerment Project (REP) can help facilitate the scaling-up of renewable energy investment. The first provides project developers with knowledge, tools, case studies and best practices (IRENA, 2015i); the second offers a virtual marketplace that brings together investors and project developers on a common platform to facilitate exchange of information; the Regulatory Empowerment Project provides targeted technical assistance to regulatory decision makers to help them overcome existing governance gaps to reduce investment risks.

IRENA also works with the Abu Dhabi Fund for Development (ADFD) to extend funding to innovative renewable energy projects in developing countries (IRENA, 2015j). The IRENA/ADFD Project Facility strives to improve energy access projects and has supported projects in Mali, Mauritania and Sierra Leone. By providing up to half of a project's needed funding, the facility reduces the investment challenges hindering efforts to extend electricity access across Africa.

SUPPORT FOR RENEWABLES FOR RURAL ELECTRIFICATION

Africa is home to the largest unelectrified population in the world, with about 600 million people lacking access, expected to reach 700 million by 2030 (UNEP, 2015). While ensuring access to reliable and sustainable modern energy services is central for development, there is a growing consensus that delivering these services requires a combination of decentralised and centralised approaches. Off-grid solutions, including mini-grids and stand-alone solutions, are necessary to complement centralised grid-extension efforts. Off-grid solutions, which can be deployed rapidly and customised to local needs, offer the only option for electrification in areas where grid extension is technically or financially unviable. Estimates suggest that nearly 60% of the additional generation required to achieve universal access to electricity in Africa will need to come from off-grid solutions (IEA, UNDP and UNIDO, 2010). With recent, rapid cost-reductions, renewable energy technologies now represent the most cost-effective option to expand electricity access in most rural areas.

Box 6 **Renewable energy-based mini-grid solutions to expand access to electricity**

Rapid deployment of mini-grids is helping to expand electricity access and stimulate socio-economic development in several countries in Africa:

- **MOROCCO** *has focused on the village-scale mini-grids, with 3 663 villages electrified with solar power, benefiting nearly 52 000 households (IRENA, 2015e).*
- **SENEGAL**, *through its rural electrification agency, has installed 35 hybrid (solar PV, battery and diesel) mini-grid systems, with plans to install 41 more (World Bank, 2014b).*
- **MALI** *is pursuing a decentralised approach to rural electrification, allowing local energy companies and initiatives (communities, women associations, NGOs) to generate electricity. Around 400 mini-grid installations are in place with a strong economic case for renewables integration. Renewable energy technologies are also providing energy services for other end-uses such as water pumping (African Development Bank Group, 2015).*

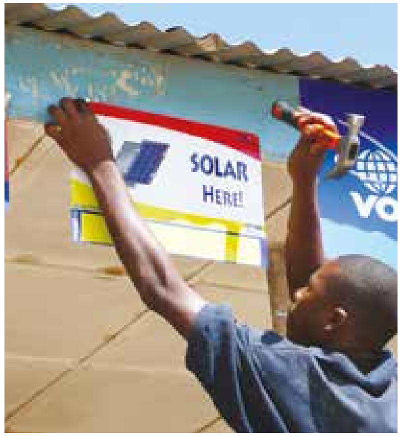
Similar developments in the mini-grid market are seen in Nigeria, Tanzania, Uganda and other African countries.

Off-grid renewables have gained significant traction in Africa, where more than 28.5 million people benefit from access to electricity through solar lighting products (Lighting Africa, 2015a). In Kenya, a leader in off-grid solar deployment, over 300 000 solar lighting systems have been deployed (TERI, 2015). Private enterprises, such as M-KOPA and d.light, now provide solar lighting to millions of people while creating local jobs and increasing savings for customers. Solar lighting represents a first step in the energy ladder. Mini-grids offer further opportunities to upgrade both the quality and quantity of energy supply. As countries introduce enabling frameworks and offer incentives, experience shows sustained growth in mini-grid development (Box 6).

While the adoption of off-grid renewables continues to expand, faster deployment is needed to make a dent in the continent's energy access challenge. The private sector will have an important role to play in this regard as they can deliver customised technology solutions to end-users in rural areas through innovative business and financing models. A dedicated policy and regulatory framework, among other aspects, for off-grid solutions would help to catalyse private-sector participation (IRENA, 2015k).

A wide array of policy and regulatory measures are being adopted across Africa to accelerate the adoption of off-grid solutions. Each country's choice of measures depends on the technology adopted (*e.g.* stand-alone systems or mini-grids), the type of energy service delivered (*e.g.* lighting, productive loads), ownership structures (*e.g.* private sector, PPPs, NGOs) and local socio-economic conditions. For example, some countries, such as Kenya and Tanzania, provide fiscal incentives in the form of exemptions from VAT and import-duty to bring down the upfront cost of stand-alone systems. In Rwanda, VAT exemptions are used as a tool to encourage the purchase of high-quality system components (UNEP, 2015).

While fiscal policies alone can prove effective for stand-alone lighting solutions, a broader array of policy and regulatory measures may be necessary for larger systems, such as mini-grids. These include, for example, legal provisions allowing private generators to service off-grid markets, access to concession schemes; and regulations that facilitate cost recovery (*e.g.* those relating to tariffs) and reduce risks associated with the arrival of the main grid. Tanzania, for example, has put in place a comprehensive policy and regulatory framework to support small power producers (Box 7).



Tanzania, Photograph: GVEP International

Niger, Photograph: IRENA/H. Lucas

Box 7 **Tanzania's policy and regulatory framework to support small power producers**

TANZANIA *has set out to expand electricity access using abundant renewable energy resources and promote the development of small power projects through local and foreign private investors. The government's policy allows small power producers to supply electricity from both grid-connected and off-grid systems. Producers with less than 1 MW generation capacity are exempted from obtaining a license. Moreover, the framework introduces a standard Power Purchase Agreement and Tariff Methodology applicable for the developer and the buyer. This is expected to reduce negotiation time and costs, thereby increasing the possibility of a scale-up in mini-grid development.*

Source: EUEI PDF (2014), EWURA (2015)

Beyond deployment-oriented policies, the broader ecosystem should also be considered. As one of the key outcomes from IRENA's International Off-grid Renewable Energy Conference (IOREC), policies need to ensure adequate capacities along different segments of the value chain; access to appropriate project financing; and sufficient quality and standards to avoid market spoilage (IRENA, 2015k).

Capacity building. Typically, renewable energy projects suffer from limited skill transfer after initial capacity installation, causing increasing maintenance problems later. Independent Power Producer (IPP)-based business models, with the private sector retaining ownership over systems and offering electricity as a service, help to address this challenge. Other models emphasise developing capacities within local enterprises or communities to take ownership, increasing system sustainability and maximising local value creation. IRENA is supporting a mentorship facility for entrepreneurs that will strengthen their innovative ideas and make them bankable as they scale up their renewable energy businesses in West Africa, particularly in solar PV (Box 8). To address the identified shortage of qualified solar PV installers and maintenance technicians in West Africa, IRENA has also designed a strategy to assist countries from the Economic Community of West African States (ECOWAS) region to implement a regionally harmonised and internationally accredited certification scheme for installers in partnership with ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Union économique et Monétaire Ouest-Africaine (UEMOA) Commission.

Box 8 **Incubation centres for energy enterprises: ECOWAS entrepreneur support facility**

Stemming from a two year capacity building program for strengthening local capacities of policymakers, financial institutions, trainers from educational or research institutions, and entrepreneurs to accelerate renewable energy and particularly solar PV systems' deployment in west Africa, IRENA and the ECREEE have established the ECOWAS Renewable Energy Entrepreneurship Support Facility in April 2015.

The Facility has been set up to provide advisory assistance to small and medium-sized renewable energy (particularly solar PV) entrepreneurs on matters related to business management and operations, project proposal refinement as well as supporting an entrepreneur to successfully bring his or her innovative ideas to fruition. The Facility is based at the International Institute for Water and Environmental Engineering (2iE) in Ouagadougou, Burkina Faso.

Since its inauguration, the Facility opened a call for applications whereby ECOWAS-based renewable energy entrepreneurs could submit their requests for assistance. These requests were analysed and training workshops are being conducted.

Access to finance. Central to the sustainability of any off-grid project is access to affordable capital at different stages of development. Since energy-access projects are distinct in their scale and risk-return profile, conventional approaches to financing may not be suitable. However, accumulated experience with off-grid renewable energy projects has resulted in successful business models and financing solutions that overcome some of the existing barriers. Concerted efforts to understand and tackle risk will help push the sector towards maturity and capitalise on growing financing commitments to the sector in Africa. For instance, instruments, such as loan guarantees and concessional financing, are being used to de-risk investments and leverage private capital. The Tanzania Energy Development and Access Project, created by the country's Rural Energy Agency, channels funds into subsidies, special collateral financing, preferential interest rates and technical assistance for off-grid projects. Rwanda's Private Sector Participation in Micro-hydro Power Supply for Rural Development (PSP Hydro) project has established an enabling policy framework to encourage private investments through standardised PPA agreements and feed-in tariff schemes (Box 9).

Standards and quality assurance. National efforts to establish stringent standards and quality assurance frameworks for off-grid technologies can substantially bolster market development. Building confidence within communities in system performance and reliability is essential for the widespread acceptance of off-grid solutions. The Lighting Africa initiative is a prime example of regional cooperation to implement quality-assurance frameworks, including minimum standards for off-grid lighting products that have been adopted by the International Electrotechnical Commission. More than 50% of the off-grid lighting market now consists of products that meet these standards, up from 3% in 2009 (Lighting Africa, 2015b).

Box 9 **Private participation in Rwandan hydropower development**

The PSP Hydro project aims to develop a private hydro power sector in ***RWANDA****. It supports the construction of micro hydropower plants and invests in capacity building activities. The Netherlands supports this project through the Energising Development Partnership. The support offered includes financing of 30–50% of investment costs, technical and business development assistance, project monitoring and financial controlling (Pigaht & Van der Plas, 2009). PSP Hydro support has resulted in the development of six private micro hydropower plants.* ***Murunda*** *(96 kW) has been operating since March 2010.* ***Mazimeru*** *(500 kW) and* ***Musarara*** *(438 kW) became operational early 2012, and three more projects are in preparation. A standard Power Purchase Agreement model with a feed-in tariff has been put in place, providing certainty for private power producers and increasing the bankability of projects. The processing time for environmental clearance and licenses has been cut from six months to two weeks.*

Rwanda, Photograph: REPRO Ltd.

In summary, off-grid renewable energy solutions offer a crucial opportunity to accelerate the pace of electrification in Africa. Affordable, reliable and environmentally sustainable energy sources can increase incomes in rural areas, open new economic opportunities and serve as a basis for broader rural development. But achieving this potential requires a different view of off-grid solutions – as a promising market rather than a mere stop-gap. Moving away from a project-by-project approach, energy-access initiatives will need to focus on creating markets, encouraging the participation of local enterprises, catalysing private capital into the sector and engaging in an integrated, cross-sectoral dialogue that considers all the different end-uses of energy including heating and cooling.

Morocco, Philip Lange, © shutterstock

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SUPPORT FOR RENEWABLES FOR HEATING/COOLING

In areas that lack access to modern energy services, some programmes promote the uptake of decentralised heating and cooling applications. These include, biogas digesters, solar dryers, improved cookstoves and solar thermal refrigerators. The introduction of such technologies has proven to bring numerous socio-economic benefits that can help alleviate poverty in those communities. Table 7 illustrates successful examples of such programmes in rural Africa.

For urban settings, successful policies and programmes have promoted **solar water heaters** in various countries. In Tunisia, the government worked with the United Nations Environment Programme (UNEP) to provide subsidies and concessional loans to facilitate the uptake of solar water heaters, whose high initial cost constituted a substantial market barrier when compared to less capital-intensive alternatives such as gas water heaters. With Programme Solaire (PROSOL), installed capacity rose from around 7 000 m^2 in 2004 to over 80 000 m^2 in 2010. At the end of 2010, the total installed collector surface area had reached around 490 000 m^2 compared to just 120 000 m^2 in 2004, creating a genuine market for over 50 suppliers, including seven manufacturers, and over 1 200 small installation businesses, of which over 400 are active (Lehr, *et al.*, 2012) (Box 10).

Table 7 **Programmes to support renewable energy technologies for heating in rural Africa**

Application	Country	Programme	Socio-economic impacts
Solar thermal refrigeration	Kenya	The ISAAC solar powered icemaker	• Produces up to 50 kg of ice per sunny day that is capable of chilling up to 100 litres of milk • Induced businesses for milk production, milk collection, packaging and sale for cooperatives, and the production of yogurt and mala that are sold at a higher price, generating additional profits
Improved cookstoves (ICS)	Kenya Uganda Tanzania	Developing Energy Enterprise Programme (DEEP) to support the deployment of ICS	• As of the end of June 2012, DEEP was supporting a total of 975 businesses across East Africa, 492 of which in the cookstove sector. Out of these, 257 are led by women. • Total revenue generated by ICS businesses in DEEP during January to June 2012 was USD 693 506. • As of June 2012, 1 305 people were employed in ICS businesses through DEEP (GVEP, 2012)
Solar dryers	Ghana	Solar dryer at Silwood Farms	• The dryer reduces moisture content in up to 600 kg of maize from approximately 20% to 10% within 6 days at 35° – 38°C. • Similar results can be achieved with other locally grown crops such as cassava, pepper, okra and pineapple.

Box 10 **Solar water heater programmes in Tunisia**

TUNISIA'S *PROSOL funding mechanism started in 2005. Its first phase,* ***supplier lending,*** *supported: a 20% subsidy on capital costs for solar water heaters; a temporary interest rate subsidy (gradually phased out after 18 months); and credit repayable over 5 years. Individual suppliers acted as indirect lenders and debt guarantors for consumers, while the Tunisian Electricity and Gas Company (STEG) collected loan repayments through utility bills.*

The second phase, ***consumers lending,*** *granted direct credit to households (via STEG) for solar water-heater installation, relieving suppliers from debt liability. The company serves as a guarantor of household repayment. Finally, bonuses of TND 200 – 400 replaced the 20% subsidy (Thabet, 2014).*

Box 11 **South Africa's solar water heater programme**

The National Energy Regulator of **SOUTH AFRICA** *allocated funds to develop the Solar Water Heating Rebate Programme which included marketing and funding the incentives for consumers. Eskom, has subsidised purchases of registered solar water heaters since 2008. By the end of 2011, more than 122 000 systems were rolled out, resulting in energy savings of approximately 60 GWh/yr (ESKOM, 2011).*

Another successful example is South Africa's Solar Water Heating Rebate Programme which led to the development of the solar water heating market and its expansion from a mere 20 suppliers in 1997 to more than 400 in 2011 (Box 11).

SUPPORT FOR RENEWABLES FOR TRANSPORT

Many African countries have the potential to expand their biofuel production, which could reduce demand for imported oil products. As shown in Table 6, mandates for blending biofuels are commonly adopted in Africa, especially in countries, such as Mozambique, with an abundance of agricultural products or waste (Box 12).

Other efforts to develop biofuels include cassava and palm oil in West Africa, as well as jatropha-based biodiesel, mostly in rural areas. Some concerns have been raised about potential risks of developing biofuels, including competition for land and water, food security and biodiversity threats, and soil erosion. Large-scale land acquisitions by foreign companies are increasingly contentious. The Economist reported in 2011 that over 40 000 hectares of land had been used in Africa, mainly for producing energy crops to export to Europe (The Economist, 2011). Blending mandates must be guided by globally accepted sustainability standards. With standards in place to minimise negative aspects, biofuel production offers significant opportunities for job creation in Africa. Currently, biofuel production accounts for 1.8 million jobs out of the 7.7 million globally in the renewable energy sector. In general, realising Africa's renewable energy potential could unleash a wide array of socio-economic benefits including job creation. A conducive policy mix could be instrumental in maximising these benefits.

Kim Howell, © shutterstock

Mozambique, Photograph: Svetlana Arapova

Box 12 **Mandates for biofuel blending in Mozambique**

Driven by the country's heavy reliance on imported fuel and in the absence of domestic capacity for refining petroleum, **MOZAMBIQUE** *began investigating the potential of biofuels about a decade ago. The government started encouraging farmers to grow energy crops to increase the country's energy security while promoting development and job creation in the agriculture sector.*

Mozambique's approach to implementing biofuels production includes strengthening the institutional framework through cross-sectorial cooperation between government ministries, the Investment Promotion Centre, NGOs, banks, universities and civil society; stimulating private sector involvement through public-private partnerships; and reinforcing cooperation with development partners.

Following resource mapping and zoning studies for sustainable biofuel production (land, water, climate etc.), the government received 17 biofuel-related proposals, including for ethanol and biodiesel projects. In addition, it has earmarked 3.5 million hectares of land for biofuels and more than USD 700 million to fund biofuel research, production and promotion.

In 2011, the government approved regulations for biofuels, blending sustainability criteria, and standards and specifications developed by the National Institute of Standards and Quality (INNOQ) (IRENA, 2012a).

SUPPORT POLICIES TO MAXIMISE RENEWABLE ENERGY BENEFITS

Policy-makers increasingly recognise the opportunities for income generation, local industrial development and job creation with renewables. Opportunities for value creation exist along the different segments of the renewable energy value chain, including project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning. Supporting processes, such as policy-making, financial services, education, research and development and consulting, offer further opportunities. Maximising the socio-economic benefits of renewable energy deployment calls for a combination of cross-cutting, tailor-made policies, in order to stimulate investment, promote education and

Box 13 **Renewables Readiness Assessment (RRA) and advisory services**

RRA is a country-driven process that helps IRENA to engage with relevant national or regional stakeholders in a dialogue to pin point renewable energy drivers, comparative advantages, enabling policies and measures. So far 12 RRAs have been facilitated in Africa namely in Djibouti, Ghana, Mauritania, Mozambique, Niger, Senegal, Swaziland, Tanzania, The Gambia, Tunisia, Zambia and Zimbabwe. The RRAs have triggered tangible changes in legislation (adoption of renewable energy laws, grid codes conducive for renewables, renewable energy IPP policies, FiTs, Integrated resource Planning, tax exemption for renewable energy equipment, etc.) and institutional set ups and have led to concrete regional advisory services and initiatives. Furthermore, to help advance post-RRA actions, targeted advisory services are offered for needs-based technical assistance, capacity building, best practice, experience and knowledge sharing.

training, support industrial development and encourage research and innovation. These policies can only be successful if they are stable over time, tailored to country-specific conditions and supported by stakeholders. Upon request, IRENA assists countries to develop effective enabling renewable energy policy and regulatory frameworks and assess the potentials and regulatory options through the Renewables Readiness Assessment (RRA) and advisory services (Box 13).

In the energy access context, value can be created from the deployment of renewable energy technologies as well as from the economic activities triggered from improved access to energy. Off-grid solutions, in particular, offer substantial opportunities for value creation in terms of both economic growth and employment. Many of the technical and commercial skills required to expand access through off-grid solutions, such as solar home systems and improved cookstoves can be developed locally, retaining value in rural areas. The *Lighting Africa* project estimates that accelerated uptake of solar lanterns alone can create more than 100 000 jobs in lantern manufacturing and distribution across the continent (UNEP, 2014). A growing body of evidence demonstrates that renewable energy solutions can contribute to the economic empowerment of marginalised social groups, along with the eradication of energy poverty and other socio-economic goals (Box 14). The potential for job creation and socio-economic development can be further enhanced when projects and initiatives are well integrated with productive uses of energy (IRENA, 2012b).

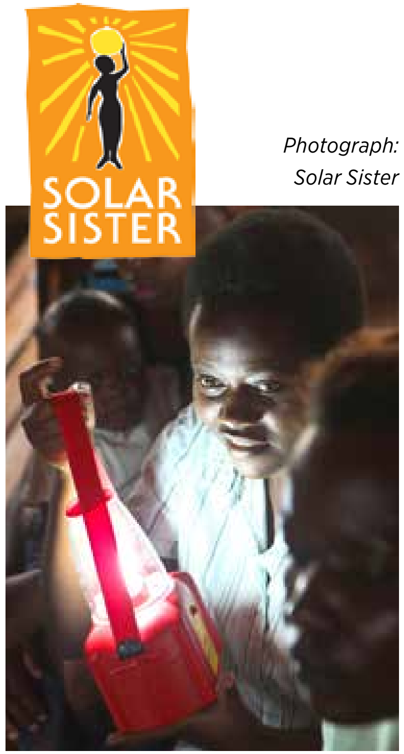
The opportunity at hand is immense. Tapping into renewable energy resources appears to be the only way Africa, as a continent, can fuel economic growth, maximise socio-economic development and enhance energy security with limited environmental impact. The technologies are available, reliable and increasingly cost-competitive. The onus is now on Africa's governments and other stakeholders to create the conditions to accelerate deployment, paving the way for Africa's unfettered, sustainable development. The next section puts forward key recommendations and areas for action to achieve this goal.

Box 14 **Solar Sister job creation initiative in sub-Saharan Africa**

SOLAR SISTER *is an initiative that retails portable solar lights in rural sub-Saharan Africa through female solar entrepreneurs. Starting with two entrepreneurs in 2010, the number reached 1 200 by 2015, mostly from Uganda, Tanzania and Nigeria.*

Solar Sister uses a system of micro-consignment: female entrepreneurs selling solar lights do not pay for their inventory until a sale is made and cash flow is available, and no interest is charged. This model addresses the specific needs of women, including their lack of access to start-up capital and low-threshold for risk, while allowing them to build sales out of their network of friends and families. When an entrepreneur sells her solar products, she earns a commission. The remainder of the money is re-invested in fresh inventory, enabling a sustainable business.

Establishing a single entrepreneur requires Solar Sister to invest USD 500, of which USD 200 covers the one-time cost of recruiting, training and sales support, and USD 300 is the inventory cost. Investment of USD 1 in a Solar Sister entrepreneur generates more than USD 46 of economic benefit in the first year, through income for the entrepreneurs, reinvestment and customers' avoided kerosene expenses.



Photograph: Solar Sister

Source: IRENA (2013f), Solar Sister (2015)

3.3 ACCELERATING THE ENERGY TRANSFORMATION IN AFRICA

Africa's abundant renewable energy resources can help accelerate economic growth while ensuring equitable access to modern energy services in an environmentally sustainable manner, as illustrated by the REmap Options presented in this report. The technologies needed for tapping into these resources are available, reliable and cost-competitive. Mobilising the necessary investments will require governments and other stakeholders to work towards an environment that is built on an enabling policy and regulatory framework. The main aspects policy-makers may consider include the following:

CREATING AN ENABLING POLICY AND REGULATORY FRAMEWORK that can catalyse investments into renewables and maximise socio-economic benefits:

- Establishing **national energy plans and renewable energy targets** translated into supportive policy and investment frameworks.
- Fostering **stable and long-term market development** while adapting to **changing technological and market conditions**.
- Implementing deployment policies as part of a broad range of cross-cutting policy instruments. **A policy mix tailored to specific country conditions** and the **level of maturity** of the sector, aimed at strengthening firm-level capabilities, building a domestic industry, promoting education and research and facilitating investment and technology transfer.
- Broadening the sources of financing to support expansion in capacity and transmission and distribution infrastructure through **regional cooperation.**
- Expanding **regional grid integration and power trade** through regional planning, harmonisation of standards and procedures, equitable commercial terms and coordination at power pool level.
- Encouraging renewable energy deployment in the **heating and transport sectors** through dedicated policies and initiatives.

ADOPTING INVESTMENT PROMOTION MEASURES to attract both domestic and foreign investors to support the development of the sector:

- Improving the **availability of local financing** by raising awareness of local commercial banks and financial intermediaries about renewable energy applications in both grid-connected and off-grid market segments.
- Using public financing to **reduce perceived risks**, in order to attract investments (either foreign direct investment, local or official development assistance).
- Establishing **Public Private Partnerships for cost and risk sharing** to attract private sector participation and financing.
- Reinforcing the liquidity of financial markets through **independent and transparent regulatory frameworks and reporting bodies.**

Promoting off-grid renewable energy solutions, which plays a fundamental role in **IMPROVING ACCESS TO MODERN ENERGY AND CONTRIBUTES TO POVERTY REDUCTION:**

- Introducing **dedicated policy and regulatory frameworks** that incentivise the private sector, foster innovation in business and financing models, and create enabling conditions for scale-up and replication.
- Shifting focus away from a project-by-project approach towards one that supports the **development of a sustainable market in the long-term.**
- Establishing an **institutional framework that enhances dialogue and coordination** between different stakeholders involved, in order to improve clarity and define roles and responsibilities for off-grid electrification initiatives.
- Adopting an **integrated approach to policy making** that leverages on the synergies with other sectors critical for socio-economic development.

1 MW Hybrid electrification project (Wind, Solar PV & Hydropower) will provide clean and reliable energy to 165 small rural villages (selected for funding in the IRENA/ADFD Project facility)

Photograph: National Agency for Development of Renewable Energy (ANADER), Mauritania

Table 8 **REmap 2030 Options for Africa**

	2013c (in PJ)						**2030** (in PJ)					
	North	**West**	**Central**	**East**	**Southern**	**Africa**	**North**	**West**	**Central**	**East**	**Southern**	**Africa**
INDUSTRY SECTOR												
Firewood for boiler	1	321	178	133	87	**721**	1	271	150	112	74	**608**
Solar thermal	2	0	0	0	0	**3**	130	35	20	23	37	**244**
Biodiesel	0	0	0	0	0	**0**	0	0	2	0	4	**7**
Bagasse CHP (heat for own use in sugar sector)	0	3	2	10	28	**43**	18	7	5	24	49	**104**
Biogas digester (heat for own use in dairy sector)	0	0	0	0	0	**1**	1	0	0	2	0	**4**
Boiler with industrial residue (heat for own use in coffee, pulp and sawn wood sectors)	4	2	0	4	64	**74**	47	32	12	28	159	**276**
Industry residue based power	0	2	1	4	11	**18**	8	13	6	12	24	**63**
Other renewable energy fuelled power (on-grid/off-grid)	26	10	26	24	69	**155**	636	193	84	185	458	**1 557**
Share of modern renewables	3%	60%	86%	63%	18%	**29%**	23%	32%	53%	46%	28%	**30%**
Share of modern renewables	3%	3%	12%	15%	12%	**8%**	23%	16%	25%	33%	25%	**23%**
BUILDING SECTOR												
Firewood used in traditional cookstove	187	4 562	1 003	2 884	1 636	**10 270**	57	1 384	304	875	496	**3 115**
Firewood used in efficient cookstove	10	253	56	160	91	**571**	70	1 710	376	1 081	613	**3 851**
Charcoal used in traditional cookstove	7	228	39	413	159	**846**	2	66	20	193	49	**330**
Charcoal used in efficient cookstove	0	13	2	23	9	**47**	2	81	25	239	61	**408**
Briquettes used in cookstove	0	6	1	5	3	**15**	1	55	6	62	27	**152**
Ethanol used in cookstove	1	2	1	4	6	**13**	0	2	2	25	53	**82**
Solar water heating	1	1	0	1	4	**7**	60	122	18	31	95	**326**
Biogas digester	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Renewable energy fuelled power (on-grid/off-grid)	62	28	20	48	41	**199**	725	232	93	267	384	**1 701**
Share of renewables	15%	94%	98%	96%	69%	**80%**	26%	63%	70%	66%	52%	**54%**
Share of modern renewables	4%	5%	7%	6%	5%	**5%**	24%	37%	42%	38%	35%	**35%**
TRANSPORT SECTOR												
Biodiesel	0	0	0	0	0	**0**	0	14	21	21	37	**93**
Ethanol	0	0	0	0	0	**0**	3	17	4	20	80	**123**
Share of modern renewables	0%	0%	0%	0%	0%	**0%**	0%	1%	6%	3%	4%	**2%**
POWER TRANSFORMATION SECTOR (generation in TWh)												
Hydropower	20	10	13	18	35	**97**	10	82	47	124	139	**402**
Solar PV	0	0	0	0	0	**0**	20	9	8	2	31	**70**
CSP	1	0	0	0	0	**1**	156	3	0	0	1	**160**
Wind	2	0	0	0	0	**2**	220	4	7	25	50	**304**
Geothermal	1	0	0	2	0	**2**	1	0	0	20	0	**21**
Distributed solar PV	0	0	0	0	0	**0**	0	2	0	0	44	**46**
Biomass	1	0	0	1	2	**5**	0	12	16	3	6	**37**
Biomass industrial residues (own production)	0	0	0	1	3	**5**	2	4	2	3	7	**17**
Share of renewables except hydropower	2%	2%	3%	14%	1%	**2%**	38%	15%	36%	28%	23%	**30%**
Share of all renewables	9%	24%	81%	75%	12%	**17%**	39%	52%	87%	92%	45%	**49%**
FINAL ENERGY CONSUMPTION												
Share of renewables	6%	82%	87%	86%	40%	**56%**	13%	42%	54%	52%	28%	**32%**
Share of modern renewables	2%	5%	7%	7%	6%	**5%**	12%	25%	32%	33%	22%	**22%**

BIBLIOGRAPHY

African Development Bank Group, 2012. *Unlocking North Africa's Potential through Regional Integration - Challenges and opportunities*, Tunis: African Development Bank Group.

African Development Bank Group, 2014. *Annual Development Effectiveness Review 2014 - Towards Africa's transformation*, Tunis: African Development Bank Group.

African Development Bank Group, 2015. *Renewable Energy in Africa: Mali country profile*, Abidjan,: African Development Bank Group.

BFAP (Bureau for Food and Agricultual Policy), 2008. *Impact analysis of the biofuels industrial strategy on the South African agricultural and biofuel subsector*, Pretoria: Bureau for Food and Agricultural Policy.

Doya, D. M., 2015. Africa's first grid-linked biogas plant starts running in Kenya; firm plans Ghana project too. [Online] Available at: http://m.mgafrica.com/article/2015-08-22-africas-first-grid-linked-biogas-plant-starts-running-in-kenya-firm-plans-ghana-project-too#.Vdllh_mqpBd

ERC (Energy Research Centre), 2012. *Residential Traditional Biomass Use in Africa*, Univesrity of Cape Town, Unpublished working paper prepared for IRENA

ESI Africa, 2015. Tanzania to initiate renewable energy auction. [Online] Available at: http://www.esi-africa.com/tanzania-to-initiate-renewable-energy-auction/

ESKOM, 2011. Solar Water Heating Rebate Programme. [Online] Available at: http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/The_Solar_Water_Heating_SWH_Programme.pdf

EUEI PDF (EU Energy Initiative Partnership Dialogue Facility), 2014. *Mini-grid Policy Toolkit - Policy and Business Frameworks for Successful Mini-grid Roll-outs*, Eschborn, Germany: European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF).

European Union, 2008. *ADIRA Handbook: A guide to autonomous desalination system concepts*. Euro-Mediterranean Regional Programme for Water Management (MEDA).

EWURA (Energy and Water Utilities Regulatory Authority), 2015. Development of Small Power Projects (SPP) In Tanzania. [Online] Available at: http://www.ewura.go.tz/newsite/index.php/sppmenu [Accessed 09 September 2015].

FAO (Food and Agriculture Organization of the United Nations), 2015. FAOSTAT - Food and Agriculture Organisation of the United Nations, Statistics Division: Crops. [Online] Available at: http://faostat3.fao.org/browse/Q/QC/E [Accessed June 2015].

FS-UNEP (Frankfurt School - UNEP Collaborating Centre for Climate & Sustainable Energy Finance), 2015. *Global Trends in Renewable Energy Investment 2015*. [Online] Available at: http://fs-unep-centre.org/publications/global-trends-renewable-energy-investment-2015 [Accessed September 2015].

Geothermal Energy Association, 2015. US-East Africa Geothermal Partnership (EAGP). [Online] Available at: http://www.geo-energy.org/EastAfrica/EAGP.aspx [Accessed September 2015].

GET FiT, 2014. Updated project status. [Online] Available at: http://www.getfit-reports.com/2014/projects/updated-project-status/ [Accessed September 2015].

Gifford, J., 2015. Mining smart management and storage. *PV magazine*, June, Issue 06, pp. 118-120.

Global Alliance for Clean Cookstoves, 2014a. Clean Cookstoves and Fuels: A Catalog of Carbon Offset Projects and Advisory Service Providers – 2015 (2nd edition). [Online] Available at: http://cleancookstoves.org/binary-data/RESOURCE/file/000/000/381-1.pdf

Global Alliance for Clean Cookstoves, 2014b. Cookstoves – The Issues. [Online] Available at: http://carbonfinanceforcookstoves.org/about-cookstoves/introduction/ [Accessed 1 September 2015].

Global Geothermal Alliance, 2014. Global Geothermal Alliance: Action Statement and Action Plan (Provisional Copy).

GlobalData, 2015. Power Generation Technologies Capacities, Generation and Markets Database, London: GlobalData.

GVEP (Global Village Energy Partnership), 2012. The Improved Cookstove Sector in East Africa: Experience from the Developing Energy Enterprise Programme (DEEP). [Online] Available at: http://www.gvepinternational.org/sites/default/files/deep_cookstoves_report_lq_for_web.pdf

GWEC (Global Wind Energy Council), 2014. *Market Forecast for 2015 – 2019.* [Online] Available at: http://www.gwec.net/global-figures/market-forecast-2012-2016/

Africa Biogas Partnership Programme, 2014. 10 000 biogas digesters in Kenya. [Online] Available at: http://africabiogas.org/blog/abpp-news/10000-biogas-digesters-in-kenya/ [Accessed 25 Jun 2015].

Africa Biogas Partnership Programme, 2015. Africa Biogas Partnership Programme. [Online] Available at: http://africabiogas.org

Hydropower and Dams, 2014. *Hydropower and Dams World Atlas*, Wallington: Aqua-Media International.

IEA (International Energy Agency), 2014a. *Africa Energy Outlook*, Paris: OECD/IEA.

IEA, 2014b. Project Summary Document: Durban Landfill-Gas to Electricity. [Online] Available at: http://www.iea.org/media/technologyplatform/workshops/southafricabioenergy2014/Sitevisit_Durban_LandillGas_to_Electricity_22_Nov.pdf [Accessed 27 May 2015].IEA, 2015. *Energy Statistics and Balances of Non-OECD countries*, Paris: OECD/IEA.

IEA Solar Heating and Cooling Programme, 2015. *Solar Heat Worldwide – Markets and Contribution to the Energy Supply 2013*, Gleisdorf: AEE – Institute for Susatainble Technologies.

IEA, UNDP (United Nations Development Programme), and UNIDO (United Nations Industrial Development Organisation), 2010. *Energy Poverty- How to make modern energy access universal?*, Paris: OECD/IEA.

IRENA (International Renewable Energy Agency), 2011a. *Scenarios and Strategies for Africa*, Working paper presentated at the IRENA-Africa high-level consultations held on 8 & 9 July 2011 in Abu Dhabi, Abu Dhabi: IRENA.

IRENA, 2011b. *Prospects for the African Power Sector, Scenarios and Strategies for Africa Project*, Abu Dhabi: IRENA.

IRENA, 2012a. *Mozambique Renewables Readiness Assessment*, Abu Dhabi: IRENA.

IRENA, 2012b. *Renewable Energy Jobs and Access*, Abu Dhabi: IRENA.

IRENA, 2013a. *Africa's Renewable Future, The Path to Sustainable Growth*, Abu Dhabi: IRENA.

IRENA, 2013b. *Road Transport: The Cost of Renewable Solutions*, Abu Dhabi: IRENA.

IRENA, 2013c. *Southern African Power Pool: Planning and Prospects for Renewable Energy*, Abu Dhabi: IRENA.

IRENA, 2013d. *West African Power Pool: Planning and Prospects for Renewable Energy*, Abu Dhabi: IRENA.

IRENA, 2013e. *Renewable Energy Auctions in Developing Countries*, Abu Dhabi: IRENA.

IRENA, 2013f. *Renewable Energy and Jobs*, Abu Dhabi: IRENA.

IRENA, 2014a. REmap 2030, *A Renewable Energy Roadmap*, Abu Dhabi: IRENA.

IRENA, 2014b. *Global Bioenergy Supply and Demand Projections: A working paper for REmap 2030*, Abu Dhabi: IRENA.

IRENA, 2015a. *Africa Power Sector: Planning and Prospects for Renewable Energy*, Abu Dhabi: IRENA.

IRENA, 2015b. *Renewable Energy Capacity Statistics 2015*, Abu Dhabi: IRENA.

IRENA, 2015c. IRENA Costs - Renewable Energy Costs, Technologies and Markets. [Online] Available at: http://costing.irena.org/ [Accessed September 2015].

IRENA, 2015d. *Renewable Power Generation Costs in 2014*, Abu Dhabi: IRENA.

IRENA, 2015e. *Off-Grid Renewable Energy Systems: Status and Methodological Issues*, Abu Dhabi: IRENA.

IRENA, 2015f. *Renewable Energy Target Setting*, Abu Dhabi: IRENA.

IRENA, 2015g. *Renewable Energy in the Water, Energy & Food Nexus*, Abu Dhabi: IRENA.

IRENA, 2015h. *Renewable Energy Auctions: A Guide to Design*, Abu Dhabi: IRENA.

IRENA, 2015i. IRENA Project Navigator. [Online] Available at: https://navigator.irena.org/Pages/default.aspx [Accessed 09 September 2015].

IRENA, 2015j. IRENA ADFD - Supporting Energy Transition. [Online] Available at: http://adfd.irena.org/ [Accessed 09 September 2015].

IRENA, 2015k. Accelerating Off-Grid Renewable Energy – IOREC 2014: Key findings and Recommendations. [Online] Available at: http://www.irena.org/Publications/ReportsPaper2014New.aspx?mnu=cat&PriMenuID=36&CatID=141&type=all [Accessed 09 September 2015].

IRENA, 2015l. Ghana Renewables Readiness Assessment, Abu Dhabi: IRENA.

IRENA, forthcoming. Solar PV Costs in Africa, Abu Dhabi: IRENA.

IRENA, unpublished. Renewable Energy for Productive Uses in Africa, Abu Dhabi: IRENA.

IRENA and IEA-ETSAP (Energy Technology Systems Analysis Program), 2015a. Solar Heating and Cooling for Residential Applications: Technology Brief, Abu Dhabi: IRENA.

IRENA and IEA-ETSAP, 2015b. Hydropower: Technology Brief, Abu Dhabi: IRENA.

Lehr, U., Mönnig , A., Missaoui, R. & Marrouki, S., 2012. *Renewable energy and energy efficiency in Tunisia – employment, qualification and economic effects*, Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. [Online] Available at: https://www.giz.de/fachexpertise/downloads/giz2012-en-employment-renewable-energy-tunisia.pdf

Lerner, A. M., 2010. SADC biofuels state of play study, Gaborone: SADC Secretariat Energy Division.

Lighting Africa, 2015a. Solar Lighting Products Improve Energy Access For 28.5 Million People In Africa. [Online] Available at: https://www.lightingafrica.org/solar-lighting-products-improve-energy-access-for-28-5-million-people-in-africa/ [Accessed 09 September 2015].

Lighting Africa, 2015b. Programme Results as of December 2014. [Online] Available at: http://www.lightingafrica.org/results/ [Accessed September 2015].

Lloyd, P. D. J. & Visagie , E. M., 2008. *A comparison of gelfuels with alternative cooking fuels*. Journal of Energy in Southern Africa, 18(3).

NEPAD, African Union, and AfDB, 2011. *Africa Energy Outlook 2040 – Study on Programme for Infrastructure Development in Africa* (PIDA)

Pigaht, M. & Van der Plas, R. J., 2009. Innovative private micro-hydro power development in Rwanda. *Energy Policy*, Volume 37, pp. 4753-4760.

Platts McGraw Hill Financial, 2015. World Electric Power Plants Database, June 2015. [Online] Available at: http://www.platts.com/products/world-electric-power-plants-database [Accessed 2015].

REN21 (Renewable Energy Policy Network for the 21st Century), 2015. *Renewables 2015 Global Status Report*. [Online] Available at: http://www.ren21.net/status-of-renewables/global-status-report/

Solar Sister, 2015. Solar Sister – Eradicating energy poverty through social enterprise. [Online] Available at: http://www.solarsister.org/impact

TERI (The Energy and Resources Institute), 2015. Solar PV for Enhancing Electricity Access in Kenya: What Policies are Required?. [Online] Available at: http://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/Policy_Brief_Solar_PV_for_enhancing_electricity_access_in_Kenya_July_2015.pdf [Accessed 09 September 2015].

Thabet, I., 2014. Business model for Solar Water Heaters development in the residential sector - Tunisian Experience. [Online] Available at: http://www.irena.org/documentdownloads/events/2014/march/12_Thabet.pdf

The Economist, 2011. When others are grabbing their land. The Economist, 5 May.

UNCTAD (United Nations Conference on Trade And Development), 2012. *Economic Development in Africa Report 2012 – Structural Transformation and Sustainable Development in Africa*, Geneva: United Nations.

UNEP (United Nations Environment Programme), 2014. *Light and Livelihood: A Bright Outlook for Employment in the Transition from Fuel-Based Lighting to Electrical Alternatives*, Geneva: UNEP.

UNEP, 2015. *Developing Effective Off-Grid Lighting Policy – Guidance note for governments in Africa*, Nairobi: United Nations Environment Programme.

UN-HABITAT (United Nations Human Settlements Programme), 1993. *Application of Biomass Energy Technologies*. Nairobi, Kenya: UN-HABITAT.

WHO (World Health Organization), 2015. *Global Health Observatory Data Repository*, Geneva: WHO.

Willis, B., 2014. Calls for Kenya to increase solar FiT or risk losing investment. [Online] Available at: http://www.pv-tech.org/news/calls_for_kenya_to_increase_solar_fit_or_risk_losing_investment

World Bank , n.d.. Regional Integration in Africa. [Online] Available at: http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/EXTREGINI/EXTAFRREGINICOO/0,,contentMDK:22548631~menuPK:7296233~pagePK:64168445~piPK:64168309~theSitePK:1587585,00.html

World Bank, 2012. *Renewable energy desalination: an emerging solution to close the water gap in the Middle East and North Africa*, Washington DC: World Bank.

World Bank, 2014a. International Development Association Project Appraisal Document on a Proposed Grant in the Amount of SDR 47.7 Million to the Democratic Republic of Congo for an Inga 3 Basse Chute and Mid-size Hydropower Development Technical Assistance Project, Washington, D.C.: World Bank.

World Bank, 2014b. *From the Bottom Up: How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa*, Washington DC: The World Bank.

World Bank, 2015. *The Power of Mine, Transformativer opportunity for Sub-Saharan Africa*, Washington DC: World Bank.

LIST OF ABBREVIATIONS

ADFD	Abu Dhabi Fund for Development
AU	the African Union
CSP	Concentrating solar power
DEEP	Developing Energy Enterprise Programme
DFI	Development Financial Institution
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EJ	exajoules
FiT	Feed-in-Tariff
GDP	Gross Domestic Product
GW	gigawatt
GWEC	Global Wind Energy Council
GWh	gigawatt-hour
GW_{th}	gigawatt-thermal
ICS	Improved Cookstoves
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
km	kilometer
kW	kilowatt
kWh	kilowatt-hour
LCOE	Levelised Costs of Electricity
Mt CO_2	Megatonnes of carbon dioxide
MW	megawatt
NEP	National Energy Plan
NGO	Non-governmental Organisation
PJ	petajoule
PPA	Power Purchase Agreement
PSP Hydro	Private Sector Participation in Micro-hydro Power Supply for Rural Development
PV	photovoltaic
REIPPP	Renewable Energy Independent Power Producer Procurement
RRA	Renewable Readiness Assessment
SHS	Solar home systems
STEG	Tunisian Electricity and Gas Company
TFEC	Total final energy consumption
TWh	terawatt-hour
USD	United States Dollar
VAT	value-added tax
W	watt
yr	year

Cover photo: Ngorongoro, Tanzania, © shutterstock

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AFRICA 2030: ROADMAP FOR A RENEWABLE ENERGY FUTURE

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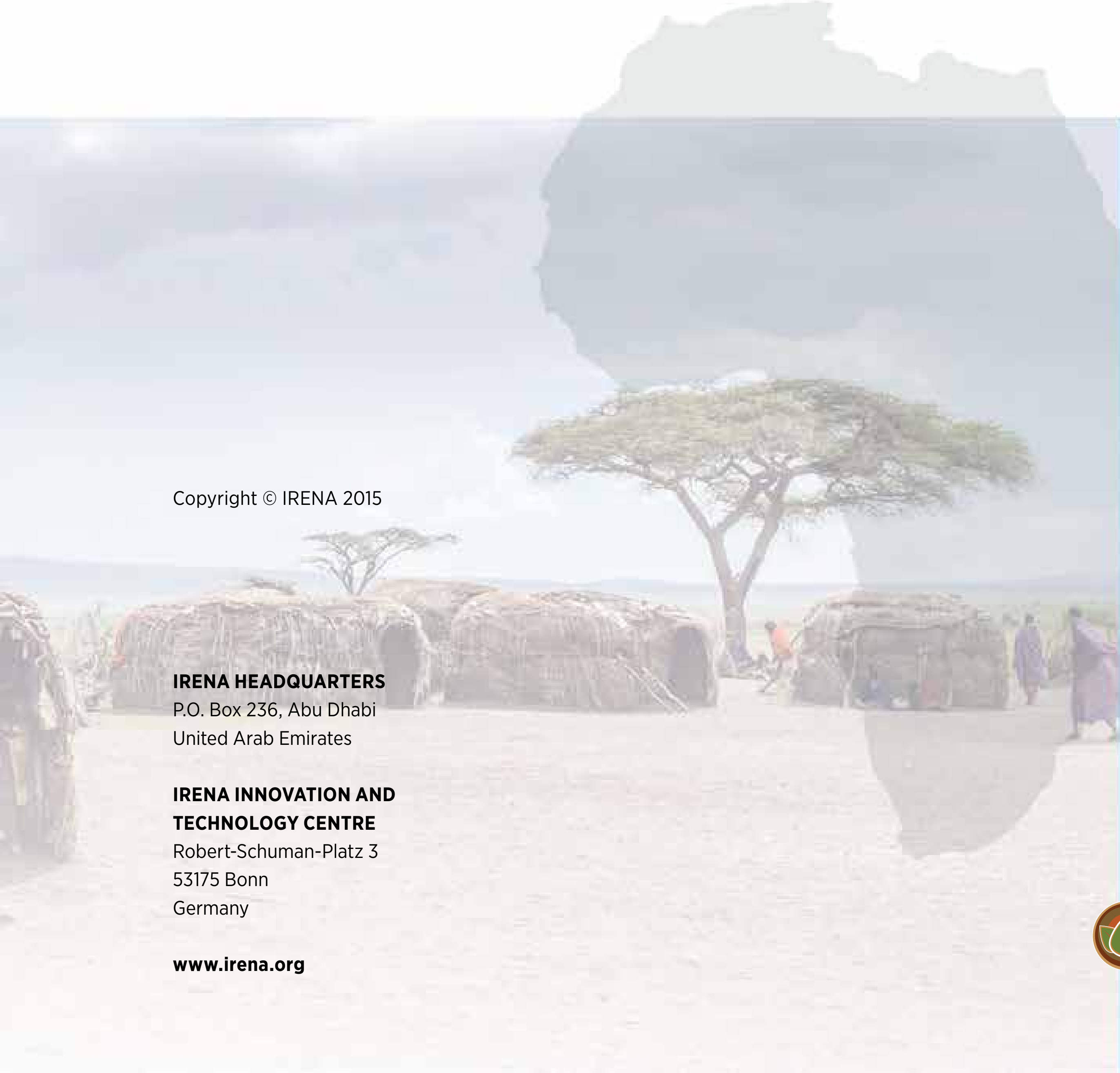

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