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Scenarios and Strategies for **Africa**

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Scenarios and Strategies for Africa

IRENA SCENARIOS AND STRATEGIES 2011: THE NEED FOR HIGH-LEVEL POLICY SUPPORT

In 2011, IRENA will start developing scenarios and strategies for Africa. This is a pilot study for a project that will ultimately encompass the whole world. The selection of Africa first indicates the priority that the IRENA work programme places on the continent.

In the framework of the 2011 IRENA work programme, the analysis of scenarios and strategies will feed into the renewables readiness assessment, which will assess policy priorities and best practices in renewable energy policy-making. This, in turn, will be the basis for financing investment and capacity building activities.

Energy policy advice must consider issues, such as the structure of energy supply and demand, the past and future energy trends, renewable energy resources, energy economics and technology access. Scenarios and strategies are key tools for such an analysis.

Regional and national differences must be considered and individual sectors and end-use categories further analysed. These include power generation, cooking, heating, industrial process heat, and transport. Urban and rural solutions will be dealt with separately, as well as centralised and decentralised solutions. The analysis will cover issues, such as potentials, technology, supply chains and investment needs.

The work will be organised in four strands:

- Technology/sector-specific analyses;
- Model-based scenario analysis for the power sector and techno-economic scenarios for end-use sectors;
- Discussions with an expert reference group; and
- Dialogue with target countries, banks, development agencies and the private sector.

The African Ministers are invited to:

- Comment on whether the proposed topics and questions cover the most relevant innovation and technology issues for renewable energy in Africa;
- Help identify recent scenario studies and strategies for Africa;
- Identify institutions and experts from Africa that should be involved in the analysis;
- Participate in high-level regional and national meetings to discuss outcomes in 2012.

Contents

1. Introduction

1.1 THE AFRICAN ENERGY CHALLENGE

With 5% of global primary energy use and 15% of the world's population, per capita energy consumption in Africa is only a third of the global average. Nearly half of the current energy use is traditional biomass, a major cause of health problems and deforestation. In 2009, 657 million Africans relied on traditional biomass and 587 million people lacked access to electricity. Limited and unreliable energy access is a major impediment for economic growth. In the coming decades, the energy mix will have to change to modern fuels, the per capita energy use will increase and the population will grow much faster than the global average. Together, these three factors will put tremendous pressure on future African energy supply.

Energy access is an important issue directly related to income and poverty. Access to modern energy rises from virtually zero for the lowest income quintile to 70-90% for the highest income quintile (Monari, 2011). Access can be split into two types; access to electricity for residential and commercial use and access to modern cooking fuels.

Adequate electricity provision is a challenge for industry and policy makers. Between 1990 and 2005, the poor performance of the power infrastructure retarded growth, shaving 0.11% from per capita growth for Africa as a whole and as much as 0.2% for Southern Africa (Foster and Briceno-Garmendia, 2010). In sub-Saharan Africa, 30 out of 48 countries experience daily power outages. These cost more than 5% of GDP in Malawi, Uganda and South Africa, and 1-5% in Senegal, Kenya and Tanzania (Foster and Briceno-Garmendia, 2010). Diesel generators are used to overcome outages and more than 50% of power generation capacity in countries, such as the Democratic Republic of Congo, Equatorial Guinea and Mauritania, and 17% in West Africa is based on diesel fuel. The resulting generation cost can easily run to USD 400 per MWh. **Reliable, affordable, low-cost power supply is needed for economic growth. Renewable energy can play an important role in filling this gap.**

While electrification programmes have improved access in some countries, many rural populations remain deprived of electricity. The average electrification rate is 30%: 71% in urban areas and 12% in rural areas. In a business-as-usual case, it will rise to 34% in 2020 (Monari, 2011). Average electricity use today is as low as 124 kWh/cap per year and will rise to 235 in 2020 in a business-as-usual case. In comparison, India consumes 640 kWh per capita (2010/11) and the world average is 2,782 kWh per capita (2008).

Some countries have achieved good progress in electricity access. Ghana has raised access from 25% in 1989 to 66% by 2011. Rural access has, over the same period, risen from 5% to 40%. In South Africa, urban electricity access has risen from 30% in 1994 to 83% today, and rural access has risen from 12% to 57%. In Morocco, a combination of grid extension and provision of photovoltaic kits to isolated villages has resulted in the electricity access rate in rural areas rising from less than 15% in 1990 to 97.2% in 2009. However, with high demographic growth, an increasing rate of access to electricity does not mean a reduction of the absolute level of population without access.

Worldwide universal energy access by 2035 will require an investment of USD 36 bn per year, namely USD 33 bn for electricity and USD 3 bn for cooking fuels. About half of those investments would have to be in Africa. Today's investment level is about a fifth of what is needed (IEA, 2010).

Africa spends about USD 10 bn per year on the power sector: USD 2.27 bn for grid extension, USD 4.59 bn for grid supply, USD 1.37 bn for off-grid renewable electricity, USD 1.07 bn for policy/regulation and USD 0.76 bn for efficient use of electricity (Monari, 2011). What would be needed is an investment of

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UN Photo/Ian Steele © Women collecting fire-wood for cooking pause on the cracked bed of the Niger River.

USD 40.6 bn per year, consisting of USD 26.6 bn capital expenditure and USD 14.0 bn operation and maintenance. This implies a quadrupling of investments. Annual capacity additions would need to rise to 7 GW per year.

Successful implementation models for electricity access vary. China is investing USD 700 million in Guinea's rural electricity system. In South Africa, Eskom, the national utility, has been in the lead. In Ghana, a self-help community electrification programme has been used, a model based on the positive experience in Thailand in the 1970s. But it should be noted that all these countries are not least developed countries (LDCs). In the poorest countries, many are not able to afford electricity. This is the core of the problem in Africa. In many cases, governance also poses a challenge, and this is a further brake on rapid expansion of the electricity supply. Renewable electricity can help to overcome these challenges because: (a) many solutions are modular and even applicable on a small village or household scale; (b) decentralised solutions can be implemented in locations without grid access; and (c) in many cases, renewable solutions are economically more attractive.

In the longer run, Northern Africa could even export electricity to Europe. Up to 15% of European electricity demand, which would be equivalent to 15% of African electricity production in 2050, could be supplied from solar and wind plants. Better quality resources in Africa create an economic incentive for such a scheme.

Apart from electricity access, another major challenge is replacement of traditional biomass, which is mainly used as cooking fuel. It can be split into solid biomass (wood and residues) and charcoal. The negative implications of the use of traditional biomass in open fires or charcoal are well covered in the literature. Both fossil and renewable energy technology solutions can be applied.

So far, transportation fuels are of lesser significance. But with car ownership rates rising, biofuels could play a more important role. Moreover, exports of biofuel are being considered.

1.2 GOAL OF THIS PROJECT

This working paper outlines the current state of knowledge that will serve as a basis for the Scenarios and Strategies for Africa project. The goal of this project is to prepare in-depth analysis and use models and scenarios to support and feed into national renewables readiness assessments.

The project will focus on innovation and technology issues for 2035, with an outlook to 2050. The longer term perspective is needed as emerging issues and constraints should be considered in decisions taken today. Key questions are addressed in individual chapters. A number of African and international institutions have developed energy scenarios for Africa, and IRENA will work with these institutions to develop optimal strategies.

A number of energy scenario and strategy studies have been published in recent years. They include: the Africa Infrastructure Study (Foster and Briceno-Garmendia, 2010), the World Energy Outlook (IEA, 2010), and the Energy Revolution Study (EREC and Greenpeace, 2010). All have a continent-wide perspective. Regional organisations have developed their own energy scenarios and energy studies; for example, for Northern Africa (OME, 2008). Finally, some country energy studies have been undertaken, such as for South Africa (Edkins et al., 2010) and for Egypt (OME, forthcoming). Many country level studies are not available or not accessible and the quality varies. Some are detailed energy system assessment studies, others are investment plans or technology needs assessments.

The focus of this analysis is limited to renewable energy and renewable energy technologies as a means to overcome energy challenges. Renewables are attractive for a number of reasons, but their use must be seen in the light of competing fossil energy use options.

Given pressing energy challenges needed to be urgently met, one may ask why policy-makers should address issues that are many years or even decades away. The reason is that decisions now can entrench technology development paths that are very hard to change later on. Moreover, the energy scene is rapidly changing. Just a decade ago, new oil-fired power plants were built in Africa based on low oil prices at the time. In hindsight, this was a very costly decision. Also, the high dependence on diesel aggregates today is a consequence of insufficient energy planning and investment in the past.

Therefore, scenario and strategy analysis can support decision-making and reduce the risk of expensive choices or energy shortages in the future.

Policy-makers need reliable independent information regarding technology costs, the reliability of equipment and systems, and recent and upcoming technological innovations that may affect their policies. This is important as significant expenditures are needed. Poor decisions can cost billions of dollars. **This project aims to provide accurate basic technology data.**

Biomass is a special renewable energy resource in the sense that it is a scarce one with a very broad field of energy applications. Moreover, growing biomass requires land use, therefore bioenergy competes with other forms of land use, such as food crops. A systems perspective is needed to assess optimal land use. The debate regarding the feasibility of large-scale land use for bioenergy crops is politically sensitive. At the same time, land use ownership points to clear developments: already 51 million hectares of African land have been acquired by foreign investors between 2001 and 2011 (Economist, 2011) - an area equivalent to 25% of sub-Saharan cropland or the cropland of France and Germany combined (including land for food and energy crops). Before such trends are further accelerated to meet energy needs, a better understanding of the development and environmental consequences is required.

The high share of traditional biomass is another continent-specific aspect of energy use, especially in sub-Saharan Africa. Many attempts to change this pattern have failed and it is not clear how this problem can be resolved. This project sheds light on the barriers to the transition away from traditional biomass and the way modern renewable energy technologies can help.

Of special importance for Africa is the nexus between energy and water. Growing biomass requires water. Pumping water requires energy. Water desalination is becoming an important energy-consuming industry in North Africa. Conventional steam cycles for power plants require significant amounts of cooling water. Hydropower reservoirs can be used for irrigation and their combined use can make projects economically viable. These issues must be considered in energy planning.

The project also deals with technology access, innovation needs and development of equipment supply industries. Technology transfer is often discussed, but what is emerging in many countries is the **critical importance of having a supply industry located within the region.** Imported equipment is costly and raises issues regarding proper operation and maintenance. Local production creates jobs, it helps to build community support and economic growth and it helps to reduce equipment cost. **For many technologies a significant share of the costs is not high-tech equipment but infrastructure, foundations, buildings, simple parts and the like that can be produced locally.**

This project seeks to answer a number of key questions on Africa's energy future including:

1. How can renewable energy help to improve access in Africa?
   - What is the role of centralised and decentralised power renewable energy solutions?
   - How can modern renewables help to replace traditional biomass for cooking and heating?
   - What can be learned from Morocco, South Africa, Vietnam and other countries in terms of access to electricity and replacement of traditional biomass?
   - What is the role of renewable energy for water desalination and pumping?
   - What is the role of renewable energy solutions for industrial applications?
2. What is the potential for second generation biofuels in Africa?
3. Can better regional integration help to accelerate uptake of renewable power?
   - Cost-effectiveness of renewable energy power generation in Africa
   - Desertec – North Africa as renewable energy exporter (solar/wind)
   - Regional integration, hydropower (Central/South Africa) and wind (East Africa)
4. To what extent can equipment manufacturing in Africa help to accelerate uptake?
5. What level of investment is needed to make a renewable energy future for Africa happen?

2. The current African energy system

The structure of the African energy system is illustrated in Figure 1. The most remarkable feature is the fact that the continent exports 40% of the energy it produces. This is largely oil and gas that is exported from the North and West African countries. As such, energy scarcity is not an issue for Africa as a whole. The problem is the uneven distribution of the resource and the fact that the indigenous population is too poor to afford commercial fossil energy.

In the centre of Figure 1 is the energy transformation sector. Energy use for power generation is small compared to other regions. Yet this is where most of the discussion on energy access takes place. Latent demand is very high. With electricity demand having a tendency to grow at the same rate or even faster than GDP, a rapid rise is likely. Therefore, the main issue is not how to deal with existing plant, but making the right choices for new plant.

Charcoal production from solid biomass is also a key energy consuming activity, which is often ignored. Efficiency tends to be low while proven higher efficiency charcoal production processes exist. Charcoal is the fuel of choice for city dwellers in large parts of Africa.

The right hand side of Figure 1 shows the end use sectors. The use of natural gas is rather low - lack of distribution infrastructure being one of the reasons. In addition, low demand for heating and the absence of a large industry are not there to sustain a distribution network in most parts of the continent.

Direct use of traditional solid biomass is very large and accounts for over half of final energy use, the highest share of any region in the world. While biomass is renewable, traditional biomass use is considered problematic for a number of reasons. The question in many countries is what can be done to overcome this

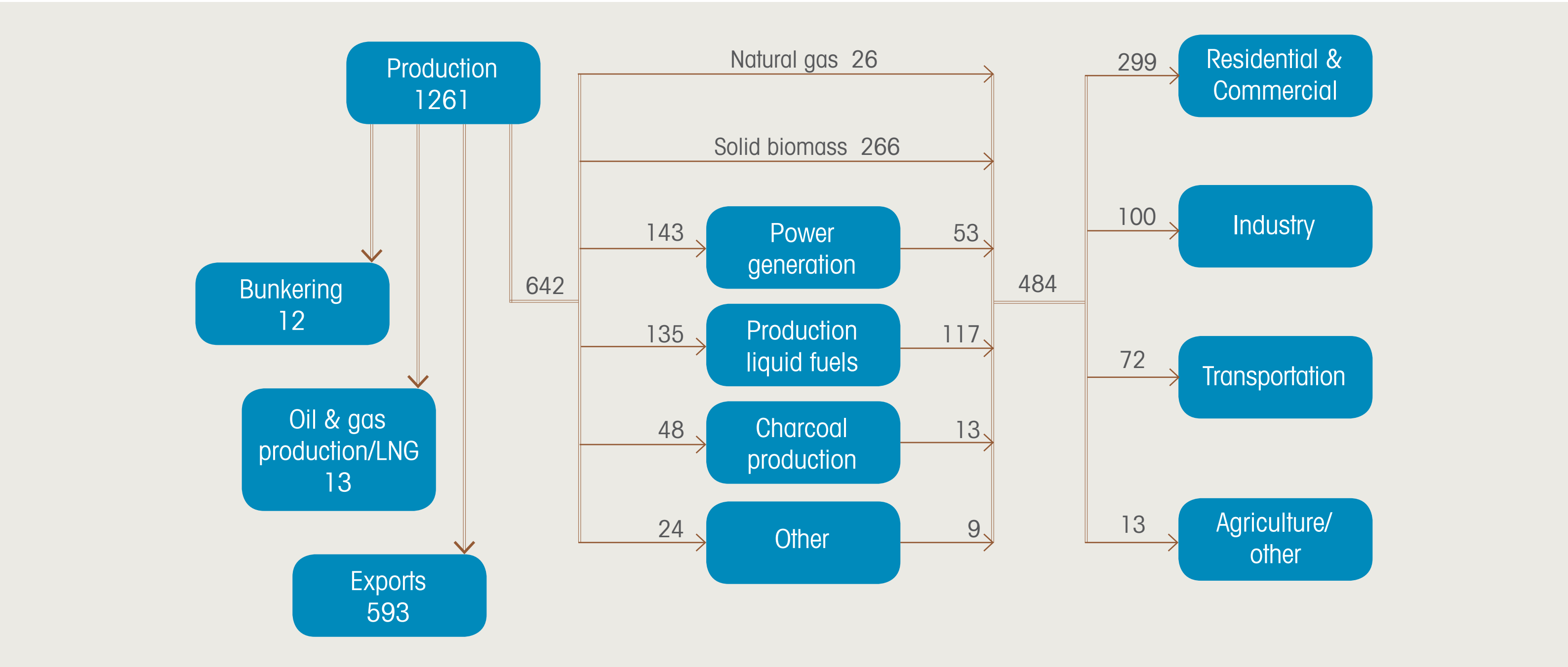

Figure 1*: African energy system, 2008 (Million Tons of Oil Equivalent, Mtoe)

Difference between inputs and outputs are accounted for by losses.

problem. Many projects have failed. This is in stark contrast with India where the use of traditional biomass for cooking has declined from 72.3% in 2001 to 55% in 2009/10 (Khan, 2011).

It should be noted that five countries alone account for nearly 60% of African primary energy use (see Figure 2). Development in these countries will, to a large extent, determine energy trends for Africa as a whole. As such, they are given special attention. In the other countries, energy poverty and energy access are most urgent issues to address.

POWER GENERATION

African power generation is dominated by fossil fuels (see **Figure 3**). Hydropower accounted for 15% and other renewables accounted for 1% of total power generation in 2008.

Africa has 129 GW of power generation capacity (Platts, 2009) as shown in **Figure 4**. This includes 24.3 GW of renewable energy capacity, with hydropower making up 95% of this figure. A total of 1,260 hydropower plants have been identified (operational, under construction or in the planning stage), with an average capacity of 46 MW. About 579 plants have a 10 MW capacity or more (large hydro), and 681 plants are less than 10 MW (small hydro). Other renewables include 63 wind farms with an average capacity of 27 MW. Bagasse dominates biomass power generation (159 plants with an average 7 MW capacity, 94% of biomass-based power generation). Finally, 19 geothermal plants have an average capacity of 19 MW.

A pertinent, very costly issue for Africa was the decision to build oil-based power plants in the 1990s when oil was cheap. Longer-term, realistic price forecasts would have shown that this was a very risky decision to take. Along the same lines, recent decisions to build new coal-fired power plants face the uncertainty of future CO_2 emissions regimes.

TRADITIONAL AND MODERN BIOMASS

Biomass accounts for half of primary energy use in Africa. Throughout sub-Saharan Africa biomass use domi-

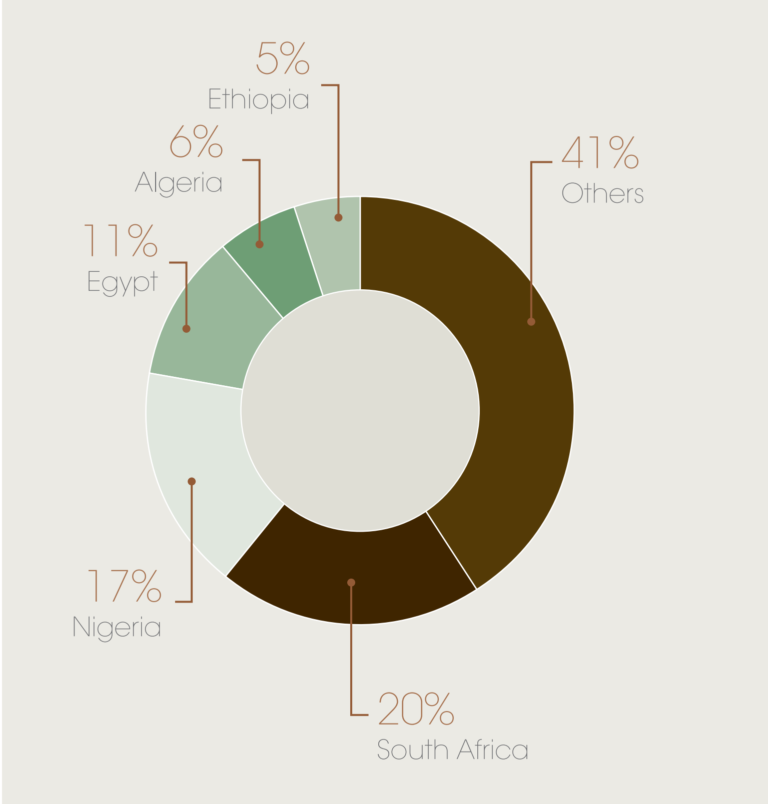

FIGURE 2: AFRICAN PRIMARY ENERGY USE BY COUNTRY, 2008 (IEA DATA)

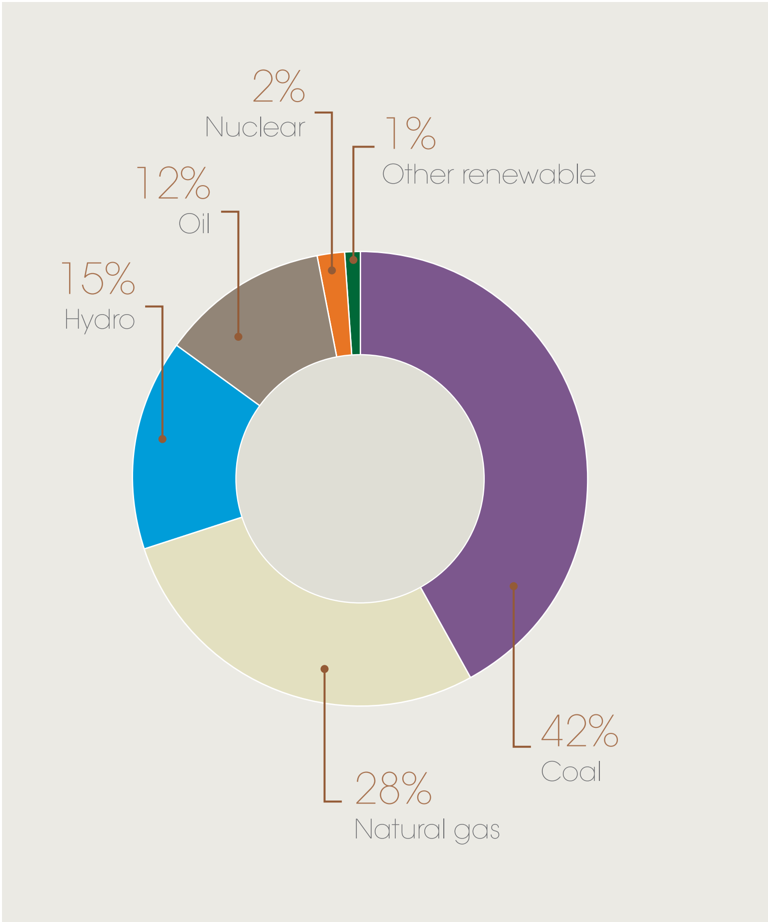

FIGURE 3: AFRICAN POWER GENERATION BY FUEL, 2008 (IEA DATA)

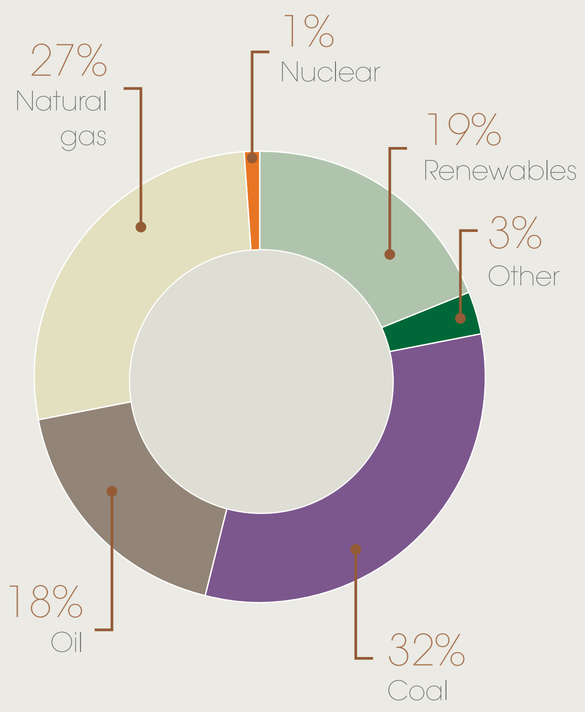

Figure 4: African power plant capacity shares (Platts, 2009)

nates for cooking. Data for Eastern Africa suggests that wood dominates in rural areas, charcoal dominates in cities. Approximately 3% of households in sub-Saharan Africa use non-woody biomass such as crop residues or dung (Bailis et al., 2005). Analysis for Nigeria in West Africa suggests that poorer geopolitical regions tend to use more wood fuel to meet their domestic requirements (Onuche, 2010).

Nigeria has the highest population in Africa (about 17% of total). In 2007, the types of fuel used for cooking in Nigeria included: wood (74%), electricity (0.7%), gas (0.7%), kerosene (24%), and coal (1.6%). Between 1996 and 2007, the amount of kerosene consumed in the country decreased steadily while the use of wood increased. This can be attributed to the rising cost of fossil fuels.

Significant efforts have aimed to introduce more efficient woodstoves. These could double efficiency and halve biomass use. However, uptake has been slow. Uptake in Kenya, Tanzania and Uganda stood at 4%, 4% and 9%, respectively, in 2010 (Muchunku, 2010). One of the challenges is that stove designs vary widely and are culture-specific. Stoves need to be developed with full consideration of cooking needs, such as pot sizes, food types, cooking position, portability. The GTZ efficient wood stove projects in Uganda and Kenya is a semi-commercial approach based on building capacity of local stove builders.

Charcoal is a more efficient cooking fuel. However, charcoal consumption is an issue because of the low efficiency of charcoal production and the unsustainable levels of production (Mwampamba, 2007). About 20 Mt of charcoal is produced every year (about 13 Mtoe, 5% of all final bioenergy use or 15-20% in primary bioenergy terms). Nearly all charcoal in sub-Saharan Africa is currently produced in traditional kilns, which have sub-optimal conversion efficiency and no emission controls (Bailis et al., 2005). Conversion efficiency rates would double if modern kilns were used.

Use of traditional biomass is a major cause of health problems. In 2000, an estimated 51% of child lower respiratory infection deaths (350,000 deaths) and 63% of adult female chronic obstructive pulmonary disease (COPD) deaths (34,000 deaths) in sub-Saharan Africa were caused by household use of wood and charcoal (Bailis et al., 2005). In arid and semi-arid areas, the need for fuel wood is a major cause of the reduction in tree cover and the primary cause of forest loss. Charcoal use reduces health damaging emissions in homes as it produces lower concentrations of pollutants like particulate matter (PM). Concentrations of PM in households using charcoal were found to be 88% lower than households using open wood fires (Bailis et al., 2005).

Apart from higher net carbon emissions due to deforestation, combustion of biomass is a major source of methane and N_2O emissions. In 2000, the net GHG emissions from residential energy use in sub-Saharan Africa were 320 million tons of CO_2 equivalents (61% from wood, 35% from charcoal, 3% from kerosene, and 1% from LPG) (Bailis et al., 2005). Moreover, combustion of biomass emits non-methane hydrocarbons and particulates.

While traditional wood fires have the highest emissions in terms of health impact, those related to charcoal use are higher from a GHG perspective. Each meal cooked with charcoal has 2-10 times the global warming effect of cooking the same meal with firewood and 5-16 times the effect of cooking the same meal with kerosene or LPG depending on the gases that are included in the analysis and the degree to which wood is allowed to regenerate (Bailis et al., 2005).

3. Important drivers for future African energy demand

The African population is growing at a fast rate. At the same time per capita income levels are rising and Africa is urbanizing. These three trends will significantly affect energy use in the coming decades.

Africa's population was 1.031 bn in 2010. It is projected to grow to 2-3 bn by 2050 (UN Population Division, 2008). The current urbanisation rate ranges from 18% in Ethiopia to 50% in Nigeria to well above 70% in some of the North African countries (UN Population Division, 2009). On average 34% of the population lives in cities.

Figure 5 provides a breakdown for sub-Saharan Africa. The trend is towards a 20 percentage point increase of the urban share by 2050. This means that more than half of the population will live in cities, and the urban population will more than double.

Africa`s economies have been growing at an average rate of around 4% in the last few years. If this trend continues, GDP will increase 2.65-fold by 2035 (compared to 2010), and 4.8-fold by 2050. Part of this projected growth can be attributed to population growth. Per capita GDP would only grow by 1.2-1.8%. This level of productivity growth can be attributed to technological advances.

Car ownership rates are still low, slightly above 100 cars/1,000 inhabitants in South Africa and between 50 and 100 in Northern Africa. The rest of sub-Saharan Africa has, on average, less than 25 cars/1,000 inhabitants. In comparison, the level in OECD countries is about 500 cars. As a result, energy use in the transportation sector is currently low, but could grow substantially in the coming decades.

African production of energy-intensive commodities is still low. Steel production is only 1% of Chinese steel production, cement production about 5% of Chinese production. Industrial energy use in Africa is not well analysed and collection of better data is recommended. If Africa follows the growth model of China and India, a significant growth of industrial production can be foreseen. The fact that the continent has abundant natural resources that can be used as feedstock for industrial activities supports such development projections.

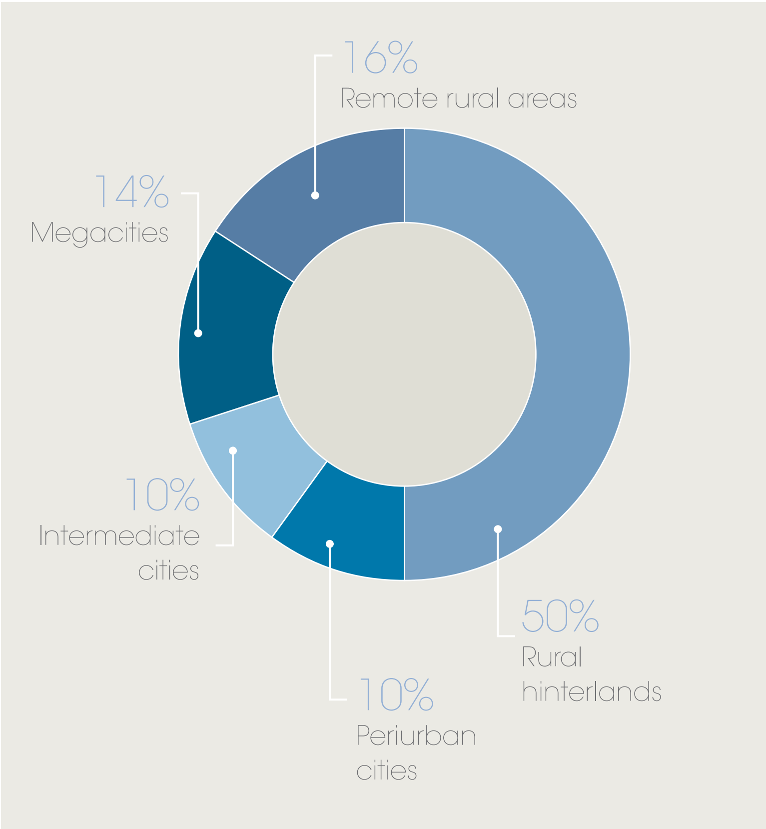

Figure 5: Sub-Saharan Population distribution by settlement type [1]

[1] *Foster and Briceno-Garmendia, 2010.*

4. African renewable energy potentials

While significant fossil fuel resources have been discovered in recent years, most oil and gas is exported. At the same time, Africa has very good renewable energy resources that are not yet widely used. The technical feasible hydropower potential is 1,844 TWh (three times current electricity production) and only 5% of this potential is exploited. The wind is over 1,000 GW, more than five times total African installed power generation capacity. Africa has an exceptional solar resource potential, well in excess of 10,000 GW. In parts of the region, biomass and geothermal resources are abundant. Action is needed now to ensure more rapid use of this sustainable energy potential. Renewables use reduces transportation needs for fossil fuels, enhances the trade balance and reduces the cost of energy.

Africa has serious development challenges to address. However, it has the great opportunity to leapfrog aging OECD capital stock and other emerging economies dependent on fossil fuels. And this is a real possibility. Brazil is an example, a modern emerging economy where 47% of all primary energy comes from renewable sources.

The first step in such development is proper planning on a national, regional and continental level. As resources are not evenly spread, energy trade across borders can help to increase reliability and reduce cost. Certain forms of renewable energy may even be exported; there are plans for electricity trade with Europe; and biofuels developments may be promising. Another reason for cooperation is that many national markets are too small to support their own equipment manufacturing industry. However, Africa as a whole is a viable market. This can create jobs and reduce equipment supply costs. In the case of Germany, nearly 1% of all jobs are in the field of renewable energy.

Table 1 shows the abundance of renewable energy resources located in Africa. Today's electricity use is a mere 600 TWh per year. Hydro, solar and wind each could supply the entire demand. The figure for geothermal is lower but this reflects only the identified projects. The potential may be significantly higher.

The most contentious natural resource projections are for biomass. Estimates in the literature range from 8 EJ (190 Mtoe) (BMVBS, 2011) to nearly 400 EJ (9,600 Mtoe) per year (Hoogwijk, 2004) in 2050. More recent studies tend to be more conservative. A value on the order of 25-50 EJ, on top of the existing 20 EJ traditional biomass, seems reasonable. But development will depend on population patterns, nutrition and trends in agricultural productivity. Climate change will probably reduce productivity but current yields are very low compared to other regions in the world and potential for substantial growth remains a reality.

Table 1: Renewable energy potentials by African region (compilation of various sources)

Region	Wind (TWh/yr)	Solar (TWh/yr)	Biomass (EJ/yr)	Geothermal (TWh/yr)	Hydro (TWh/yr)
East	2,000 – 3,000	30,000	20 - 74	1 - 16	578
Central	-	-	49 - 86	-	1,057
North	3,000 – 4,000	50,000 – 60,000	8 - 15	-	78
South	16	25,000 – 30,000	3 - 101	-	26
West	0 - 7	50,000	2 - 96	-	105
Total Africa	5,000 – 7,000	155,000 – 170,000	82 - 372	1 - 16	1,844

Sources: See "Sources for Renewable Energy Sources" page 31.

5. Energy scenarios for Africa

Figure 6 shows electricity generation projections from the World Energy Outlook (IEA, 2010). Demand should double between 2008 and 2035 and the energy mix will depend on the policy regime. In a business-as-usual scenario, coal and gas represent the bulk of the growth. With policies under consideration today, demand is 10% lower than in the current policies scenario and the share of renewables grows. In the most extreme (normative) 450 ppm scenario, the share of renewables grows to around 60% and demand is again 10% lower due to end-use efficiency gains.

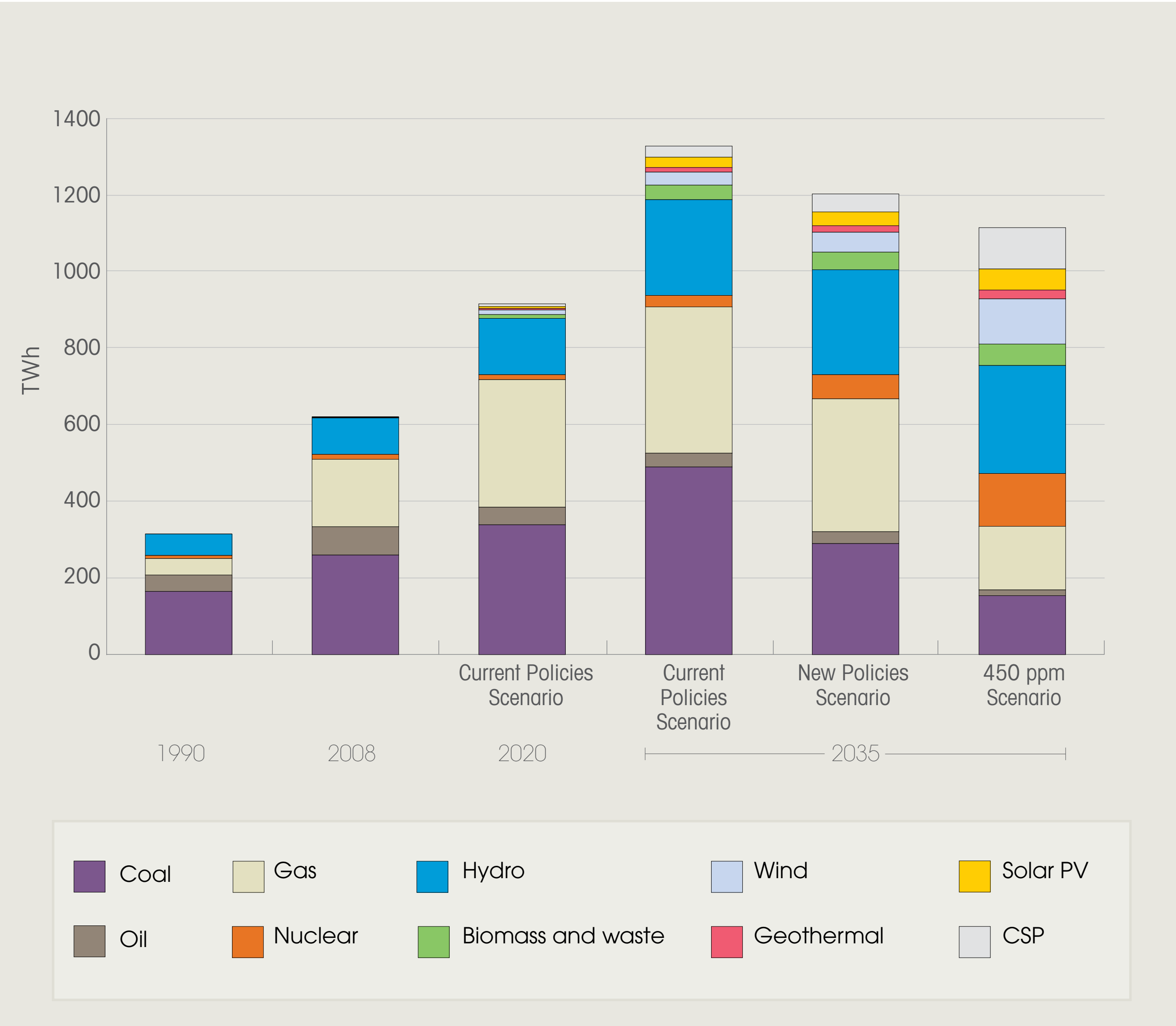

Figure 6: Electricity supply projections for Africa 2008-2035 (IEA, 2010)

Source: IEA, World Energy Outlook 2010

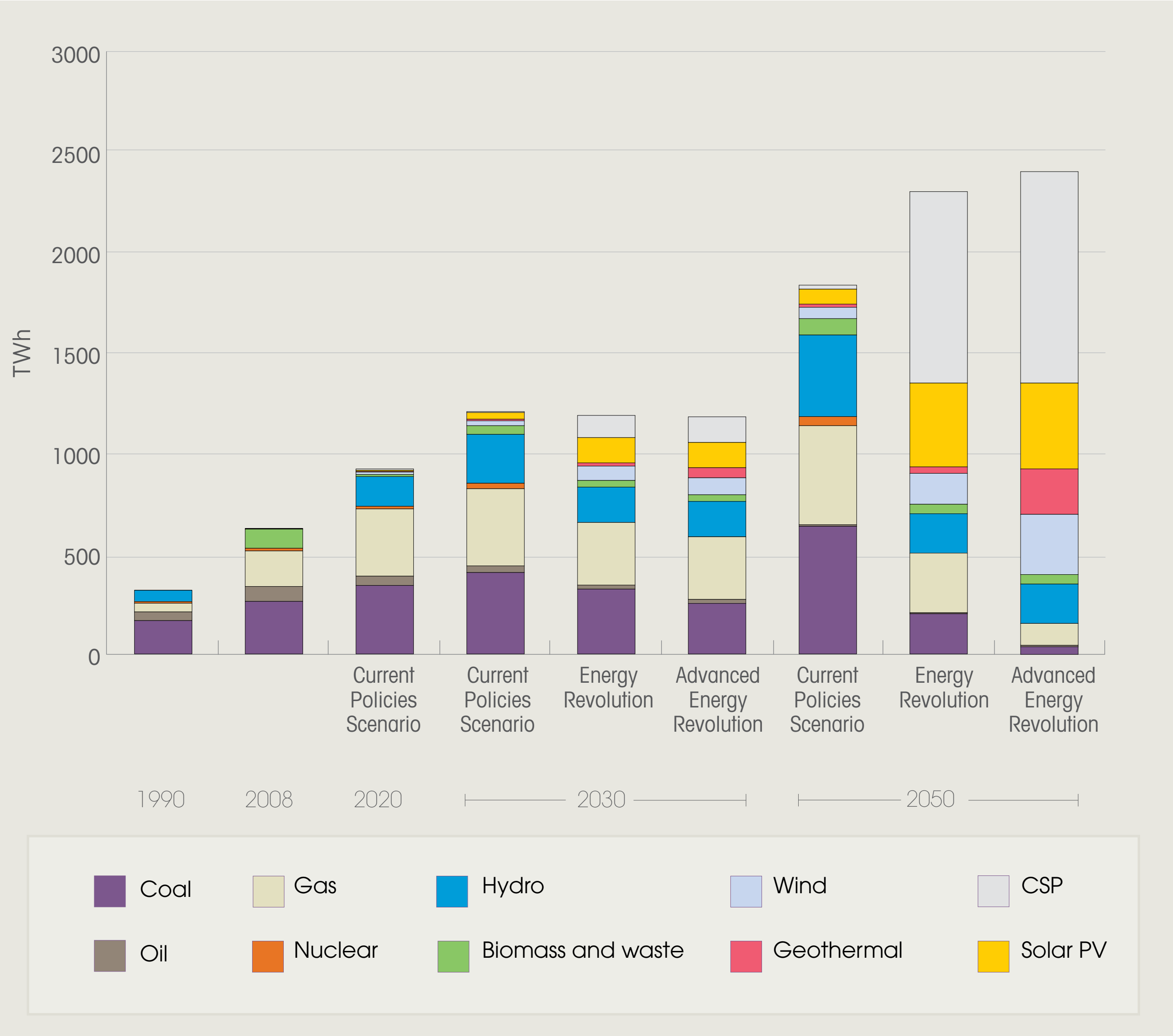

FIGURE 7: ELECTRICITY SUPPLY PROJECTIONS FOR AFRICA 2008-2050 (EREC/GREENPEACE, 2010)

Figure 7 illustrates electricity supply projections by EREC/Greenpeace that extend to 2050. The 2030 projections are comparable with the IEA 2035 projections (Figure 6). The 2050 time horizon leaves sufficient room for a radical change. While coal and gas dominate in the business-as-usual scenario, in the policy scenarios (Energy Revolution and Advanced Energy Revolution), solar solutions dominate. The EREC/Greenpeace scenarios exclude nuclear and are less optimistic on hydropower. Analysis suggests that the two energy revolution scenarios are cheaper than the business-as-usual scenario (discounted cost). However, upfront investment costs are significantly higher. Electricity demand in 2050 is higher in the policy scenarios compared to the current policies scenario because of the introduction of massive numbers of electric vehicles. The additional demand created by electric vehicles is greater than the efficiency savings.

There is, therefore, consensus that the use of renewable energy for power generation will increase in the coming two decades. Still, fossil fuels remain the most important source of electricity generation; except if transformational new policies are introduced.

Figure 8 shows primary energy demand projections. Only modest demand growth is forecast in the light of the economic growth projections. In the current policies scenario, demand would grow by half in 2035 compared to 2008. Demand growth would be reduced to a quarter in the most extreme (450 ppm) scenario. Biomass would continue to be the primary source of energy and its use

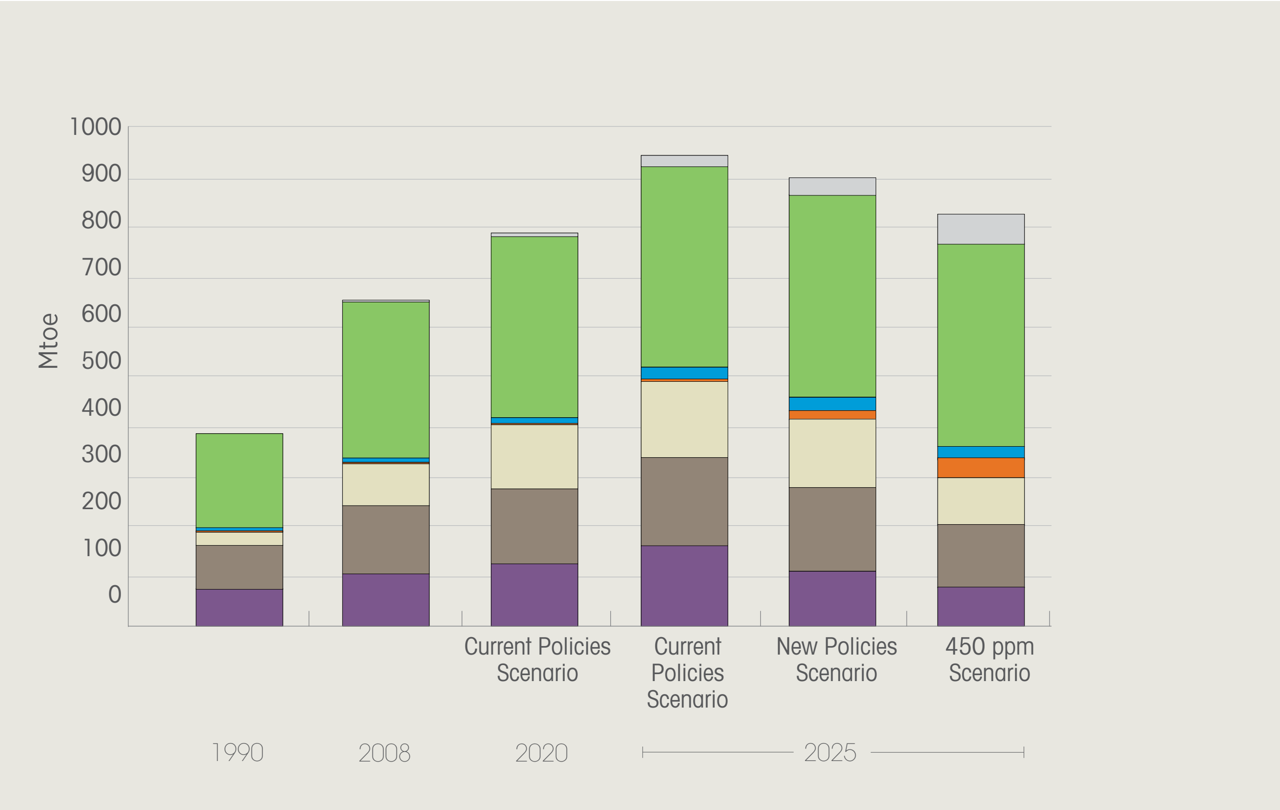

Figure 8: Primary energy demand projections 2008-2035 (IEA, 2010)

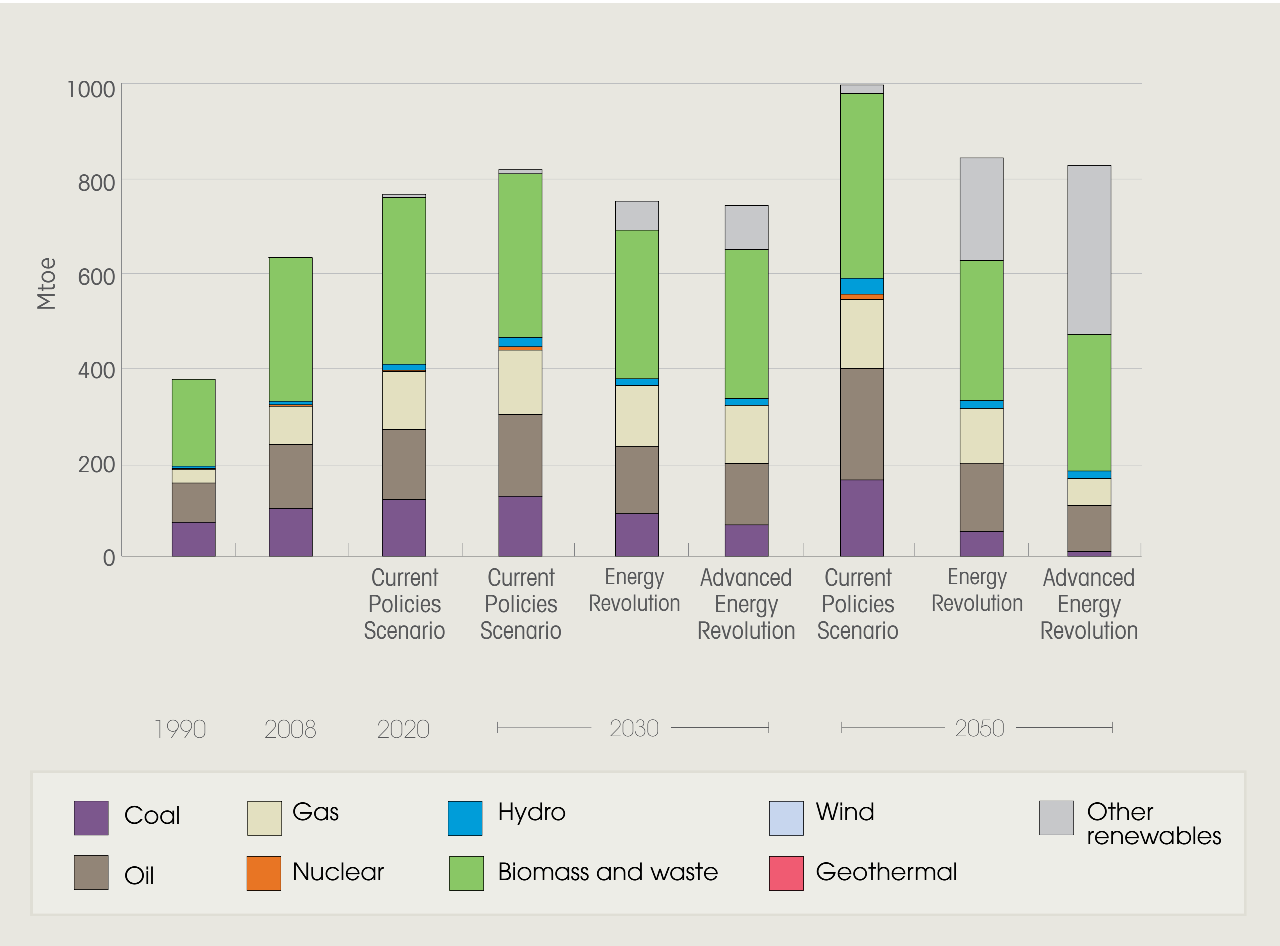

Figure 9: Primary energy demand projections 2008-2050 (EREC/Greenpeace, 2010)

would increase substantially. The use of fossils would be stagnant. The role of other renewables is small in all of the scenarios, less than 10% of primary energy demand.

In the EREC/Greenpeace scenarios demand in 2050 (in the ER and AER scenarios) is roughly at the same level as in 2030 (**Figure 9**). However, other renewables play a much larger role and account for approximately 25-45% of primary energy use. The difference between ER and AER is the much higher growth of geothermal energy use in the AER scenario. In all scenarios biomass remains the dominant energy source.

The results, on a regional level, can be compared to the developments in individual key countries. South Africa is the largest energy-consuming country in Africa, accounting for around 20% of primary energy use. It has more than 40 GW of installed generating capacity. This is projected to more than double by 2030. In a business-as-usual scenario, coal would dominate. However, if ambitious new policies are introduced, all new capacity could be renewable and its share in generating capacity could exceed 60% by 2030. Concentrated solar power (CSP) and wind are considered promising options (**Figure 10**).

Thermal and hydropower dominate the electricity generation in Egypt. While the hydropower potential is nearly exhausted, there is substantial potential for wind and solar. The quality of the wind and solar resources are amongst the best in the world. Egypt has already defined its policies for developing these resources and for ensuring security of supply.

In Egypt, the large increase in demand across all sectors is leading to high electricity generation growth rates (around 7 to 8% a year). Electricity consumption has been forecast to rise to 150 TWh by 2012 and 250 TWh by 2020.

In February 2008, the Supreme Council of Energy set a target of 20% renewables (including hydro) in Egypt's power generation mix by the year 2020. Currently, installed hydropower capacity makes up 12% of the mix. Without further investment, this will decline to 8% by the year 2020. Addressing this deficit means that a 12% contribution from renewable sources other than hydro needs to be planned by 2020. Emphasis is given to the development of the wind resource. By 2020, it is expected that wind be contributing 7,200 MW, with an additional 550 MW each year to reach the target.

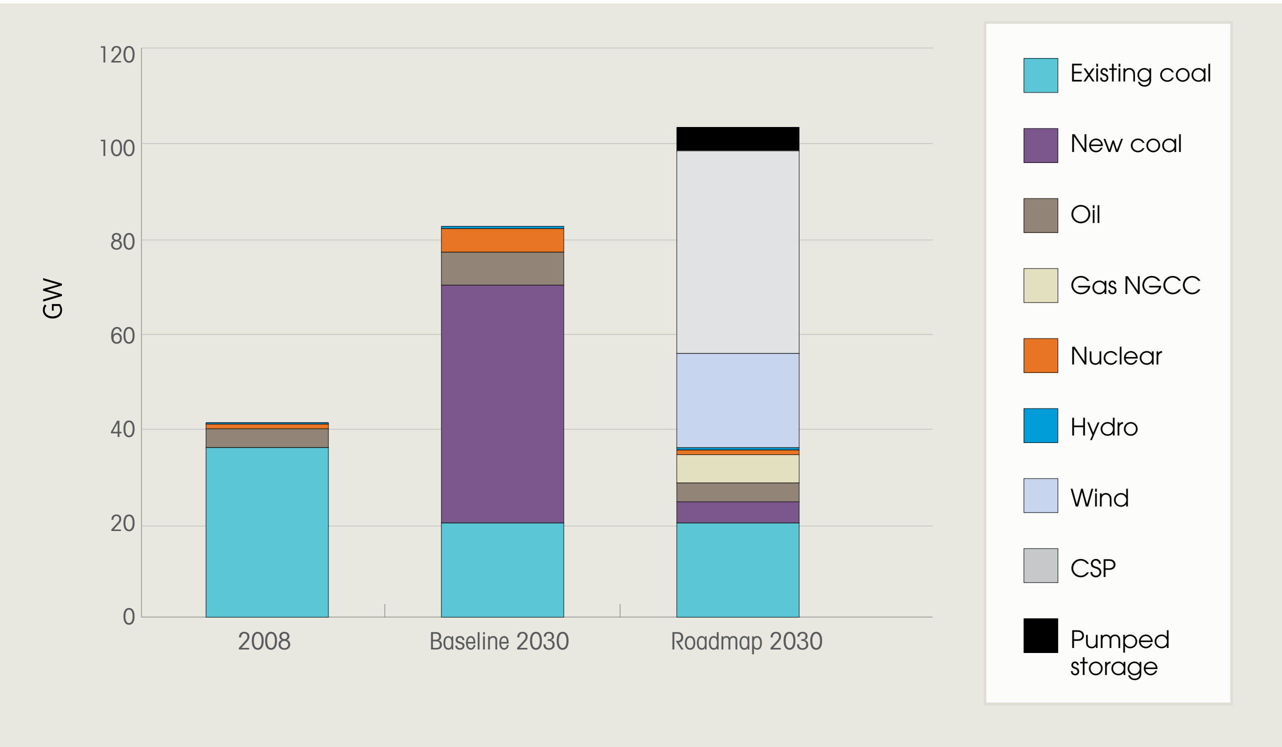

Figure 10: South Africa power generation capacity projections 2010-2030 (Edkins et al., 2010)

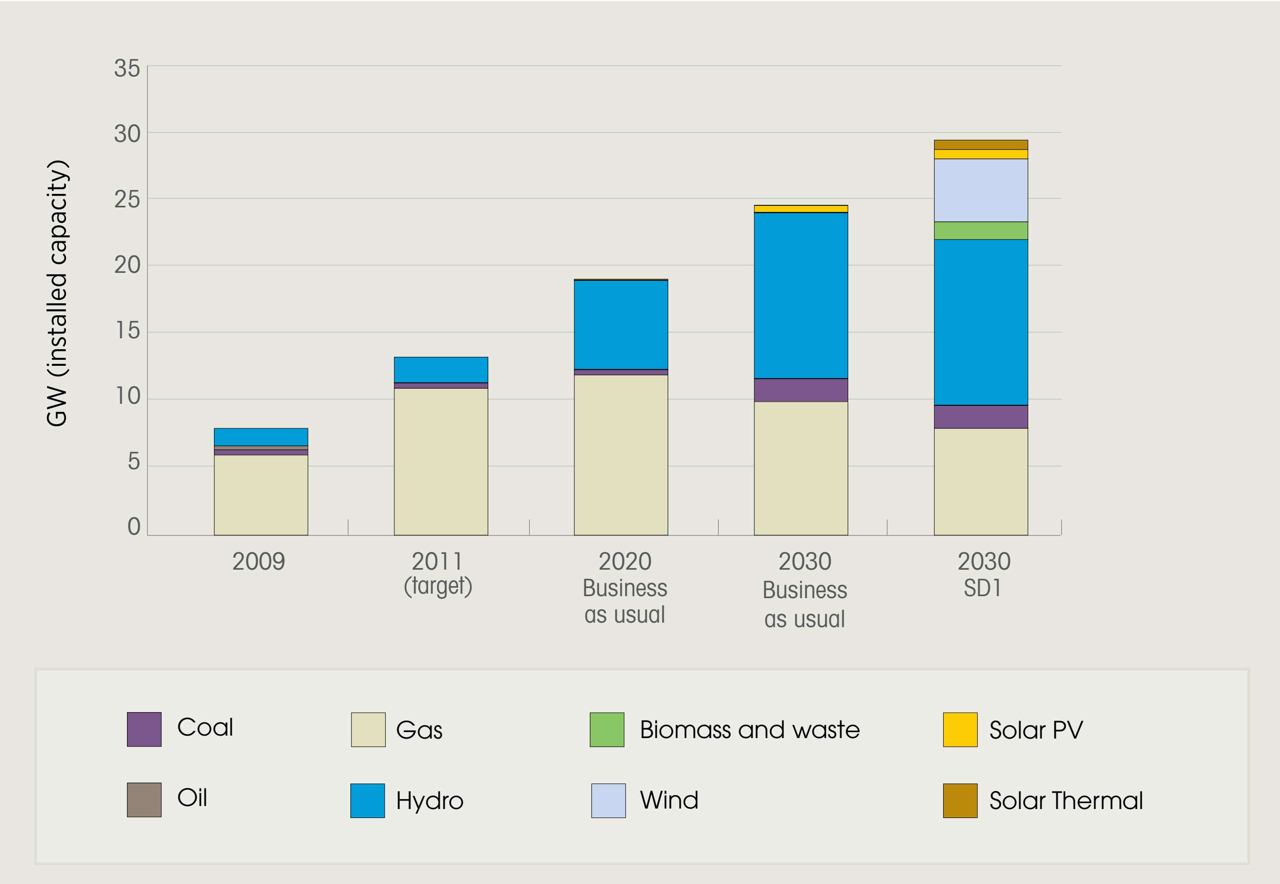

Figure 11: Nigeria power generation capacity projections 2009-2030 (Gujba et al., 2011)

Nigeria is the most populous country in Africa with 158 million inhabitants in 2010. It has a renewable energy master plan (ECN and UNDP, 2005). Nigeria had 6.2 GW of thermal power capacity and 1.9 GW of hydro capacity in 2008, of which only 60% was operational (Wade, 2009). Another 3 GW was under construction. Demand projections vary widely. Sambo (2009) projects that demand will grow substantially to 119.2 GW-250 GW in 2030 (a 10 to 20-fold increase). Other estimates are much lower, at 25 GW in 2030 (Gujba, 2011), while Wade (2009) estimates a growth to only 12 GW for the same year. The average estimate is used here. Nigeria has 14.75 GW of hydro potential, and its development should be a priority. Opinions regarding wind potential vary (Gujba, 2011). About 144 Mt of biomass residues are available on an annual basis. The solar resource is good in the northern part of the country. However, so far, solar has not been considered in renewable energy plans because of its high cost (Sambo, 2009). **Figure 11** shows business-as-usual developments and a more sustainable scenario (SDI), where wind plays a more prominent role.

The use of solar is small in all scenarios, yet solar seems the only viable large-scale domestic renewable power option once hydropower potential has been exhausted. This could be supplemented with imports, either electricity generated by wind from the Western Sahara region or hydropower from Congo (Inga).

Ethiopia is the second most populous African country, with 85 million inhabitants. In 2010, power generation capacity reached 2.22 GW, heavily dominated by hydropower. Important hydropower potential remains (**Figure 12**). About 1 GW of geothermal power and significant wind power potential exist.

Moreover, Ethiopia plans to produce 63 Ml of ethanol and 620 Ml of biodiesel by 2015 (in total, the equivalent of 0.55 Mtoe). About 150,000 solar home systems, 300 wind pumps, 300 solar pumps, 3,000 institutional PV systems, 3 million solar lanterns, 10,000 solar cookers and 9 million improved biomass cooking stoves are planned for 2015 (EPA, 2010).

Algeria plans to install up to 22,000 MW of generating capacity from renewable sources between 2011 and 2030, of which 12,000 MW will be intended to meet domestic electricity demand and 10,000 MW destined for export. This last option depends on the availability of long-term assured demand, as well as attractive external funding. It is expected that about 40% of electricity produced for domestic consumption will be from renewable energy sources by 2030. Algeria is aiming to be a major actor in the production of electricity from solar photovoltaics and concentrating solar power, which will be drivers of sustainable economic development. The Algerian programme provides for the development by 2020 of about 60 solar photovoltaic and concentrating solar power plants, wind farms and hybrid power plants.

Electricity consumption is expected to reach 75 to 80 TWh in 2020 and 130 to 150 TWh in 2030 (**Figure 13**). By 2030 solar should account for more than 37% of national electricity production. The share of wind is expected to reach about 3% in 2030. The energy efficiency programme includes developing solar water heating and solar cooling systems and desalinating brackish water using renewable energy.

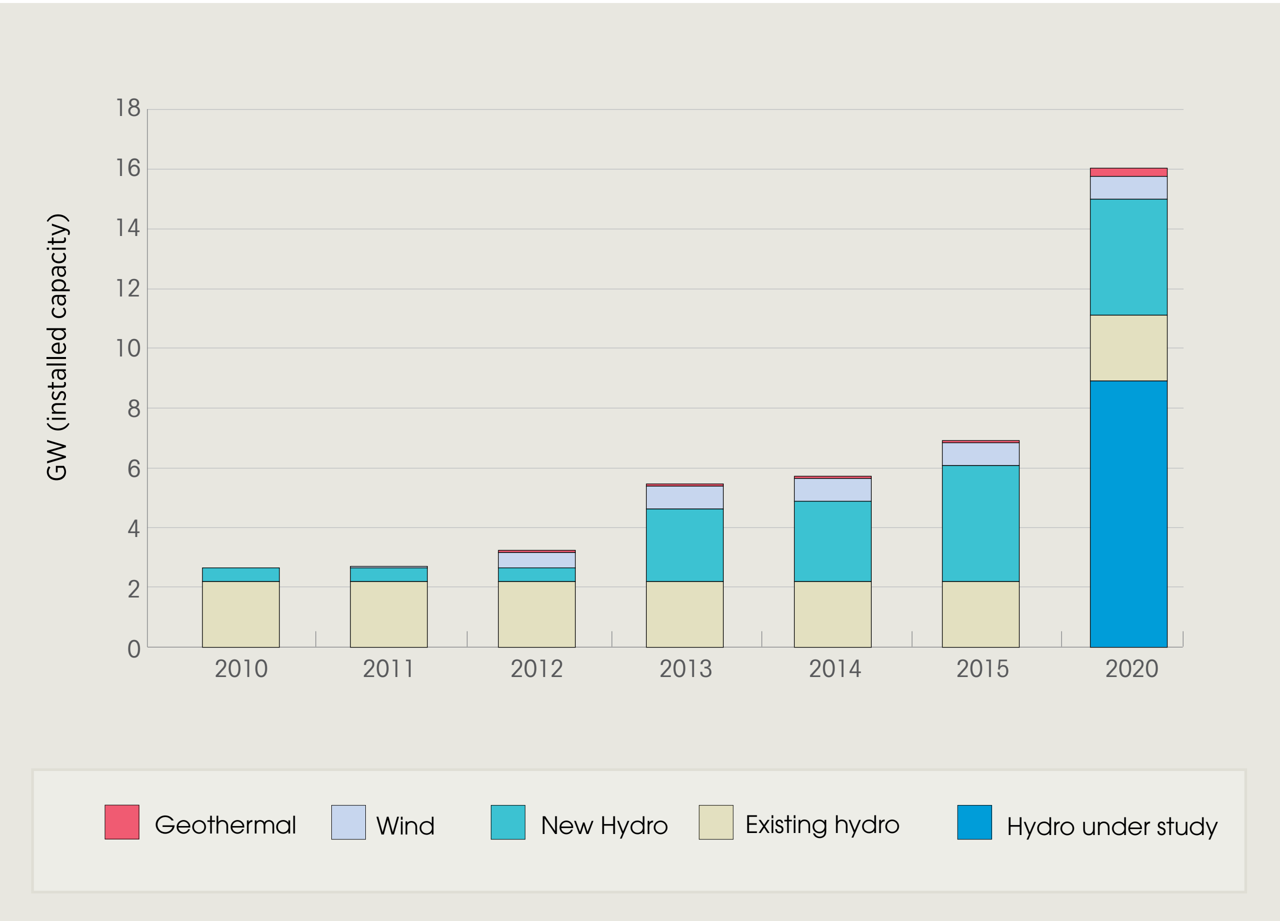

Figure 12: Ethiopia power generation capacity projections 2010-2020 (EPA, 2010)

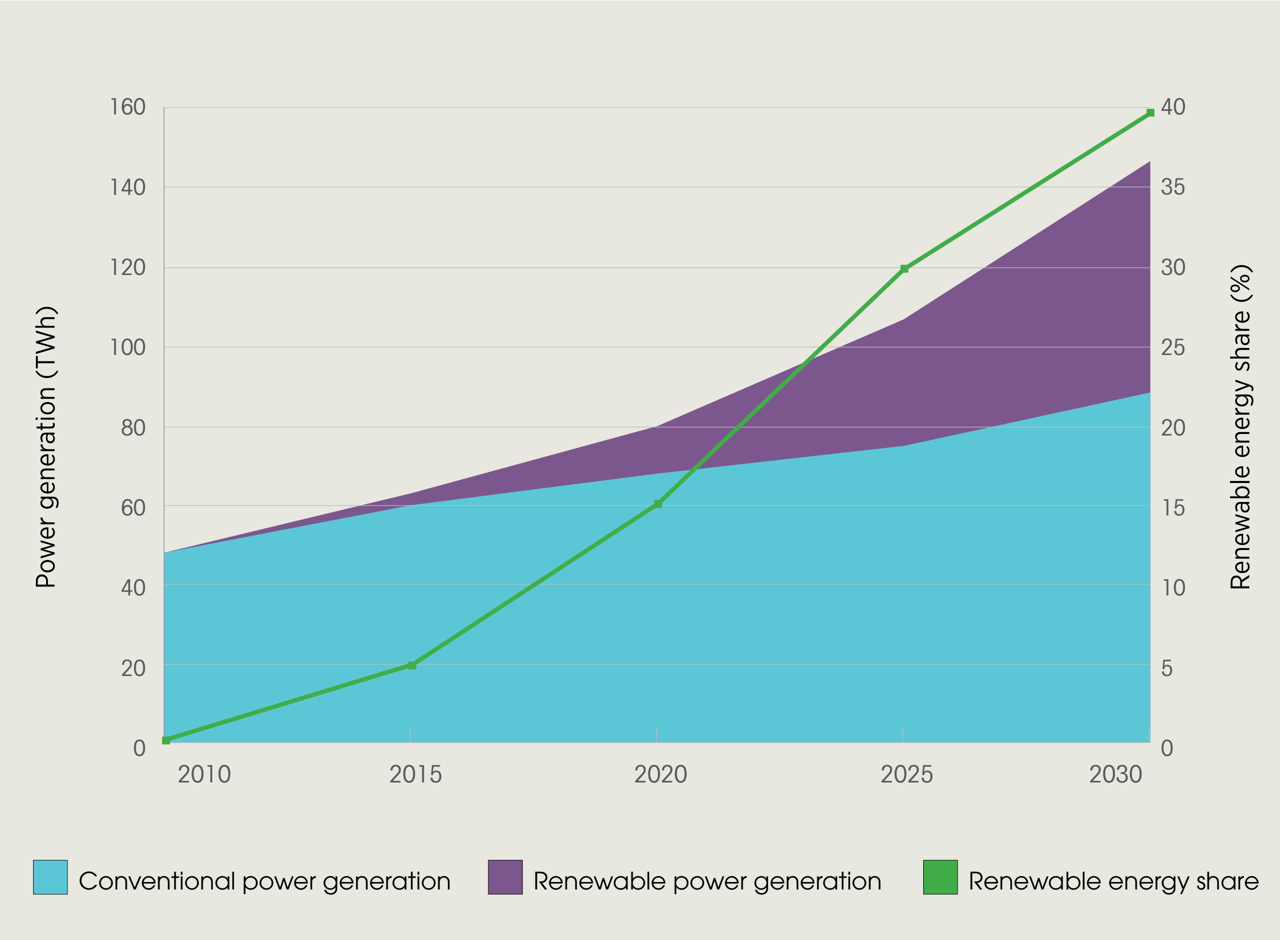

Figure 13: Algerian power generation projections 2010-2030 (Ministry of Energy and Mines, 2011)

> "The use of solar is small in all scenarios, yet solar seems the only viable large-scale domestic renewable power option once hydropower potential has been exhausted."

6. Renewable energy options for Africa

6.1. POWER GENERATION

Africa has some of the best renewable energy potential in the world. These include wind, solar and significant remaining hydropower potential. Good geothermal potential is geographically limited to the Rift Valley. Bioenergy includes bagasse processing in sugar cane producing countries. The potential for solar is good virtually everywhere but other resources are confined to specific parts of the continent.

Costs vary by project and by site. In case of remote siting, transmission systems must be added. Costs for renewables tend to come down over time as learning effects occur with increasing installed capacity.

Costs for African projects tend to be higher than in other countries due to the need to import equipment, transportation costs and import levies. Where elements can be constructed locally, costs are reduced. This is the case for items such as dams for hydropower projects, foundations and towers for wind turbines.

Equipment from OECD countries tends to be more expensive than equipment imported from China and India. However, quality also varies and so does the energy yield, as well as operation and maintenance costs. Given the scarcity of operation and maintenance skills, there is a trade-off.

Important economies of scale exist. Larger plants tend to be cheaper per unit of capacity. Typically, a size increase of one order of magnitude reduces the unit capital cost by half.

Costs for new renewable energy equipment tend to decrease rapidly. For each doubling of installed capacity, costs tend to come down by a fixed percentage. Much progress has been achieved in recent years in the reduction of the capital cost for solar. These considerations mean that cost projections are not straightforward.

A typical measure for cost comparison is the levelised cost of electricity (LCOE). This excludes any subsidies or taxes and treats all electricity as being equally valuable, be it supplied to meet base load or peak load. It does not account for the cost of grid integration, such as backup or storage capacity in the case of intermittent renewables. At the same time, external effects are excluded. This is therefore only one indicator of electricity cost. Cost will, in reality, be higher.

The cost of financing is also a key factor. The calculation in **Table 2** assumes a 12% real cost of financing. With high political risk and high inflation, the financing cost may be twice as high or even higher. However, concessional loans and risk guarantees can reduce the cost of capital. This is very pertinent for capital-intensive renewable energy technologies.

The cost of working capital is significant and can drive overall costs significantly higher. This is particularly true for large projects that require substantial infrastructure works, for example hydropower dams. The longer the time between the initial start-up of the project and completion, the higher the working capital cost.

Solar PV and solar CSP have been corrected for dust, heat impacts on performance and for gradual degradation as the equipment ages (Performance Ratio PR in Table 2).

Table 2: Typical Levelised Cost of Electricity (LCOE) in 2010, good African conditions[4]

	Investment cost	Capacity factor	Fuel cost	Electricity price	Grid connection plus T&D	Tendency coming 10 yrs
	(USD/kW)	-	(USD/GJ)	(US cents/kWh)	(US cents/kWh)	
Solar PV grid connected (85%PR)[6]	3,000	0.2		24-28	3-7	Decrease 0%/yr
CSP grid connected no storage (90% PR)	5,500[1]	0.3-0.4		35-47	3-7	Decrease 10%/yr
CSP grid connected 8 hrs storage (90% PR)	8,500	0.5-0.7		31-43	3-7	Decrease 10%/yr
Large hydropower above 10 MW	1,000	0.5		4.5	3-7	Flat
Onshore wind 2 MW	1,750[2]	0.25-0.35		11-16	3-7	Flat
Onshore wind 0.2 MW	3,000	0.2-0.25		27-34	3-7	Decrease
Biomass bagasse boiler	2,500	0.5	0.5-3	12-15	3-7	Flat
Biomass co-combustion in coal-fired power plant	1,250	0.75	1-5	5-9	3-7	Flat
Geothermal high quality resource	5,000[3]	0.8		14	3-7	Unclear
Decentralised solutions						
Solar PV no battery[6]	3,500-4,500	0.2		30-47		Decrease 10%/yr
Solar PV with battery 2.4 kWh/kW[5,6]	5,000-6,000	0.2		45-65		Decrease 10%/yr
Small hydropower 0.1-1 MW	2,500-5,000	0.5		11-22		Unclear

[1] USD 6,000/kW for 100 MW Shams-1 plant in Abu Dhabi

[2] USD 3,750/kW for 100 MW Cape Town wind park project in South Africa, USD 2,175/kW for 300 MW Turkana wind park project in Kenya. This includes all project cost (AFD, 2011).

[3] USD 7,000/kW for 185 MW Olkaria project expansion in Kenya (AFD, 2011).

[4] Assumes 15% annuity plus 5% O&M. Excludes inflation and taxes/subsidies

[5] Given a 20% capacity factor, a 1 kW panel produces 1,740 kWh. If half of the electricity is stored, evenly divided over the days of the year, 2.4 kWh of daily storage is needed. If battery decharging is limited to 25%, 10 kWh of battery storage capacity is needed. For deep-cycling lead acid batteries this capacity costs USD 1500.

[6] The kW price refers to standard testing conditions of 1000 W/m^2. In practice average irradiation in Africa ranges from 5-6 kWh/day. Therefore the test condition with a 20% capacity factor would have an annual irradiation of 1,752 kWh. In reality the irradiation is 1,825-2,190 kWh. Therefore the panel in Africa will yield in practice 5-20% more electricity than under the test conditions.

As illustrated in Table 2, large hydropower is a clear winner in terms of production cost. It is followed by biomass co-combustion. However, this excludes the cost for grid connection, transmission and distribution. If these are added, the decentralised solutions seem cost-competitive.

All listed options have costs that are below those for diesel generators. However, for most options, the costs are somewhat higher than for coal- or gas-fired power plants. For fossil-fuelled plants, the fuel costs are highly variable and depend on market developments. Such risk does not exist for renewables plants. Also, renewables plants tend to be smaller, which reduces transmission cost and allows a more gradual expansion avoiding major supply variations. Decentralised generation reduces the risk of massive power outages.

But LCOE will not be the only factor that determines successful uptake of renewable electricity. Consumer ability to pay will also be a key factor. According to the World Bank:

"Surveys held in Mali concluded that the willingness to pay for electricity in rural areas averaged EUR 11.1/month (about USD 15), ranging from EUR 8.2 to EUR 16.7 (about USD 11 to USD 22.5) (Mostert, 2008). In Senegal, most rural households already spend USD 2-24 per month on kerosene and dry cell batteries to meet their lighting and small power needs, and hence are likely to be willing and able to pay for electricity use (de Gouvello et al., 2007). In Guinea, rural surveys obtaining data on avoided costs found that the willingness to pay for basic electricity services was about USD 1.6/month (Mostert, 2008), which would cover the cost of 12 kWh per month at the average tariff of the Sub-Saharan region (USD 0.13/kWh)." (WB, 2010).

Any form of electricity is a major expense under such conditions. A logical response is an emphasis on least cost solutions. However, this can be misleading. As stated earlier, LCOE is not always the right measure for economic evaluation of projects, and it is recommended that other economic valuation methods be explored.

6.2. NON-POWER RENEWABLE ENERGY OPTIONS

Renewable energy can also be used in heating applications, for transportation fuels and, in the case of biofuels, as a feedstock for synthetic organic materials, such as plastics. In the heating sector, low temperature building applications and higher temperature industrial applications can be discerned. Residential applications include hot water and heating. Heating is only needed in parts of Africa. Energy-efficient building design should be a priority. South Africa has started a large-scale solar water-heating programme. This could be expanded to other parts of the continent. Solar building heating requires a more fundamental change in building design. Solar cooling is still in a demonstration stage and not high priority for the coming five years.

6.3. BIOGAS

Biogas can be produced in large-scale plants connected to animal farms or in smaller-scale domestic units. Large-scale plants (more than 2,500 tpa of bio-waste and/or biogenic industrial waste) run on a well-established technology. In OECD countries, about 200 plants are in operation. In China, there are over one thousand bigger plants, many of which use industrial waste from paper, sugar and the pharmaceutical industry as feedstock. Domestic biogas units also run on a well-established technology. In 2010, China installed 4.9 million units for a total of 40 million operational plants. India constructed almost 120,000 units in the fiscal year 2009-2010 within the National Biogas and Manure Management Programme (NBMMP). In March 2010, it had a total of 4.25 million biogas plants. SNV installed 4,750 domestic biogas plants in nine African countries between 2007 and 2010 (SNV, 2011). In Kenya, Tanzania and neighbouring countries, biogas is traditionally used in small and very small installations for household energy and for social institutions. With GTZ support, over 1,000 small and medium-size plants and one bigger digester of over 100m^3 capacity were installed in Tanzania from 1983 on. In Niger, a system for a household with seven members needs dung from five head of cattle yielding around 11.3 m^3 of biogas per day. Estimates suggest a significant potential in rural areas, from 9% of rural households in Mali to 8-15% in

Burkina Faso, 23-28% in Uganda, 29% in Senegal and 35% in Rwanda (GTZ, 2010).

A study for Niger estimates an installation cost of USD 875 per household and annual operating and maintenance costs of 4% of the investment. Biogas use reduces wood fuel and kerosene use and residues can be used as a substitute for commercial fertiliser. The return on investment is 22-28% (EPM Consulting, 2008).

A recent study examined the theoretical potential of power generation from 13 types of biomass from agro-industrial businesses in Kenya to municipal waste in Nairobi (GTZ, 2010). The report concludes that the potential electric capacity of generated biogas is high. Biogas from all examined sub-sectors could cover up to 16% of total Kenyan electricity production. Municipal solid waste, sisal and coffee production are the most promising sectors with the greatest potential. However, specific electricity production costs for small plants (50 kWel) range from 0.11 to 0.29 USD/kWh. In comparison with the cost estimates in Table 2, this is in line with other new renewables options.

6.4. SOLAR WATER HEATING

In a region where only a small part of the population has access to running water, the need for hot water is still comparatively limited. However, it is estimated that approximately 40% of residential electricity consumption in South Africa can be attributed to water heating. Solar water heaters represent a low-cost alternative. In comparison to the electric geyser, the most commonly used technology for heating water in South Africa, the payback period for solar water heaters is estimated at 4 – 5 years, and up to 7 years for evacuated tubes. A "1 million solar hot water heaters by 2014" demand-side management (DSM) programme commenced in 2010 (Edkins et al., 2010).

Industrial applications for solar heating are just emerging. There are a few hundred demonstration projects around the world, virtually all in low-temperature heat demand applications such as dairies, other food processing industries, and laundries. Expansion of CSP will result in cost reductions for higher temperature and larger-scale solar heating applications, such as for the chemical industry (Taibi et al., 2011).

6.5. BIOMASS FOR INDUSTRIAL USE

Biomass is widely used as a fuel in cement kilns, brick and ceramics production and other higher temperature processes. So far use in Africa is low, and there is room for growth. Bagasse is already widely used for co-generation. Other forms of residues could be used more widely and more efficiently. In practice, collection and storage pose constraints and flexible systems that allow co-combustion of biomass during periods of abundance may often be preferable (Taibi et al., 2011).

6.6. BIOFUELS FOR TRANSPORTATION

Sub-Saharan Africa has nearly 200 million hectares of cropland. Yields are generally low. Only seven million hectares are irrigated, while there is a potential for 30 million hectares of irrigation. If better farming techniques were applied, crop yields could be raised substantially. In combination with reduced wastage of harvested food crops, there is room for biomass crops. But enhanced agriculture and water management are prerequisites.

The production of, and possibilities for investment in, biofuels in Africa requires consideration of such factors as geographical location, land use patterns, preferences, income distribution patterns, as well as cultural and social aspects. Provided that work is done, there is much scope for improving agricultural productivity. Furthermore, many countries already have policies in place, or are developing them, in order to regulate biofuels production. These policies are sophisticated, but the capacity to implement and monitor them may be limited (Chavez-Diaz et al., 2010).

Improved management practices could triple yields on land currently under cultivation. This would, potentially, free up land for biofuel production. But, given rapid population growth and increasing consumption of richer food, the remaining surplus land and biomass quantities may be limited. At the same time, some countries only cultivate a small part of available arable land (for example, in Mozambique, only 10% of arable land is currently under cultivation).

A number of crops are being considered. It is estimated that the area under sugar cane in the region could be doubled without reducing food production or destroying valuable habitats. Sweet sorghum shows promise for integration with sugar cane and extending production into drier areas. Both crops can be used for ethanol production. As for oil crops, jatropha (a diesel substitute) is being planted in southern Africa with plans for expansion, but is relatively unproven and has yet to reach commercial-scale oil production. Prospects for jatropha on marginal lands in Rwanda are considered marginal (DB). Oil palm is the crop with, by far, the highest biofuel yield. Today oil palm is mostly grown in West Africa but cold-tolerant varieties have been successfully demonstrated in southern Africa (Edkins, 2010).

These are all first generation biofuel options. Second generation biofuels are produced from wood, grasses and food crop residues. This opens up a different resource potential. However, the available residue quantities are unclear and more analysis is needed. Also, the technologies are not yet mature and the second generation fuels are still considerably more expensive than first generation fuels. It is projected that second generation biofuels production could grow worldwide to around five million litres by 2015, about 5% of total biofuel production. Enzymatic hydrolysis (ethanol production) has, at present, a production cost of 0.9-1.1 USD/lge. Rapid technology improvements are occurring that may bring cost down further, such as co-fermentation of Xylose C5 sugars. Gasification for the production of biodiesel costs at present 1.4-1.9 USD/lge. Cost reductions are more challenging but important economies of scale exist.

If a ten million hectare potential is assumed for Africa as a whole, with an average yield of 5 t biofuels per hectare, the biofuel potential is around 50 bn litres, more than half of current total global biofuel production. This is equal to around 50 Mtoe or two-thirds of total African transportation fuel demand (Figure 1). However, these numbers are speculative and more work is needed to assess bioenergy potential.

UN Photo/Sebastiao Barbosa © Bundles of sugarcane from which sugar can be extracted.

7. Technology transfer and deployment

Technologies face a number of barriers to widespread deployment. Policies must be designed to overcome these. IRENA is working in a number of areas, such as:

1. Independent technology cost and status information;
2. Enhanced technology access through a renewable energy patent database;
3. Work on standardisation, test procedures and best practices;
4. Establishment and strengthening of technology centres that can support clusters and supply chains for technologies adjusted to local conditions; and
5. Capacity building for technology transitions and information dissemination.
6. As part of the Africa Scenarios and Strategies project, the equipment supply situation will be assessed, as will the main barriers for technology transfer in Africa. This includes the following topics:
7. Analysis of the current renewable energy equipment supply situation in Africa for wind, solar PV, solar CSP, hydro, biomass combustion, biomass gasification, first and second generation biofuels, industrial biofuels and solar water heaters;
8. Evaluation of equipment supply and/or operation and maintenance as a potential barrier for building a manufacturing base and/or for using renewable energy equipment. Identification of the main issues (patents, technical expertise, capital, economies of scale, etc.);
9. Identification of the potential, need and viability of building up renewable energy equipment supply industry in Africa, and its impact on equipment cost and access;
10. Evaluation of current and projected import tariffs and non-commercial cost for establishing a renewable energy base in Africa; and
11. Evaluation of the existence of renewable energy equipment quality standards and gaps.

While these activities will help governments develop their technology policy, this alone is not sufficient. Successful transition to renewable energy requires action on the part of governments and the donor community. Government ownership, energy roadmaps, scenarios and strategies, sizeable efficient investment funds, transparent decision-making processes - all play a role. But government action alone is not sufficient. A massive roll-out of renewable energy investments is only possible through private sector participation. The private sector requires a credible long-term policy framework and a credible outlook for revenues from investments with a life span of decades. In a high-risk environment, investments will be limited to the few projects with exceptionally high returns.

The levels of carbon funding that are discussed today are small compared to the levels of investment that are needed in Africa. The future of CDM is unclear. Government policies should not be based on this uncertain source of revenues. The technology mechanism that is being discussed under the UNFCCC is still under development and it is not clear whether it will have a significant impact. However, it is important to account for the fact that the CO_2 challenge is here to stay and that high emitting assets may quickly lose value.

The access challenge has been widely studied. The World Bank concludes with regard to electricity that change of the policy framework is an imperative:

"In Sub-Saharan Africa, it is essential to overcome the current power sector performance problems for an electrification effort to be sustainable. The challenge could prove insurmountable if electricity prices remain below costs in favour of the few who have access to electricity. The power sector in sub-Saharan Africa is in the midst of a serious crisis, characterised by sub-optimal development of energy resources, high costs, under-pricing, and large inefficiencies in performance linked to governance constraints and a distorted set of incentives. In particular, under-pricing and regressive subsidies have become a serious impediment to providing electricity to rural areas and the urban poor. Also, technical and nontechnical losses are, on average, very high (30 to 35%). It is obvious that any effort to extend access will not be sustainable if there is no progress in addressing these sector-wide problems." (WB, 2010).

The World Bank also notes:

"Extending access is particularly challenging for low-income countries with low electrification rates. Once a country reaches a medium level of electrification and a certain income level—for example, 50% electrification and an average per capita income above USD 3,000 (valued at purchasing power parity)—it becomes easier to achieve universal access because there is an increasing critical mass of taxpayers and electricity consumers able to provide the funds needed to make electrification financially sustainable. The challenge is tougher in low-income countries where available resources and the numbers of consumers and taxpayers capable of contributing to subsidies tend to be limited. This situation is often aggravated by poorly performing utilities and regressive pricing policies subsidising those who can afford to pay cost-reflective tariffs and contributing to systematic deterioration of the operational and financial state of the power sector and its institutional capacity. The consequence is a perverse situation, in which higher-income consumers receive benefits they do not need (through subsidised rates and/or unbilled consumption), leaving few or no resources to expand access. However, outstanding cases of success among low income countries, clearly illustrate that it is possible to overcome these difficulties through sustained government commitment to a long-term approach with arrangements and procedures that maximise efficiency in the design and implementation of policies, strategies and programmes aimed at expanding access, combined with actions to improve the existing tariff systems and subsidisation schemes, as well as in the operational performance of utilities in charge of service provision." (WB, 2010).

Certain types of renewable energy can help to overcome some of these shortcomings of the policy environment. Especially small-scale solutions deserve attention in the African context because they can be implemented easier. Smaller projects can be financed locally and they can be introduced gradually. The transportation challenge for the equipment is reduced. While the risk of failure of individual systems is increased, their sheer number virtually precludes failure of the whole supply at once. Offgrid solutions and mini-grids avoid the need for transmission infrastructure. Of course these benefits must be weighted against cost and other aspects. But it is fair to say that consideration of renewables will significantly broaden the range of options available to any African decision-maker. Increasingly cost-effectiveness will also favour renewables. And active technology deployment policies can help to broaden the application of renewables.

8. Conclusion

AFRICAN GOVERNMENTS MAY WANT TO:

1. Consider renewables as an option and ensure that their evaluation is based on the latest data;
2. Assess their renewables resource potential on a sufficiently detailed level;
3. Consider explicitly the role of renewables in all major market segments (power, transportation and stationary applications);
4. Consider key renewable energy options: large and small hydro, solar PV, solar CSP, solar water heating, biogas, solar water heating, first and second generation biofuels;
5. Integrate land use planning, water planning, agricultural productivity enhancements with energy planning;
6. Develop sufficiently specific project concepts and rank these in terms of priorities;
7. Consider how to reduce equipment supply cost, for example through an import tax exemption framework, development and strengthening of national equipment supply chains and clusters and high shares of nationally manufactured content;
8. Use energy planning tools and scenarios for development of strategies and portfolios;
9. Evaluate and adjust their policy frameworks to reduce risk for investors;
10. Minimise market distortions such as subsidies. Ensure a level playing field;
11. Consider development of improved public datasets, including energy balances and technology information; and
12. Reduce outages through massive capacity additions and better maintenance of existing capital stock.

UNDP-GEF Photo library © Solar Water Heaters (SWHs) for Low-income Housing in Peri-Urban Areas. South Africa.

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Acronyms and abbreviations

AER	Advanced Energy Revolution
CDM	Clean Development Mechanism
CSP	Concentrated Solar Power
DSM	Demand Side Management
EJ	ExaJoule
ER	Energy Revolution
EREC	European Renewable Energy Council
GDP	Gross Domestic Product
GHG	Greenhouse gas
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (since 2010 GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit)
GW	GigaWatt
KWel	Kilowatt electric
LCOE	Levelised Cost of Electricity
Lge	Litres of gasoline equivalent
LPG	Liquefied Petroleum Gas
Mtoe	Millions of tons of oil Equivalent
NGCC	Natural gas combined cycle
O&M	Operation and maintenance
OECD	Organisation for Economic Co-operation and Development
ppm	Parts per million
SNV	Netherlands Development Organisation
T&D	Transmission and distribution
Tpa	Tonnes per annum
TWh	TeraWatt Hour
UNFCCC	United Nations Framework Convention on Climate Change

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