Module 2

The energy sector in Africa

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

CONTENTS

1. MODULE OBJECTIVES

1.1. Module overview

Africa's energy sector is broad and a few sectors were selected in this module to illustrate the status and recent developments in the power, renewable energy and energy efficiency issues in the region. The module specifically provides a broad overview of the energy sector in Africa and in its later sections delves into specific overviews of the power sector, renewable energy and energy efficiency.

The module is organized into three sections. Section 1 provides an overview and the status of the power sector in Africa. Section 2 provides a broad overview of renewable energy technologies and their status in Africa. The section continues to discuss the potential benefits of renewable energy technologies in Africa. Section 3 describes the status of energy efficiency in Africa and the barriers faced in enhancing renewable energy and energy efficiency in the region. The section concludes by describing the efforts required in overcoming the barriers to energy efficiency.

In each of the sections, a set of questions is provided for discussion. The questions would enable learners to discuss specific sections of the module and provide experiences in their own countries. The concluding section presents the main points discussed in the module. Other sections provided in the module include references, Internet resources, answers sections, and a glossary/ definitions of key concepts.

1.2. Module aims

The aims of the present module are listed below:

- Provide an overview of the energy sector in Africa;
- Present the status of the performance of the power sector in Africa;
- Highlight key characteristics of the power sector in Africa;
- Review the status and the benefits of renewable energy in Africa;
- Provide an overview of energy efficiency in Africa;
- Review the benefits of energy efficiency with special emphasis on the industrial sector.

1.3. Module learning outcomes

The present module attempts to achieve the following learning outcomes:

- Broad appreciation of key elements of the energy sector in Africa;
- Enhanced understanding of the current status of the power sector, renewable energy and energy efficiency in Africa;
- Better grasp of the benefits of renewable energy and energy efficiency in Africa.

2. INTRODUCTION

While this module uses Africa-wide data, emphasis is placed on sub-Saharan Africa—the region where the need to improve modern energy services for the poor is particularly acute. In addition, although the title of this module includes the wider term “energy”, the bulk of the module focuses on the power sector, renewable energy and energy efficiency. It therefore does not explore other sources of energy such as oil and natural gas.

It is widely recognized that the availability of modern, reliable and efficient energy services is an important and indeed essential driver for economic development. Most countries in Africa, however, face major challenges in trying to achieve their development and social obligations because of inadequate access to modern energy services—a situation which needs to change if the continent and its sub-regions are to be economically competitive with other developing regions of the world and realize their sustainable development goals.

Many countries in Africa are still meeting a large proportion of their national energy demands from traditional biomass, which often has adverse environmental and health impacts. Renewable energy and energy efficient technologies have not attracted the level of investment or policy commitment they require and have not been widely disseminated in the region. Resources allocated to developing renewable energy technologies and energy efficient systems are negligible in comparison to resources allocated to the conventional energy sector.

3. POWER SECTOR

3.1. Definition and key players in the power sector

The power sector can be defined as an energy sector that consists of both electricity generation plants (and combined heat and power (CHP) plants) and transmission and distribution infrastructure, and whose primary business is to generate, transport and sell electricity (or electricity and heat in the case of CHP) to the public. Key players in the sector in Africa include utilities, independent power producers (IPPs), transmission system operators and distributors, rural electrification agencies and funds, as well as ministries and regulators (for policy design and policy implementation—through regulation—respectively).

Other players include manufacturers and consulting engineers who supply equipment and services for the generation, transmission and distribution of electric power by utilities and other power producers. The sector includes issues related to management and regulation of the players in the sector, production, transmission, and distribution of power as well as services related to the production, installation, overhaul and maintenance of power equipment and related consulting engineering.

3.2. Status of the power sector in Africa

Electricity is needed both to industrialize and provide basic energy for the majority of the people living off the grid in rural areas. Most sub-Saharan African (SSA) countries face a major challenge in trying to achieve their development and social obligations because of inadequate modern energy services. Low levels of electricity access in SSA demonstrate this deficiency as an estimated 17 per cent of the region's population, and less than 5 per cent of rural areas are electrified (Davidson and Sokona, 2002). This situation needs to change if sub-Saharan Africa is to be economically competitive with other developing regions of the world and realize its sustainable development goals.

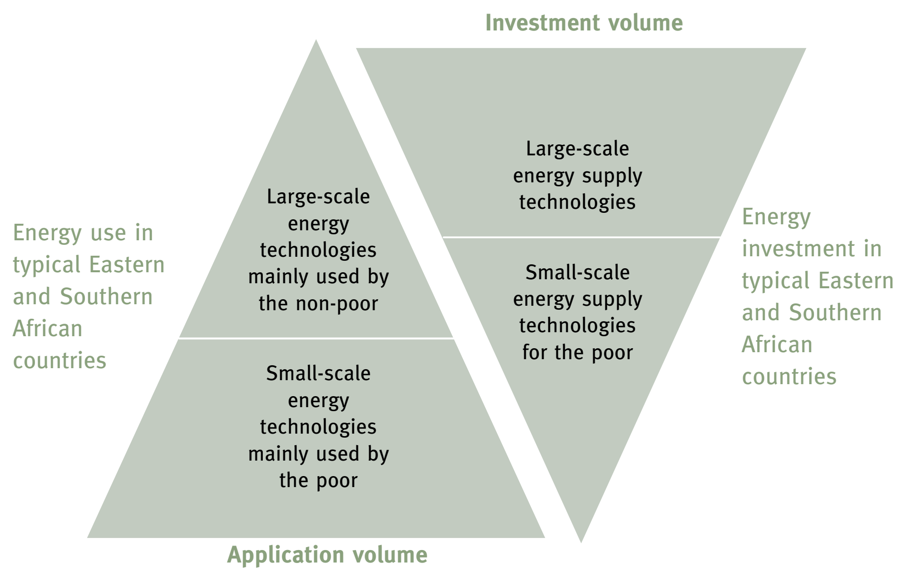
Characteristics of the African power sector

Sources of power supply in Africa broadly reflect each sub-region's energy resource endowment. For example, oil and gas reserves are concentrated in North and West Africa—consequently, the power sector of these two sub-regions is dominated by fossil fuel fired electricity generation systems. On the other hand, the electricity industries of Eastern and Central Africa are dominated by hydroelectric power plants with some limited use of geothermal based and biomass based power stations. Coal (and to a lesser extent hydropower) is the dominant fuel for much of the Southern African power industry.[1]

Figure I. **Map of Africa showing North, South and sub-Saharan African countries**

The African power sector is characterized by small systems, with over three-quarters of the continent's installed capacity coming from South Africa and North Africa (World Bank, 2003 a; IEA, 2002). This is in spite of the fact that the large-scale conventional energy sector (electricity and petroleum) receives the bulk of energy investment in most African countries (Wolde-Ghiorgis, 2002) and serves only a small proportion of the population, with provision of electricity being largely confined to urban middle and upper income groups and to the formal commercial and industrial sectors. Figure II illustrates this somewhat paradoxical situation.

Figure II. **Energy use vs. energy expenditure in typical Eastern and Southern African countries**



[1]Africa is a diverse group of countries in many respects, especially in terms of economic system and level of economic development. Nonetheless, it has become common for countries of Africa to be grouped according to the system used by the African Development Bank (AfDB). The system contains North Africa (Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, Tunisia); West Africa (Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo); East Africa (Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Uganda, United Republic of Tanzania); and Southern Africa.

In spite of substantial investment, the power sector in sub-Saharan Africa is characterized by unreliability of supply, low capacity utilization and availability factor, deficient maintenance, poor procurement of spare parts and high transmission and distribution losses. The financial performance of many power utilities throughout Africa is largely unsatisfactory (Karekezi and Kimani, 2002, AFREPREN/FWD, 2001b; Teferra, 2000; Mapako, 2000; Kayo, 2001; Dube, 2001; NER, 2001).

In addition, power utilities in Africa have, by and large, failed to provide adequate electricity services to the majority of the region's population, especially to rural communities and to the urban poor (Karekezi and Kimani, 2002; Karekezi et al, 2004). In spite of abundant resources of both fossil and non-fossil energy resources, the majority of the population in African countries is without access to electricity for lighting and relies on low quality energy resources, such as firewood and charcoal to satisfy cooking needs.

Table 1. Access to electricity and modern cooking fuels in 2002. (*World Bank, 2000 and IEA, 2004*)

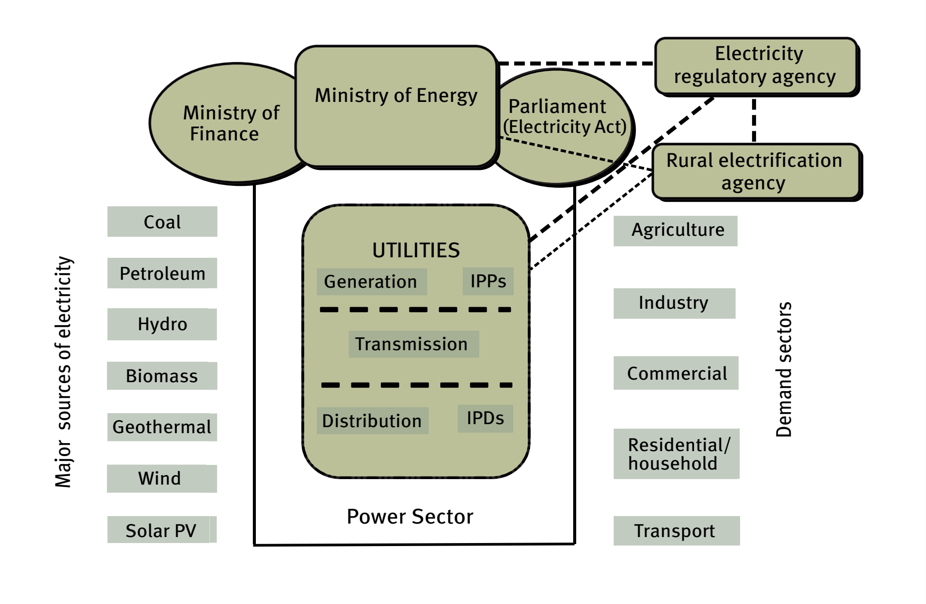
Country or region	Population using biomass for cooking (million)	Population without electricity (million)	Urban population with electricity (%)	Rural population with electricity (%)
North Africa	n.a.	**9**	**99**	**88**
Sub-Saharan Africa (SSA)	**575**	**526**	**52**	**8**
Africa	n.a.	**535**	**62**	**19**
South Asia	713	798	69	33
Latin America	96	46	98	61
China and East Asia	998	216	96	83
Middle East	8	14	99	78
Developing economies	**2,390**	**1,615**	**85**	**52**

It is estimated that 64 per cent of Africa's population—equivalent to about more than 500 million people have no access to electricity. These figures mask huge differences between the various African countries. Most North African countries have high levels of access to electricity. Except for Ghana, Mauritius, Seychelles and South Africa, none of the SSA countries have electricity rates that exceed 50 per cent, and in about half of the African countries, the electrification rate is under 25 per cent. In more than 10 countries, less than 10 per cent have access to electricity. While 52 per cent of the population in SSA in urban areas have access, the rate is as low as 8 per cent in rural areas.

Institutional structure of the African power sector

Figure III illustrates the typical institutional structure of the power sector prevailing in many African countries covered in the study.

Figure III. **Typical institutional structure of the power sector in Africa**



Source: Compiled by authors.

Key:

IPPs = Independent power producers.
IPDs = Independent power distributors.

Prior to power sector reforms, very few African countries had an Electricity Regulatory Agency and IPPs. With the on-going reforms, IPPs now constitute important new players alongside the state-owned utility at the generation and distribution levels. Independent power distributors (IPDs) are few and far between.

Another important development is the growing number of relatively independent rural electrification agencies whose principal responsibility is to enhance access to electricity among the rural population through investments in electricity transmission and distribution infrastructure and in some cases subsidizing capital investment in rural electricity generation.

Power sector reforms have transformed the parliament into a crucial institution in the sector due to its important mandate of formulating and amending the Electricity Act that governs the power sector. In a few cases, parliamentary committees in charge of energy have begun to flex their oversight roles over their respective country's energy sector. The Ministry of Energy[2] continues to be the dominant player even in the new "reformed" power sector through the Ministry's control over policy formulation, implementation and, more importantly, control over key senior appointments in state-owned power sector entities. The Ministry of Finance is also an important institution because of its critical role in key power sector financing and investment decisions.

Installed capacity, electricity generation and consumption in Africa

As shown in figure III, there are seven major sources of electricity supplying electricity to the main demand sectors. However, the core sources of electricity in most sub-Saharan African countries are hydropower, oil products and coal. In Southern Africa, the dominant sources of electricity are coal (e.g. in South Africa and Zimbabwe) and hydropower (e.g. Lesotho, Malawi and Zambia). Kenya is the only country to commercially exploit geothermal energy for electricity generation (Ethiopia has attempted to exploit its geothermal resources but with less success). This is in contrast to North African countries, which depend on petroleum-based electricity generation. In most of sub-Saharan African countries, biomass in the form of bagasse is used for cogeneration in sugar industries. Wind power use is growing in North Africa. Solar PV systems are mainly used in rural areas to meet light electrical loads such as lighting, radio and television.

The major electricity demand sectors are industry, commerce and households. Use of electricity for transport is largely limited to electric trains in parts of Southern and Northern Africa. In agriculture, some electricity is used in large farms as well as in agro-industries.

The total electricity production for Africa in 2000 was 441 TWh (IEA, 2002). The bulk of the electricity produced in Africa is from thermal stations, because of the large coal plants in South Africa and oil fired generation units of Nigeria and North Africa. In spite of the massive exploitable hydropower capacity in Africa, its contribution to total power generation is relatively low. Hydropower contributes about 18 per cent of the total power generation in Africa (figure IV).

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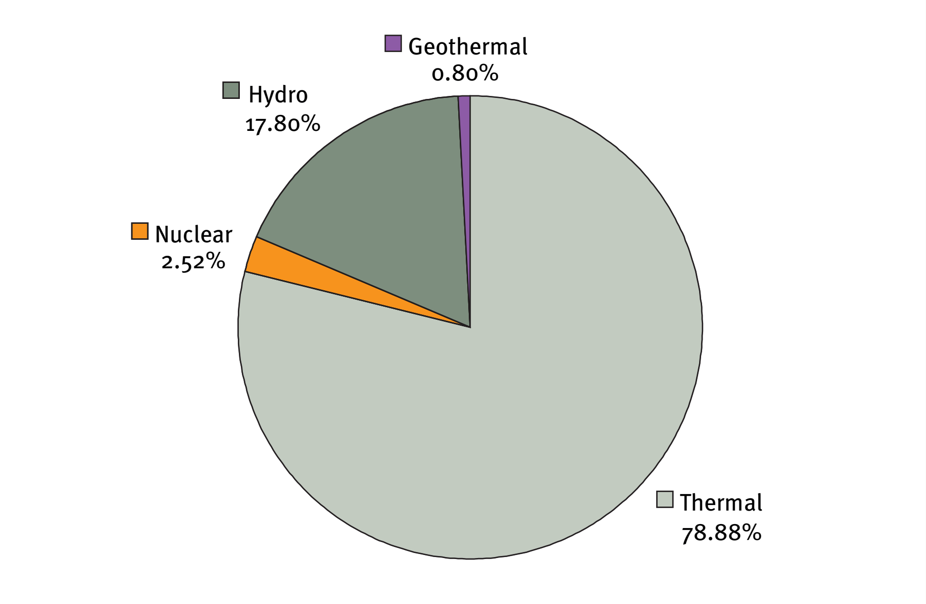
[2]For some countries in Africa, the Ministry in charge of the energy sector may not always be the Ministry of Energy. Others could be: Ministry of Natural resources or Ministry of Mines and Energy.

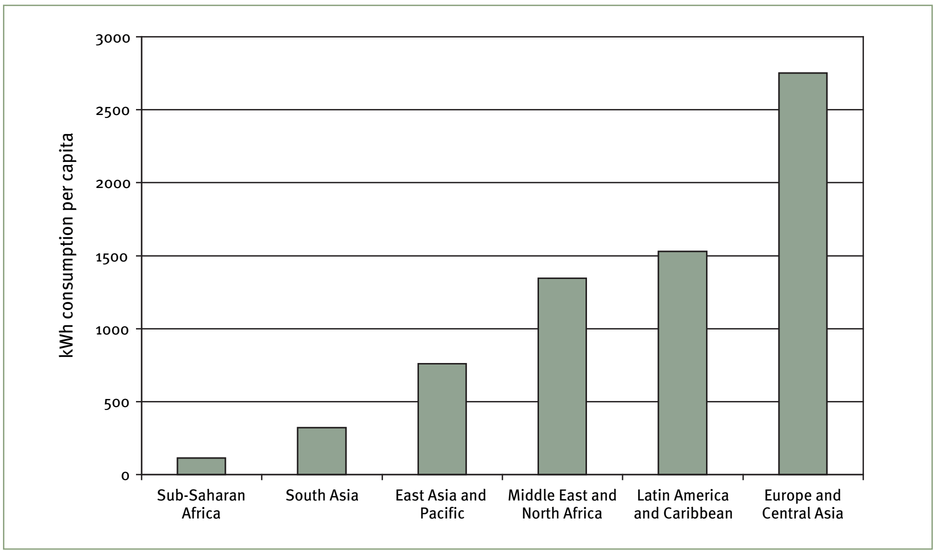
Figure IV. **Electricity production in Africa (2004)[a]**



[a]Does not include cogeneration, back-up power plants and other off-grid power generators, which could total to a significant contribution to the region's power supply. Many cogeneration plants especially in agro-processing industries are used for own consumption (used by plant/factory generating the electricity) and may not be registered in national electricity statistics. For example, in Mauritius, cogeneration accounts for 40 per cent of the country's power supply (Veragoo, 2003).

Source: IEA, 2005.

Figure V. **Electricity consumption per capita by regions of the world (2000)**



Source: World Bank, 2003a.

Electricity demand in the region, on a per capita consumption basis, is very low. The average electricity consumption per capita in sub-Saharan Africa (excluding South Africa) is estimated to be about 112.8 kWh (World Bank, 2003). A more detailed assessment of the annual per capita consumption of electricity at national level reveals extremely low levels of electricity use for some sub-Saharan African countries, as shown in table 2.

Table 2. Electricity consumption per capita for selected sub-Saharan African countries (2000)

Country	kWh per capita
Ethiopia	22.1
D.R.Congo	40.2
Eritrea	40.7
Mozambique	52.6
United Republic of Tanzania	55.6
Uganda	57.9
Benin	63.6
Sudan	66.2
Malawi	73.3
Nigeria	80.9
Congo	86.1
Angola	88.2
Kenya	117.0
Zimbabwe	874.0

Sources: IEA, 2002; AFREPREN/FWD, 2003, World Bank 2003a

3.3. Performance of the power sector in Africa

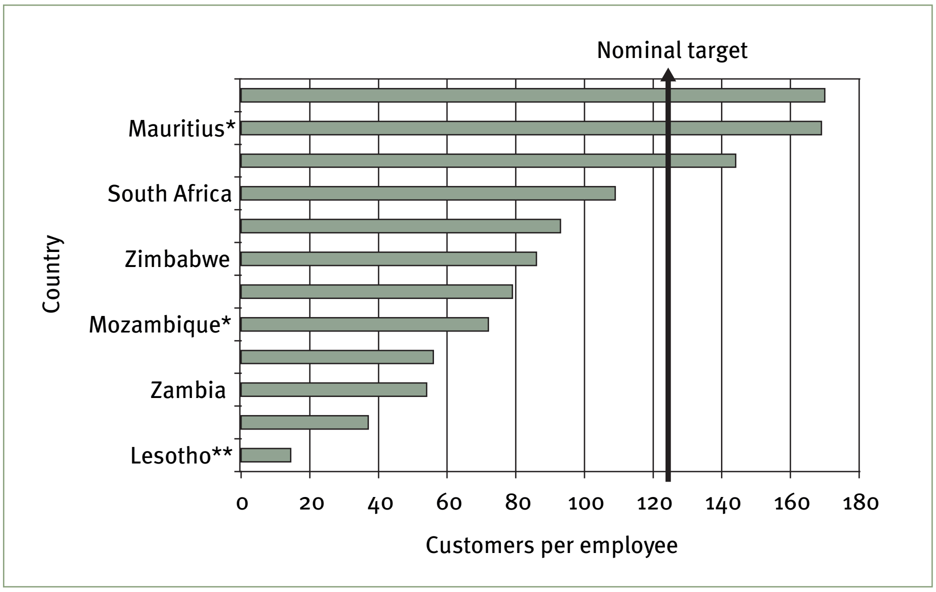
The performance of the power sector in the African region varies widely depending on the level of economic development of a particular country, political conditions as well as the approach used to reform the electricity industry. This section provides a detailed assessment of the performance of the power sector in the region based on the findings of country studies. The performance of the power sector can broadly be categorized into two: *(a)* technical performance—taking into account indicators of utilities' technical and management operations; and, *(b)* financial performance.

Technical performance

Traditionally, power utilities in Africa have enjoyed a monopolistic hold over their national electricity industry. There is growing consensus that this monopoly has contributed to the undeniable under-performance in the delivery of electricity services (Karekezi and Mutiso, 1999). As mentioned earlier, power sector institutions are mainly characterized by unreliability of power supply; low capacity utilization and availability factors; deficient maintenance; poor procurement of spare parts; and high transmission and distribution losses among other problems.

With the exception of Côte d'Ivoire, Egypt, Eritrea, Mauritius and Uganda, customers per employee ratios of most sub-Saharan African utilities are below the international norm, as shown in figure VI. This measure of performance should, however, be treated with some caution because of its inability to differentiate between utilities that are essentially generation-only entities from those which encompass both generation and distribution.[3]

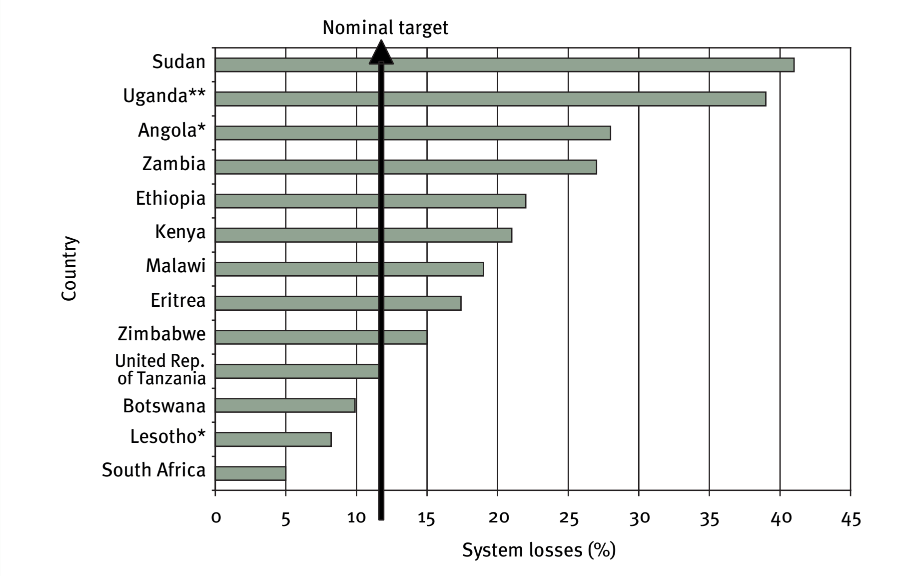
Figure VI. **Customers per employee in selected African countries (2001)**



Sources: AFREPREN/FWD, 2003; Okumu, 2003; Kinuthia, 2003.
*1999 data.
**1996 data.

[3]In many French-speaking African countries, national power utilities are often in charge of water distribution as well. This distorts the customer per employee indicator.

Figure VII. **System losses in selected African countries (2001)**



Sources: AFREPREN/FWD, 2003; Okumu, 2003; Kinuthia, 2003.
*1996 data.
**2002 data.

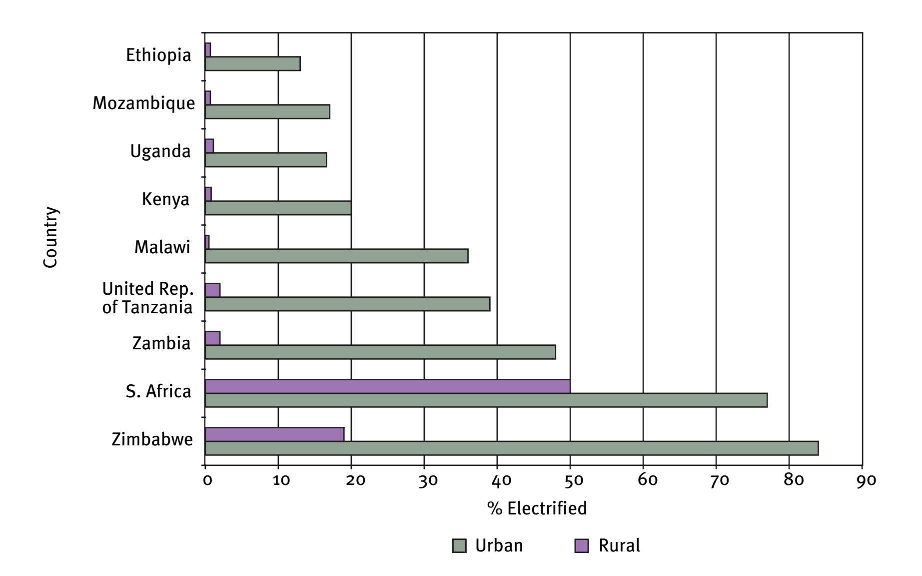
The electricity supply industry in Africa is characterized by high system losses when compared with the international target of about 10-12 per cent (figure VII). Some of the power systems in Africa record figures as high as 41 per cent.

As mentioned earlier, most power utilities in Africa have failed to provide adequate levels of electricity services to the majority of the region's population, especially to rural communities and the urban poor. Provision of electricity is largely confined to the privileged urban middle and upper income groups as well as the formal commercial and industrial subsector.

Household electrification is low especially in the rural areas of sub-Saharan Africa—where the majority of the poor in Africa reside. With the exception of Zimbabwe and South Africa, statistics also show that even in urban areas, the percentage of households served with electricity is still relatively small (figure VIII).

At national level, with the exception of North African countries, Côte d'Ivoire, Ghana, Mauritius, Nigeria, South Africa and Zimbabwe, and the rest of sub-Saharan Africa generally register electrification levels well below 30 per cent. This is a very low figure, compared to other developing countries in Asia and Latin America, which are able to supply more than 70 per cent of their population with electricity.

Figure VIII. **Urban and rural electrification in selected African countries (2001)**



Sources: AFREPREN/FWD, 2003; Okumu, 2003; Kinuthia, 2003.

Financial performance

The financial performance of utilities in most African countries is equally unsatisfactory. The debt owed by customers in most utilities is usually a sizeable amount. In most cases, governments and their parastatals account for a large share of the utility debt. For instance, by 1997, the Government of the United Republic of Tanzania owed its national utility 30 billion Tanzania shillings ($US 47.62 million). This, according to Tanzania's Prime Minister, has exacerbated the country's power problems (Kibanga, 1997).

The inability of utilities to mobilize sufficient investment capital for the development and expansion of the electricity sector is an important reason for embarking on comprehensive reforms. The development of power supply has absorbed a relatively large share of the public investment in many African countries. Governments have traditionally guaranteed the financing of power sector investment. In addition, most governments have adhered to the belief that low-priced electricity is critical to achieving economic and social development. Consequently, electricity tariffs in some African countries still demonstrate the legacy of non-sustainable pricing policies. Low tariffs are often an indication of substantial subsidies from the Government. On the other hand, countries in West Africa, particularly French-speaking countries, seem to record very high tariffs which may be attractive to investors but could have a detrimental impact on low-income electricity consumers. Reform of the electricity sector in Eastern and Southern Africa has also led to steep increases in electricity prices.

In most countries, the cost of poor financial management in the utility has, in the past, been transferred to the whole population in the form of increased national debt or inclusion of electricity debt in debt relief programmes (which takes resources away from other sectors such as health and education). This is an inequitable arrangement given that the entire population is responsible for repayment of a debt incurred by a power utility that serves on average, less than 30 per cent of the population (AFREPREN/FWD, 2001a).

To conclude, most African power utilities routinely record unsatisfactory technical and financial performance which compares poorly with their counterparts in other developing countries in Latin America and South-East Asia. In the past, it has been observed that, even when a new effective management team took over an African utility, the improved performance that ensued petered out over time. The utility usually reverted to its historically poor performance. This was largely attributed to the continued influence of Government.

Consequently, many utility analysts became convinced that only more drastic structural changes to the power sector could lead to sustained improvements in technical and financial performance. It is this reasoning that, in part, led to power sector reform.

Review questions

1. Define the power sector.
2. List some of the main players in the power sector.
3. What are some of the key characteristics of the power sector in Africa?

Discussion questions/exercises

1. List some of the key players in the power sector in your country and discuss their role.
2. Discuss with colleagues the performance of the power sector in your country.

4. RENEWABLE ENERGY

4.1. What is renewable energy?

Renewable energy refers to energy forms that cannot be easily depleted. Renewable energy sources occur naturally, and encompass energy forms, such as wind, solar, hydro, biomass, geothermal, tide and wave energy. A wide range of renewable energy technologies has been disseminated in Africa, with varying levels of success. Africa is endowed with substantial renewable energy resources. The region has 1,100 MW of hydropower capacity, 9,000 MW of geothermal potential (hot water and steam based), abundant biomass, and significant solar and wind potential (Karekezi and Ranja, 1997; BCSE, 2003). The following sections highlight the status of renewable energy in Africa and their benefits to the region.

4.2. Status of renewable energy technologies in Africa

The following subsections review the status of renewables in Africa. To begin with, small and medium renewable energy technologies are reviewed, after which the focus turns to two medium to large-scale renewable energy technologies namely, biomass cogeneration and geothermal.

Small hydropower

Small hydropower is often categorized into mini and micro hydro, referring to the harnessing of power from water at a small scale (capacity of less than 10 MW). Small hydro has the advantage of multiple uses: energy generation, irrigation and water supply. It is also a very reliable technology with a solid track record, well suited to rural areas outside the central power grid (Hydronet 3, 1994; Pandey, 2002).

Figure IX. **Small hydro powerhouse**

Figure X. **De-silting tank**

Much of the unexploited potential for small hydro is in remote areas of Africa (Hydronet 3, 1994). Eastern and Southern Africa have many permanent rivers and streams providing excellent hydropower development potential. However, as shown in table 3, small hydro utilization in the region is still very low.

Table 3. Small hydropower developed and potential in selected African countries

Country	Small hydro potential (MW)	Harnessed (MW)
Uganda	46	8.00
Mauritius	—	6.70
Kenya	600	14.00
Burundi	42	18.00
Zambia	4	1.05
United Rep. of Tanzania	70	9.00
Lesotho	—	8.74
Malawi	—	5.10
Botswana	—	1.00
Rwanda	20	3.00
South Africa	—	0.40
Swaziland	—	0.30
Mozambique	—	0.10

Source: Karekezi and Ranja, 1997; www.small-hydro.com; *Innovation Energies Developpement (IED)*, 2006; Presentation, Unilever Kenya, 2006.

Solar energy

Direct solar energy can be broadly categorized into solar photovoltaic (PV) technologies (converting the sun's energy into electrical energy) and solar thermal technologies (using the sun's energy directly for heating, cooking and drying, etc.) Solar energy is the best-known renewable energy technology in Africa. It has been in use for a long time for drying animal skins and clothes, preserving meat, drying crops and evaporating seawater to extract salt (Karekezi and Ranja, 1997).

Substantial research has been undertaken over the years into exploiting Africa's huge solar energy resource. Today, solar energy is utilized at various levels. On a small-scale, it is used at the household level for lighting, cooking, water heaters and solar architecture houses. Medium-scale appliances include water heating in hotels and irrigation. At the community level, it is used for vaccine refrigeration, water pumping, purification and rural electrification. On the industrial scale, it is used for pre-heating boiler water for industrial use and power generation, detoxification, municipal water heating, telecommunications, and, more recently, transportation (solar cars) (Karekezi and Ranja, 1997; Ecosystems, 2002).

Solar PV has been promoted widely in the region, with almost every sub-Saharan African country having had a major PV project. There is growing evidence, however, that solar PV projects in the region have mainly benefited high-income segments of the population, due to the high cost of solar PV. Solar PV is unaffordable to the majority of the population in Africa (Karekezi and Kithyoma, 2002; Mulugetta, et al 2000, Mapako, 2001; Cloin, 1998).

Table 4. Estimated number of solar PV systems disseminated

Country	Number of systems	Estimated installed capacity (kWp)
Angola	—	10
Botswana	5,700	1,500
Burundi	1,800	—
Djibouti	941	—
Eritrea	2,000	400
Ethiopia	5,000	1,200
Kenya	150,000	3,600
Mozambique	—	100
Malawi	900	40
South Africa	150,000	8
Swaziland	1,000	50
United Rep. of Tanzania	2,000	300
Uganda	3,000	152
Zambia	5,000	400
Zimbabwe	84,500	1,689

Source: AFREPREN, 2004; AFREPREN, 2003; Mapako and Mbewe, 2004; MPWE, 1994; Kgathi et al., 1997; www.uneprisoe.org; Karekezi and Ranja, 1997; Karekezi et al., 2004.

Solar thermal technologies that have been disseminated in Africa include solar water heaters, solar cookers (Kammen 1991; 1992), solar stills and solar dryers. With increased efficiency and reduced cost of solar water heaters, small-scale solar water heaters have a payback period of 3-5 years (Karekezi and Karottki, 1989; Karekezi and Ranja, 1997). However, the diffusion of these systems has been slower than anticipated. In some developing countries, LPG subsidies make it difficult for solar water heaters to be competitive (Vanderhulst et al., 1990).

In sub-Saharan Africa, not much aggregate data on the dissemination of these systems has been gathered (Ward et al., 1984; Karekezi and Ranja, 1997). The data available are from just a few country studies. For example, in Botswana, about 15,000 domestic solar water heaters have been installed (Fagbenle, 2001). In Zimbabwe, about 4,000 solar water heaters are in use (AFREPREN, 2001). Additional estimates on solar water heater installed capacity are provided in table 5. The bulk of the solar water heaters in use are bought by high-income households, institutions and large commercial establishments such as hotels and game lodges.

Table 5. Domestic solar water heater installed capacity

Country	Installed capacity (1000 m^2)
Botswana	50
Malawi	4.8
Mauritius	40
Namibia	24
Seychelles	2.4
South Africa	500
Zimbabwe	10

Source: DBSA, 1999; Mogotsi, 2000; Mandhlazi, 2000; Mapako, 2000; AFREPREN, 2002.

Wind energy

Low wind speeds prevail in many sub-Saharan African countries, particularly in land-locked countries. South Africa, North Africa and the Red Sea coast have some of the highest wind potential in the region. Average wind speeds of 7.2–9.7 m/s have been recorded around Cape Point and Cape Alguhas in South Africa (Diab, 1986; Afriwea, 2005). The North African coast is another attractive wind speed region.

Large-scale wind power generation projects to exploit this abundant energy source are now under way in Morocco, Egypt and South Africa. Kenya has a few wind generators that are connected to the grid (Afriwea, 2005; KPLC, 2003; KENGEN, 2003).

In comparison with other parts of the world, Africa has seen little development of modern wind turbines and most of its wind machines (found in Eastern and Southern Africa) are used for water pumping, rather than for electricity generation. Wind pumping supplies water for household use, irrigation and for livestock (Harries, 2002). South Africa and Namibia possess large numbers of wind pumps. An estimated 300,000 wind pumps are in operation in South Africa. The dissemination of wind pumps in selected African countries is shown in table 6.

Table 6. Average wind speed potentials and number of wind pumps for selected countries

Country	(Average) wind speed potential (m/s)	Number of wind pumps
Botswana	2-3	200
Burundi	>6	1
Djibouti	4	7
Ethiopia	30.5-5.5	—
Eritrea	3-8	<10
Guinea	2.0.40	—
Kenya	3	272
Mauritius	8.0	—
Morocco	>10	—
Mozambique	0.7-2.6	50
Namibia	—	30,000
Rwanda	—	—
Seychelles	3.62-6.34	—
South Africa	7.29-9.7	300,000
Sudan	3	12
United Rep. of Tanzania	3	58
Uganda	4	7
Zambia	2.5	100
Zimbabwe	3-4	650

Sources: Diab, 1988; Stassen, 1986; Linden, 1993; Fraenkel et al., 1993; Kenya Engineering, 1994; IT Power, 198; Mosimanyane et al., 1995; Sampa, 1994; Sawe, 1990; Mwandosya and Luhanga, 1983; Turyahikayo, 1992; Razanajatovo et al., 1994; Karekezi and Ranja, 1997; Karekezi and Kithyoma, 2002.

Small-scale biomass energy

In the past 20 years, substantial efforts have been made towards modernizing small-scale biomass energy systems. Two of the most sustained efforts have been the development of an energy efficient charcoal kiln and an environmentally sound improved cooking stove for rural and urban households in sub-Saharan Africa. Both of these initiatives have delivered significant benefits to the urban and rural poor. The informal sector, which provides employment to the urban poor, is the principal source of improved stoves (Karekezi, 2002).

In terms of energy used per system, small-scale traditional bio-energy systems appear marginal. However, their importance lies in the very large number of users of such systems—bio-fuelled cookstoves meet the bulk of cooking, heating and lighting needs of most rural households in Africa (Karekezi, 2002; Karekezi and Kithyoma, 2002).

Charcoal is an important household fuel and to a lesser extent, industrial fuel. It is mainly used in the urban areas where its ease of storage, high-energy content and lower levels of smoke emissions make it more attractive than wood fuel. It is the primary fuel for the urban poor in Africa (Kalumiana, 2002).

Traditional charcoal production, a major source of employment for the rural poor, relies on the rudimentary earth kiln considered to be a contributor to land degradation in many peri-urban regions of sub-Saharan Africa. Efforts to improve and modernize small-scale biomass energy constitute an important component of national energy strategies in many sub-Saharan African countries and could potentially yield major benefits to both the urban and rural poor (Karekezi, 2002).

Another small-scale biomass energy technology that has attracted considerable attention over the last three decades is biogas. Conceptually, biogas technology appears simple and straightforward. The raw material is animal dung, plentiful in many rural areas of sub-Saharan Africa; the technology appears not to be overly complicated; and it requires a relatively limited level of investment. The technical viability of biogas technology has been repeatedly proven in many field tests and pilot projects. However, numerous problems have arisen when mass dissemination is attempted (Karekezi, 2002).

Table 7. Small and medium-scale biogas units in selected sub-Saharan African countries

Country	Number distributed
United Republic of Tanzania	>1,000
Kenya	500
Botswana	215
Burundi	279
Zimbabwe	200
Lesotho	40
Burkina Faso	20

Source: Karekezi and Ranja, 1997; Karekezi, 2002.

First, dung collection has proved more problematic than anticipated, particularly for farmers who do not keep their livestock penned in one location. Second, small-scale farmers with small herds were not able to get sufficient feedstock to feed the bio-digester unit and ensure steady generation for lighting and cooking. The investment cost of even the smallest biogas unit is also prohibitive for most poor African rural households (Karekezi and Ranja, 1997; Karekezi, 2002).

Though evidence from many African countries is still limited, the general consensus is that the larger combined septic tank/biogas units that are run by institutions such as schools and hospitals are more viable than small-scale biogas digesters (Karekezi, 2002).

Large-scale biomass energy (cogeneration)

Large-scale biomass utilization encompasses direct combustion for process heat; ethanol production; gasification; heat cogeneration; biogas production; and briquetting. The best-known large-scale biomass energy systems with sound economic track records are cogeneration using biomass as fuel stock and the production of ethanol as a substitute for petroleum fuel (Karekezi and Ranja, 1997). This section focuses on biomass cogeneration.

Cogeneration is the simultaneous production of electricity and process heat from a single dynamic plant. A cogeneration plant heats up steam that drives a turbine to produce electricity. Various forms of biomass can be used to fuel the plant including bagasse (sugarcane waste) from sugar industries and wastes from paper and pulp, palm wood and rice industries. For instance, in cane milling industries, cane stalks are shredded and crushed to extract cane juice while a by-product, bagasse, is sent to the boiler to provide steam and electricity for the factory (Deepchand, 2001).

Cogeneration offers substantial opportunities for generating electricity and/or heat energy with limited capital investments, while avoiding the negative environmental effects of increased fossil fuel combustion. Industries can be located in remote areas not linked to the electricity grid. Extra electricity can be made available to other users through mini-grids. For industries close to the grid, sale of surplus to the national utility would increase their income (Deepchand, 2001).

The sugar industry is a major user of cogeneration technology. By the beginning of the year 2000, worldwide sugar mill cogeneration had reached almost 1,100 MW installed and operating, with another 450 MW under construction. Most developments are being registered in India and Mauritius (Deepchand, 2002).

Mauritius provides an example of a very successful use of cogeneration, meeting over 40 per cent of its electricity generation, with over half of this coming from bagasse from the sugar industry (Herbrard, 2003; Veragoo, 2003)—see box 1.

Sugar is produced in a number of Eastern and Southern African countries. It is a major agricultural export for Ethiopia, Madagascar, Malawi, Mozambique, Swaziland, Zambia and Zimbabwe. The potential for electricity generation from bagasse is high, since cogeneration equipment is almost always an integral component of sugar factory design. Estimates show that up to 16 sub-Saharan African countries could meet significant proportions of their current electricity consumption from bagasse-based cogeneration in the sugar industry (Deepchand, 2001).

Box 1. **Cogeneration in Mauritius**

The Mauritian experience in cogeneration is one of the success stories in the energy sector in Africa. As a result of extensive use of cogeneration in Mauritius, the country's sugar industry is self-sufficient in electricity and sells excess power to the national grid. In 1998, close to 25 per cent of the country's electricity was generated from the sugar industry, largely using bagasse, a by-product of the sugar industry. By 2002, electricity generation from sugar estates stood at 40 per cent (over half of it from bagasse) of the total electricity demand in country.

Government support and involvement has been instrumental in the development of a cogeneration programme in Mauritius. First, in 1985, the Sugar Sector Package Deal Act (1985), was enacted to encourage the production of bagasse for the generation of electricity. The Sugar Industry Efficiency Act (1988) provided tax incentives for investments in the generation of electricity and encouraged small planters to provide bagasse for electricity generation. Three years later, the Bagasse Energy Development Programme (BEDP) for the sugar industry was initiated. In 1994, the Mauritian Government abolished the sugar export duty, an additional incentive to the industry. A year later, foreign exchange controls were removed and the centralization of the sugar industry was accelerated. These measures have resulted in the steady growth in the export of bagasse-based electricity to the country's grid.

Bagasse-based cogeneration development in Mauritius has delivered a number of benefits including reduced dependence on imported oil, diversification in electricity generation and improved efficiency in the power sector in general. Using a wide variety of innovative revenue sharing measures, the cogeneration industry has worked closely with the Government of Mauritius to ensure that substantial benefits flow to all key stakeholders of the sugar economy, including the poor smallholder sugar farmer. The equitable revenue sharing policies that are in place in Mauritius provide a model for emulation in ongoing and planned modern biomass energy projects in other African countries.

Sources: Veragoo, 2003; Deepchand, 2001.

Table 8. Cogeneration (bagasse) potential for Eastern and Southern Africa, 2003

Country	Installed capacity in 2003 (MW)	Total generation in 2003 (GWh)	Cogeneration potential	
			Quantity (GWh)	% of total generation
Ethiopia	493*	1,812*	150.3	8.3
Kenya	1,143	4,563	530.3	11.6
Malawi	306	1,177	250.8	21.3
Mauritius	725	1,564*	600.0	38.4
Sudan	1,380	3,165	643.5	20.3
United Rep. of Tanzania	863*	2,770*	100.8	3.6
Uganda	303	1,756	173.4	9.9
Zimbabwe	1,961	7,906	686.4	8.7
Swaziland	180	395	—	—
Total	7,354	25,108	3,135.5	122.1

Source: Deepchand, 2002, 2006; Karekezi and Kimani, 2002; AFREPREN/FWD, 2004.
*2001 data.

Geothermal energy

Geothermal energy is the natural heat from the earth's interior stored in rocks and water within the earth's crust. This energy can be extracted by drilling wells to tap concentrations of steam at high pressures and at depths shallow enough to be economically justifiable. The steam is then piped to turbines to generate electricity. Worldwide, around 8,100 MW of geothermal power is generated, out of an estimated global potential of 60,000 MW (BCSE, 2003). This estimated potential does not include non-steam and non-hot water based geothermal potential. The potential of geothermal energy that exploits the difference in temperatures between the earth's surface and its underground is huge but it requires very high upfront investments.

Table 9. Land use requirements for different energy technologies

Technology	Land occupied (m^2 per MWh-year for 30 years)
Coal (including pit coal mining)	3,700
Solar thermal	3,600
Photovoltaic	3,200
Wind (land with turbine and roads)	1,300
Geothermal	400

Source: Bronicki, 2001

Geothermal power exploitation has numerous advantages over other energy sources (Bronicki, 2001). Among the benefits of geothermal power are near-zero emissions (true for modern closed cycle systems that re-inject water back to the earth's crust), and very little space requirement per unit of power generated (in contrast to other energy sources such as coal or hydro-dam based electric power (table 9).

Using today's technology, Africa has the potential to generate 2,500 MW of energy from geothermal power (BCSE, 2003). Of this geothermal power potential, only 127 MW has been tapped in Kenya, and less than 2 MW in Ethiopia (KENGEN, 2003; Wolde-Ghiorgis, 2003). These estimates of existing geothermal power generating capacity do not include direct thermal use of geothermal energy, which is widely practised in Africa. The geothermal potential for selected African countries is provided in table 10.

Table 10. Geothermal potential for selected African countries

Country	Potential generation in MW
Kenya	2,000
Ethiopia	>1,000
Algeria	700
Djibouti	230-860
Uganda	450
United Republic of Tanzania	150

Source: BCSE, 2003; Khennas, 2004.

Varying levels of geothermal exploration and research have been undertaken in Djibouti, Eritrea, Madagascar, Malawi, Uganda, the United Republic of Tanzania and Zambia, but the potential for grid connected geothermal exploitation is highest in Ethiopia, Kenya, Uganda and the United Republic of Tanzania, which are all covered by the Great Rift Valley. Government representatives from Eritrea, Ethiopia, Uganda and the United Republic of Tanzania are considering the use of small-scale geothermal plants for rural electrification mini-grid systems, although this has not yet been attempted (BCSE, 2003).

Kenya was the first country in sub-Saharan Africa to exploit geothermal energy. As mentioned earlier, Kenya has 127 MW of installed geothermal electricity capacity (KENGEN, 2003; Mbuthi, 2004). The government has plans to increase geothermal power capacity to 576 MW by 2019 (KPLC, 2000).

In Kenya, both the private and public sector are involved in the development of geothermal energy (BCSE, 2003). A feasibility study carried out to evaluate Olkaria's potential for generating electricity found that the geothermal field covered 80 km^2 with sufficient steam for 25,000 MW-years (with re-injection, this potential could be indefinite). The present area, covering 11 km², has steam for 400 MW-years. Out of the total 127 MW installed capacity, Kenya Electricity Generating Company, KenGen, Kenya's public utility company, has an installed capacity of 115 MW and OrPower 4, an independent power producer, has an installed capacity of 12 MW. Together, these plants meet 11 per cent of the national electricity supply (Mbuthi, 2004), once again demonstrating the viability of the 10 per cent renewable energy target proposed at the 2002 World Summit for Sustainable Development (WSSD) conference.

4.3. Potential benefits of renewables to the African energy sector

There is growing evidence that investment in small and medium-scale renewable energy technologies can have significant and sustainable impact in improving energy services for the majority of sub-Saharan Africa's population, especially the poor (Mapako and Mbewe (eds.), 2004; Karekezi and Kithyoma, 2002; UNDP, 2004; World Bank, 2004; The Economist Newspaper Ltd., 2004). The modular nature of most renewables (i.e. the fact that they can be applied incrementally) and the consequent low and progressive nature of investment requirements make them particularly suitable for capital-constrained African countries. Some of the key benefits of RETs are discussed in the following subsections.

Balance of payments

The energy sector in numerous African countries is characterized by high levels of imports of petroleum products, accounting for a significant proportion of export earnings (Karekezi and Kimani, 2001; AFREPREN, 2001). Such high imports increase the vulnerability of African countries to external oil price shocks and have an adverse impact on balance of payments.

Renewable energy could play a vital role in minimizing fuel imports by providing an alternative to thermal-based electricity in the form of, for example, small hydro power units, cogeneration (using biomass as fuel) and geothermal energy (Mbuthi, 2004; Yuko, 2004). They offer diversification in energy generation, thus strengthening energy security.

For example, with the exception of Sudan, all of the oil/petroleum products consumed in Eastern and Horn of Africa countries are imported as these countries do not have commercial deposits that can be used economically (the United Republic of Tanzania, however, has significant gas deposits that it has began to exploit). Fossil fuels are still a major source of commercial energy in these countries, accounting for over 70 per cent of commercial energy used (IEA, 2003).

In countries where oil and petroleum is used for electricity generation, the use of renewable energy technologies such as biomass-based cogeneration could replace the use of oil products, and lead to considerable savings in foreign exchange. Table 11 estimates the potential for replacing electricity generation from fossil fuels by biomass-based cogeneration in three Eastern and Horn of Africa countries.

Table 11. Potential of cogeneration that could replace electricity generation from fossil fuels

Country	Electricity generation from oil and petroleum (GWh)	Biomass-based cogeneration potential (GWh)
United Republic of Tanzania	143	315
Kenya	1,509	2,606
Ethiopia	19	1,750

Sources: Adapted from IEA, 2003; EIU, 2003.

Poverty alleviation, job and enterprise creation

Small and medium-scale RETs can play an important role in poverty alleviation. This is particularly true of small-scale RETs that are made locally and operate on the basis of solar, thermal or animate power. Such systems can not only provide energy that is affordable to the poor but can also be a source of employment and enterprise creation for both the rural and urban poor in the East and Horn of Africa. Examples include (Mapako and Mbewe (eds.), 2004; Karekezi and Kithyoma, 2002) UNDP, 2004; World Bank, 2004; The Economist Newspaper, 2004):

- Low cost and more efficient biomass-based combustion technologies (e.g. improved cooking stoves, efficient charcoal kilns, brick making kilns, fish smokers, tea dryers and wood dryers).
- Pico and micro hydro for shaft power that can be used to process agricultural produce and increase its value, as well as for water pumping.
- Low cost efficient hand tools and animal drawn implements, which would increase the agricultural productivity of rural areas of Eastern and Horn of Africa;
- Treadle and ram pumps for irrigation, which increase agricultural outputs thus generating income for the rural farmer.
- Solar dryers that can lower post-harvest losses and enable the rural farmer to market his/her produce when prices are higher.
- Solar water pasteurizers that provide clean potable water and reduce water borne diseases, which translates to increased availability of labour and thus increases agricultural output and income.

Geothermal resource development and exploitation can create significant job and enterprise opportunities both directly and indirectly. In 2002, the 45 MW plant at Olkaria I (Kenya) employed 493 people: 15 scientists, 21 engineers, 82 technicians, 175 artisans/craftsmen and 200 support staff (Mariita, 2002), which translates to over 5,000 people who directly or indirectly depend on the 45 MW plant.

The following table provides estimates of the job creation potential of various electricity generation options. As the table shows, RE options (geothermal and wind) have much higher job creation potential than conventional energy systems (coal and natural gas):

Table 12. Estimated job creation potential of energy technologies

Energy option	Construction, manufacturing and installation (employees/MW)	Operation and maintainance (employees/MW)	Total employment (employees/MW)
Geothermical	4.00	1.70	5.70
Wind	2.51	0.27	2.78
Natural gas	1.00	0.10	1.10
Coal	0.27	0.74	1.01

Source: Adapted from Kammen, et al., 2004; EERE, 2006.

It is also possible to ensure that benefits from medium to large-scale RE projects flow to the low-income groups. Using a wide variety of innovative revenue sharing measures, the cogeneration industry in Mauritius has worked closely with the Government of Mauritius to ensure that substantial benefits flow to all key stakeholders of the sugar economy, including the low-income smallholder sugar farmers (Deepchand, 2003, see box 2). In many respects, the equitable revenue sharing policies that are in place in Mauritius provide a model for emulation in ongoing and planned large and medium-scale energy development programmes of sub-Saharan African countries.

Box 2. **Sharing of revenue from bagasse energy in Mauritius**

Cogeneration of bagasse energy in Mauritius on a commercial basis is a win-win situation for all the stakeholders in the sugar industry. A ministerial statement issued in 1985 mandated all stakeholders to get a share of revenue from electricity sales to the grid. Consequently, a Bagasse Transfer Price Fund (BTPF), in which proceeds from the sale of excess bagasse used to generate electricity sold to the grid are placed, was set up. Cogenerators receive all their payments from the Central Electricity Board (CEB) in addition to a share of 50 per cent of the BTPF on a pro-rata basis, with respect to their electricity export.

Moreover, millers are provided with fiscal incentives for energy savings, and if operating next to a power plant, they are no longer required to operate, repair and maintain a boiler and turbo-alternator. In addition, the agreement between the co-generator and the miller specifies a given amount of exhaust steam (around 450 kg per tonne cane). Any improvement in exhaust steam consumption lower than 450kg/tonne cane brings additional revenue to the miller.

The planters who do not own mills (non-miller planters) share 38 per cent of the BTPF on the basis of individual sugar production. In addition, they earn dividends from their shares in the Sugar Investment Trust (SIT) set up in 1994. The miller-planters, on the other hand, are entitled to 12 per cent of the BTPF, shared on a pro-rata basis with respect to their individual sugar production. The agricultural and non-agricultural workers of the sugar estates and factories as well as their respective staff, and the employees of the parastatal organizations dealing with the sugar industry are all beneficiaries due to being shareholders of SIT.

Source: Deepchand, 2003.

Independent technology development

In addition, and in contrast to conventional energy technologies (e.g. oil, coal, natural, gas and large hydropower), RETs due to their modularity and small-scale generally do not require large amounts of capital.

In addition, a significant industry could be developed in Africa even where currently technical expertise is limited. The chances of an African country (with the exception of South Africa) becoming a significant player in the world's conventional energy market are slim but, with increased financial support, it may be possible for an African country to become a significant player in the small and medium-scale RET market. For example, Kenya is now a global leader in geothermal energy development, with experts from Kenya offering their expertise in developing geothermal power plants in other countries in the region, and even in developed countries (Mariita, 2002).

Environment

In addition to their global contribution to reducing greenhouse gases, RETs reduce local and regional energy-related environmental impacts. For example, cleaner and more efficient bio-stoves fitted with chimneys can reduce indoor air pollution, which is a major contributor to respiratory illness (Kammen and Ezatti, 2002; Smith 1991; Smith, 1994). Cleaner fuels can reduce transport-related pollution and wind, solar, hydro or geothermal energy can reduce the need for coal or other fossil fuel plants that cause significant local and regional pollution (Johansson et al., 2005).

Increasing use of bagasse-based cogeneration in sugar factories has a positive global environmental impact and would reduce greenhouse gas emissions that are linked to the greenhouse effect. For example in Mauritius, the impact of bagasse energy projects on the environment has been quantified. In the short term, bagasse projects avoid the use of 215,000 tons of coal, the emission of 650,000 tons of CO_2 and generation of 35,000 tons of coal ash. The long-term figures are 375,000 tons of coal, 1,130,000 tons of CO_2 and 60,000 tons of coal ash when the target of producing 110 kWh of electricity for each ton of sugarcane is achieved. Eastern and Horn of Africa countries could derive significant environmental benefits from the increased development of cogeneration (Deepchand, 2001). While Africa's contribution to greenhouse gases is negligible, the climate benefits of renewables can be used to access existing climate-related financing.

As pointed out before geothermal power offers the combined environmental advantages of very low emissions and a very low land requirement when compared to conventional energy sources (Bronicki, 2001).

These environmental benefits could be used to attract Clean Development Mechanism (CDM) financial support to the country. Similarly, Eastern and Horn of Africa countries could derive significant environmental benefits from the increased development of cogeneration (Deepchand, 2001).

Power deficits

The general unreliability of large-scale conventional energy supply in Africa has already been mentioned. In particular, large-scale energy sources such as hydropower can prove unreliable. Hydropower is dependent on rainfall, and is therefore vulnerable to drought. Many sub-Saharan African countries have experienced serious droughts in the past, which have affected hydro power generation (table 13). Droughts are likely to become more frequent in the future (UNDP, 2004).

Table 13. Drought and its effect on hydropower generation

Country	Drought period	Consequences
Uganda	2004/2005	Reduction in water levels at Lake Victoria resulting in reduction in hydro-power generation by 50 MW
Kenya	1992	Failure of rains led to power rationing in April-May 1992
Kenya	1998-2001	Massive drought decreased hydro generation (25 per cent in 2000), which had to be replaced by more expensive fuel-based generation. Power rationing in 1999-2001.
Lesotho	1992	Hydro operation limited to 6 months, leading to 20 per cent reduction compared to 1991.
Malawi	1997-1998	Engineering operations affected by drought. Amount of hydro energy generated was 6 per cent less than in years of normal rainfall.
Mauritius	1999	Massive drought led to 70 per cent drop in normal annual production of electricity.
United Rep. Tanzania	1997	The Mtera dam reached its lowest ever level resulting in a of 17 per cent drop in hydro generation, use of thermal generation to meet the shortfall, and power rationing.
Zambia	1992	Poor rainfall resulted in a 35 per cent reduction in hydro generation in relation to the previous year.
Zimbabwe	1993	Drought led to a drop of over 9 per cent in energy production compared to 1992.

Source: AFREPREN, 2004.

Renewables that are not reliant on rainfall (e.g. geothermal, solar, wind) can reduce the weather-related risks associated with heavy reliance on hydroelectric schemes. For instance, bagasse-based and geothermal-based power plants were used to meet the power deficits caused by drought in Mauritius (in 1999) and in Kenya (in 1998-2000). During the drought period, Kenya's two geothermal plants offered almost 100 per cent availability to cover base load needs regardless of prevailing weather conditions (Mbuthi, 2004).

Review questions

1. What is renewable energy?
2. What is the most popular renewable energy technology in Africa and why?
3. What are some of the advantages of renewable energy in Africa?

Discussion questions/exercises

1. Discuss the renewable energy sources and their applicability in your country.

5. ENERGY EFFICIENCY

5.1. What is energy efficiency?

Energy efficiency means using less energy to accomplish the same task. More efficient use of energy throughout a country will result in less money spent on energy by homeowners, schools, government agencies, businesses and industries. The money that would have been spent on energy can instead be spent on other things like consumer goods, education, services and products.

5.2. Status of energy efficiency in Africa

Energy efficiency in Africa is generally low, both at the industrial, transport and domestic level. Conversely, higher energy efficiency is often associated with higher productivity, as energy and production technologies are often linked, and energy efficiency implies lower costs. Consequently, this observation triggered most efficiency-oriented energy projects in Africa. Numerous programmes for development aid or technical assistance have been focusing on improving access to sustainable energy in recent years. Apart from a few success stories, however, experience shows that positive appraisals of many projects evaporate after completion and withdrawal of the implementing expert team. Altogether, the diffusion of sustainable technologies with higher energy efficiency and renewable energies for cooking, heating, lighting, electrical appliances and building insulation in developing countries has been slow.

In most cases, the reasons for non-sustainable efficiency programmes are related to high transaction costs, lack of capacity, and the fact that implementation of innovative institutional structures in the form of energy agencies is lacking (Praetorius, B. and Bleyl, W., 2006). In overall terms, efficiency programmes are largely absent in most countries. In Kenya for example, it is estimated that between 10 and 30 per cent of primary energy input is wasted (IEEN, 2002). Plans are, however, underway to initiate energy efficiency programmes in some countries in the region while countries such as the United Republic of Tanzania have already existing initiatives in place (see the full case study at the end of the module). Most of these initiatives are donor funded mainly by GEF, UNDP, REEEP, UNIDO, ADB and the World Bank.

Box 3. **GEF-UNDP initiative in Kenya**

A GEF-UNDP funded project on industrial energy focusing mainly on energy efficiency in industries is currently being implemented in Kenya, and is likely to result in significant energy savings. The Kenya Power and Lighting Company has also benefited from a World Bank-funded project on demand side management. However, demand side management has largely been limited to public awareness and sensitizing consumers, as opposed to the installation or application of energy efficient technologies by the utility.

UNDP-Kenya with the aim of increasing energy efficiency and conservation in small and medium enterprises in Kenya through the industrial energy efficiency project (IEEP) sponsored a training course on "energy efficiency financing" in 2002. The aim of the course was to train managers and engineers in Kenyan small and medium-scale industries how to use manufacturing techniques that are more efficient, less costly and more profitable.

The training was a success and this is visible through the many local companies. A small local company was able to save $US 429 per month on fuel costs by installing an economizer on its boiler.

In the year 2004, the industrial sector in Kenya consumed an estimated total of 514 million tonnes of oil equivalent. This constitutes about 18.2 per cent of the total commercial energy consumed in the country in that year. It has been estimated that in the industrial sector, savings in excess of $US 36 million are possible. The rate of economic growth in the country has, meanwhile, peaked in the period between 2003 and 2006 and is expected to continue at that level or to grow at an even faster rate in the years ahead, with attendant increase in the demand for petroleum and petroleum products. All these should set the stage for higher savings in energy consumption in the industrial sector if the necessary measures are put in place. The expected increase in the price of energy too will further enhance the prospect for energy efficiency in the industrial sector. Increasing local as well as international competition is causing Kenyan enterprises to look at their energy use critically. Potential energy savings exist in highly efficient, well-managed industrial plants.

Source: UNDP website: http://www.ke.undp.org/Energy%20and%20Industry.htm
Exchange rate used: $US 1/69.95 Ksh.

At the regional level, there are enough resources available to meet the future energy demand. However, they are unevenly distributed and many of the countries in the sub-Saharan African region will, for the foreseeable future, depend on imported oil—a major contributor to the balance of payments problem experienced by most sub-Saharan African countries. In most countries in the region, the present pattern of energy utilization is sub-optimal and industrial energy use, in particular, is very inefficient. These inefficiencies constitute a large drain on many of the economies in the region.

Although sub-Saharan Africa has enough energy resources to meet the requirements of any plausible future industrial development scenarios, the present largely inefficient pattern of energy consumption has an adverse impact on:

- The cost of energy supply;
- The prices of goods produced;
- The environment.

A number of renewable energy technologies such as bagasse-based cogeneration, solar water heaters and geothermal combined heat and power plants can also be considered energy efficiency technologies.

It is estimated that one of the largest consumers of domestic electricity is water heating. This typically accounts for about 30 to 40 per cent of electricity bills (Energy Management News, 1999). In many cases the domestic hot water systems are only about 60 per cent efficient. Over 25 per cent of the energy leaks out of water heaters due to standing losses, and another 15 per cent may be lost in the hot water pipes. Solar water heaters provide an excellent opportunity for reducing the amount of electricity used for water heating, thus shaving the two peaks in electricity demand (morning and evening). Solar water heater projects have been launched in Morocco with an aim of initially installing 80,000 m^2 of solar water collectors (REPP, 2002). A utility in Egypt is providing incentives for domestic consumers who install solar water heaters.

At the industrial level, solar water heaters can be useful in pre-heating water for use in boilers, therefore reducing the amount of electricity or fossil fuels needed to heat the water to produce steam. This could yield significant savings to energy intensive industries.

Cogeneration also provides an opportunity for energy efficiency. A significant part of any cogeneration initiative is aimed at increasing the efficiency of local energy use to free up more electricity for export to the grid. It is estimated that modest capital investments combined with judicious equipment selection, increased efficiency in the sugar manufacturing process (reducing energy use) and proper planning could yield a 13-fold increase in the amount of electricity produced by sugar factories and sold to the national grid in Mauritius (Baguant, 1992). The promotion of cogeneration for sale of electricity to the grid is therefore an important energy efficiency tool for sugar industries in the region.

Combined heat and power geothermal energy plants can also be considered as energy efficiency technologies. The heat part of a geothermal plant (which has not been exploited in the region) could be used for heating water for several uses, namely:

- Greenhouse flower farming—tried in Kenya;
- Fish farming as currently practised in parts of Asia;
- Heating water for domestic supply and district heating as practised in parts of the developed world.

Review questions

1. List some of the common barriers to energy efficiency in Africa.
2. Define energy efficiency.

Discussion questions/exercises

1. Are there any energy efficiency programmes in your country?
2. What are some of the barriers to investment in energy efficiency in your country's industrial sector?

6. BARRIERS TO RENEWABLE ENERGY AND ENERGY EFFICIENCY IN AFRICA

While it is recognized that renewable energy and energy efficiency cannot solve all of Africa's energy problems, they are perceived as having significant potential to meet growing energy requirements in the region. If properly harnessed, these systems could meet a significant proportion of energy demand for the bulk of African countries (Karekezi and Kithyoma, 2005). However, renewable energy and energy efficiency have not attracted the level of investment or policy commitment they require and have not been widely disseminated in the region. Resources allocated to developing these systems are negligible in comparison to resources allocated to the conventional energy sector. The success of renewable energy and energy efficiency in the region has been limited by a combination of factors that include:

- Poor institutional framework and infrastructure;
- Inadequate planning;
- Lack of coordination and linkage in RET programmes;
- Pricing distortions that place them at a disadvantage;
- High initial capital costs;
- Weak dissemination strategies;
- Lack of skilled manpower;
- Poor baseline information; and
- Low maintenance capacity (Karekezi and Kithyoma, 2005; Karekezi et al., 2003).

Other deficiencies that limit the use of energy efficiency measures in particular, especially in the industrial sector, include:

- Lack of commitment by management;
- Lack of proper instrumentation and controls;
- Inadequate data collection and analysis capability;
- Substandard plant house-keeping measures;
- Poor equipment maintenance;
- Inadequate insulation of hot water and steam piping.

Investments in energy efficiency measures are often more than cost-recovering over their lifetime cycle, and therefore, the standard model of economic theory would suggest that any cost-effective measure should be automatically implemented. Empirical research, however, shows that this is often not the case—and many energy saving measures with high rates of return on capital are not being realized, a phenomenon commonly labelled as the "efficiency gap".

The Efficiency Gap is the potential energy efficiency that is precluded by the possibility of market failures.

This section discusses the following common barriers the development of renewable energy and energy efficiency in Africa is faced with:

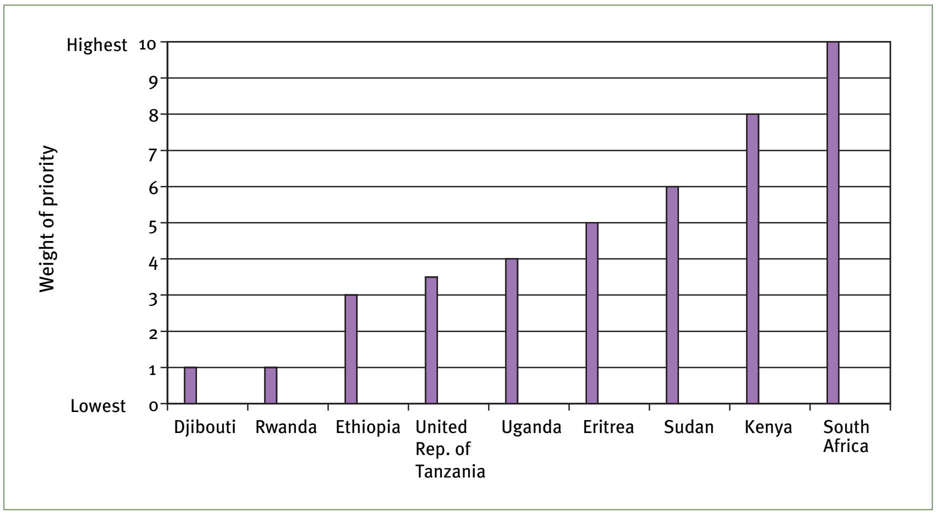
- Policy/regulatory barriers;
- Financial/investment barriers;
- Research/technology barriers.

Policy/regulatory barriers

Experience in the region shows that the introduction and success in the use of any renewable energy technology and energy efficiency measure highly depends on the existing policy framework. Government policies are a crucial factor in terms of their ability to create an enabling environment for energy efficient systems, to mobilize resources and to disseminate results, as well as encouraging private sector investment (Sampa and Sichone, 1995). Most of the early policy initiatives on renewable energy and energy efficiency in the region were driven by the oil crises of the 1970s. In response, governments established either an autonomous Ministry of Energy or a department dedicated to the promotion of sound energy policies, including support for renewable energy and energy efficiency. For example, in its Third National Development Plan (1979-1983), Zambia proposed to develop alternative forms of energy as partial substitutes for conventional energy resources. Unfortunately, once the energy crisis subsided, government support for renewable energy and energy efficiency systems diminished. This was common across the region. Most of the remaining support is now at a rhetorical level (Karekezi and Kithyoma, 2005)

Often governments in the region do not have a comprehensive vision, policy and plan on the development and dissemination of renewable energy and energy efficiency measures. Consequently, the promotion of renewable energy and energy efficiency is often undertaken within an energy planning and policy vacuum. As a result, the development of these systems often follows an ad hoc path with no reference to a coherent vision and plan. For example, in Malawi, the policy vacuum has meant that the majority of renewable energy and energy efficiency dissemination efforts have not only been ad hoc in nature, but operated largely as an informal activity outside the formal Government planning and budgeting cycle, thus failing to attract significant support from the national treasury and donor agencies (Kafumba, 1994)

Figure XI. **Policy support for renewable energy and energy efficiency**



Source: Karekezi and Kithyoma, 2005

Key:

0-3: Low priority, no specific mention of renewable energy and energy efficiency in policy
4-6: Lukewarm support for renewable energy and energy efficiency, mentioned in policy but in general statements with no specific targets
7-10: High priority with specific targets and significant budgetary allocation for renewable energy and energy efficiency

Limited policy support for renewable energy and energy efficiency is further demonstrated by the low budgetary allocations in most countries. For example, the budgetary allocation for the energy sector in Zambia in 2002 indicates a heavy emphasis on electrification (mainly grid extension). Only 0.2 per cent of planned investments in the public investment plan are allocated to renewable energy and energy efficiency mainly regarding wood fuel efficiency (Ministry of Finance and National Planning, 2002). In addition, a survey carried out in Botswana revealed that about 57 per cent of the respondents had no knowledge of government policies designed to promote the use of renewable energy an energy efficient systems (Karekezi and Kithyoma, 2005). In Malawi, the policy vacuum has meant that the majority of energy efficiency dissemination efforts are largely informal sector activities. They lack the fiscal support of the central government and its major donors (Kafumba, 1994; Karekezi and Kithyoma, 2005).

As mentioned earlier, emphasis is placed on the petroleum and power sub-sectors, which supply a small portion of the population, at the expense of renewables. For example, investment trends in Ethiopia's energy sector reveal heavy investments in the electricity and petroleum subsectors. Investments in petroleum quadrupled from 1990-2000, while investments in electricity almost tripled in the same period. In contrast, expenditure on traditional and alternative energy (including renewables and energy efficient systems) has steadily decreased from about 1 per cent of total expenditure in 1990, to 0.1 per cent of total expenditure in the year 2000 (Karekezi and Kithyoma, 2005).

In the newly deregulated electricity industry, renewable energy and energy efficiency measures face new challenges and barriers. With the exception of South Africa, few other regulators have made the preparation of integrated resource plans (IRPs) which include renewable energy and energy efficiency as an important prerequisite for licensing. In most countries of the region, there are, at the moment, no explicit and effective incentives in place for the promotion of energy efficiency or demand side management (DSM).

Renewable energy and energy efficiency programmes in Africa, therefore, are unlikely to register significant development and dissemination without supportive government policies and plans, which are backed by the requisite budgetary allocations.

Investment and financing barriers

Studies have shown that one of the main obstacles to implementing renewable energy and energy efficiency programmes is often not the technical feasibility of these initiatives but the absence of low-cost, long-term financing (News at Seven, 1994).

Banking institutions lay down stringent conditions for the financing of these systems. Conditions required included a feasibility study conducted at the applicant's expense, due to the limited knowledge of renewable energy and energy efficiency systems by bank officials. In addition, the banks required land titles as collateral, portfolios of project sponsors and managers, data on past and current operations, approximate value of existing investments, valuation reports, raw material procurement plans, and marketing strategies for the finished product (Turyareeba, 1993b). In certain countries (e.g. United Republic of Tanzania), banks are unwilling to accept land titles as collateral because of the uncertain land ownership infrastructure. This means that in the case of the bagasse-based cogeneration industry, sugar factories cannot use the title deeds of their sugar cane fields as collateral to obtain credit for investment in cogeneration plants.

However, it is important to note that stringent conditions set by banks also apply to conventional energy investments. As renewable energy and energy efficiency projects are a relatively new type of investment, it is simply much more difficult to collate the required information and track history.

Another barrier to the promotion of renewables and energy efficiency is the lack of awareness of existing innovative local and international financing options. For instance, there is limited knowledge and expertise on how utility financing could be used to underwrite renewable energy and energy efficiency investments. Some utility officials may be worried that investment in energy efficiency can lead to lower revenues, but it is a matter of demonstrating that the initial investment in energy efficiency can yield significant benefits for the utility by reducing high-cost peak loads and improve the profile of the power demand curve that the utility has to meet or supply.

There appears to be limited ability to access to internationally available "sustainable energy financing", e.g. from the Global Environment Facility (GEF) and various other financing schemes such as Activities Implemented Jointly (AIJ), the Clean Development Mechanism (CDM), the Prototype Carbon Fund and Community Development Carbon Fund.

Research, technological and skills barriers

In most sub-Saharan African countries, there is inadequate information on the potential of energy efficient systems and the possible savings from energy efficiency initiatives. In addition, there is limited availability of comprehensive and well-documented data sets on the dissemination of energy efficient systems in the region and their potential benefits in the economic development of the region, such as job creation and poverty alleviation.

The region's poor baseline information on energy efficient systems is exacerbated by inadequate documentation and library services. Information on past experiences that would help avoid duplication and the recurrence of past errors has been dumped instead of being transferred to libraries and the public domain. For instance, the Mauritian experience with cogeneration as a sustainable source of electricity is not widely known in the region nor is Seychelles and North-Africa's relatively successful experience with solar water heater programmes (considered both a renewable energy and energy efficiency intervention). The few industrial energy efficiency programmes that have been implemented in the region are also not well documented.

At a macro-economic level, the potential positive impact of energy efficient systems on the national balance of payments through the reduction in the import of fossil fuels is poorly documented. Consequently, energy efficient systems have not been given due attention in national economic policy, planning and budgetary allocations. In addition, power master plans in most African countries largely focus on conventional energy sources with limited reference to energy efficiency.

The importance of technical know-how in the increased utilization of renewables and energy efficiency measures has been recognized in the region, but there remains a continuing shortage of qualified personnel. Technical knowledge is needed to build a critical mass of policy analysts, economic managers and engineers who will be able to manage all aspects of efficient systems development. Trained manpower capable of developing and manufacturing energy efficient systems is a prerequisite for their successful dissemination (Karekezi and Kithyoma, 2005).

Governments and ministries in Africa suffer from a shortage of qualified renewable energy personnel. In Kenya, for example, there was a lack of expertise in wind energy when a Dutch aid organization was hoping to finance wind projects in the country. In Zambia, at one time, only one engineer was responsible for coordinating all renewable energy activities of the government. This deficit is largely responsible for the generally underdeveloped research and technological capability and the poor management of renewable energy programmes. A British-financed project to map out the wind regime in Seychelles was unsuccessful due to the absence of trained personnel (Karekezi and Kithyoma, 2005)

Although Government, donors and NGOs have, in the past, invested in building renewable energy skills and expertise, the trained personnel often move into other sectors. This is primarily due to the embryonic nature of the renewable energy and energy efficiency industry and the limited business development training provided to trainees (Karekezi and Kithyoma, 2005).

7. OVERCOMING THE BARRIERS TO RENEWABLE ENERGY AND ENERGY EFFICIENCY IN AFRICA

The following are proposed measures that could help in overcoming the barriers faced in developing both renweable energy and energy efficiency systems in the region.

Energy efficiency and renewable energy policy programmes

Pro-active and long-term policy-oriented energy efficiency and renewable energy programmes aimed at senior decision-makers in both Government and the private sector should be initiated. Such policy programmes should be designed to demonstrate the economic and environmental benefits of energy efficient systems and renewable energy technologies for Africa, specifically for the region's poor population, and propose short- and medium-term policy initiatives that would engender large-scale dissemination of renewable energy and energy efficiency systems (Karekezi and Kithyoma, 2005; Karekezi et al., 2003).

Priority should be given to the real and tangible economic benefits (such as job creation and income generation) that renewable energy and energy efficiency programmes can deliver at both the micro and macro levels. For example, renewable energy technologies and energy efficiency measures are generally more labour-intensive than conventional energy projects and can help to address problems of employment of the poor. Unfortunately, empirical data on the actual livelihood potential of renewable energy technologies and energy efficient systems measures are not widely available. Such data would assist in encouraging higher budgetary allocations to the development of these systems (Karekezi and Kithyoma, 2005).

Of particular interest to policy-makers in sub-Saharan Africa would be revenue neutral policies and institutional measures. For example, it is possible to make the case that the loss of revenue associated with the removal of duties and taxes on renewable energy technologies and energy efficient systems can be recouped from the long-term savings in imports of petroleum fuels that require foreign currencies as well as from the tax remittances from a functional and vibrant domestic renewable energy and energy efficiency (REEE) industry (Karekezi and Kithyoma, 2005).

With a clear and well-defined vision, policy and plans on renewable energy and energy efficiency in place, a regulatory structure would be required to ensure the implementation of the policies. Regulation would be undertaken at both regional and national level, and could be undertaken using a wide range of instruments. For example, measures that encourage national utilities to purchase/generate/promote renewable energy and energy efficiency as a mechanism for diversifying generation may also yield positive results. Regulators could ease licence requirements for cogenerators to encourage entry, and regulators could ensure attractive prices for cogenerators. In addition, regulators can play the important role of educating consumers on renewable energy and energy efficiency. The South African National Electricity Regulator (NER) provides a useful model (Karekezi et al., 2003).

Appropriate technology, technology transfer and building local capacity

The choice of energy efficient systems and renewable energy technologies for dissemination and development in sub-Saharan Africa should take into account the existing technical knowledge and local industries. Energy efficient systems and renewable energy technologies that improve existing methods and build on already established industries are likely to be successfully disseminated. In addition, these technologies can become self-sustainable in the long-term (Karekezi and Kithyoma, 2005).

Experience has shown that most energy efficient systems and renewable energy technologies (especially those that can be locally manufactured) require subsidies in the initial stages, but can become financially sustainable in the short to medium term after a certain level of technology dissemination has been attained. After attaining a dissemination of a critical number of units and assemblers/manufacturers, each industry can become self-sustaining and subsidies can be gradually withdrawn without any adverse effects on continued dissemination (Karekezi and Kithyoma, 2005).

One of the key factors that led to the high penetration rates of improved stoves in Kenya was the low cost of the stoves (about $US 2). In addition, the stove dissemination programme did not attempt to install a new production and marketing system, but instead used the same network that produced and marketed the traditional stove. The stove programme utilized both mechanized and semi-mechanized stove producers thus creating job opportunities and keeping the price of the improved stove affordable (Karekezi and Ranja, 1997).

It is necessary to consider the training of individuals, the business systems by which they will work and the systems by which they will continue to be paid.

Where training or capacity is inadequate, manufacture, assembly and dissemination of the technology will not be successful. For example, unlike the Kenyan stove dissemination scene where the informal sector forms the backbone of the stove's manufacture, assembly and dissemination, the informal sector in Khartoum forms the weakest link in stove production. Production of liners is limited to a few formal producers with an installed capacity of 7,500 liners per month, but the capacity to produce the metal component is much lower (Karekezi et al., 2006).

Sub-Saharan African countries need to develop rural energy technologies strategies that rely on a diverse set of technologies that are not confined to PV electrification and that reflect their national natural endowment profiles as well as the incomes of the poor. If a proportion of the funds for rural electrification were allocated to the promotion of non-electrified technologies, this would result in their low cost and in the significant dissemination of these technologies. In the near term, the ideal situation would be to transform current rural electrification programmes and agencies into rural energy agencies that are given the mandate to disseminate rural energy technologies (Mapako and Mbewe, 2004).

Long-term renewable energy and energy efficiency training programmes designed to develop a critical mass of locally trained personnel with technical, economic and social-cultural skills are urgently needed. Many of the engineering and technical courses that are currently taught at universities and colleges in Africa provide little exposure to appropriate energy efficient technologies and to essential business development skills. Modest changes in the curricula of existing colleges and universities could significantly increase the supply of skilled renewable energy and energy efficiency engineers, policy analysts and technicians with the requisite business development expertise (Karekezi and Kithyoma, 2005).

In addition, efforts are needed to integrate analytical expertise within the energy sector with that of other key actors in the development process: the banking or micro-finance industry; social/rural development and public health communities. This is the key to understanding not only the resources and technologies available, but also the institutional setting through which they may be adopted and accepted by the target communities (Karekezi and Kithyoma, 2005).

Information exchange and sharing at the regional level on renewable energy and energy efficiency should be encouraged. Countries with more successful experiences of renewable energy and energy efficiency development can provide model examples for other countries that are still at the early stage of project/programme development. For example, Mauritius and Kenya could provide useful lessons for other countries in the region that are embarking on cogeneration and geothermal power, respectively (Karekezi et al., 2003).

Innovative financing mechanisms

Priority should be given to the establishment of innovative and sustainable financing programmes for energy efficiency systems and renewable energy technologies. These may range from the creation of a specific National Fund financed by a modest tax on fossil fuels to credit schemes aimed at developing renewable energy and energy efficiency industries and developing endowments for renewable energy and energy efficiency agencies. In Ghana, a national energy fund has been successfully utilized to finance RE and EE activities on a sustainable basis. An important challenge is the bundling of discrete renewable energy and energy efficiency projects into large programmes, which can be financed by major bilateral and multilateral donor and financing agencies.

African countries could tap into the various international and regional initiatives, (including GEF, NEPAD, and the FINESSE programme of the African Development Bank) which can initiate, support and be linked into the national policy strategy.

The UNFCCC-related Clean Development Mechanism (CDM) presents a new financing opportunity for Africa. It allows industrialized countries to meet part of their commitment to reduce emissions of GHGs by investing in projects in African countries that reduce those countries' emissions. The rationale is that the negative impacts of emissions are independent of their source and that emissions reductions may be less costly in developing countries. The CDM also provides a way to engage African countries in the emissions reduction process and should provide them with additional funding, allowing them to follow a less emissions-intensive path than they would otherwise follow.

The CDM could help mitigate the high up-front financing barrier that faces renewable energy and energy efficiency projects in Africa in several ways. Firstly, one of the basic requirements of the CDM is that the projects that industrialized countries invest in should meet the host country's development priorities. This provides room for the host country to select the projects for investment. Hopefully this will ensure that the host country has more leverage on the implementation of the project than has been the case with development projects in the past. The range of technologies being considered under the CDM project is wide, but includes many renewable energy technologies and energy efficiency systems. CDM projects, however, have very high transaction costs and require specialized skills that limit the participation of African countries with limited expertise. The projects also require setting up new institutional entities, for example designated national authorities (DNAs).

Review questions

1. List the common barriers to energy efficiency in Africa.

Discussion questions/exercises

1. What are the main barriers to investment in renweable energy and energy efficiency in your country's industrial sector?

8. CONCLUSION

The following conclusions can be drawn:

- The poor state of managerial and financial performance justified the reform of the power utilities in Africa. These reforms, in part, led to better financial performance in some countries, e.g. Uganda and Zimbabwe and an improvement (albeit for a limited period) in the general technical performance of national utilities in others, e.g. Kenya.
- Though endowed with substantial renewable energy sources, Africa's potential has not been fully exploited, mainly due to the limited policy interest and investment levels. Renewable energy offers substantial opportunities for generating electricity and/or heat energy with limited capital investments, while avoiding the negative environmental effects of increased fossil fuel combustion.
- Although sub-Saharan Africa has enough energy resources to meet the requirements of any plausible future industrial development scenarios, the present pattern of energy consumption is far from efficient.
- In spite of the region's limited consumption of modern energy, energy efficiency is a key option for supplying energy to more consumers without increasing adverse environmental effects. However, this option has not been adequately exploited.

LEARNING RESOURCES

Key points covered

These are the key points covered:

- The module recognizes that the availability of modern, reliable and efficient energy services is an important and indeed essential driver for economic development.

- Most countries in Africa are faced with major challenges in trying to achieve their development and social obligations because of inadequate access to modern energy services. The majority of the population still depend on traditional biomass, which often has adverse environmental and health impacts.

- Sources of power supply in Africa broadly reflect each sub-region's energy resource endowment with North and West Africa concentrated with oil and gas reserves; Eastern Africa with hydroelectric power (with some limited use of geothermal-based and biomass-based power stations), while Southern Africa is reliant on coal (and to lesser extent hydropower).

- The core sources of electricity in most sub-Saharan African countries are hydropower and oil products.

- The African power sector is characterized by small systems, with over three-quarters of the continent's installed capacity in North Africa and the Republic of South Africa. The large-scale conventional energy sector though receiving the bulk of energy investment only serves a small proportion of the population. Consequently, there are low levels of electricity access in sub-Saharan Africa with an estimated 17 per cent of the region's population, and less than 5 per cent of rural areas having electricity. Electricity is largely confined to urban middle and upper income groups and to the formal commercial and industrial sectors.

- The modular nature of most renewable energy technologies (i.e. the fact that they can be developed incrementally) and the consequent low and progressive nature of investment requirements make them particularly suitable for capital-constrained African countries.

- Energy efficiency means using less energy to accomplish the same task. Using less energy would mean a cost saving which could then be used on consumer goods, education, services and products. Energy efficiency in Africa is, however, generally low, both at the industrial, transport and domestic level.

- Despite their recognition as important contributors to the region's energy sector, energy efficiency systems have not been widely disseminated in the region.

Answers to review questions

Question: Define the power sector.

Answer: The power sector can be defined as an energy sector that consists of both electricity generation plants (and combined heat and power (CHP) plants) and the transmission and distribution infrastructure, and whose primary business is to generate, transport and sell electricity (electricity and heat in the case of CHP) to the public.

Question: Who are some of the main players in the power sector?

Answer: The main players in the sector in Africa include government ministries, utilities, independent power producers (IPPs), transmission and distribution operators, regulators and rural electrification agencies. Other players include manufacturers and consulting engineers who supply equipment and services for the generation, transmission and distribution of electric power by utilities and other power producers.

Question: What are some of the key characteristics of the power sector in Africa?

Answer: Use of small systems, with over three quarters of the continent installed capacity in North Africa and the Republic of South Africa.

Sources of power supply in Africa broadly reflect each subregion's energy resource endowment. For example, fossil-fuel fired electricity generation systems in North and West Africa, hydroelectric power plants with some limited use of geothermal-based and biomass-based power stations in Eastern and Central Africa, and coal (and to lesser extent hydropower) in the Southern African power industry.

The large-scale conventional energy sector (electricity and petroleum) receives the bulk of energy investment in most African countries whilst serving only a small proportion of the population.

Provision of electricity in Africa is largely confined to urban middle and upper income groups and to the formal commercial and industrial sectors.

Low levels of electricity access only an estimated 17 per cent of sub-Saharan Africa's population is electrified.

Question: What is renewable energy?

Answer: Renewable energy refers to energy forms that cannot easily be depleted and include energy forms such as wind, solar, hydro, biomass, geothermal, tide and wave energy.

Question: Which is the most popular renewable energy technology in Africa? State the reason.

Answer: Solar technology is the most widely disseminated technology in Africa both in urban and rural areas and mostly used in schools and dispensaries. Solar energy as a resource has been in use for a long time for drying clothes and animal skins, for preserving meat, drying crops and evaporating seawater to extract salt.

Question: What are some of the advantages of renewable energy in Africa?

Answer: They have greater impact on improving energy services for the majority of Africa's population, especially the poor.

Renewables could play a vital role in minimizing fuel imports by providing an alternative to thermal-based electricity in the form of, for example, small hydro power units, cogeneration (using biomass as fuel) and geothermal energy

They offer diversification in energy generation, thus strengthening energy security.

Small and medium-scale renewable energy technologies (RETs) can play an important role in poverty alleviation.

They are relatively new technologies that due to their modularity do not require large amounts of capital. They are also relatively less sophisticated meaning that a significant industry could be developed in Africa even where technical expertise is limited. They are often cost competitive over their life cycle compared to conventional energy.

In addition to their global contribution to reducing greenhouse gases, RETs reduce local and regional energy-related environmental impacts and lastly,

Renewables that are not reliant on rainfall (e.g. geothermal, solar, wind) can reduce the weather related risks associated with heavy reliance on hydroelectric schemes.

Question: List some of the common barriers to energy efficiency in Africa.

Answer:

- Policy/regulatory barriers
- Financial/investment barriers
- Research/technology barriers

Question: Define energy efficiency.

Answer: Energy efficiency means using less energy to accomplish the same task. More efficient use of energy in a country means less money spent on energy by homeowners, schools, government agencies, businesses and industries, making this money available for other goods and services.

Exercises

1. Discuss the characteristics of the energy sector in Africa.
2. Using relevant documents, write a 2-3 page essay on renewable energy applications in your country.
3. What are some common barriers to energy efficiency in Africa? Discuss.

Presentation/suggested discussion topic

Presentation:

ENERGY REGULATION – Module 2: The Energy Sector in Africa

Suggested discussion topic:

1. Discuss the potential benefits of renewable energy applications in your country?

Relevant case studies

1. Cogeneration in Mauritius

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INTERNET RESOURCES

AFREPREN: www.afrepren.org

UNIDO: www.unido.org

REEEP: www.reeep.org

IT-Power: www.itpower.co.uk

UNDP: www.ke.undp.org/Energy%20and%20Industry.htm

KAM: kenyamanufacturers.org

ADB: www.undp.org/seed/eap/projects/FINESSE

UNFCCC on Climate Change: www.climatenetwork.org/eco

World Bank: www.weea.org/Newsletter/02/02.htm

Energy management training (India): www.energymanagertraining.com/new_index.php

GTZ: www.gtz.de/wind

Small hydro: www.small-hydro.com

www.consumerenergycenter.org/renewables/solarthermal/hotwater.html

www.nrel.gov/learning/re_solar_hot_water.html

www.retscreen.net/ang/g_solarw.php

www.eere.energy.gov/femp/technologies/renewable_solar.cfm

www.renewableenergyac-
cess.com/rea/tech/solarhotwater;jsessionid=E2902B7917317131FF920F01C845D4F6

www.worldbank.org/retoolkit

www.retscreen.net/ang/menu.php

www.risoe.dk

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www.consumerenergycenter.org/renewables/biomass/index.html

www.nrel.gov/learning/re_basics.html

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cogen.unep.org/Downloads

www.eere.energy.gov/femp/technologies/derchp_chpbasics.cfm

GLOSSARY/DEFINITION OF KEY CONCEPTS

Bagasse	The fibrous residue of sugar cane left after the extraction of juice and often used as a fuel in cogeneration installations.
Biogas digesters	Structure used for producing biogas from animal and crop residues under anaerobic conditions.
Bio-gas	A mixture of methane, carbon dioxide and water vapour.
Biofuels	Liquid fuels and blending components produced from biomass (plant) feedstocks, used primarily for transportation.
Boiler	A device for generating steam for power, for heating purposes; or for generating hot water for heating purposes or hot water supply.
Clean development mechanism (CDM)	One of the flexible mechanisms under the Kyoto Protocol which allows industrialized countries to meet part of their commitment to reduce emissions of greenhouse gas emissions by investing (money and/or technology) in emission reducing projects in developing countries. The rationale is that the negative impacts of emissions are independent of their source and that emissions reductions may be less costly in developing countries. The CDM provides a way to engage African countries in the emissions reduction process and should provide such countries with additional funding, allowing them to follow a less emissions-intensive path than they would otherwise follow.
Climate change	All forms of climatic variations, especially significant changes from one prevailing climatic condition to another.
Charcoal	Charred wood in the absence of oxygen.
Cogeneration	Simultaneous production of electricity and heat energy.
Developing countries	Countries which fall within a given range of GNP per capita, as defined by the World Bank.
Distribution losses (%)	The proportion of electricity lost in the process of distribution of electricity to consumers including losses due to pilferage. It is expressed as a percentage of generated electricity.
Electrification levels (%)	The percentage of the population or households that are connected to electricity from the grid.
Efficiency (in licensing)	The ability of the licensing agency to process applications within the shortest possible time and in the least number of stages the application needs to go through.

Electricity/power sector reforms	Deliberate changes in the structure and ownership of the electricity sector aimed at improving performance, efficiency and investment.
Electricity regulator	The agency in charge of monitoring the electricity sector.
Electrification	This is the process of connecting additional households, institutions and enterprises to the national grid.
Energy demand (millions toe)	The amount of modern energy required by various sectors of a country.
Energy efficiency (EE)	Using less energy to accomplish the same task.
Energy efficiency measures	The whole of investments done and systems and technologies adopted to increase energy efficiency.
Energy production (million toe)	The amount of modern energy produced within the country.
Energy reserves	Estimated quantities of energy sources that have been demonstrated to exist with reasonable certainty on the basis of geological and engineering data (proven reserves) or that can reasonably be expected to exist on the basis of geological evidence that supports projections from proven reserves (probable or indicated reserves).
Energy services	The end use ultimately provided by energy.
Energy sources	Any substance or natural phenomenon that can be consumed or transformed to supply heat or power.
Energy supply	Amount of energy available for use by the various sectors in a country.
Fossil fuel	An energy source formed in the earth's crust from decayed organic material e.g. petroleum, coal and natural gas.
Geothermal energy	Natural heat from within the earth, captured for production of electric power, space heating or industrial steam.
Geothermal plant:	A plant in which the prime mover is a steam turbine that is driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the earth. The fluids are extracted by drilling and/or pumping.
Greenhouse effect	The effect produced due to certain atmospheric gases that allow incoming solar radiation to pass through to the earth's surface, but prevent the radiation which is reradiated from the earth, from escaping into outer space.
Greenhouse gas	Any gas that absorbs infrared radiation in the atmosphere.

Household	A group of people who share a common means of livelihood, such as meals regardless of source of income and family ties. Members who are temporarily absent are included and temporary visitors are excluded.
Independent power producers (IPPs)	Privately owned power companies that produce electricity and sell it for a profit to the national grid or to a distribution utility.
Legal and regulatory framework (LRF)	Combination of the laws, institutions, rules and regulations governing the operations of the electricity industry.
Licensing	The act of issuing licenses allowing investors to operate legitimately within the electricity sector, usually as IPPs or independent power distributors (IPDs)
Liberalization	The removal of restrictions on entry and exit of the electricity industry making it open to any prospective and interested players. Often implies reduced state intervention.
Modern energy	Refers to high quality energy sources, e.g. electricity and petroleum products, as opposed to traditional energy sources such as unprocessed biofuels.
Micro hydro	Small-scale power generating systems that harness the power of falling water (above 100 kW but below 1 MW).
Population (millions)	The total number of people living within the borders of a country, whether citizens or not.
Primary energy	Energy sources in their crude or raw state before processing into a form suitable for use by consumers.
Renewable energy (RE)	Non-fossil and non-nuclear energy sources, i.e. wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.
Renewable energy technologies (RETs)	Technologies using renewable energy sources.
Small and micro enterprises	An enterprise that generates income up to a certain predefined limit.
Small hydro	Small-scale power generating systems that harness the power of falling water (1-15 MW).
Solar dryer	A special structure that uses the sun's energy to dry agricultural produce (fruits, vegetables, meat).
Solar photovoltaic (PV) technologies	Devices that convert the sun's energy into electricity for use in lighting, refrigeration, telecommunications, etc.
Solar thermal technologies	Devices that use the sun as the primary source of energy for heat appliances, e.g. solar water heaters, solar dryers.

Solar water heaters	Devices that use solar energy to heat water for domestic, institutional, commercial and industrial use.
Traditional energy	Low quality and inefficient sources of energy, predominantly biomass in nature and not often traded (e.g. wood fuel, crop residues and dung cakes).
Wind pumps/mills	Devices that use wind energy to lift water from underground sources.
Wind turbines	Devices used to generate electricity using kinetic energy from wind.
Utility	An entity partially or wholly involved in electricity generation, transmission, and/or distribution.
System losses (%)	The power that is lost during generation, transmission and distribution of electricity.
Total electricity consumption (GWh)	Total amount of electricity consumed within a country.
Transmission losses (%)	The proportion of electricity lost in the process of transmission of electricity.

Case study 1.

COGENERATION IN MAURITIUS

CONTENTS

1. COGENERATION IN MAURITIUS

1.1. Background

Mauritius, as a Small Island Developing State forming part of the African continent, is devoid of any fossil fuel and depends heavily on imported energy for use in the various sectors of the economy. Hydropower and sugar cane bagasse are the two renewable resources that can potentially be used for electricity generation. Hydropower is limited to availability of rainwater, seasonal in nature, and this resource is fully exploited in Mauritius. Interest in the use of bagasse for electricity generation and export to the grid intermittently in Mauritius started in 1957 from one sugar factory and since then more and more of these factories have joined in. But the most significant developments occurred in 1980 when a 10 MW continuous power plant (where the term "continuous" indicates bagasse fueling only) was commissioned to export electricity to the grid during the crop season only and in 1984 when another factory invested in a firm power plant (21.7 MW) (where the term "firm" indicates that the plant operates using both bagasse and coal when no bagasse is available) to export electricity to the grid all year round.

With the success achieved in those plants and pressed by events in the Gulf area in 1991, the Government in collaboration with the private sector worked out a Bagasse Energy Development Programme. The objectives of the programme were to displace investments to be effected by the utility, to reduce the reliance of the country on petroleum products and diversify its energy base, to allow for the modernization and rehabilitation of the sugar industry and improve its viability, to save on foreign exchange through reduction in imports of fossil fuel and finally to contribute in the mitigation of the enhanced greenhouse effect by displacing fossil fuel.

A number of factors contributed to the eventual success of bagasse energy development. A clear policy on bagasse use for electricity was defined by the Government and agreed to by all stakeholders. A number of plans, policies, actions and legislations to facilitate bagasse energy development were put in place. Constraints identified all along the implementation of these plans were attended to in consultation with all stakeholders including Government agencies and the utility, with the Mauritius Sugar Authority acting as the focal point/facilitator.

While providing incentives to entrepreneurs to invest in power plants as independent power producers, the interests of the small cane growers and the workers had not been ignored. Through legislation and the creation of a Sugar Investment Trust, the Government ensured that this vulnerable group in the sugar industry shares in the profits.

1.2. Status of cogeneration in Mauritius

The sugar industry's future is at stake. In the local context, the cost of production is increasing and on the international scene, sugar prices are decreasing. These factors will impact negatively on the industry if measures are not taken to mitigate these effects. Factory modernization, centralization and exploitation of the by-products for more value added products are measures that will ensure the long-term viability of the industry. Energy from bagasse was one option that was given top priority in this context.

With the centralization of cane milling activities, investments were made in seven continuous power plants and three firm power plants. Some characteristics of these power plants are given in table 1.

Table 1. Bagasse-based power plants in Mauritius up to year 2000

Factory	Tonnes cane per hour	Power	Start date	Units from bagasse (GWh)	Units from coal (GWh)	Total units from bagasse and coal (GWh)
FUEL	270	F	Oct. 1998	60	115	175
Deep River Beau Champ	270	F	April 1998	70	85	155
Belle Vue	210	F	April 2000	105	220	325
Médine	190	C	1980	20	—	20
Mon Trésor Mon Désert	105	C	July 1998	14	—	14
Union St Aubin	150	C	July 1997	16	—	16
Riche en Eau	130	C	July 1998	17	—	17
Savannah	135	C	July 1998	20	—	20
Mon Loisir	165	C	July 1998	20	—	20
Mon Désert Alma	170	C	Nov. 1997	18	—	18
Total		3 F		360 GWh	420 GWh	780 GWh
		7 C		235 GWh F		
				125 GWh C		

F = Bagasse during crop and coal during intercrop
C = Bagasse during crop season only

1.3. Impact of cogeneration development in Mauritius

Impacts of cogeneration in the power sector

Over the 10-year period (1993-2002), the installed capacity of the sugar industry located power plants increased from 43 MW to 242 MW, with the concurrent increase in electricity export to the grid (table 2). In 1996, 119 GWh of electricity were exported from bagasse-based generation. This was achieved through investment mostly by private sugar mills implementing cogeneration technology with their own private funds. By the year 2002, cogenerated energy increased significantly with investment in more efficient bagasse-to-electricity processes and in a greater number of units, so much so that the electricity exported to the grid from bagasse increased to 300 GWh from the 160 MW installed (or 33 per cent) firm duel-fuel installed capacity, with 10 of the 11 sugar factories operating bagasse units and contributing to the total. With coal being burnt in three firm power plants the total electricity export from the sugar industry reached 746 GWh in 2002. This represented 43.5 per cent of the total electricity exported to the grid for the island.

Table 2. Evolution of cogeneration (1991-2002)

	Cogeneration			Island total		Bagasse (%)		Bagasse + coal (%)
	Bagasse		Coal					
Year	IC	GWh	GWh	IC	GWh	IC	GWh	GWh
1993	43	71	40	308	870	14.0	8,2	12,8
1994	43	77	46	308	945	14.0	8,1	13,0
1995	43	84	41	332	1047	13.0	8,0	11,9
1996	43	119	—	332	1151	13.0	10,3	10,3
1997	53	125	23	370	1252	14.3	10,0	11,8
1998	90	225	62	397	1365	22.7	14,2	18,7
1999	90	184	155	425	1424	21.2	12,9	23,8
2000	160	274	327	478	1527	33.5	17,0	39,4
2001	246	300	411	660	1657	37.3	18,1	42,9
2002	242	299	447	656	1715	36.9	17,4	43,5

Source: CEB reports, Commercial scale cogeneration of bagasse energy in Mauritius, Deepchand, 2002; Veragoo, 2003.

The kWh/tonne cane processed in 1991 was 12 and even after implementation of the projects in the year 2002, the value had only reached 61 kWh per tonne of cane (table 3). This is well below the 110 kWh/tonne cane obtained in Réunion where only two factories are in operation, each processing around 900,000 tonnes of cane annually. Each factory is equipped with 2 x 30-35 MW power plants operating at a pressure of around 82 bars. In Mauritius only the Compagnie Thermique de Bellevue (CTBV) operates with this efficiency in Mauritius and has reached a conversion efficiency of 130 kWh/tonne cane.

Table 3. Evolution of electricity production from the sugar industry (GWh) and kWh/tonne cane

Power	Fuel source	Year											
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Firm	Bagasse	39	50	39	44	46	70	66	81	111	167	186	171
	Coal	54	43	40	46	41	10	23	62	155	327	411	447
Continuous	Bagasse	21	28	27	28	30	33	53	109	78	107	114	128
Intermittent	Bagasse	10	6	4	4	5	7	6	4	1	0.5	0	0
Total GWh (bagasse)		70	84	70	76	81	110	125	194	190	274.5	300	299
Total GWh (bagasse & coal)		124	127	110	122	122	120	148	256	345	601.5	711	746
Total tonne cane x 10^6		5.62	5.78	5.40	4.81	5.16	5.26	5.79	5.78	3.88	5.1	5.78	4.87
kWh/tc		12	15	13	16	16	21	22	34	49	54	52	61

Impact of cogeneration on the sugar sector

Bagasse energy projects are linked with sugar factory modernization in that boilers, turbo alternators and other energy efficient equipment represent a major proportion (up to 50 per cent) of the cost of a sugar factory. Investing in an energy project ensures that this part of the investment (useful life of 25 years), crucial to sugar processing, is financed independently of sugar activities. In addition, the sale of electricity adds to the revenue of sugar companies. Furthermore, linking energy projects to centralization brings about a reduction in the cost of production. In 1985, 21 sugar factories were in operation and the number decreased to 11 in 2005. Ten of these factories export energy to the grid and only three of them are firm duel fuel power plants. It has been projected that by 2010, only four sugar factories will be in operation through the process of centralization and it is envisaged that each one of them will be equipped with a firm power plant which is generally more efficient in energy cogeneration and export to the grid.

Environmental impact/benefit of cogeneration

From an environmental life cycle perspective, sugar cane bagasse energy is associated with a net positive global benefit in that sugar cane is an annually renewable crop and contributes to a reduction in greenhouse gas emissions from energy which would have otherwise been generated from fossil fuels. The carbon dioxide released from the combustion of bagasse is re-absorbed in the ensuing crop and hence is carbon neutral. With the use of cane field residues for energy, more electricity can be generated, otherwise the residues decay and release methane, another greenhouse gas.

With the export of around 300 GWh of cogenerated electricity to the grid, around 200,000 tonnes of coal are avoided, thus alleviating the burden on foreign exchange for such imports. In addition the projects also generate carbon emission credits that are potentially tradable under the Kyoto Protocol Clean Development Mechanism. The value of such credits could be as much as $US 20 per tonne of carbon dioxide. The revenue derived therefore further enhances the financial viability of this renewable energy project.

The environmental control technology adopted in the power plants results in improved thermal efficiency (that is, less heat is rejected compared to older systems and fewer particulate matter emissions ($< 100\ mg/Nm^3$) are produced. Sulphur dioxide (SO_2) emission is insignificant (bagasse contains no sulphur) and nitrogen oxide (NO_2) emissions are also reduced due to the use of spreader stoker technology.

Impact of cogeneration on the Mauritian economy

Bagasse-based cogeneration development in Mauritius has delivered a number of benefits including reduced dependence on imported oil, diversification in electricity generation and improved efficiency in the power sector in general. Using a wide variety of innovative revenue sharing measures, the cogeneration industry has worked closely with the Government of Mauritius to ensure that substantial benefits flow to all key stakeholders in the sugar economy, including the poor smallholder farmer. The equitable revenue sharing policies that are in place in Mauritius provide a model for emulation in ongoing and planned modern biomass energy projects in Africa.

2. TECHNIQUES ADOPTED IN SUCCESSFUL DEVELOPMENT OF COGENERATION

The following factors have contributed to the success of cogeneration:

- Clearly spelled out policy on sugar cane bagasse for cogenerated electricity and provision for appropriate incentives to induce investment in sugar factory modernization and investment in power plants.
- Adoption of energy efficiency and conservation measures in cane juice heating, evaporation, sugar boiling and crystallization to bring down process steam consumption.
- Electrification of drive processes of all prime movers in cane milling.

- Targeting a cane crushing capacity of around 200 tonnes of cane per hour to match with one module of 35-40 MW installed capacity power plant operating at a steam pressure of around 82 bars. This is a commercially proven technology.
- Use of coal as a complementary duel fuel in case of shortage of cane to enable year round power export to grid.
- Undertaking centralization of cane milling to ensure bagasse availability on site rather than saving bagasse in clusters and transporting it to a central power plant.
- Working out and establishing the kWh price independently of the utility and the IPP or alternatively inviting requests for proposals with set guidelines in a competitive bidding process.
- Make provision for participation of small planters and workers in the equity portion of investment.
- Negotiating and presenting a power purchase agreement describing in detail the obligations of the IPP towards the utility and vice versa, including in particular payment obligations by the utility. This PPA is used inter alia in negotiating a loan from the bank.

3. POTENTIAL FOR REPLICATION IN THE AFRICAN CONTINENT

The success achieved with bagasse energy cogeneration in Mauritius can be replicated in almost all the cane sugar producing countries on the African continent. Sharing of experiences and opportunities for training can be offered given the variety of power plants in terms of capacities, operating pressures and degrees of sophistication linked with plant efficiency.

Table 4 gives the production statistics of sugar and cane in countries on the African continent. The potential amount of electricity that can be exported to the grid using two commercially proven technologies (steam pressures of 44 and 82 bars respectively) have also been worked out on the basis of results obtained in Mauritius. It must be highlighted that such plants require a minimum cane crushing capacity of 200 to 300 tonnes cane per hour and many of the African countries at present have cane production well below these capacities. However, it has been observed that the cane sugar industry in a number of these countries is being rehabilitated and modernized and there is merit in coupling these plants with a cogeneration facility. All the cane sugar factories in Mauritius and Réunion have successfully integrated sugar and electricity production. The total potential in the countries in Africa is around 9,600 GWh on the basis of present cane production. Only Mauritius and Réunion are exploiting sugar cane bagasse in a significant manner for energy production.

Table 4. Production of sugar and sugar cane and potential for cogeneration in Africa (2002)

African countries	Sugar (x 10^3t)	Sugar cane[a] (x 10^3t)	Cogeneration potential (GWh) @ 31 bars[b]	@ 44 bars[c]	@ 82 bars[d]
Angola	31	282	104	20	31
Benin	5	45	2	3	5
Burkina Faso	40	364	18	25	40
Burundi	21	191	10	13	21
Cameroon	113	1,027	50	72	113
Chad	33	300	15	21	33
Congo	55	500	25	35	55
Côte d'Ivoire	158	1,436	71	101	158
Egypt	1,397	12,700	635	889	1,397
Ethiopia	294	2,672	131	187	294
Gabon	18	164	8	11	18
Guinea	26	236	12	17	26
Kenya	423	3,845	192	269	423
Madagascar	32	291	15	20	32
Malawi	257	2,336	117	164	257
Mali	34	309	15	22	34
Mauritius	552	5,018	250	351	552
Morocco	156	1,418	71	99	156
Mozambique	242	2,200	110	154	242
Nigeria	20	182	9	13	20
Réunion	210	1,909	95	134	210
Senegal	93	845	42	59	93
Sierra Leone	6	55	3	4	6
Somalia	21	191	10	13	21
South Africa	2,755	25,045	1252	1,753	2,755
Sudan	792	7,200	360	504	792
Swaziland	520	4,727	236	331	520
United Rep. of Tanzania	190	1,727	86	121	190
Togo	3	27	1	2	3
Uganda	244	2,218	111	155	244
Zaire	75	682	34	48	75
Zambia	231	2,100	105	147	231
Zimbabwe	565	5,136	257	360	565
Total	9,612	87,378	4,362	6,117	9,612

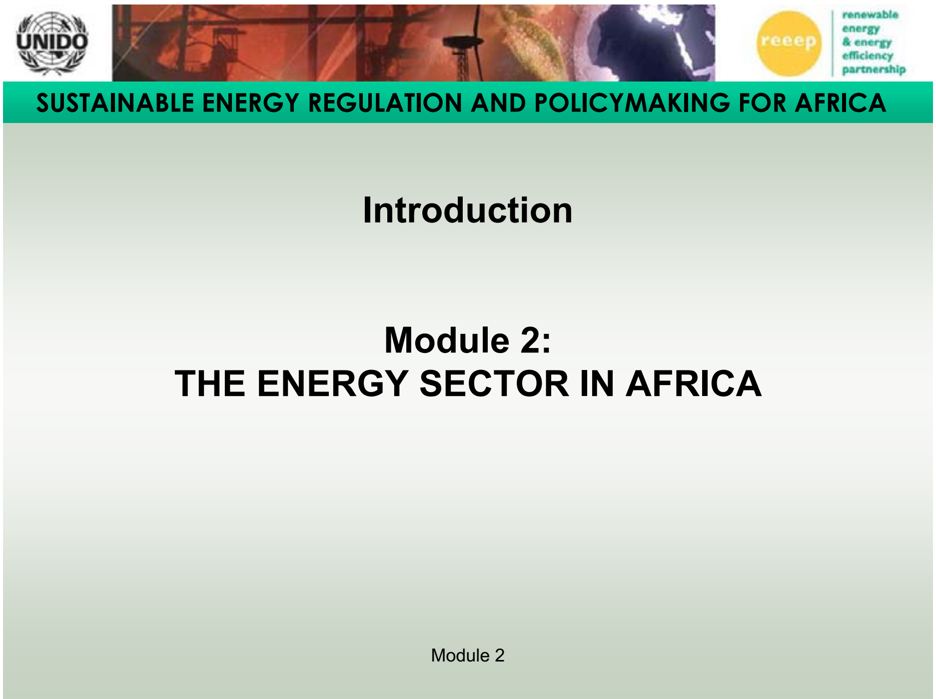
[a]Estimated at sugar recovered % cane of 11%
[b]Based on 50 kWh/tonne cane
[c]Based on 70 kWh/tonne cane
[d]Based on 110 kWh/tonne cane

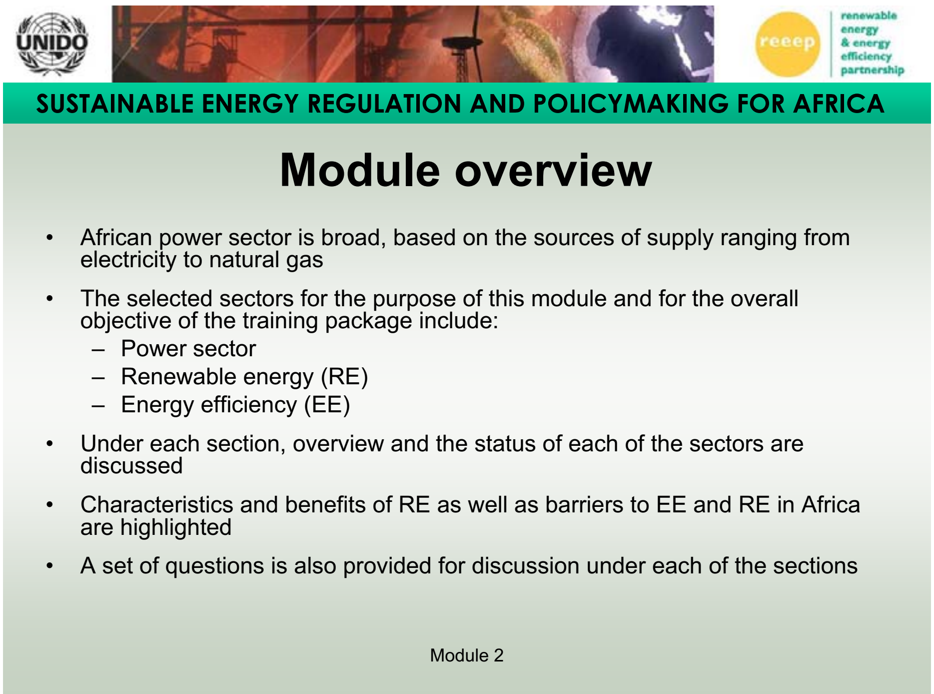
CONCLUDING REMARKS

The sugar cane crop is an agriculturally grown crop, which is known to have a high bioconversion efficiency of the capture of sunlight; this results in a high amount of atmospheric carbon being fixed into biomass. Until recently, the main interest in sugar cane was only to recover sugar from this biomass, but in the light of recent successful experiences in cogeneration, it can now be considered as a major renewable energy resource in cane sugar-producing countries. The majority of the countries on the African continent are endowed with agro-climatic conditions which are conducive to sugar cane production and, with proper investment and management of resources, high yields are potentially obtainable.

Amongst other energy carriers, electricity from the fibrous fraction of cane known as bagasse has been shown to be commercially viable in island states such as Mauritius and Réunion which are devoid of fossil fuel reserves. On the African continent, around 10,000 GWh of electricity is potentially exportable to the grid based on the current amount of cane production when using state-of-the-art technology for conversion of bagasse into electricity. Power sector reforms in the African countries should take on board this option of cogeneration through the inclusion of independent power producers to undertake power generation.

Opportunities for the replication of this success in other countries in the region should be examined, especially as this technology is environment friendly and can attract funds from international agencies such as the GEF, the Prototype Carbon Fund and activities implemented jointly under the Clean Development Mechanism of the Kyoto Protocol.


SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA
Introduction
Module 2:
THE ENERGY SECTOR IN AFRICA
Module 2


SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA
Module overview
• African power sector is broad, based on the sources of supply ranging from electricity to natural gas
• The selected sectors for the purpose of this module and for the overall objective of the training package include:
– Power sector
– Renewable energy (RE)
– Energy efficiency (EE)
• Under each section, overview and the status of each of the sectors are discussed
• Characteristics and benefits of RE as well as barriers to EE and RE in Africa are highlighted
• A set of questions is also provided for discussion under each of the sections
Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Module aims

- Provide an overview of the energy sector in Africa
- Present status and performance of the power sector in Africa
- Highlight key characteristics of the power sector in Africa
- Review the status and the benefits of RE in Africa
- Provide an overview of EE in Africa
- Review the benefits of EE with specific emphasis on the industrial sector

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Module learning outcomes

- Broad appreciation of key elements of the energy sector in Africa
- Enhanced understanding of the current status of power sector, RE and EE in Africa
- Better grasp of the benefits of RE and EE in Africa

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Introduction

- While this module uses Africa-wide data, emphasis is placed on sub-Saharan Africa because of the low access levels of modern source of energy especially for the poor
- The module recognizes that the availability of modern, reliable and efficient energy services is an important and indeed essential driver for economic development
- Most countries in Africa are faced with a major challenge in trying to achieve their development and social obligations because of inadequate access to modern energy services
- Majority of the population still depend on traditional biomass, which often has adverse environmental and health impacts
- Governments in the region also invest more in conventional energy sources rather than in renewable energy sources (RES)

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Definition of the Power Sector

- The power sector can be defined as an energy sector that consists of both electricity generation plants (and combined heat and power (CHP) plants) and the transmission and distribution infrastructure, and whose primary business is to generate, transport and sell electricity (electricity and heat in the case of CHP) to the public.

Module 2

Key Players of the Power Sector

- Key players in the power sector include;
  - government ministries (for policy design)
  - utilities
  - independent power producers (IPPs)
  - distributors
  - regulators (for policy implementation / regulation)
  - rural electrification agencies and funds
- Other players include manufacturers and consulting engineers who supply equipment

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Status of the Power Sector in Africa

- Electricity is needed to both industrialize and provide basic energy
- Most African countries have a challenge in meeting their energy needs especially sub-Saharan countries
- Low levels of electricity access in sub-Saharan Africa (SSA) demonstrate this deficiency as an estimated 17% of the region's population, and less than 5% of rural areas are electrified
- This situation needs to change if the SSA is to be economically competitive with other developing regions and realize its sustainable development goals

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Characteristics of the Power Sector in Africa

- Sources of power supply in Africa broadly reflect each subregion's energy resource endowment
  - oil and gas reserves are concentrated in North and West Africa (power sector dominated by fossil-fuel fired electricity)
  - hydroelectric power with some limited use of geothermal-based and biomass-based power stations in Eastern Africa
  - Coal (and to lesser extent hydropower) in the Southern Africa industry

Map of Africa showing North, South and sub-Saharan Africa

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Characteristics of the Power Sector in Africa (2)

- The African power sector is characterized by small systems, with over three quarters of the continent's installed capacity coming from the Republic of South Africa and North Africa
- The large-scale conventional energy sector (electricity and petroleum) receives the bulk of energy investment in most African countries and this serves only a small proportion of the population
- Provision of electricity is largely confined to urban middle and upper income groups and to the formal commercial and industrial sectors

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Characteristics of the Power Sector in Africa (3)

- In spite of substantial investment, the power sector in sub-Saharan Africa is characterized by;
  - Unreliability of supply
  - Low capacity utilization and availability factor
  - Deficient maintenance
  - Poor procurement of spare parts
  - High transmission and distribution losses
- The financial performance of many power sector utilities in Africa is largely unsatisfactory
- Power utilities have failed to provide adequate electricity services to the majority of the region's population, especially the rural communities and the urban poor

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Access to Electricity and Modern Cooking Fuels in 2002

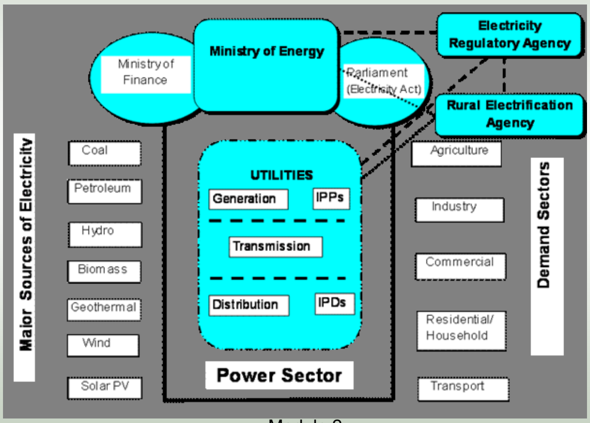
Country or region	*Population using biomass for cooking (million)*	*Population without electricity (million)*	*Urban population with electricity (%)*	*Rural population with electricity (%)*
North Africa		***9***	***99***	***88***
Sub-Saharan Africa (SSA)	***575***	***526***	***52***	***8***
Africa		***535***	***62***	***19***
South Asia	*713*	*798*	*69*	*33*
Latin America	*96*	*46*	*98*	*61*
China and East Asia	*998*	*216*	*96*	*83*
Middle East	*8*	*14*	*99*	*78*
Developing economies	***2,390***	***1,615***	***85***	***52***

Sources: World Bank, 2000 and IEA 2004

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Institutional structure of the African Power Sector

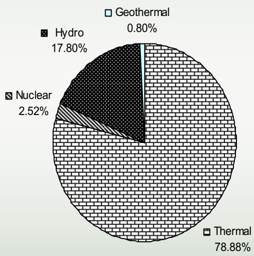


Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Electricity Production in Africa

- The core sources of electricity in most sub-Saharan African countries are hydropower and oil products
  - Specifically the following are highlighted:
    - Coal in Southern Africa
    - Geothermal in Eastern Africa, e.g. Kenya
    - Cogeneration in Eastern Africa, e.g. Mauritius
  - The total electricity production for Africa in 2000 was 441 TWh
  - Hydropower contributes about 18% of the total power generation in Africa

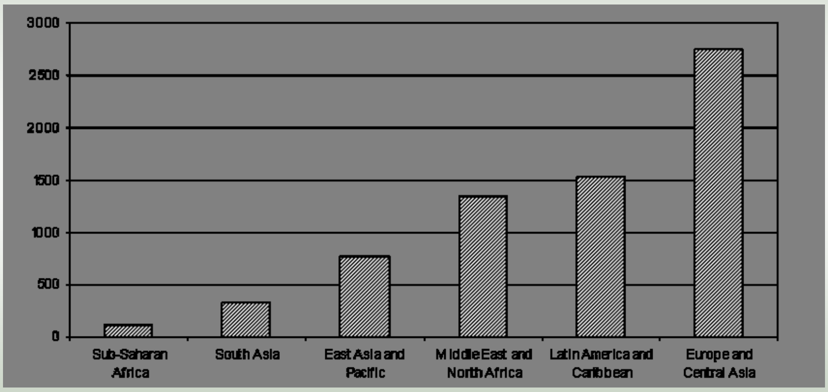


Sources: IEA 2005

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Electricity Consumption by Region in 2000



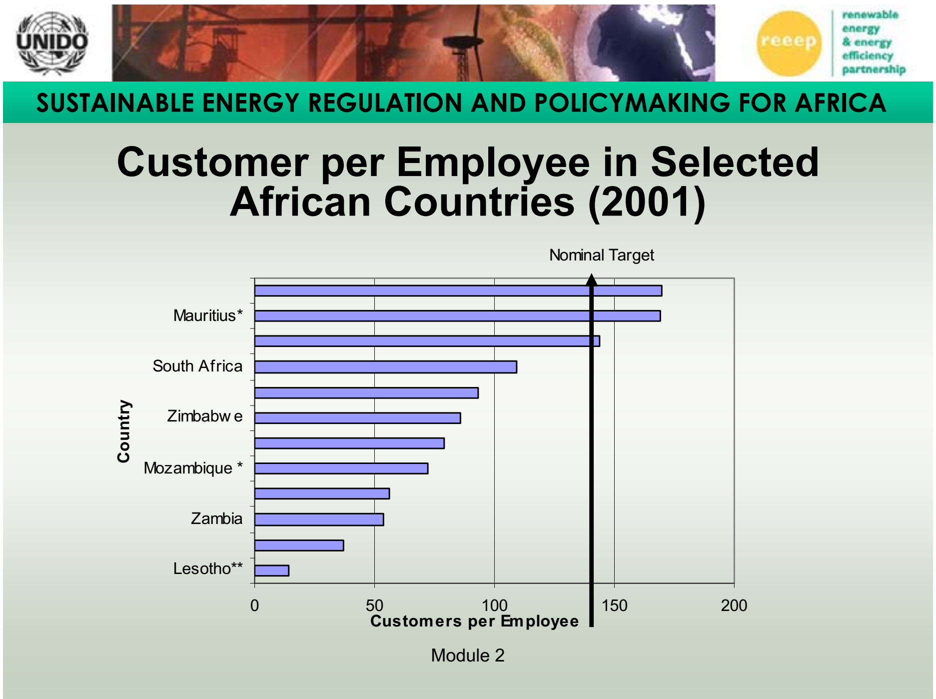
Module 2

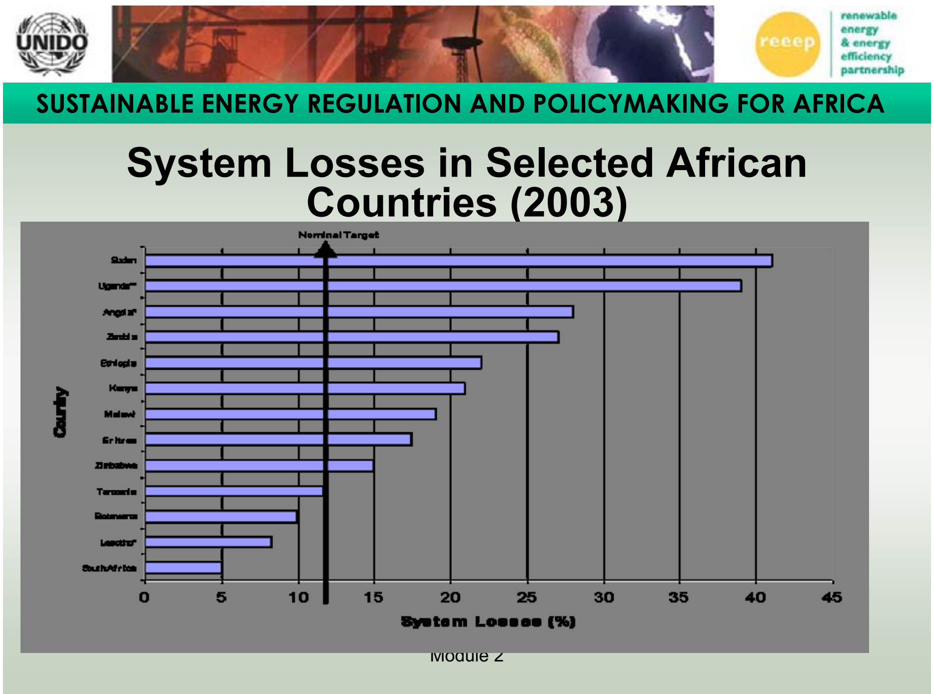
SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Technical Performance of the African Power Sector

- Monopolistic nature of the national electricity industry has contributed to under-performance in the delivery of electricity services
- Power sector institutions are characterized by: unreliable power supply; low capacity utilization and availability factor; deficient maintenance; poor procurement of spare parts; high transmission and distribution losses
- With the exception of Egypt, Côte d’Ivoire, Uganda, Mauritius and Eritrea, the customers per employee ratios are below norm

Module 2


UNIDO
reeep
renewable energy & energy efficiency partnership
SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA
Customer per Employee in Selected African Countries (2001)
Nominal Target
Mauritius*
South Africa
Zimbabw e
Mozambique *
Zambia
Lesotho**
Country
0
50
100
150
200
Customers per Employee
Module 2


UNIDO
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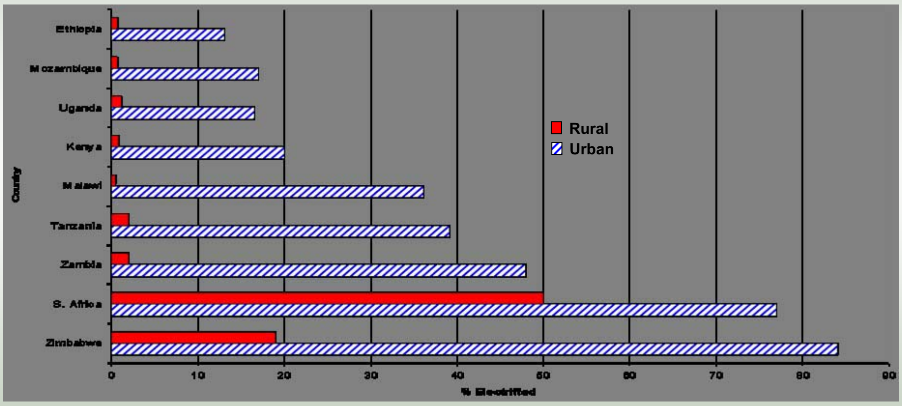
renewable energy & energy efficiency partnership
SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA
System Losses in Selected African Countries (2003)
Nominal Target
Sudan
Uganda**
Angola*
Zambia
Ethiopia
Kenya
Malawi
Eritrea
Zimbabwe
Tanzania
Botswana
Lesotho*
South Africa
0
5
10
15
20
25
30
35
40
45
System Losses (%)
Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Urban and Rural Electrification in Selected African Countries (2004)



Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Financial Performance of the African Power Sector

- The financial performance of most African utilities is unsatisfactory as:
  - Debt owed by customers is usually sizable. In most cases, the government and its parastatals account for a large share of this debt
  - Inability of utilities to mobilize sufficient investment capital
  - Non-sustainable pricing policies
  - Poor financial management of the utility

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Questions/Activities

1. List some of the players in the power sector in your country and discuss their role
2. Discuss with colleagues the performance of the power sector in your country

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Definition of Renewable Energy (RE)

- Definition: energy forms that can not be easily depleted
- Examples:
  - wind
  - solar
  - hydro
  - biomass
  - geothermal
  - tide and wave energy
- Africa has 1,100 MW of hydro-power capacity, 9,000 MW of geothermal (hot water and steam based) potential, abundant biomass and significant solar and wind potential

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Status of Renewable Energy Technologies in Africa

- The following technologies have been highlighted in describing the status of renewable energy technologies;
  - Small and medium renewables e.g.
    - Small hydro
    - Solar
    - Wind
    - Small scale biomass energy
  - Large-scale renewables e.g.
    - Large-scale biomass (cogeneration)
    - Geothermal

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Small Hydro

- Small hydropower is often categorized into mini and micro hydro, referring to the harnessing of power from water at a small scale (capacity of less than 10MW)
- Small hydro has the advantage of multiple uses: energy generation, irrigation and water supply
- Small hydro is a reliable technology that is well suited to rural areas outside the central power grid

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Small Hydro (2)

Development in Selected African Countries

Country	Small hydro potential (MW)	Harnessed (MW)
Uganda	46	8 .00
Mauritius	-	6.70
Kenya	600	14.00
Burundi	42	18.00
Zambia	4	1.05
United Republic of Tanzania	70	9.00
Lesotho	-	8.74
Malawi	-	5.10
Botswana	-	1.00
Rwanda	20	3.00
South Africa	-	0.40
Swaziland	-	0.30
Mozambique	-	0.1

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Solar Energy

- Can be broadly categorized into:
  - solar photovoltaic (PV) technologies (converting the sun's energy into electrical energy)
  - solar thermal technologies, which use the sun's energy directly for heating, cooking and drying, etc.
- It is the best known RE in Africa and has been in use for a long time for:
  - drying animal skins and clothes
  - preserving meat
  - drying crops and
  - evaporating sea water to extract salt

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Solar Energy (2)

- Solar energy is now utilized at various levels e.g.
  - Small-scale: household level for lighting, cooking, water heaters and solar architecture houses
  - Medium-scale appliances: water heating in hotels and irrigation
  - Industrial scale: used for pre-heating boiler water for industrial use and power generation, detoxification, municipal water heating, telecommunications, and, more recently, transportation (solar cars)

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Solar Energy (3)

Dissemination of Solar PV Technology

- PVs have been promoted widely in the region and almost every sub-Saharan African country has had a major PV project
- The solar PV projects in the region have mainly benefited the high-income population segments
- Due to its cost, Solar PV is unaffordable to majority of the population in Africa

Country	Number of Systems	Estimated Installed Capacity(kWp)
Angola		10
Botswana	5,700	1500
Burundi	1800	
Djibouti	941	
Eritrea	2,000	400
Ethiopia	5,000	1200
Kenya	150,000	3600
Mozambique	-	100
Malawi	900	40
South Africa	150,000	8
Swaziland	1,000	50
Tanzania	2000	300
Uganda	3,000	152
Zambia	5,000	400
Zimbabwe	84,500	1,689

Estimated number and capacity disseminated solar PV Systems

Module 2

Renewable Energy: Solar Energy (4)

Dissemination of Solar Thermal Technology

- Solar thermal technologies that have been disseminated in Africa include;
  - Solar water heaters
  - Solar cookers
  - Solar driers
  - Solar distillers
- Diffusion of these systems has been slower than anticipated
- In some developing countries, LPG subsidies make it difficult for solar water heaters to be competitive
- The bulk of solar water heaters are used by high income households, institutions, hotels, lodges etc.

Country	Installed capacity (1000m^2)
Botswana	50
Malawi	4.8
Mauritius	40
Namibia	24
Seychelles	2.4
South Africa	500
Zimbabwe	10

Installed capacity of domestic solar water heaters

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Wind Energy

- Low wind speeds prevail in many sub-Saharan African countries
- South Africa, North Africa and the Red Sea coast have some of the highest wind potential in the region
- Africa had seen little development of modern wind turbines and most of its wind machines (found in eastern and southern Africa) are used for water pumping, rather than electricity generation

Country	Potential (m/s)	Number of Wind Pumps
Botswana	2-3	200
Burundi	>6	1
Djibouti	4	7
Ethiopia	3.5 – 5.5	-
Eritrea	3-8	<10
Guinea	2.0.4.0	-
Kenya	3	272
Mauritius	8.0	-
Morocco	>10	-
Mozambique	0.7-2.6	50
Namibia	-	30,000
Rwanda	-	-
Seychelles	3.62-6.34	-
South Africa	7.29-9.7	300,000
Sudan	3	12
United Rep. of Tanzania	3	58
Uganda	4	7
Zambia	2.5	100
Zimbabwe	3-4	650

Wind energy and dissemination of wind pumps in selected African countries

Renewable Energy: Biomass
Small Scale

- Efforts in modernizing small-scale biomass energy systems led to the development of an energy efficient charcoal kiln and an environmentally sound improved cook stove
- Charcoal is an important household fuel, and to a lesser extent, industrial fuel. Its mainly used in the urban areas as its ease of storage, highenergy content and lower levels of smoke emissions, make it more attractive than fuel wood
- Biogas technology is also used as it is relatively simple and straightforward. The raw material is animal dung, which is plentiful in many rural areas of sub-Saharan Africa. The investment cost of the technology has been prohibitive for most poor African households

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Biomass (2)
Large Scale - Cogeneration

- Cogeneration is the simultaneous production of electricity and process heat from a single dynamic plant
- Various forms of biomass can be used to fuel the plant including bagasse, waste from paper pulp, palm wood and rice husks
- Cogeneration offers opportunities for generating electricity and process heat with limited capital investments, while avoiding the environmental impacts of increased fossil fuel combustions
- Mauritius provides an example of a very successful use of cogeneration, meeting over 40% of its electricity generation, with over half of this coming from bagasse

Country	Installed Capacity in 2003 (MW)	Total generation in 2003 (GWh)	Co generation potential	
			Quantity (GWh)	% of total generation
Ethiopia	493*	1,812*	150.3	8.3
Kenya	1,143	4,563	530.3	11.6
Malawi	306	1,177	250.8	21.3
Mauritius	725	1,564*	600.0	38.4
Sudan	1380	3,165	643.5	20.3
United Republic of Tanzania	863*	2,770*	100.8	3.6
Uganda	303	1,756	173.4	9.9
Zimbabwe	1,961	7,906	686.4	8.7
Swaziland	180	395		
Total	**7,354**	**25,108**	**3,135.5**	**122.1**

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy: Geothermal

- Geothermal energy is the natural heat from the earth's interior stored in rocks and water within the earth's crust
- Worldwide, around 8,100 MW is generated, out of an estimated global potential of 60,000 MW
- Advantages of geothermal energy include;
  - near-zero emissions and
  - very little space requirement per unit of power generated
- Africa has the potential to generate 9,000 MW from geothermal power but little has been done to exploit it
- The potential for grid connected geothermal exploitation is highest in Ethiopia, Kenya, Uganda and Tanzania, which are all covered by the Great Rift Valley.
- Kenya was the first country in sub-Saharan Africa to exploit geothermal energy and has installed capacity of 127 MW

Country	Potential Generation in MW
Kenya	2,000
Ethiopia	>1,000
Algeria	700
Djibouti	230-860
Uganda	450
United Republic of Tanzania	150

Geothermal potential in selected African countries

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Potential Benefits of RE for Africa

- Provides favourable balance of payments
- Plays an important role in poverty alleviation, job and enterprise creation
- Most renewable energy technologies (RETs) are less sophisticated and require less capital. RETs, therefore, can encourage independent technology development in African countries
- RETs reduce negative environmental impacts
- Assists countries in reduction of power deficits

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Questions/Activities (2)

1. What is renewable energy?
2. Discuss some of the renewable energy applications available in your country

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Definition and Status of Energy Efficiency (EE)

- Energy efficiency means using less energy to accomplish the same task. Using less energy would mean a saving which could then be used on consumer goods, education, services, and products
- Energy efficiency in Africa is generally low, both at the industrial, transport and domestic level. In Kenya, for, example, it is estimated that between 10 and 30% of the primary energy input is wasted
- The present pattern of energy consumption is far from efficient and has adverse effects on the cost of energy supply, prices of goods produced and the environment.

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Energy Efficiency: Major Barriers

- Energy inefficiencies experienced in most industrial settings include:
  - Lack of commitment by management
  - Lack of proper instrumentation
  - Lack of or inadequately accurate reporting
  - Lack of acceptable standard of plant house-keeping
  - Inadequate control
  - Poor maintenance
  - Failure to monitor performance
- Major barriers to energy efficiency are:
  - Policy / regulatory barriers
  - Investment / financing barriers
  - Research / technological barriers

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Questions/Activities (3)

1. Are there any energy efficiency programmes in your country?
2. What are some of the barriers to investment in energy efficiency in your country's industrial sector?

Module 2

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

CONCLUSIONS

- Though endowed with substantial renewable energy resources, Africa's resource potential has not been fully exploited
- Renewable energy offer substantial opportunities for generating electricity and/or heat energy with limited capital investments, while avoiding the negative environmental effects of increased fossil fuel combustion
- Regulation is necessary to ensure investment in industrial energy efficiency

Module 2