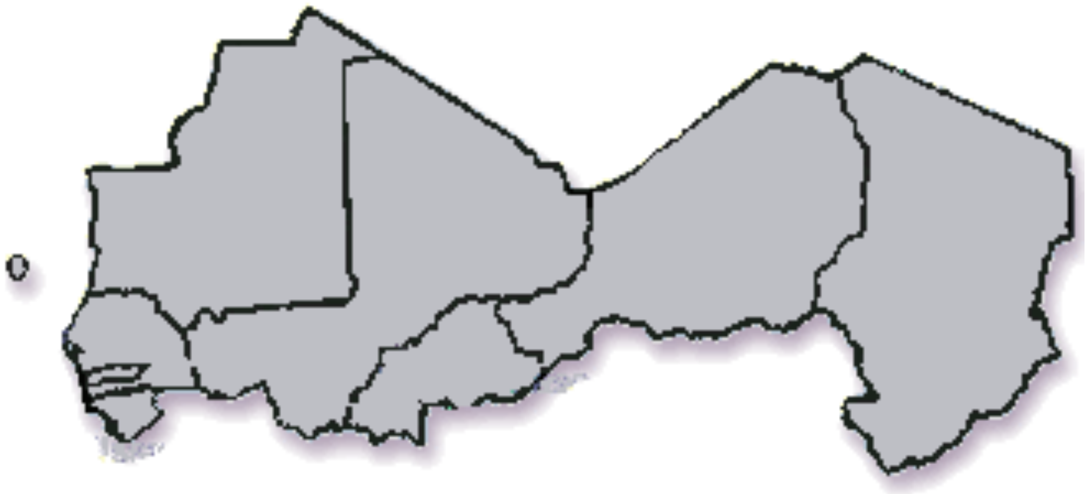
Intelligent Energy Europe

Energy for Poverty Alleviation in Sahel

IE4Sahel



Deliverable 4
Assessment of potential energy sources

Contract Nº. EIE/04/131/S07.40673

Participants:
IST – Instituto Superior Técnico - Portugal
ESD – Energy for Sustainable Development Ltd. - UK
CRES – Centre for Renewable Energy Sources – Greece
ARC - AGRHYMET Regional Center – Niger - subcontractor

LIST OF POTENTIAL ENERGY SOURCES - D4
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Preface to D4 Report for Work Package 4: Assessment of the potential energy sources

This WP was designed to assess the potential energy sources for each of the nine target countries, with a special focus on the supply side assessment. This objective would be achieved by analysing the potential energy sources, namely in RES (including mapping of this potential, whenever adequate data is available), by identifying the adequate information sources, such as local energy plans, macro data and population studies. The WP would also assess the potential for the introduction of good practices with respect to rational use of energy (RUE). This WP would also identify the existing barriers associated to these sources and propose solutions to overcome these barriers.

The final deliverable would be a list of potential energy sources and information gathered on supply side and linked to the specific energy policies assessed in WP3 for each of the beneficiary countries. The document would also include a similar analysis at global Sahel level.

The methodology outlined by CRES for carrying out the work described in this Work Package was based around a survey, with the help of a questionnaire, that was also designed by CRES with feedback from all IE4Sahel partners, that was provided to ARC at the early months of the project, which in turn would circulate it and attempt to receive responses and information from various African stakeholders in the energy field in all nine Sahelian countries **(for Questionnaire see Annex 6.4).**

Unfortunately, due to administrative problems out of CRES responsabilities, the result was the absence of the necessary field surveys. Therefore, CRES had to deliver the best possible literature survey for the potential energy sources in each country. This proved quite challenging as the amount of reliable and up to date studies regarding resource estimation for the Sahel is extremely limited. However it should be noted that the questionnaire may prove to be a useful tool to institutions like ARC in the future, for assessing more accurately the renewable energy potentials.

Renewable Energy Potentials Definitions

In a broad sense renewable energy sources refer to hydropower, biomass energy, solar energy, wind energy, geothermal energy, and ocean energy.
The term 'new' renewables suggests a greater focus on modern and sustainable forms of renewable energy, in particular: modern biomass energy, geothermal heat and electricity, small-scale hydropower, low-temperature solar heat, wind electricity, solar photovoltaic and thermal electricity, and marine energy.
Discussions on biomass are sometimes clouded by problems of definition. The term combustible renewables and waste (CRW) includes all vegetable and animal matter used directly or converted to solid fuels, as well as biomass-derived gaseous and liquid fuels, and industrial and municipal waste converted to energy. The main biomass fuels in developing countries are firewood, charcoal, agricultural residues and dung, often referred to as traditional biomass [31].

Table 1: Global Renewable Resource Base (Exajoules a Year)

Resource	Current use[a]	Technical potential	Theoretical potential
Hydropower	10.0	50	150
Biomass energy	50.0	>250	2,900
Solar energy	0.2	>1,600	3,900,000
Wind energy	0.2	600	6,000
Geothermal energy	2.0	5,000	140,000,000
Ocean energy	-	-	7,400
TOTAL	**62.4**	>7,500	>**143,000,000**

a. The current use of secondary energy carriers (electricity, heat and fuels) is converted to primary energy using conversion factors involved.
Adapted from: Goldemberg, J. (ed) 2000. World Energy Assessment: Energy and the Challenge of Sustainability. New York: UNDP.

Table 2: Types and Examples of Plant Biomass

Woody biomass	Non-woody biomass	Processed Waste	Processed fuels
• Trees • Shrubs and scrub • Bushes such as coffee and tea • Sweepings from forest floor • Bamboo • Palms	• Energy crops such as sugarcane • Cereal straw • Cotton, cassava, tobacco stems and roots • Grass • Bananas, plantains and the like • Soft stems such as pulses and potatoes • Swamp and water plants	• Cereal husks and cobs • Bagasse • Wastes from pineapple and other fruits • Nut shells, flesh and the like • Plant oil cake • Sawmill wastes • Industrial wood bark and logging wastes • Black liquor from pulp mills • Municipal Waste	• Charcoal from wood and residues • Briquette and densified biomass • Methanol and ethanol • Plant oils from palm, rape, sunflower and the like • Producer gas • Biogas

Source: Goldemberg, J. (ed) 2000. World Energy Assessment: Energy and the Challenge of Sustainability. New York: UNDP.

[31]

One common way of defining renewable energy potentials, at least for EU countries, based on the Fraunhofer Institut is as follows:

Theoretical potential: energy flow;

Technical potential: technical constraints are considered;

Realisable potential: market growth rates, planning constrains limit the penetration at a certain time;

Biomass and biogas

For the calculation of the **theoretical potential of biomass** the area used for agriculture and forestry is taken into account. For these areas the amount of biomass produced is known from agricultural or other statistics. Taking a specific yield per area for the different biomass crops and average heat values the theoretical potential is calculated.

The **theoretical potential for biogas** is derived from the livestock of agricultural animals and average values for the specific amount of excrements.

The t**echnical potential for biomass and biogas** is derived by applying typical conversion efficiency for specific technologies. Furthermore biodegradable waste materials are considered as a source for electricity generation.

Wind energy: A region's mean wind speed and its frequency distribution have to be taken into account to calculate the amount of electricity that can be produced by wind turbines.

The **theoretical potential** can be derived from average wind speeds.

The **technical potential** is defined by the available area for installing wind power capacity. The potential for electricity generation is then assessed by applying wind maps on this specific areas to get the average wind speed and roughness class of the area. Power output is calculated from power curves of typical wind turbines.

Further the technical potential is limited by the number of turbines in a specific area, distance to rural areas, natural protection areas and so on leading to the social acceptable potential.

Geothermal energy: Geothermal energy is generally defined as heat coming from the Earth. It has large theoretical potential but only a much smaller amount can be classified as resources and reserves. Still, even the most accessible part, classified as reserves, exceeds current annual consumption of primary energy. But like other renewable resources, geothermal energy is widely dispersed. Thus the technological ability to use geothermal energy, not its quantity, will determine its future share. High-temperature fields used for conventional power production (with temperatures above 150 degrees Celsius) are largely confined to areas with young volcanism, seismic, and magmatic activity. But low-temperature resources suitable for direct use can be found in most countries.

The **theoretical potential i**s given by the average heat flow from the earth's interior to the earth's surface.

For the **technical potential** typical values for conversion efficiency and available area for the installation of geothermal power plants are considered.

The **realisable potential** is calculated with a bottom up approach considering all the specific sites that can be used for geothermal electricity generation.

Solar power

The **theoretical potential** is the average solar radiation on a specific area over a year multiplied with the total area of the country.

The **technical potential** takes into account the conversion efficiency and the available area for installing PV systems, which mainly are roofs, facades and fields.

The **technical potential for solar thermal power plants** is calculated by assuming a specific amount of agricultural land can be used. The generated electricity is calculated with a typical conversion efficiency of a solar thermal power plant **[30]**.

1. Sahel Countries Characteristics

1.1 Macro data (GDP, population, poverty data etc.)

Table 1.1.1 Demographic

	Total Population (millions) 2005	Avg. Population Growth rate (%) 2005	% Living in Urban Areas 2003	Agricultural population/ha arable & perm. crop land 2002
Cape Verde	0.507		55.9	2.2
Mauritania	3.1	2.9	62	2.9
The Gambia	1.5	2.6	26	4.3
Senegal	11.7	2.3	50	2.9
Guinea Bissau	1.6	3.0	34	2.2
Chad	9.7	3.0	25	1.7
Mali	13.5	2.9	32	2.1
Burkina Faso	13.2	3.0	18	2.6
Niger	14.0	3.3	22	2.2

Source: [20] UNFPA 2005. State of World Population 2005 – The promise of equality. Gender, Equity, Reproductive Health and the Millenium Development Goals. United Nations. New York.

Table 1.1.2 Economic Performance

	Human Development Index Value (HDI)	GDP (US$ billions) 2003	GDP (PPP US$ billions) 2003 [a]	GDP per capita (US$) 2003	GDP per capita (PPP US$) 2003 [a]
Cape Verde	0.721	0.8	2.4	1,698	5,214
Mauritania	0.477	1.1	5.0	384	1,766
The Gambia	0.470	0.4	2.6	278	1,859
Senegal	0.458	6.5	16.9	634	1,648
Guinea Bissau	0.348	0.2	1.1	160	711
Chad	0.341	2.6	10.4	304	1,210
Mali	0.333	4.3	11.6	371	994
Burkina Faso	0.317	4.2	14.2	345	1,174
Niger	0.281	2.7	9.8	232	835

a Estimates based on regression

Source: [21] UNDP 2005. Human Development Report 2005 – International cooperation at a crossroads. Aid, trade and security in an unequal world. United Nations. New York.

Table 1.1.3 Poverty

	Human Poverty Index (HPI-1)		MDG – Population below income poverty line (%)		
	Rank	Value (%)	$1 a day 1990-2003 [b]	$2 a day 1990-2003 [b]	National poverty line 1990-2002 [b]
Cape Verde	45	18.7			
Mauritania	79	40.5	25.9	63.1	46.3
The Gambia	88	44.7	59.3	82.9	64.0
Senegal	87	44.2	26.3	67.8	33.4
Guinea Bissau	93	48.2			48.7
Chad	100	58.8			64.0
Mali	101	60.3	72.3	90.6	63.8
Burkina Faso	102	64.2	44.9	81.0	45.3
Niger	103	64.4	61.4	85.3	63.0 [c]

b Data refer to the most recent year available during the period specified

c Data refer to a period other than that specified

Source: [21] UNDP 2005. Human Development Report 2005 – International cooperation at a crossroads. Aid, trade and security in an unequal world. United Nations. New York.

Table 1.2.1.a Energy

	Traditional fuel consumption (% of total energy requirements) 2002 [d]	Electricity consumption per capita (kWh) [e]	
		1980	*2002*
Cape Verde		55	99
Mauritania		60	58
The Gambia	63.6	70	96
Senegal	72.1	115	141
Guinea Bissau	50	18	41
Chad	97.2	10	12
Mali	85	15	33
Burkina Faso	89.4	16	32
Niger	85.3	39	40

d Incl. fuelwood, charcoal, bagasse (sugar cane waste), animal & vegetable wastes

e Refers to gross production, in per capita terms, which includes consumption by station auxiliaries and any losses in the transformers that are considered integral parts of the station. Also includes total electric energy produced by pumping installations without deduction of electric energy absorbed by pumping.

Source: [21] UNDP 2005. Human Development Report 2005 – International cooperation at a crossroads. Aid, trade and security in an unequal world. United Nations. New York.

Table 1.2.1.b Energy

	Primary energy consumption (Mtoe)		Household electricity consumption per capita (kWh)		LPG + Lamp Oil consumption per capita (koe)	
	1980	*1999*	*1980*	*1999*	*1980*	*1999*
Cape Verde	0.039	0.119	24	116	18	44
Mauritania	0.14	0.78	23	33	5.1	23
The Gambia						
Senegal	1.92	2.99	16	35	4.7	13.9
Guinea Bissau	0.15	0.20	13	27	1.3	5.3
Chad						
Mali	1.1	2	8	15	2	6
Burkina Faso	1.66	2.55	5	10.5	1.7	4.1
Niger	0.97	1.71	11	12	0.9	0.4

Source: [22] Institut de l'energie et de l'environnement de la Francophonie (IEPF) 2001. Profil inergitiques. http://www.iepf.org/ressources/profil.asp#pays248

1.2 Energy Sector Characteristics & Geographical

Cape Verde

Cape Verde is the smallest nation in the Sahel, consisting of 12 islands, covering an area of 4,033 km2, with a population of 507 thousands. ELECTRA is the public utility for power and water supply. In areas not covered by ELECTRA, municipalities or private consumers independently own and operate electricity production and distribution facilities, but ELECTRA provides technical support to some municipalities.

Part of the World Bank's project goal, is that ELECTRA will be privatized as a vertically integrated company by means of a bidding process to select a private strategic partner.

ECOWAS member.

Mauritania

1,030,700 km^2

The Gambia

The Gambia is the second smallest country in the Sahel with a total land area of 11,300 km2 (1,300 km^2 water) and a population of 1.5 million, growing annually at 2.6%, with 74% living in rural areas. With the exception of the Atlantic Ocean, the Gambia is completely enveloped by Senegal. Fuel wood is the dominant energy resource, accounting for about 81% of total energy consumption; petroleum products, including LPG, account for about 17%. Total installed electricity capacity is estimated to be 22 MW. The National Water and Electric Company (NAWEC) was the major body responsible for production and distribution of electricity and water. However in an ever worsening energy crisis, NAWEC and the rest of the energy Directorate were transferred to the Office of the President. GAMPOWER ref. 12). In 2000 NAWEC served 25,000 customers, of which more than 95% in the Greater Banjul area (ref.11). ECOWAS member.

Senegal

Senegal, occupying an area of 196,190 km2 (4,190 km2 water), with a population of 11.7 million, rising at a rate of 2.3% annually, is the only country in West Africa to have achieved some economic progress. Half of the population lives in urban centers, with the majority living in the Dakar region.

ECOWAS member.

Guinea Bissau

The country covers a land of 36,120 km2 (8,120 km2 water), that is mostly swampy terrain on the coast and low lying inland areas with the exception of the regions in the NE. The population is 1.6 million, rising at a rate of 3% annually, with 66% of the people living in rural areas.

ECOWAS

Chad

1.284 million km^2 (24,800 km^2 water – Lake Chad)

Mali

Mali is a landlocked country, with a total area of 1.24 million km^2, 65% of it being desert. The current population is 13.5 million, rising at a rate of 2.95% annually, with 68% of the people living in rural areas.

EDM was the state owned power utility that was poorly managed and lacked funds to ensure quality and reliability of service and to expand access. Through a now closed project, the GoM undertook a restructuring of the power sector and established in March 2000 an independent regulatory authority (CREE). In December 2000 the new operator (SAUR International) assumed responsibilities.

The country's domestic energy resources consist of biomass (fuelwood, charcoal, agricultural and agro-industrial residues), hydro and solar. Presently only biomass for household energy and hydro for electricity generation are exploited on a significant scale.

The country's hydro potential based on the Senegal and Niger river system is estimated at about 1000 MW capable of producing 5000 GWh in an average year. Of this only 250 MW have been developed so far at the Selingue and Sotuba dams on the Niger River and the Manantali dam on the Senegal River. Mali has no significant fossil fuels and petroleum product consumption is entirely dependent on imports (~300,000 tons/annually). Mali is a part of ECOWAS. (ref.7)

Manantali 200MW, 807 GWh/year, an agreement between the States defines the sharing of power generated at Manantali among the 3 countries: 52% in Mali, 33% in Senegal and 15 % in Mauritania.

Burkina Faso

Burkina Faso is a landlocked country, with a total area of 274,200 km^2, that shares borders with Ghana, Mali, Ivory Coast and Niger. The total population of Burkina Faso is 13.2 million growing annually by 3 %. The majority of the population (82%) lives in the rural areas. The country's installed capacity was 171 MW in 2002, with an annual production of 444.6 GWh and a fuel mix consisting of 78,4 % Thermal, 21,6 % Hydro (in 2003). There are 30 thermic plants and 4 hydro plants. The urban electrification was estimated at 45.7 % for 2003 and rural electrification at 1.1 %. The state utility SONABEL handles generation, transmission and distribution. The parliament has authorised the privatisation of SONABEL that should be completed by 2007. Burkina Faso is part of the ECOWAS, and participates in the project to implement a West African Power Pool (WAPP) **(17 & 19)**

Niger

The Republic of Niger is a landlocked country, inhabited by about 14m people, growing at a rate of 3.3%. Seventy-eight percent (78 %) of the population live in rural areas with the rest living in the urban centres. Significant portions of the Niger's 1,267,000 km^2 total land area lie in the Sahara Desert belt (80% desert – 20 % savannah fields). The installed capacity is 103 MW (2003), with an annual production of 191 GWh (2003), all of which are thermal. Also, the country imports 275 Gwh from Nigeria (2003), that being hydroelectric power from the Kainji Dam. The electrification level is 6.49% total, 0.5 % rural and 43% urban (2003). NIGELEC, a public company, handles production, transmission and distribution in most of the country. SONICHAR (69% state owned) produces electricity at 90% for the needs of the uranium mines, and for the rest 10% for NIGELEC. Niger is part of the ECOWAS, and participates in the project to implement a West African Power Pool (WAPP) **(12 & 17 & 18)**

2. The Potential of Renewable Energy Resources

This chapter explore the resource availability, already exploited potential, types of existing (maybe add success stories) & expected installations.

2.1 The Renewable Energy Sources, Rational Use of Energy – The Technologies/Current & Expected Installations – Costs – Country Potentials

2.1.1 Biomass (Household/Commercial Level & Large Scale)

Besides residues from agriculture and forestry, from other residues like municipal solid waste (MSW) or sewage sludge, from energy crops and biofuels, biomass mainly comprises firewood.

2.1.1.1 According to the FAOs study, The Role of Wood Energy in Africa [34]**, Wood fuels** include all categories of primary or converted wood used for energy: **fuel wood, charcoal and black liquor.**

Fuel wood: Primary wood combusted as it is for satisfying energy needs, and they can be used under different forms (direct, indirect, recovered/recycled)

Charcoal: energy item that is derived from fuel wood and used to satisfying final sectorial energy demand or even for electricity generation where relevant.

Black liquor: specific wood-derived fuel that is recovered and used as fuel for paper manufacturing. The derived energy comes from the lignin removed from the wood pulp.

Carbonization Ratio (Tons Wood/1 Ton Carcoal): Usually 4.35 tons wood for 1 ton charcoal, but in the case of Africa, where the carbonization efficiency is significantly lower, it ranges from 5 to 12.6 tons of wood for 1 ton of charcoal.

Africa is the most intensive user of wood fuels in per-capita terms, with an average annual per-capita consumption of 0.77 m3, or 0.18 toe. In Africa, almost all countries rely on wood to meet basic energy needs. The share of wood fuels in African primary energy consumption is estimated at 60% to 86%, with the exception of North African countries and South Africa. On average, about 40% of the total energy requirement in Africa is met by fuel wood.

Households

Wood fuels, as well as other traditional sources of energy such as agricultural residues and animal dung, have an important role in the lives of the rural populations in developing countries. Fuel wood and charcoal, are used widely as household power sources in poor rural neighbourhoods in developing countries. Dependence on wood fuels to meet household energy needs is especially high in most of sub-Saharan Africa, where 90% to 98% of residential energy consumption is met by wood fuels.

Industry

Most of the non-household fuel wood consumption occurs in agro-based rural industries such as crop drying, tea processing and tobacco curing, as well as in the brick and ceramic industries. Wood fuel consumption by such users is smaller than that of households; nevertheless, it should not be overlooked as it can constitute 10% to 20% of fuel wood use in some Asian countries. In Africa, in 1994, it was estimated that traditional industries accounted for about 9.5% of wood fuel consumption.

2.1.1.2 Biomass other than wood

This includes agricultural and wood/forestry residues, other residues like MSW or sewage sludge and herbaceous crops grown specifically for energy

For biomass energy to have a future, it must be able to provide people with things they want, e.g. lighting, electricity, water pumping, etc. Modern applications simply mean clean, convenient, efficient, reliable, economically and environmentally sustainable uses. There already exist many mature technologies which can meet such criteria, and which are not necessarily more expensive than fossil fuels if all costs are internalised.

The modernization of biomass embraces a range of differing technologies that can be grouped into:

- biomass-fired electric power plants/CHP;
- liquid fuels e.g. bio-ethanol and bio-diesel;
- biogas production technology;
- improved cook stove technology.

There are many modern applications including:

- household applications, e.g. improved cooking stoves, use of biogas, ethanol, etc;
- cottage industrial applications e.g. brick-making, bakeries, ceramics, tobacco curing, etc;
- large industrial applications, e.g. CHP/electricity generation, etc.

One of the most promising areas for modernisation of biomass energy on a large industrial scale is the sugar cane, pulp and paper and sawmill industries, as demonstrated by various studies.

[26]

2.1.1.3 Biomass Uses in Africa

Household Energy

The bulk of energy consumed in rural areas is used in households. Households require energy mainly for cooking, lighting and space heating. Cooking accounts for between 90 and 100% of energy consumption. The rest of the energy consumed is for lighting, provided either by wood fuel (cooking fire), kerosene lamps and candles. Space heating is required in areas with cold climates, and is often catered for by energy used for cooking (WEC/FAO, 1999).

Household energy consumption levels and the types of energy used depend on a variety of factors, such as the availability and costs of energy sources. Table 5 shows that as incomes increase, the use of modern energy becomes more prevalent in rural households. For instance, while low-income rural households rely mainly on biomass fuels for cooking, high-income households use modern fuels such as kerosene and LPG.

Table: Rural energy use patterns in sub-Saharan African countries by end uses

End Use	Rural Household Income		
	Low	Medium	High
Cooking	Dung, residues, wood	Dung, residues, wood, kerosene & coal	Wood, kerosene, coal, LPG & biogas
Lighting	Kerosene, candles	Kerosene, candles & batteries	Kerosene, LPG, electricity
Space Heating	Dung, residues, wood	Dung, residues, wood	Dung, residues, wood
Other	None	Grid/ Genset based electricity & batteries	Grid/ Genset based electricity & batteries

Table: Fuels used for cooking in rural households for selected African countries (% of fuel used) – World Bank 2000 data

Country	Firewood	Gas, Kerosene	Charcoal	Electricity	Other
Gambia	97	1	1	0	1
Mali	97	0	0	02	
Burkina Faso	91	1	1	0	7
Niger	90	1	0	0	9
Senegal	84	2	12	0	2

Agriculture

A number of renewable energy technologies (RET) have demonstrated an encouraging level of success in meeting the demand for energy for agriculture in rural Africa.

Table: RET Applications in Agriculture

RET	Selected Agricultural Process
Bio-fuel cook stoves	Milk pasteurization, heat energy for poultry, crop drying, crop processing
Biogas plants	Fertiliser production
PV Technologies	Pumping, lighting, cooling, crop processing
Solar water heaters	Dairy processing, heat energy for poultry
Wind pumps	Irrigation, crop processing

The following technologies have shown promise: Small hydro plants for shaft power and electricity generation; biogas plans, which provide sludge for use as fertiliser; and, solar crop dryers. One technology that could have considerable impact in the region's agricultural sector is wind driven machines for water pumping and for irrigation. Most countries in the region have wind energy potentials that are sufficient for water pumping (3m/s). However, this potential has not been exploited fully in most countries mainly due to the high initial costs - US$1,000 – $7,000.

Small and Micro Rural Enterprises

A wide range of small and micro enterprises (SMcE) exists in rural areas. The term, 'small and micro-scale enterprises' refers to entities that largely rely on family/household members with limited use of non-household members. Most of these enterprises are based in the informal sector, and can be categorised into commercial/service enterprises and production enterprises. Commercial/service enterprises include small shops, rural guesthouses, beer halls and battery recharging centres. Production enterprises are largely agro-based or forest based activities, and includes saw milling, grain milling and pottery making. Biomass consumption is still dominant in many small and micro rural enterprises. Examples of enterprises that largely rely on biomass include beer brewing, fish smoking, baking and tobacco curing.

Table: RET for Small and Micro Rural Enterprises

RET	Production Enterprises	Commercial & Service Enterprises
Cookstoves	Beer brewing	Food kiosks, food preparation for clinics, hospitals & schools
Charcoal Kilns	Production of charcoal for sale in rural & urban areas	
PV	Dairy processing	Electrification of small shops, bars, food kiosks & powering of mobile communication devices
Solar water heaters	Crop processing	Clinics, schools
Solar drying	Processing of tobacco, timber, coffee, tea, wood & fruits	

[8]

Country Data Availability & Quality Issues

The wood fuel figures presented below for each country (and included in the Biomass Annex) reflect as far as possible those reported by WEC Member Committees; where information was not available from this source, the WEC derived estimates from information provided by the FAO's study - The Role of Wood Energy in Africa. It is important to show, in detail, word for word, that even in this study, the FAO reports the following under the Executive Summary chapter, with regard to data quality issues:

"Data quality issues

Despite its important interactions with development, environment, and social welfare, there have only been a few attempts in Africa to include wood fuels as a basic sector in planning processes. Such ambition is seriously hampered by the scarcity, limited scope, and poor quality of existing data, despite several past efforts to improve wood fuel information systems. These shortcomings make it very hard to undertake relevant :

- *impact studies of wood fuel use on environment in general and on forestry resources in particular;*

- *energy and forest planning and forecasting studies.*

Evaluation of the various existing wood fuel data sources in Africa led to the following major conclusions:

- *The FAO database is the only source of data that includes almost all African countries (except 6 minor consuming countries) and provides continuous time series for each country. However, the FAO database presents estimates rather than actual figures, and provides no detailed sectorial figures.*

- *The IEA database presents individual data for only 23 countries, and provides approximate global estimates for the 31 other countries under the heading "OTHER AFRICA". In addition, sectorial consumption of wood fuels is only available for the years 1995 and 1996, while the data for the remaining years are presented in aggregated form (Aggregate Primary Supply of Combustible Renewable and Waste).*

- *The ESMAP documents considered data for 39 countries among 55, with various quality levels, and generally reported only one reference year rather than historical series.*

- *The ENDA/IEPE documents reported data for only 28 countries and one reference year. In addition, no detailed sectorial consumption figures were provided.*

- *The other national and international sources of data identified, provided various levels of details, consistency and accuracy. Unfortunately, these sources used to focus on the demand side of the wood fuel issues, neglecting the supply side, and did generally not mention any indication related to the origin, quality, or even the estimation approach of the data, making it difficult to undertake adequate assessment.*

Main Recommendations

Wood fuels are likely to remain a major energy source and a determining environmental and development issue in Africa in the mid-term future and even in the longer term. Therefore, a relevant effort aiming at improving knowledge on wood fuel demand and supply, as well as on its economic and social role, should clearly be undertaken in the future, particularly through sustainable and systematic data collection, compilation and analysis processes, with a unified approach and with the involvement of the major international organizations in this field." [34]

Cape Verde

The accessible forest cover has been estimated at 1000 km2, with an annual production (1999) of 100,000 tons of fuel wood (see Biomass Annex).

The country's firewood resources meet 57% of household energy needs (of which 92% are rural); wood resources are scarce though and have low regeneration capacity [6].

Mauritania

The accessible forest cover has been estimated at 3,000 km2, with an annual production (1999) of 200,000 tons of fuel wood and 125,592 tons of charcoal (see Biomass Annex).

The consumption of wood fuel in Mauritania continues to grow at a higher rate than the average annual increment of forest cover. National consumption is estimated at 380,000 tons of fuel wood and 70,000 tons of charcoal [10].

The Gambia

The accessible forest cover has been estimated at 5,000 km2, with an annual production (1999) of 700,000 tons of fuel wood and 45,605 tons of charcoal (see Biomass Annex).

Senegal

Traditional fuels still account for 58% of the country's energy consumption, and the bulk of the population in rural areas uses firewood or charcoal for cooking. In Senegal direct burning of firewood, charcoal and crop residues represents 93% of the rural energy consumption. In 1992, households had consumed roughly 1.5 million toe fuel wood, while the amount for commercial energy was 660,000 toe [3].

There are significant biomass resources, but so far they have only been utilized using traditional methods both for production and end use. These resources are:

- ***Wood***, culled from natural woodland: used for heating and making charcoal. Senegal has 6.205 million hectares (62,050 km2 - see also Biomass Annex) of forestry resources, of which 5.942 million hectares (59,420 km2) are natural forests and 263 hectares (2.63 km2) are plantations. In 1999 there was a production of 3.3 million tons of fuel wood and 110,708 tons of charcoal (see Biomass Annex).

- ***Agricultural residues***, such as groundnut shells, palm kernel shells, bagasse, rice stalks, cotton stems, filao spindles, which are all resources that could be harnessed to generate energy. Typha Australis (Bulrush - an invasive aquatic plant) in the River Senegal has very recently boosted biomass resources, a potential of some 3 million tons of fresh material, or 500,000 tons of dry material. This is equivalent to 150,000 tons of biomass charcoal. The table below shows the quantities of agricultural residues (1998 data).

Production Type	Quantity (tons)	Agricultural Residue (MS tons)
Groundnut	544,800	871,680
Sorghum	118,300	343,070
Maize	60,300	126,630
Millet	426,500	1,322,150
Watermelons	261,300	182,910
Rice	173,700	312,660
Manioc	46,600	88,540

Cotton	40,000	4,400

The estimated potential availability of bagasse in 1999 was 310,000 tons (see Biomass Annex). The WEC Member Committees reported in 2000/2001 that there is a potential of 250,000 tons (20 MW) of sugar cane bagasse per annum.

Also some additional quantities are:

- Charcoal and not Coal dust appraised at 15 tons per day, or 4,380 tons per annum in the Dakar region alone;
- Domestic waste evaluated in 1999 in the Dakar area at 4 million tons. This is in addition to the existing stock in Mbeubeuss dump, which has accumulated some 6.3 million tons of refuse over the last 25 years [14].

Current Applications/Installations

Only two agro-industrial companies, the National Company of Oleaginous (SONACOS) and the Sugar Cane Company (CSS), generate electricity from biomass residues. However, recently a small enterprise (Delta 2000) has been attempting to valorise the lignocellulosic biomass with a prototype unit for briquetting crop residues, namely rice stubble and groundnuts husks. Delta in collaboration with CERER (for technical advice and support) is conducting on- going surveys for improving methods of production and market analysis. A new factory (Charbonage du Senegal-CDS) has been built by private investors at Dakar for carbonisation of agricultural residues. The product is now available with a good commercial network in Dakar area. Another attempt to address fuel wood problems and deforestation is through biogas production. At the end of 1994, ten biodigesters were in operation for lighting, cooking, pumping, refrigeration and grain milling. The viability of small- scale family type biodigesters designed for cooking and lighting purposes has been demonstrated by ENDA Tiers-Monde, a NGO working on environmental issues and sustainable development. The National Agronomy Research Centre (CNRA) has developed a biogasification/diesel dual engine saving 75% of fuel to supply electricity for water pumping. Biomethanisation, that employs anaerobic digestion of biomass has not been disseminated satisfactorily, despite efforts to transfer biogasifier technology to local users.

Guinea Bissau

The accessible forest cover has been estimated at 22,000 km2, with an annual production (1999) of 300,000 tons of fuel wood (see Biomass Annex).

Chad

The accessible forest cover has been estimated at 127,000 km2, with an annual production (1999) of 1.7 million tons of fuel wood and 301,287 tons of charcoal. The estimated potential availability of bagasse in 1999 was 105,000 tons (see Biomass Annex).

The wood fuels situation in Chad is not that different from most of its neighboring countries. Wood fuels are and will be used for some time in Sub-Saharan cities and the sustainability is questionable. However, Chad has started to implement a new village based management programme, with the help of a new autonomous private agency, AEDE, and the introduction of a new Law and Decree to support the proper efficient management of the wood fuel sector. This case is presented in detail in the following Chapter, 4, under Proposed Solutions, as a good example of natural resource management.

Wood fuel Supply: The case of N'Djamena (capital)

Van der Plas and Abdel Hamid [15] have carried out a study focusing on the case of the capital of Chad, N'Djamena, reporting varying figures for wood fuel consumption from different sources, a fact which indicates once again the lack of data quality. In N'Djamena, surveys in the early 1990's showed that most households used firewood as their primary cooking fuel , 84% of the 406,000 people living there used firewood and 16% used charcoal. Charcoal as a secondary fuel was used by 45% of the population. The study reports that total wood fuel consumption in 1991 was 250,000 tons (ESMAP study World Bank data 1994), in 2002 this had increased to 612,500 tons, with almost 100% of the 100,000 households using now charcoal as their primary fuel (AEDE ongoing surveys).

The obvious benefits from using charcoal may explain the rapid switchover from firewood to charcoal in N'Djamena. Such benefits include: the clean burning characteristics of charcoal (firewood smokes); the power output of charcoal stoves is easier to control; charcoal stoves are safer for children (no flames licking around the pot); one uses small quantities of charcoal per day; charcoal can be easily stored (firewood is much heavier and bulkier, and attracts insects); and finally, unlike firewood, charcoal has an image of being a modern fuel.

Mali

The accessible forest cover has been estimated at 132,000 km2, with an annual production (1999) of 5.7 million tons of fuel wood and 93,148 tons charcoal. The estimated potential availability of bagasse in 1999 was 102,000 tons (see Biomass Annex).

Traditional biomass energy in the form of fuel wood, charcoal, and dung represents about 90% of the final energy consumption in Mali. The use of charcoal in urban areas is estimated to be increasing by about 20% a year. High rates of urbanization experienced in Mali are likely to further increase the rate of utilization of charcoal. Total wood fuel consumption in Bamako is estimated to have grown from 600,000 tons in 1994 to about 800,000 tons in 2000 [7, 29].

Cotton the leading crop of Malian agriculture. It is estimated that about 8,000 tons of crop residues are generated from cotton production alone annually. The Jatropha curcas, is a shrub that grows in southern and western Mali, that is drought resistant. Jatropha seeds contain about 35% of non-edible oil, which could be extracted and used as a substitute for diesel oil in diesel engine. For generations, Malian farmers have protected their gardens/farms with hedges of Jatropha, which is not eaten by livestock. In 1996, Mali had about 10,000 km of Jatropha hedges with a growth rate of 2,000 km per year, which represents a then potential of 5 million litres of oil [12]

Past & Present Projects

Mali Household Energy Project

The GOM concluded a Household Energy Project in 2000, financed by the GEF and the Government of the Netherlands and managed by the World Bank. This project has demonstrated an innovative approach to achieving sustainable management of the natural forest cover with the involvement of rural communities. Based on a management plan, agreed upon between villagers and the forestry service, a village management committee is responsible for the use of forest resources. The wood fuel harvested is sold to commercial transporters at a market created by the village and at a price determined by the villagers themselves. The transporters pay a wood fuel tax on entering the urban area, where the origin of the wood fuel is checked by a forestry service control post. Urban consumers thus pay the price of wood fuel (determined at the rural market) plus a transportation cost, a mark-up and a tax element, and thus a wood fuel price that reflects economic cost. In order to discourage the marketing of wood fuels from non-managed forests, the tax paid at the control post by transporters with wood from non-managed areas is higher than the tax plus the fuel wood cost at the rural markets. Effective control and monitoring systems did not worked well. Further interventions should pay particular attention to these aspects and design appropriate systems to ensure effective functioning of the rural markets. This approach will consolidate achievements on policy and legislative fronts.

More than 250 village management plans exist covering about 346,377 ha. Also, about 250 rural firewood markets were established, of which 50 are managed by 14 private operators. Better management of the forests and better carbonization techniques have been introduced for greater efficiency in the production of wood fuels. Furthermore, to encourage conservation of wood fuel, improved stoves and substitute fuels were promoted. More than 150,000 low cost charcoal stoves costing about US $5 each and fully manufactured locally have been sold in cities where the project intervened.

Mali Household Energy and Universal Access Project (HEURA)

This project's duration is from 2004 to 2008 and will finance:

- the updating of 10 woodland management master plans
- the production of 5 new woodland management master plans
- the creation of 1000 rural markets
- the implementation of village woodland management systems in woodfuels supply basins covering an area of about 1,4 million hectares in the regions of Bamako, Segou, Mopti, Koutiala, Niono, Kayes and San to provide about 70 percent of urban consumption of wood fuels
- the modernization of wood fuel production and trade (a target of 80 percent of tax collection on wood fuels by year 3 of the project)
- the creation of more than 300 modern charcoal production associations with efficient techniques and adequate management capacity;
- the support to the central and regional forestry service departments to elaborate legislative measures applicable at communal levels
- the promotion and scale up of improved wood (300,000) and charcoal (210,000) stoves utilization
- the promotion of alternative household fuels (61,000 kerosene stoves , 10,000 tons of wood briquettes) [29].

Jatropha Projects

Although the potential for Jatropha oil as a near-perfect substitute for diesel oil was recognized way back in the 1930s, it is only in 1987 that the first research to evaluate the oil as a fuel in engines that powered milling machines, was initiated in Mali by the **German Technical Assistance (GTZ)**. The project was terminated in 1996 when cost comparisons between jatropha and diesel showed jatropha to be more expensive [28]. Currently, the **Mali Folkcenter (MFC)** Toyota pick-up runs directly on Jatropha oil, the standard 2.8litre diesel engine was converted to run on the oil, and the MFC continues to carry out a great deal of research projects on Jatropha and its utilization. Also the oil is utilized within the context of the **UNDP/UNIDO Multifunctional Platform** project [12]. Jatropha seed price is lower than a few years ago (45-50 CFA compared to 200 CFA) [28].

Burkina Faso

The accessible forest cover has been estimated at 71,000 km^2, with an annual production (1999) of 9.2 million tons of fuel wood and 110,000 tons of charcoal. The estimated potential availability of bagasse in 1999 was 97,000 tons (see Biomass Annex).

In Burkina more than 90% of total population use wood-energy as main source of cooking energy and 85% of this population use kerosene for light; only 29% of the population of Ouagadougou (capital) have access to electricity as source of lighting energy.

The dominating source of household cooking energy in Ouagadougou is wood-energy which is used by 76.3% of the households; 70.1% mainly use firewood and 6.2% charcoal. LPG is this city's second most preferred source of household energy with 13% of the population using it on a daily basis. Kerosene is used by 3.4% of the households and only 0.6% use electricity for cooking. If total of 6.7% of the households use other solid fuels such as concentrates of agricultural residue and animal waste (cow dung) [13].

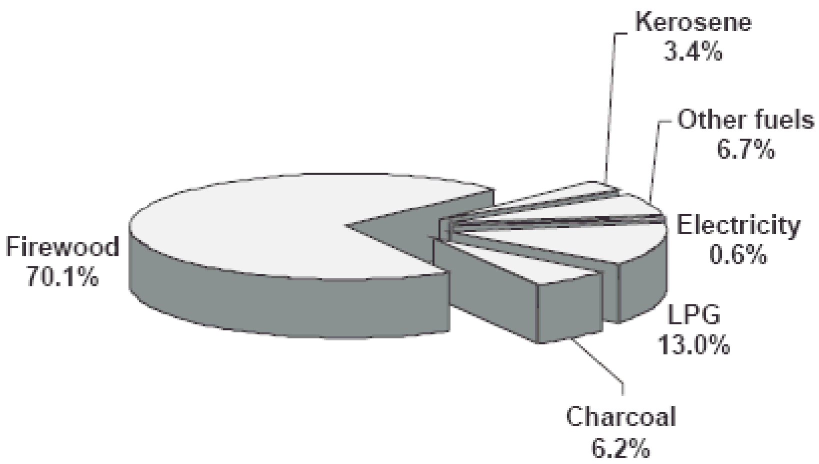

Figure 1: Energy matrix for Burkina Faso.

In the early 1990's there were approximately 200,000 improved biofuel stoves disseminated in Burkina and approximately 20 small-medium scale biogas units (<100 m3) [5a].

Niger

The accessible forest cover has been estimated at 13,000 km^2, with an annual production (1999) of 3.1 million tons of fuel wood and 409,798 tons of charcoal (see Biomass Annex).

In the early 1990's there were approximately 200,000 improved biofuel stoves disseminated in Niger [5a].

2.1.2 Solar

Active solar systems

Active solar systems are those which collect solar radiation and convert it in the form of heat to water, air, or some other fluid. The technology which is applied is fairly simple and there are many possible applications of it for low temperature systems heat uses. The most common application of these systems is the production of domestic hot water, known to all as solar water heaters.

A typical solar hot water production system is composed of solar flat plate collectors, a heat storage vessel and piping. Solar radiation is absorbed by the collector and the heat collected is transferred to the storage vessel. The solar collectors are usually placed on the roof of the building, facing south and at an inclination of 30° – 60° with respect to the horizontal plane, so as to optimize the amount of radiation collected on a yearly basis.

Besides household use, which is the most common at present, active solar systems can be used anywhere low temperature heat is needed. Thus, the use of solar energy for the production of cooling, for air conditioning buildings and other applications, is emerging as one of its most promising prospects because of the increased solar radiation at precisely the season when cooling loads are greatest.

PV Systems

The photovoltaic phenomenon was discovered in 1839 and was used for practical purposes at the end of the 1950's in space applications powering satellites. Photovoltaic systems (PV) can convert solar energy to electricity. A typical PV system is composed of a P/V module or solar electricity generator and the electronic systems which manage the electricity produced by the solar array. In autonomous systems, there is also an energy storage system which uses batteries.

<u>The main categories of PV systems are as follows:</u>

Consumer products (1 mW – 100 Wp)

The systems in this category are used in small scale applications, such as mobile homes, recreational boats, garden lighting, refrigeration and for products such as small portable computers, lanterns, etc.

Autonomous or micro-grid systems (100 Wp – 200 kWp).

This category includes electricity generation systems for homes and small villages which are not grid connected. They are also used for:

- Desalination/pumping/purification of water
- Outdoor lighting systems for roads, parks, airports, etc.
- Telecommunication systems, remote measurement, and alarms.
- Traffic control systems for roads, shipping, air navigation, etc.

- Agricultural applications such as water pumping, aquaculture, refrigeration for agricultural products and medicines, etc.

Large Grid Connected PV Systems

Included in this category are PV electricity production plants ranging in size from 50 kWp to several MWp which deliver the electricity directly to the grid.

Connected PV Systems – Household Sector

This category includes PV systems with a typical size between 1,5 kWp and 20 kW, which are installed on the roofs or facades of houses and supply electricity directly to the building. Surplus energy is sent to the grid. Again, this category comprises the largest part of the global market for PV systems.

The benefits from incorporating PV into buildings are:

- Coincidence of summer cooling loads for buildings with the P/V system output at its maximum.
- Land surface is not needed for installation.
- Decentralization of energy production and local consumption of the energy produced.

Also, PV arrays can be used as part of the structure of buildings, if they are designed properly. In this way the economic effectiveness of the system can be increased because the cost of ordinary building materials is avoided.

The **basic characteristics** of PV systems which differentiate them from other forms of renewable energy are:

- Direct electricity production, even on a very small scale, for example, several tens of W or mW.
- Ease of use. Small systems can be installed by users.
- They can be installed in cities, incorporated into buildings where they do not visually disturb the surrounding environment.
- They can be combined with other energy sources (hybrid systems).
- They are scalable systems, which mean that they can be expanded later on to meet users' increased needs without disposing of the original system.
- They are quiet, non polluting and do not have an impact on the environment.
- They are practically maintenance free.
- They have a very long life and operating reliability. Manufacturers guarantee more than 25 years of good operation for their PV generators.

The user's energy independence is the greatest advantage of PV systems. The value of the energy produced by PV systems is comparable today to the price for peak power which power producers charge their customers.

Passive solar systems & bioclimatic architecture

Passive solar systems are the integrated parts – elements of a building which function without mechanical parts or additional energy supply and are used for heating as well as cooling buildings naturally. Passive solar systems are divided into three categories:

Passive Solar Heating Systems

Passive (Natural) Cooling Systems and Techniques

Systems and Techniques for Natural Lighting

These systems can contribute to significant reduction of energy consumption in buildings.

Cape Verde

Solar energy potential is good and relatively constant along the year, with an estimated average of 5 kWh/m^2/day. PV systems are expected to play an increasingly important role in the decentralized supply of electricity in the rural areas of the country. There are about 12,000 households that are not expected to be connected to a grid, even in the long term and a further 20,000 who are not connected now and will have to wait for a considerable period.. Promoting renewable energy with the help of the private sector would enable the Government to save foreign exchange on fuel oil and improve social conditions [6].

Mauritania

To complete

The Gambia

To complete

Senegal

Annual sunshine of more than 3000 hours and average irradiation of 5.4 kWh/m^2/day promises significant opportunities for generating thermal and photovoltaic power in Senegal. [ENDA]

Guinea Bissau

To complete

Chad

To complete

Mali

The ENDA study reports that there is a solar potential of 6 kWh/m^2/day

Burkina Faso

The ENDA study reports that there is a solar potential of 5.5 kWh/m²/day

Niger

The ENDA study reports that there is a solar potential of 6 kWh/m²/day

2.1.3 Wind

Wind energy is the kinetic energy which is produced by the power of the wind and is converted into usable mechanical energy and/or electricity.

The modern systems for the use of wind energy are primarily machines which convert wind energy into electricity and are called wind turbines.

The most economically important application for wind turbines is their connection to a country's electricity grid. In this case, a wind farm, i.e. a grouping of many wind turbines, is installed and operates in an area with high wind potential, and the entire production is transmitted to the electricity grid.

Mechanical energy applications of wind energy are:

Water pumping

The wind has been used as a reliable and inexpensive water pumping power source for generations. Either a mechanical or electric water pumping system could be ideal for rural and remote locations to supply livestock, a household or even a small community.
Grain grinding

Wind energy systems come in many sizes, from very small micro systems, which can be mounted on a pole, to 1.5 megawatt turbines that can supply energy to the electrical grid. Most stand-alone systems fall into one of three categories: micro systems (100 W or less), mini systems (100 W to 10 kW) and small systems (10 kW to 50 kW).

In remote communities where diesel generators often supply electricity, the use of wind energy not only makes environmental sense, it makes economic sense.

Cape Verde

According to the Strategic Study of Wind Energy Deployment in Africa, commissioned by the African Development Bank with the support of The Canadian International Development Agency, carried out by Helimax, Cape Verde is one of the 15 African countries, identified as having the best wind resource in Africa. The study has also produced a quantitative map of wind speeds for the African continent at a resolution of 50 km, using a WEST1 model (see Wind Annex) where the wind speeds for Cape Verde can be seen, ranging from less than 4 m/s for Fogo and Brava, 4-5 m/s on the north coast of Santo Antao and 6.5-7 m/s on the east coast, 5-6 m/s for Sao Vicente, Sao Nicolau, Santa Lucia, Ilheu Branco and Raso, 4-5 m/s on the southwest of Santiago and 5-6 m/s on the north and southeast, 5-6 m/s on the south of Maio and 6-6.5 on the north and 6.5-7 on the east coast, 6-6.5 on the northern half of Boa Vista and 6.5-7 on the southern half, and 6.5-7 for Sal. The good wind resource of Cape Verde is confirmed by wind monitoring [1].

According to the World Bank [6], the country has excellent potential at an average velocity of 7.5 m/s. Wind is a good option for substituting diesel generation. So far the Danish Risø National Laboratory has acted as the principal adviser to Cape Verde utility ELECTRA, and has supervised the project which since 1995 has supplied 15% of the country's electricity (Mindelo 900 kW, Praia.900 kW, Sal 600 kW) Risø studied the feasibility of a further 35% wind energy penetration expansion, a project for which has been approved for World Bank funding [6, 23].

The context seems favourable for wind energy to be competitive with respect to other available energy sources. The country is fairly interested in small scale wind projects for small electrical grids in remote locations. Cape Verde is more favourable to small and medium scale projects mainly because of the characteristics of the demand of electricity and the electrical grid. In any case, the development of wind energy projects will be hampered because of restrictions on investment, a misunderstanding of the wind energy potential and the need for further capacity building [1].

Mauritania

Mauritania is also one of the 15 African countries, identified by Helimax, as having the best wind resource in Africa, with wind speeds of 5-6 m/s for the largest part of the country, some lower speeds of 4-5 m/s in the northeast and parts of the south, and some higher ones, 6-6.5 m/s and 6.5-7 on the west coast, on the Atlantic (see Wind Annex). The good wind resource of Mauritania is confirmed by wind monitoring [1].

The context seems favourable for wind energy to be competitive with respect to other available energy sources, The country is fairly interested in small scale wind projects for small electrical grids in remote locations. Mauritania is more favorable to small and medium scale projects mainly because of the characteristics of the demand of electricity and the electrical grid. In any case, the development of wind energy projects will be hampered because of restrictions on investment, a misunderstanding of the wind energy potential and the need for further capacity building [1].

The Gambia

Not any significant, technically and economically viable wind potential.

Senegal

In Senegal wind energy offers poor potential due to the very low wind speeds and the abrupt variations in peak wind conditions. The annual wind velocities over most of the country are 2-3 m/s [3]. According to a study carried out in 2002, only on the narrow 200 Km long strip of land, 20 Km wide, between Dakar and St. Louis, are there wind speeds which reach 5-5.9 m/s (at 50 m) [14]. The potential energy to be exploited in this area is estimated at 1.5 kWh per day [3].

Wind Pumping

Wind can be harnessed however for water pumping. Over 200 FIASA systems (International Windmill Corp. water pumping windmills) were installed in 1983-1984 from funding of the Argentinian government. But, a study 3 years later showed that 60% were no longer operational, with the situation deteriorating even further. The Lay Volunteers International Association (LVIA) later installed 120 new types of wind powered amenities and was successful due to reliable equipment and the fact that it was owned by the local community.

The LVIA was the precursor to today's **"Vent Eau pour la Vie" (VEV) wind pumping programme**, based in Thiès 70 km from Dakar, which now serves as a best practice example of North-South technology transfer thanks to effective appropriation by the VEV group. It aims to prove that RETs can be used to help alleviate poverty by bolstering food security, creating wealth for rural women (by enabling them to indulge in market-gardening, sell water, etc.), and relieving women's work load. The mills are now produced in VEV's workshop using local materials, except the filter and rudder spring, which are still imported from Italy. In other words, 95% of the technology is made from Senegalese materials. The price of a ready-to-use mill is 5,500,000 CFA Francs, or $8,350 [14].

Wind Cooling for Agricultural/ Fishing Product Storage

In Mboro (is a rural community in the region of Thies), a team Asera – non-governmental organization working on renewable energy and rural development – has set up a renewable energy pilot project to help the rural agricultural population as well as protect the environment. The rationale behind the project is to reduce local reliance on generators for irrigation or petrol for electricity. 9 The aim of the project according to the General Secretary of Asera is to help the rural population to have energy in order to develop activities where they can get money. The GEF funded project aims to install a 4 kW wind turbine to power a cooling chamber. The cooling chamber is used to store agricultural and fishing products [12].

Another interesting project was Alizé Senegal, which was implemented by a Senegalese engineering firm (SEMIS) in tandem with two French NGOs (GRET and EER) in 1987. Its goal was to revamp and disseminate windmills for pumping and rural electrification in northern Senegal. From 1997 to 2003, the project received a total of 223 orders, conducted 130 pre-selection inspections, chose 41 villages, got 30 joint-investment proposals and finally carried out installations in 28 villages27. In addition to insisting that any decision-making process aimed at acquiring a wind system are participatory (whereby discussions are held to raise funding; management committees are formed and ways of using surplus water are planned collectively, etc.), the project introduced a scheme whereby after-sale services are also included in contracts. This represents an innovative way of ensuring maintenance needs are taken into account on an organisational level [14].

Guinea Bissau

Not any significant, technically and economically viable wind potential.

Chad

Chad, also one of the 15 African countries with very good wind resource, seems to have a good wind potential, with central parts of the country capable of reaching speeds of 7-7.5 m/s (see Wind Annex), however that still needs to be confirmed by detailed wind measurements.

The problem is that the government has not yet taken a stance regarding wind energy. One reason for the government's hesitancy could be the possible technical and environmental constraints which could obstruct the development of wind energy projects. Another possible reason is the existence of other forms of renewable energy, projected or being developed, which may be perceived as more competitive or more appropriate in the national context of the country, for example PV energy [1].

Mali

Not any significant, technically and economically viable wind potential.

Burkina Faso

Not any significant, technically and economically viable wind potential.

Niger

Not any significant, technically and economically viable wind potential.

2.1.4 Hydro

2.1.4.1 Large Scale

To complete

2.1.4.2 Small Hydro

To complete

Cape Verde

Mauritania

Mauritania's water resources are relatively limited; the surface water resources are essentially those of the Senegal River and its tributaries. There are also underground resources, which are characterized by unequal geographic distribution, with the situation being favorable in the south, southeast and southwest

Mauritania receives 15% of the power generated at Manantali Dam (approximately 121 GWh/year) [24].

The Gambia

The country's topography revolves around the Gambia River, the main waterway which has its origin in Guinea and meanders along 1000 miles to join the sea. The river runs its last 300 miles through Gambia and at the capital Banjul, it is at its narrowest, 3 miles.

Senegal

Senegal's principal rivers are the Senegal and the Gambia. Regulation and management of these rivers come under the auspices of the Organization de Mise en Valeur de fleuve Senegal - River Senegal Development Organization (OMVS), and the Organization pour la Mise en Valeur du fleuve Gambie (OMVG). The OMVS members include Senegal, Mali and Mauritania. While Senegal, the Gambia and Guinea-Bissau, are members of the OMVG.

In 1986, the technically feasible hydropower potential of Senegal was estimated at 4250 GWh/year [25]. From that, the only potential that has been exploited is at the Manantali Dam from which Senegal receives 33% of the power generated (approximately 266 GWh/year) [24].

Gross theoretical capability according to the WEC [26] is 11 TWh/yr. Technically exploitable capability is 4 TWh/yr and economically exploitable capability is 2 TWh/y.

Guinea Bissau

Gross theoretical capability according to the WEC [26] is 1 TWh/yr.

Chad

Chad's economically and technically feasible potential is approximately 150 GWh/year. The country's first hydro plant with a 6 MW capacity….. [2].

Mali

Large Hydro

The country's potential, based on the Senegal and Niger River, is estimated at about 1000 MW, capable of producing an average of 5000 GWh/year [2, 7]. Only 250 MW have been developed so far (2003) at the Selingue and Sotuba Dams on the Niger River, and the Manantali Dam on the Senegal River [7].

Manantali Dam

Eskom Energie Manantali (EEM) is the Independent Operator for River Senegal Development Organization (OMVS) Interconnected Network (RIO) composed of:

1. the Manantali Interconnected Network (RIMA) with the following features:
    - A hydroelectric power station with an installed capacity of **200 MW**;
    - 12 high-tension posts;
    - 1700 km of high-tension lines: 225 kV, 150 kV and 90 kV;
    - An average power generation of **807 GWh /year**
2. the national networks of 3 countries: Mali, Mauritania and Senegal

An agreement between the States defines the sharing of power generated at Manantali among the 3 countries: **52% in Mali, 33% in Senegal and 15 % in Mauritania** [24]. Mali receives approximately 420 GWh/year.

Gross theoretical capability according to the WEC [26] is >12 TWh/yr. Technically exploitable capability is >5 TWh/yr.

Small Hydro

A total of 8 mini and micro hydropower sites have been identified since 1988. Two have been developed with installed capacity of 5.8 MW, but the rest have only been studied to the feasibility level.

Farako Micro Hydropower Project

The Malian government and UNIDO launched a joint action and a feasibility study was carried out for a 35 kW project from March to September 2002. The project aim is to demonstrate the feasibility of micro & mini hydro for providing modern energy services to off-grid rural communities in the Sahel. Expertise and funding for the project will be provided by UNIDO, the Austrian government, GEF and any other public or private donor that may be interested [12].

Burkina Faso

Large Hydro

Management of the Burkina Faso's water resources is the responsibility of the Ministry for Environment and Water. The total mean annual precipitation volume is 165 km^3, of which only 9 km^3 is runoff. The country has eight large dams in operation, of about 2100 dams in total. The total storage volume of all reservoirs is approximately 4.6 km^3. A Burkina Committee on Large Dams was established in the 1990s.

Work at two dams began in February 1998. The first, Ziga, on the Nakambe river with a storage capacity of 207×106 m^3 and was being built to supply water to the capital, Ougadougou. The second dam, Diebuugou, is located on the Brugruriba River. Diebuugou Dam is 18 m high with a storage capacity of 1450 x 106 m^3. This dam was built for the purpose of hydropower production with a 12 MW hydro plant. In 1998, construction of several large dams was planned. These included:

1) Nounibiel, 60 MW hydro; for power production and irrigation;

2) Samandeni, for flow regulation, 2.5 MW hydro and irrigation;

3) Yengue, for river regulation and irrigation;

4) Suo, also for river regulation and irrigation.

The gross theoretical hydro potential of Burkina Faso has been evaluated at 150 MW (approximately 1316 GWh/year), and the technically and economically feasible potential is now estimated to be 75 MW (approximately 215 GWh/year) [2, 25]. About 45 % of the economic potential has been developed. In 1997, 30 MW were in operation, of a total capacity of 109.6 MW. The average annual generation from hydroelectricity in 1997 was 95 GWh.

Development of the 12 MW hydro at Diebougou, on the Brugruriba River, in the south-west of the country, began in 1998. This project was 70% funded by Hydro-Afrique, a group made up of a consortium of South African companies. SONABEL contributed the remaining 30% and will only take over ownership of the hydroelectric plant approximately 14 years after commissioning. The plant is to be commissioned towards the end of 1999.

Gross theoretical capability according to WEC [26] is 1 TWh/yr.

At the end of 1999, 32 MW were in operation, generating 125 GWh in 1999.

Small hydro

Two small-hydro plants are in operation in Burkina with a total capacity of 2MW. No additional small-hydro plant projects were planned in 1997 except the 2.5MW Samandeni project [25].

Niger

Economically and technically feasible potential 1300 GWh/year [2].

Kanadji hydro plant 125 MW [2].

Hydro potential 273 MW [14].

Gross theoretical capability according to the WEC [26] is >3 TWh/yr. Technically exploitable capability is >3 TWh/yr and economically exploitable capability is 1 TWh/y.

2.1.5 Geothermal

Geothermal energy is thermal energy which is produced in the Earth's interior and manifests itself in natural steam, in surface or underground hot water and hot dry rock.

As demonstrated by volcanoes, hot springs and measurements from drilling, the interior of the earth is very hot, and the temperature at its core is more than 5000 °C. Going from the surface of the earth towards the core, we observe that the temperature increases according to the depth. This is called the geothermal gradient. Near the surface of the earth, the geothermal gradient has an average value of about 30 °C/km. In some areas, either due to volcanic activity during a recent geological age, or due to the rise of hot water from very deep levels through fissures, the geothermal gradient is significantly greater than the average. The result is that aquifers can be found at relatively shallow depths which contain hot water or high temperature steam. These areas are called **geothermal fields** and exploiting their geothermal energy is very cost effective.

The wide range of uses for geothermal energy can be divided into:
- **Electricity generation**
- **Direct Use**

The temperature and conditions of a particular geothermal field determine which type of generation technology is used:

- Dry steam
- Flash steam
- Binary cycle

Direct use involves using geothermal heat directly (without a heat pump or power plant) for such purposes as heating of buildings, industrial processes (e.g. milk pasteurization), domestic heating, greenhouses, drying crops, heating water at fish farms (aquaculture), public baths and pools. Direct use can utilise high and moderate to low temperature geothermal resources.

Geothermal Heat Pumps

Besides geothermal fields, with today's technology, heat from rock at a shallow depth, as well as low temperature underground or surface water can be used for heating and air conditioning. This technology involves the use of a very long pipe with a small diameter buried in the ground, or in wells, where it acts as an underground heat exchanger, coupled with a water cooled heat pump which provides heating or cooling to a building. Geothermal heat pumps consume one quarter of the electricity consumed by an electrical resistor and 1/2 that of an air conditioner. If the cost of energy is calculated over the life cycle of the system, geothermal heat pumps cost less than a system which consumes oil or natural gas.

Applications of geothermal energy vary according to their temperature:

- Power generation(□>90 °C)
- Space heating (with radiators, □>60 °C, fan-coils, □>40 °C, floor heating systems, □>25 °C)
- Refrigeration and air conditioning (using absorption heat pumps, □>60 °C, or with water cooled heat pumps, □<30 °C)
- Heating greenhouses and soil because plants grow more quickly and become bigger with heat (□>25 °C), and also for protection from frost.
- Aquaculture (□>15 °C) because fish require a specific temperature to grow.
- Industrial applications such as desalination of seawater (□>60 °C), drying agricultural products, milk pasteurization etc.
- Thermal spas (□ = 25-40 °C) [CRES 2006]

Table: Potential energy use at various indicative field temperatures is:

Field Temperature	Uses
30 - 69 ºC	thermoculture, bathing
70 - 140 ºC	space & water heating, drying
140 - 220 ºC	drying, process heat, binary electrical plant
220+ ºC	steam turbine & binary electricity or process steam

Geothermal Energy in Africa

The only geothermal resources are located in East Africa . The East African countries of Tanzania, Djibouti, Malawi, Burundi, Ethiopia, Zambia, Comoros, Eritrea, Kenya, Rwanda, and Uganda all lie in the highly volcanic East African Rift.

There is no geothermal potential detected so far in the Sahel region. There may be low temperature heat, maybe in deep aquifers, but there have been no measurements so far, probably due to the cost.

3. Barriers to the Penetration of Renewable Energy

The main barriers associated with the limited penetration of renewables in Sahelian countries are mainly Political, Regulatory, Institutional and Market barriers.

Political, Regulatory and Institutional Barriers:

- It has to be acknowledged that African countries have designed their energy policies on the basis of supplying modern energy services and have restricted their renewable energy initiatives to disparate isolated or scattered projects. It would be much more fruitful to apply well thought-out policies rather than a series of projects.
- There is a lack of cohesion of intervention methods in the renewable energy field. By always undertaking actions in isolation, the various national and regional institutions, projects and programmes stifle opportunities for synergies.
- Little attention has been paid to RETs by national energy policies;
- Lack of fiscal measures likely to stimulate local production;
- Lack of consultation between actors.

Market Barriers:

- Renewable energy technologies have made significant advances in terms of technology and organisation in recent years, but a genuine market for them does not yet really exist because of:
- Lack of competitiveness of renewable energy compared to conventional types: the initial investment cost is $8500 for wind systems, which far exceeds most peoples' means.
- Lack of funding mechanisms (RET promotion funds, credit lines, etc.) and measures for encouraging use of RETs
- Low demand - this has prevented the emergence of a well-structured national supply capable of fostering the development of the sector. In many cases, operators who get involved in the sector have become disillusioned and abandoned their activities because of the lack of a sufficient market.
- Compartmentalisation of actors – this hinders the development of a mutually-beneficial relationship, and prevents synergies between the strengths of various actors. A prime example is the gap between research and development bodies and private operators. The net result is that research findings are often of little relevance to the needs and demands of the market. This is one of the reasons why there is no RET production infrastructure.
- The insufficient propagation of an appropriate funding mechanism [14].

For wood fuels and their supply, we have identified the barriers in particular:

The main wood fuel supply problems relate to land and tree ownership, fiscal issues, and decentralization. Forestry departments cannot possibly manage all the resources in their country, and the only solution is to devolve control to the local communities and provide these with a regulatory framework to support proper management. For this to happen, the decentralization process needs to provide the organizational structure and the institutional responsibilities, while the land tenure and/or forestry law needs to allow local communities to become the outright owner or at least that they should enjoy long-term usufruct rights to the products of the land falling within village territory [15].

In this chapter the barriers are specifically presented and analysed for most of the Sahelian countries investigated in this project, varying at times for each renewable source.

Cape Verde

Institutional and regulatory framework: ELECTRA operates without a sound policy and regulatory framework. There is neither an electricity law nor a regulatory entity for power sector activities, which hinders significantly the possibility to involve the private sector in the provision of services. Municipality-managed secondary urban centres suffer from the same generic institutional weaknesses. The recently restructured Ministry of Trade, Industry and Energy is responsible for energy policy formulation and sector coordination, but it would require strengthening to comply this function efficiently. Power tariff structures lack transparency and do not reflect economic costs by type of use. These distortions together with non-explicit Government subsidies, in particular for desalinized water and fuel prices, result in the wrong incentives for producers and consumers.

In the case of grid-connected wind energy, the main barriers are: (a) the high up-front capital cost of the first large-scale commercial grid connected systems in Cape Verde; (b) the perceived limits to grid penetration for the technology, due to concerns about potential voltage and frequency fluctuations as wind capacity approaches or exceeds 30% of generating capacity on each grid (one of the highest in the world); and (c) lack of technical capacity to manage the grid at this high level of penetration. The GEF will fund the incremental costs of removing the capital cost, system control and technical capacity barriers to proving that wind generation is technically-feasible and economic at a high level of penetration.

In the case of PV technology, the barriers are: (a) lack of consumer information on and confidence in the technology; (b) lack of a supply, installation and service mechanism; (c) lack of adequate technical capacity to provide these services; and (d) the high up-front cost of supply when the initial PV market is virtually non-existent. These barriers will be removed by financing the incremental start-up costs of suppliers, who will compete for supply concessions and bring in international expertise, experience and financing; by subsidizing, on a declining scale over four years, the cost of the first few thousand systems that are installed; and by creating the necessary information, regulatory and oversight capacity in government. The removal of these barriers will stimulate the entry of private sector firms, NGOs and cooperatives into the market for meeting currently-suppressed demand for off-grid solar and wind electrification at the individual household level and for public services such as school lighting, health dispensaries and water pumping [6].

Mauritania

The development of wind energy projects will be hampered because of restrictions on investment, a misunderstanding of the wind energy potential and the need for further capacity building [1].

The Gambia

According to the KITE study [12], the barriers are:

High Initial Cost - The initial capital outlay needed for installing solar PV systems, for example, has been quite high, such that Government funding has not been adequate enough to provide them for the needy. Virtually all the solar PV systems installed have been provided by bi- lateral and multi- lateral donors.

Technical Barriers – Unreliability and unavailability of solar PV systems in remote rural areas is major barrier to the RETs; Related to the Technical Barriers is the lack of training in the use, maintenance and security of solar PV systems;

Institutional barriers - Lack of clear-cut policy on RETs;

With respect to energy efficiency, there is lack of awareness among potential users regarding the benefits associated with efficiency improvements.

Senegal

In terms of policy, like most African countries, Senegal has for a long time based its energy policy on providing modern energy services. By concentrating solely on the supply side, they for many years neglected the benefits of renewable energy. Even now, as the new rural electrification strategies are being implemented and emphasis is being placed on cost-efficiency (in the ASER approach), there is no guarantee that the State will take concrete steps to broaden application of renewable energy, notably photovoltaic or wind-powered systems

Fiscal and regulatory aspects - Senegal was quick to introduce fiscal and regulatory measures aimed at stimulating the use of RETs. The most assertive one was decision no. 0706/DGD/DERD/BE.1 of 4 May 1993, which granted tax exemption to solar material and lifted fiscal duties, customs duties and taxes on added value.

In 2000, however, this measure was rescinded when the WAEMU imposed common external tariff as part of the sub-regional harmonisation of fiscal and regulatory measures. Solar products are now subject to more than 25% tax, made up of VAT (18%), royalty, a WAEMU community solidarity levy, an ECOWAS community solidarity level, etc.

In summary then, there is still a long way to go for regional market integration and for fiscal measures to encourage the establishment of RET infrastructure [14].

As already discussed, a range of players are involved in RETs. Each of these possesses disparate types of information relevant to a specific area of intervention and this can be broadly summed up in the following table:

Players	Available Data
Public authorities	General data on energy sector and major projects
Private companies	Technical and economic data on RET facilities
Design firms	Data on future and existing projects
NGOs	Socio-economic data on project areas
Research centers	Technical data on equipment
Village groups and associations	Populations needs and benefits and disadvantages of energy sources used

At present, there is little evidence to indicate that there is a pressing information deficit, since all the data required to inform decisions is, in fact, available. What is more, each player knows how to update their data in their fields of expertise (by conducting surveys, technical and economic data from suppliers, project evaluations, etc.)

However, the fact that all this data is compartmentalised by sector creates a significant 'gap'; all signs point to relatively few spontaneous exchanges between the various players. This is one of the biggest institutional hurdles in the area of RETs.

There is currently a real need for information pooling and a coherent institutional arrangement to facilitate this.

This is particularly vital to eliminate the duplication of roles currently evident among institutions involved with RETs. For example, Senegal has a Renewable Energy Study and Research Centre (CERER) , which is much like Mali's CNESOLER, Burkina Faso's IRSAT and Niger's CNES. All of these organisation struggle to accomplish their goals because of the dearth of resources [14].

Biogas Barriers

Major factors behind the development and diffusion of biogas technology in Senegal (and can also be considered for other Sahelian countries) are: low degree of operability, lack of feedstock and high initial investment costs. In fact, to introduce biogas technology, emphasis was put on the use of animal manure as the sole feedstock, while little attention was given to other potentials for biodigester feedstock. These include municipal solid wastes and wastewater and agro-industrial residues. On the basis of their organic matter content, these materials have an enormous potential for conversion into biogas and peasantry usually vulnerable to price and supply fluctuations could benefit from biogas production for household cooking and lighting. However, acceptance of biogas technology by the community will depend on including community representatives and decision makers in all stages of development and dissemination [3].

The main barriers identified by the KITE study [12] for Senegal are:

Lack of long-term credit;

High up- front cost of RETs. These two barriers necessitated the setting up of an innovative financing mechanism.

Guinea Bissau

To be completed by the results of the questionnaires.

Chad

The problem with development of wind energy projects is that the government has not yet taken a stance regarding wind energy. One reason for the government's hesitancy could be the possible technical and environmental constraints which could obstruct the development of wind energy projects. Also, the wind potential still needs to be confirmed by detailed wind measurements.

The supply of wood fuels is quite efficient: there are hardly any shortages throughout the year, charcoal is available all over town from a multitude of sales points. Although, during the annual rainy season, some roads become inaccessible for several months and the price of wood fuels increases sharply, availability never becomes an issue. In 1991, there were at least 9000 persons active in the wood fuel supply chain, from cutting to transforming, transporting, and selling. Firewood and charcoal are brought into the city by individuals (either by head or bicycle load), or by several hundreds of professional transporters who use horse carts to transport the fuels for up to some 50km from the city and pickup trucks or lorries for distances that may reach over 200 km.

All land belongs in principle to the State, and villagers cannot effectively prevent a group of outsiders from cutting down trees on their land. Control over forestry resources is under the authority of the Forestry Department (Ministry of Environment and Water), but the Department is simply unable to provide any real supervision for reason of sheer numbers: even if there were 1000 foresters. However, there are only about 100 or 200, each would have to control 128,000 ha (some 36 km x 36 km).

Given the poor institutional and road infrastructure in the country in combination with a lack of budget, supervision of the whole area is a virtually impossible task.

At present, the rural population only marginally benefits from the wood fuel market, even though people literally live in the midst of the resources. Legally they are not able to use and manage the resources on their village land. A sustainable solution for the urban wood fuel demand will be difficult to conceive and implement unless the rural population truly benefits from these resources [15].

Mali

Barriers to widespread diffusion of renewable energy resources in Mali can be categorized into institutional, technical, financial and informational.

Institutional Barriers

a. Limited coordination on existing activities on renewable energy between various government agencies, research and academic institutions, NGO's, financial institutions and the private sector;

b. The lack of an association of renewable energy technology providers/companies prevents coordinated advocacy at the decision making levels and hence the delay of required policy changes in favour of widespread adoption of renewable energy;

c. Unfavourable regulatory framework for the widespread diffusion of RETs.

Technical Barriers

a. Norms and standards in terms of renewable energy performance, manufacture, installation and maintenance are weak and/or non-existing

b. Lack of private sector capacity in manufacturing, distribution, installation and maintenance of renewable energy systems;

Financial Barriers

a. Heavy subsidies to extend the national electricity grid;

b. Low electricity tariffs not reflecting the costs for transmission and distribution;

c. Absence of mechanisms to underwrite demand side loans (consumer loans) for renewables;

d. Import duties on renewables distort the level of playing field in favour of fossil fuel-based energy technologies;

e. Lack of capacity within the electricity utilities to appraise renewable energy proposals.

Information, Education and Training Barriers

a. Limited access to necessary information and dissemination of existing information;

b. Limited knowledge on the renewable energy markets, including energy needs and the ability to for services of target groups;

c. Lack of public awareness of RETs;

d. No empirical knowledge of the costs and benefits of the range of technologies available for water heating, water pumping, etc;

e. Lack of capacity within the electricity utilities to undertake least cost energy planning in the provision of energy services.

Burkina Faso

According to the KITE study [12], the following barriers have been identified as the key obstacles to the pursuit of energy efficiency and conservation in Burkina Faso:

Institutional barriers – there is inadequate or no regulatory framework within the Ministry of Mines and Energy to support energy efficiency, conservation and climate change benefits.

Information barriers – there is hardly information on energy audits and most of the times consumers are not aware of measures to be undertaken to promote energy conservation and efficiency.

Technological cost barriers – there are hardly energy efficiency technologies in Burkina Faso, in particular in cooling, heating and lighting. This means that the technologies would have to be imported at prices unaffordable to Burkinabes.

Education and Training barriers – there is inadequate education and technical training for local experts to promote energy efficiency and conservation in Burkina Faso.

Regarding solar PV systems the following barriers have been identified:

Financial barriers

There is lack of dedicated financial mechanisms to support development and application of PV systems in Burkina Faso. The high initial costs of PV technologies limit potential consumers from accessing the technologies;

There are no funds to electrify a majority of the rural areas;

No local financial institutions are lending for commercial PV enterprises and potential consumers.

Market barriers

Burkina Faso has low income levels with populations concentrated in urban cities of Ouagadougou, Kodougou, Dedougou, etc and sparsely populated rural areas. Developing a PV market under such conditions is potentially difficult and expensive;

Although there are a few international and local agencies involved in the PV market, the market is not fully developed. The absence of a PV market is a barrier because PV standards on installation, use, maintenance and performance are not adequately applied. This result in misuse of PV systems and could discourage potential users and further development of the market.

Niger

The following have been identified as the key barriers in Niger by the KITE study [12]:

High Cost of Technology – all the renewable energy technologies are imported with no local manufacture of equipment. This makes the cost of technology expensive and unaffordable given that income levels are low in Niger;

Financial barriers – there is lack of adequate financial resources from government to develop RETs;

Market barriers – the market for renewable energy technologies is small.

Fiscal barriers – taxes on imported RETs are still high even though the government is still trying to lower them;

Absence of local entrepreneurs to deploy RETs in the rural areas;

In the case of energy efficiency, poor architectural design of buildings and unfavorable climatic conditions have been found to be main barriers.

4. Capacity Assessment & Proposed Solutions to Overcome Barriers and Technology Costs

Ongoing.

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6. Annexes

6.1 Biomass Annex

Table 6.1. Wood: land area, forest area and fuelwood production in 1999 [26]

	Total land area	Forest area	Fuel wood production (million tonnes)	Charcoal production (tonnes) [30]
	thousand square km			
Senegal	193	62	3.3	110,708
Mali	1,220	132	5.7	93,148
Mauritania	1,025	3	0.2	125,592
Niger	1,267	13	3.1	409,798
Burkina Faso	274	71	9.2	110,000
Gambia	10	5	0.7	45,605
Guinea-Bissau	28	22	0.3	
Cape Verde	4	1	0.1	
Chad	1,259	127	1.7	301,287

The data shown on Fuelwood production reflect as far as possible those reported by WEC Member Committees in 2000/2001; if information was not available from this source, estimates for 1999 were projected from FAO time-series of fuelwood production (FAO 1999 The Role of Wood Energy in Africa).

Table 2. Bagasse: estimated potential availability in 1999 [26]

	Cane sugar production (thousand tonnes)	Bagasse potential availability (thousand tonnes)
Burkina Faso	30	97
Chad	32	105
Mali	31	102
Senegal	95	310

Bagasse = the pulp remaining after the extraction of juice from sugar cane, used as a fuel or for making paper.

The energy content of one ton of bagasse is 2.85 GJ/ton cane milled.

The bagasse potential availability conversion factor from UN Energy Statistics Yearbook 1997 assumes a yield of 3.26 tons of fuel bagasse at 50% humidity /ton cane sugar produced.

Table 3: Fuels used for cooking in rural households for selected African countries (% of fuel used) – World Bank 2000 data [8]

Country	Firewood	Gas, Kerosene	Charcoal	Electricity	Other
Gambia	97	1	1	0	1
Mali	97	0	0	0	2
Burkina	91	1	1	0	7

Faso					
Niger	90	1	0	0	9
Senegal	84	2	12	0	2

6.2 Solar Annex

Figure 1. Solar Insolation (Source [26]: Earth Observatory NASA)

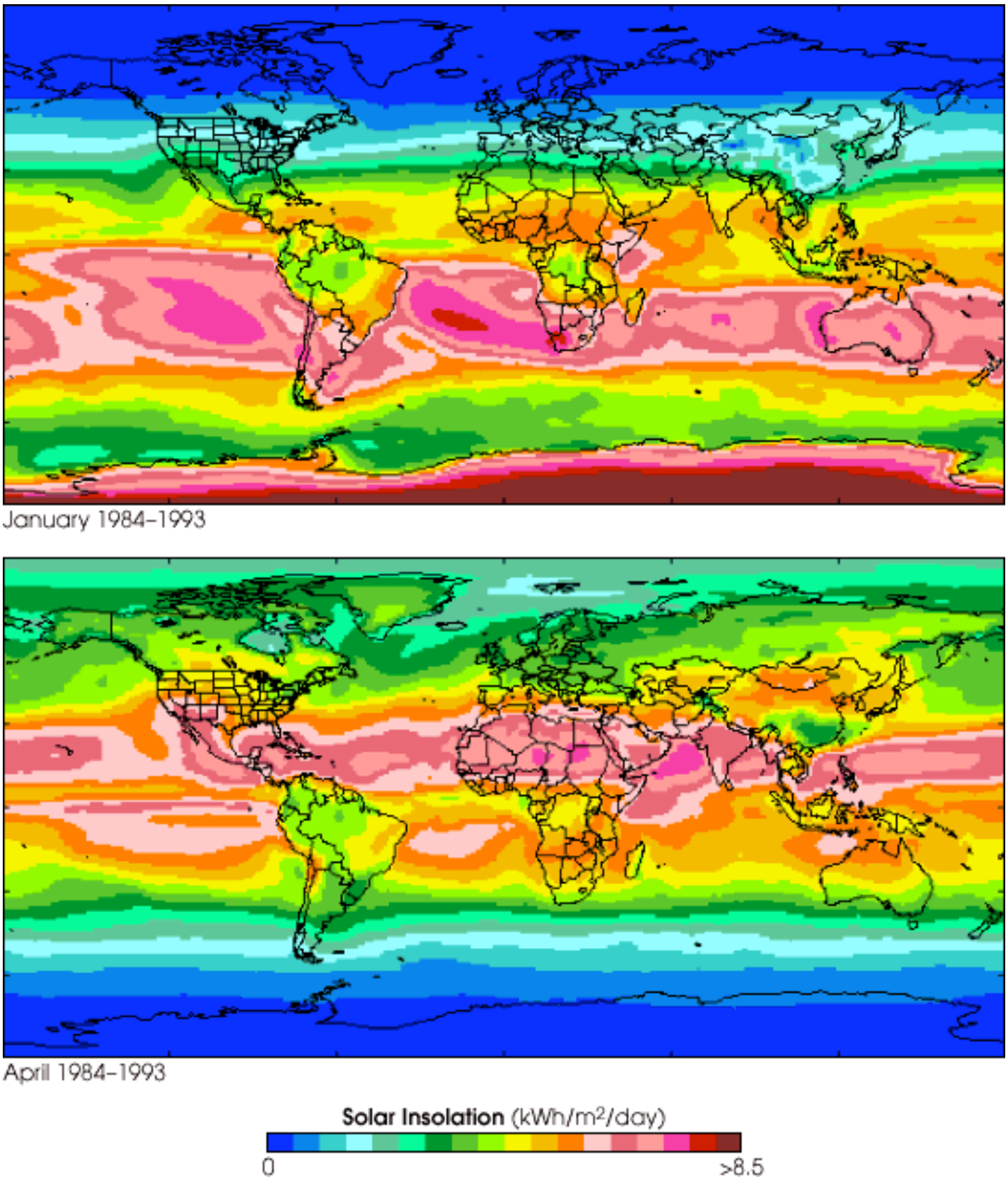


Figure 2. Annual sum of direct normal irradiation – 1998 [4]

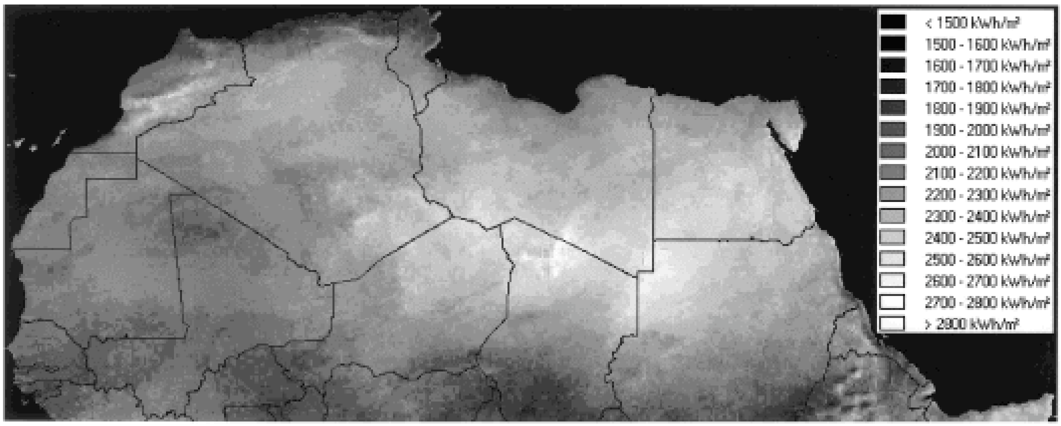


Figure 3. Annual solar electricity yield per km2 of land area [4]

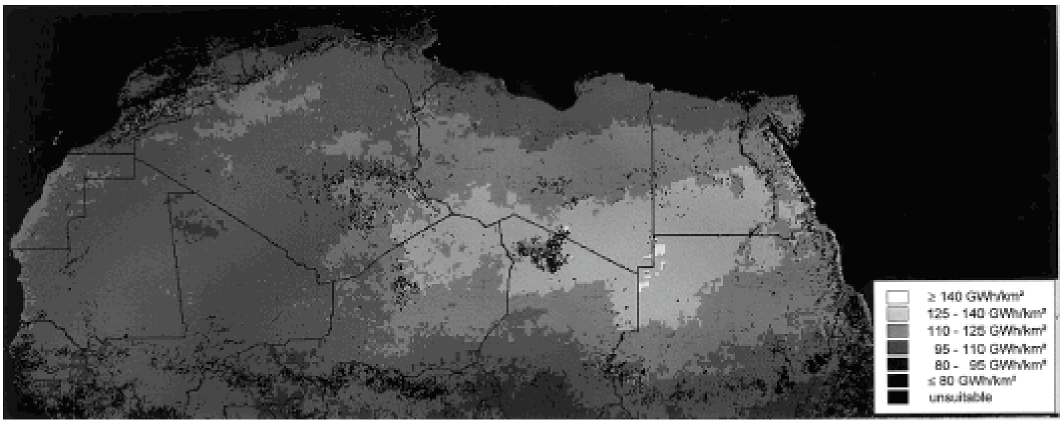


Figure 4. Assessment of solar electricity potentials based on satellite data and a geographic information system [4]

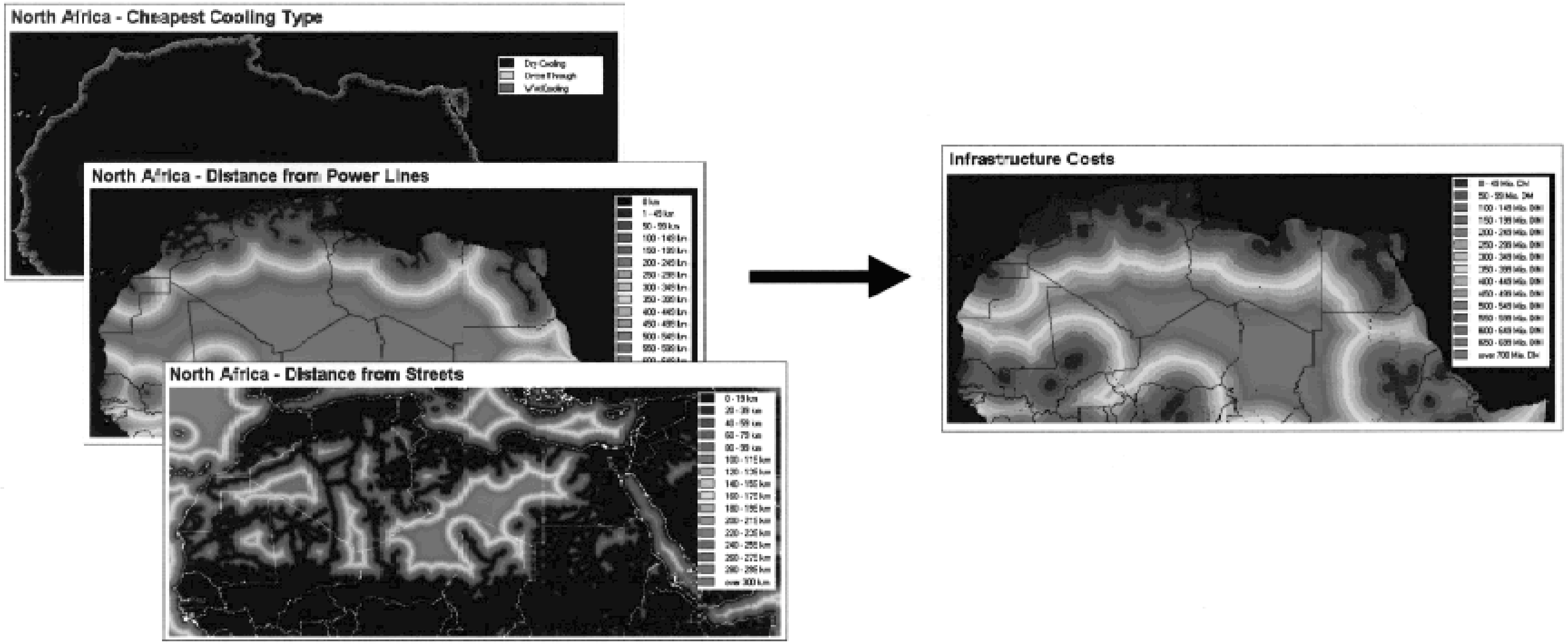
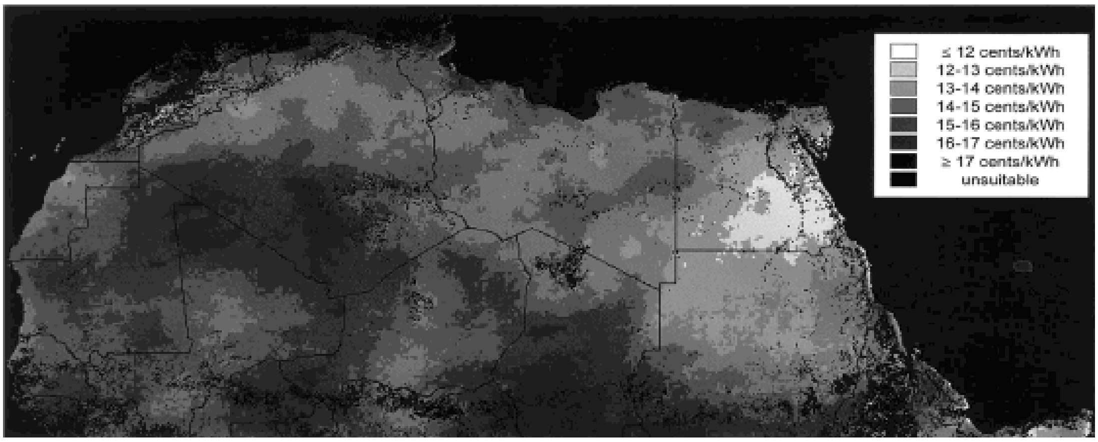
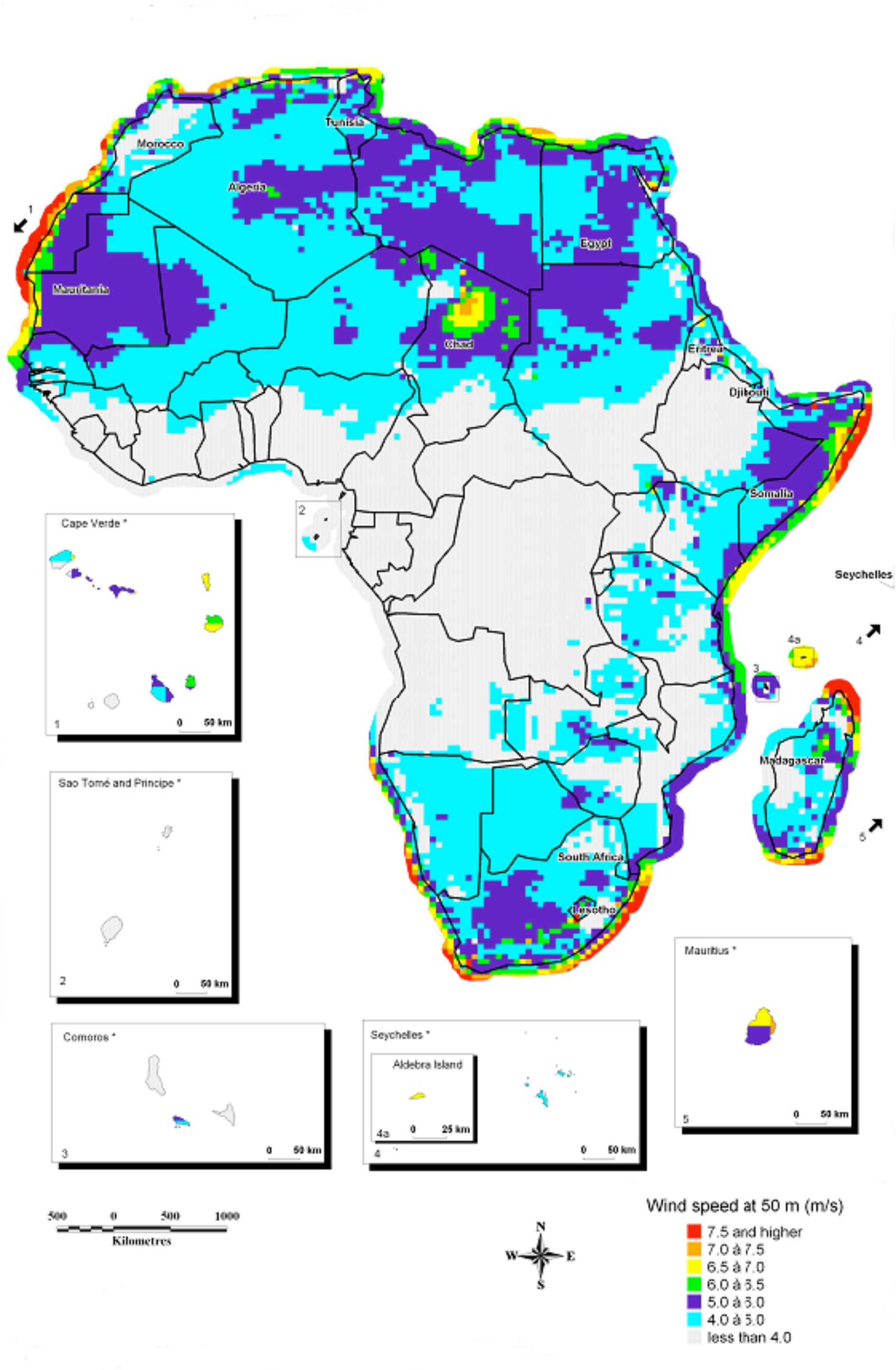


Figure 5. Solar electricity cost per kWh (200 MW SEGS, solar only, price level 1998) [4]



6.3 Wind Annex

Figure 1. Africa Wind Map – Mapping of Wind Speeds as Simulated by the Meso Scale Model at a Resolution of 50 Km



Note: At the resolution used for the simulation the islands were modeled as being water. Therefore the wind energy potential indicated should be interpreted as an overestimate of the actual resource

Image Source: [1] Hélimax Énergie Inc. (2004). Strategic Study of Wind Energy Deployment in Africa - Strategic Plan for Wind Energy Deployment in Africa (Executive summary). Presented to African Development Bank, Côte d'Ivoire. Montreal, Canada.

6.4 Questionnaire Survey Annex

Contact ID

Sahelian Country	
Name	
Organization	
Position/Duties	
Address	
Telephone/Fax	
E-Mail	
Website	

Area - Infrastructure Data

1.What is the availability of electricity & road network information?	
2. What is the availability of land use information in electronic or hard copy format?	
3. What is the area under investigation? Please provide a draft map, (if it is available estimate the extent in km2)	

Biomass – Household & SMEs

1. What is the availability of resource information for:	a. agricultural production for each product
	b. forestry
	c. food industry
	d. others
2. Are there any previous studies available for the area, supported by national or international projects (incl. official statistics)?	
3. What are the types of installations expected, associated with pre-processing this fuel (processing units or retails for final users etc.)?	a. carbonization yards
	b. briquetting or pelletizing units
	c. recover of fines
	d. local markets
	e. equipment suppliers
	f. others
4. How are these fuels used by the final client (what type of appliance	a. direct combustion in open fire
	b. improved stoves

is needed)?	c. efficient stoves
5. Are there any social organizations that could address the issues at local level?	a. association of local residents
	b. local sellers/retailers & market association
	c. gender, religious, policy representation

Biomass – Large Scale

1. What is the availability of resource information for:	a. agricultural production for each product
	b. forestry
	c. food industry
	d. others
2. Are there any previous studies available for the area, supported by national or international projects (incl. official statistics)?	
3. What are the types of installations expected (combustion, gasification, anaerobic digestion etc.)?	a. carbonization yards
	b. briquetting or pelletizing units
	c. recover of fines
	d. local markets
	e. combustion units
	f. gasification units
	g. anaerobic digestion units
	h. equipment suppliers & maintenance services
	i. engineering & consulting firms
	j. others
4. Are there any social organizations that could address the issues at local level?	a. association of large energy consumers
	b. local energy market association
	c. policy representation

Wind Energy

1. What is the availability of resource information? Are there any wind velocity measurements available inside the area? Describe the time frame of the measurements, the methods followed and the availability of results.	
2. Are there any previous studies available for the area, supported by national or international projects (incl. official statistics)?	
3. Has there been any kind of theoretical potential estimation performed, in the form of mean annual wind velocity fields, using a mathematical model (incl. official statistics)?	
5. What are the types of installations expected?	a. large wind farms for electricity generation
	b. isolated units for electricity generation
	c. small units for mechanical use (e.g. water pumping)
	d. small units for other use - specify

	e. equipment suppliers & maintenance services
	f. engineering & consulting frims
	g. others
6. Are there any social organizations that could address the issues at local level?	a. association of large energy consumers
	b. local energy market association
	c. policy representation in cluster regions

Hydroelectric

1. What is the availability of resource information? Are there any measurements in specific streams, in the type of flow duration curves or other?	
2. Are there any previous studies available for the area, supported by national or international projects (incl. official statistics)?	
3. What are the type of installations expected?	a. large hydro (>100 MW)
	b. medium hydro (10-100 MW)
	c. small hydro (10 MW - 500 kW)
	d. mini hydro (100 kW- 500 kW)
	e. micro hydro (<100 kW)
	f. equipment suppliers & maintenance services
	g. engineering & consulting firms
	h. others
4. Are there any social organizations that could address the issues at local level?	a. association of large energy consumers
	b. local energy market association
	c. policy representation in cluster regions

Geothermal

1. What is the availability of resource information? In the type of geothermal zone maps (heat flow density trends and geological framework, subsurface temperatures, thermal springs).	
2. Are there any previous studies available for the area, supported by national or international projects (incl. official statistics)?	
3. What are the types of installations expected?	a. direct use - space heating, hot water for aquaculture, greenhouse heating, drying of agricultural products
	b. ground source heat pumps - heating & cooling of buildings
	c. electricity generation (high temperature)

	d. systems for mechanic use - water desalination
	e. equipment suppliers & maintenance services
	f. engineering & consulting firms
	g. others
4. Are there any social organizations that could address the issues at local level?	a. association of large energy consumers
	b. association of local residents
	c. local sellers/retailers & market association
	d. policy representation in cluster regions

Active Solar

1. What is the availability of resource information? In the type of sunshine hours for each month of the year, total horizontal solar radiation, hourly earth temperature readings etc.	
2. Are there any previous studies available for the area, supported by national or international projects (incl. official statistics)?	
3. What are the types of installations expected?	a. water heating (autonomous & central systems)
	b. space heating & cooling
	c. agricultural application (e.g. product drying, greenhouse heating)
	d. equipment suppliers & maintenance
	e. engineering & consulting firms
	f. others
4. Are there any social organizations that could address the issues at local level?	a. association of local residents
	b. local sellers/retailers & market association
	c. association of large energy consumers
	d. policy representation in cluster regions

PV

1. What is the availability of resource information? In the type of sunshine hours for each month of the year, total horizontal solar radiation, hourly earth temperature readings etc.	
2. Are there any previous studies available for the area, supported by national or international projects (incl. official statistics)?	
3. What are the types of installations expected?	a. electrification of isolated islands
	b. electrification of remote dwellings
	c. systems for mechanic use - water pumping & desalination, irrigation etc.
	d. street lighting
	e. roof mounted - residential & tertiary sector

	f. equipment suppliers & maintenance
	g. engineering & consulting firms
	h. others
4. Are there any social organizations that could address the issues at local level?	**a. association of local residents**
	b. local sellers/retailers & market association
	c. association of large energy consumers
	d. policy representation in cluster regions