Energy Systems:
Vulnerability – Adaptation – Resilience (VAR)

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Regional Focus: sub-Saharan Africa

Mali

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Executive Summary

Vulnerability – Adaptation – Resilience: three issues that any consideration of or approach to development, whether local or global, must address. This is essential for countries like Mali that are characterised by a mainly agro-pastoral economy (and therefore subject to the vagaries of climate), inadequate health and educational systems, and by energy systems that are highly dependent on foreign investment. Mali has no oil resources and is therefore energy poor; its main source of energy is biomass. Extreme poverty denies access to modern forms of energy to much of the population.

Furthermore, world developments—characterised in recent years by measures backed by the World Trade Organisation (WTO) to reduce tariff barriers and obstacles to free trade, thereby accelerating the liberalisation of trade and globalisation of economies—combined with the recent sharp increases in oil prices further threaten the country's overall position. This situation seriously undermines efforts made and leads to an impression of an endlessly repetitive cycle.

The current financial crisis is weakening poor countries and will restrict flows of capital. Changes in the climate and their impacts on production systems are a further hindrance. Poor countries will remain as vulnerable as they have been throughout their histories.

Large-scale popular unrest is also to be feared, with the attendant risk of serious destabilisation in many of these countries.

HELIO International's initiative to stimulate national thinking on these fundamental issues is welcome as it will contribute to the development of recommendations that could make the situation sustainable, especially in the energy sector.

This report, on Mali, attempts to throw some light on the key vulnerabilities affecting the country's energy system and proposes a set of recommendations to strengthen and adapt it. Obviously not all vulnerabilities can be addressed, nor can all possible solutions for the country be proposed. The report is intended to be a contribution to the overall effort.

The recommendations made relate to ways and means of reducing the vulnerability of systems for producing, transporting and distributing energy and to ways of increasing resilience. They are technical, economic, social, environmental, institutional and political.

In the short term there is a need to:

1. Plan the construction of plant taking account of the variations in climate, especially where hydropower stations are concerned.
2. Ensure security of systems for the transmission of electricity.
3. Ensure the country's security of supply of petroleum products.
4. Ensure flexibility in electricity generating.
5. Promote decentralised generating of electricity.

In the long term, there is a need to:

1. Develop and implement a proactive policy for energy management and saving.
2. Ensure proactive monitoring of the supply/demand balance for the electricity system.
3. Intensify rational management methods for fuelwood.
4. Promote research and development, training and supervision of stakeholders.
5. Promote small and medium sized enterprises (SMEs) and technology transfer in the energy sector.
6. Improve governance in the energy sector.
7. Increase the share of the national budget given over to building of energy infrastructure.

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About the Author

Mr Cheick Ahmed Sanogo is currently Head of the Studies and Planning Division of Mali's National Energy Department.

Mr Sanogo has an MSc in Technology and Processes, specialising in the Technology of Inorganic Substances and Industrial Pollution. He has 27 years of professional experience, 17 of them developing and managing energy programmes and projects.

He has also worked in the areas of energy policy and planning, capacity building for the energy sector and applied research into and promotion of promising technologies for household energy, within the framework of projects/programmes funded by international organisations: World Bank, World Environment Fund, United Nations Environment Programme, US AID and CILSS (21 years).

Mr. Sanogo has also worked on socio-economic and environmental impact assessments for initiatives to disseminate energy equipment and in drawing up energy balances.

Cheick Sanogo is the focal point for numerous sub-regional programmes (UEMOA Biomass Energy Programme, *CILSS Energie Domestique et Alternative au Sahel*, Enda CRETAS, etc.).

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List of Abbreviations

AMADER	Agence Malienne pour l'Energie Domestique et l'Electrification Rurale
AUREP	Autorité pour la Promotion de la Recherche Pétrolière
BOOT	Build Own Operate and Transfer
CMDT	Compagnie Malienne de Développement des Textiles
CREE	Commission de Régulation de l'Electricité et de l'Eau
CSCRP	Cadre Stratégique pour la Croissance et la Réduction de la Pauvreté
DNACPN	Direction Nationale de l'Assainissement et du Contrôle de la Pollution et des Nuisances
DNCN	Direction Nationale de la Conservation de la Nature
DNE	Direction Nationale de l'Energie
DNSI	Direction Nationale de la Statistique et de l'Informatique
EDM	Energie du Mali
GoM	Government of Mali
IDB	Islamic Development Bank
IG/IC	Interconnected Grid/Isolated Centres
ktoe	thousands of tonnes of oil equivalent
kWh	Kilowatt-hour
LPSE	Lettre de Politique Sectorielle de l'Energie
LPSEE	Lettre de Politique Sectorielle de l'Energie et de l'Eau potable
LV/MV	Low voltage/Medium voltage
MDG	Millennium Development Goals
MEIC	Ministère de l'Economie de l'Industrie et du Commerce
MEME	Ministère de l'Energie, des Mines et de l'Eau
MF	Ministère des Finances
MW	Megawatt
MWh	Megawatt-hour
OMVS	Organisation pour la Mise en Valeur du Fleuve Sénégal
ONAP	Office National des Produits Pétroliers
PAS	Plan d'Actions Stratégique
PD	Politique de Décentralisation
PDER	Plan Directeur de l'Electrification Rurale
PDES	Programme de Développement Economique et Social
PEDASB	Projet Energie Domestique et Accès aux Services de Base
PEN	Politique Energétique Nationale
PNPE	Politique Nationale de Protection de l'Environnement
PRODER	Programme Décennal d'Electrification Rurale
PRONAME	Programme National de Maîtrise et d'Economie d'Energie
RE	Rural Electrification
REF	Rural electrification fund
RETs	Renewable Energy Technologies

Country Overview

Geography and Climate

Mali is a continental African country between the 10th and 17th northern parallels; it has borders with Algeria, Niger, Burkina Faso, Côte d'Ivoire, Guinea, Senegal and Mauritius. Mali's surface area is 1,241,238 km², two-thirds of which are in the sub-Saharan desert area. The country's inter-tropical climate varies from arid to very arid in the north to pre-Guinean in the extreme south. Average rainfall varies from 100 mm in the north to more than 1,200 mm in the south. Frequency of droughts (1972−1973, 1977−1979, 1982−1983 and 1985−1987) seems to fit with a changing climate pattern that is tending towards aridness, evidenced by reduction in useful rainfall and shifting of isohyets 200 km to the south. This allows the country to be divided into four main agri-climatic zones, as shown below.

Table 1: Agri-climatic zones

Climatic zones	Characteristics	Area
Sudanian/Guinean zone	To the south, with rainfall of 800–1,200 mm /yr; rain-fed crops with some bottomlands	6% of territory, i.e. 74,468.28 km² or 7 ,446,828 ha
Sudanian zone	In the central region, with annual rainfall of 600−1,000 mm, occupied by rain-fed and irrigated crops, strong presence of herders, either sedentary or moving seasonally	17% of territory, 210,993.46 km² or 21,099,346 ha
Sahelian zone	Northern region, with rainfall of 200−600 mm/yr, agro-pastoral system as well as rain-fed, irrigated and flood recession crops	26% of territory, 322,695.88 km² or 32,269,588 ha
Saharan zone	Extreme northerly region with less than 200 mm/yr and dominated by purely pastoral and mixed systems including crop growing	51% of territory 632,980.38 km² or 63,298,038 ha

The main hydrographic system is constituted by the Niger and Senegal rivers and their tributaries as well as numerous lakes, both natural and resulting from building of storage dams, of which the largest are Manantali and Sélingué, and wetlands (Gossi, Gourou, Banzana). The River Niger crosses 1,700 km of Mali's territory, the River Senegal 900 km. The volumes of water flowing in the Niger and Bani rivers are estimated at between 20 and 25 billion m^3. There are large potential groundwater

resources, around 2,720 billion m^3, with an annual recharge rate of around 66 billion m^3. The inner Niger Delta, estimated at 40,000 km^2, is ecologically rich and diversified (water, soils, flora, fauna).

There are major regulating structures on some of Mali's rivers:

1. the hydroelectric dam at Sélingué, with a storage capacity of 2.17 km^3;
2. the hydroelectric dam at Manantali, with storage capacity of 11.27 km^3; and,
3. the Markala dam, for irrigation; (iv) and the Sotuba hydroelectric dam.

Over time, the environmental, biological and human impacts of the dams and reservoirs have contributed to environmental degradation, especially slowing river flow resulting in sediment particles settling out and being deposited on the beds of lakes (sedimentation, silting); increased salinity; erosion of river banks; and disruption of fish ecology. Moreover, the health of local populations is suffering due to recrudescence of water-related diseases (bilharzia, malaria, philariasis, etc.).

The estimated volume of the country's forests is over 520 million m^3, i.e. 416 million tonnes of wood. These resources are spread unevenly across the territory, with less than 10 m^3 per hectare in the shrub savannah, 20−40 m^3 per hectare for the tiger bush, and 50−60 m^3 per hectare for the wooded savannah in the Guinean zone and gallery forests. Within these areas of vegetation, the ‘karité’ (shea) park has the sub-region's highest almond growing potential of 250,000 tonnes per year.

The main threats to the environment are overexploitation of the ligneous vegetation for energy purposes, (extensive) agricultural practices, overgrazing and uncontrolled bush fires. Such practices have effects on the soil (water and wind erosion), and on the flora and fauna (loss of biodiversity). However, vigorous efforts to modernise agriculture and raise the awareness and level of knowledge of populations (especially rural) are under way. In Mali, areas that are now semi-desert were densely wooded savannas 40 to 50 years ago some were forests with abundant fauna including large mammals and a wide variety of birds. Over the past 30 years, Mali's climate has become increasingly arid. Average annual rainfall between 1950 and 1971 was 95.3 mm in the north and 1,380.8 mm in the south. Between 1971 and 2000, these values were 70.7 mm in the north and 1,121.1 mm in the south. The isohyets shifted 200 km south during that period.

Economic Aspects

Mali's economy is based mainly on rural activities, which employ around 75 percent of the economically active population. Like other member countries in the West African Economic and Monetary Union, Mali's agricultural sector is highly dependent on the weather. The overall contribution of food crops to value added is, on average, 52 percent, with an overall annual growth rate of 3.6 percent, 12.7 percent for rice. The expected growth in gross domestic product (GDP) was estimated as 5.3 percent in 2006, resulting from the good 2006/2007 harvest and an increase in gold production.

With the return of the rains, cereal production went from 3,398,627 tonnes for the 2005/2006 season to 3,693,240 tonnes in 2006/2007, an increase of 8.7 percent. Cotton production, however, experienced a 23 percent reduction, going from 534,000 tonnes to 414,000 tonnes. Low cotton prices explain this drop in production.

Where gold is concerned, production was biased by the runaway world gold price of USD22 per gram in December 2006. All of the mining companies in Mali increased their production. Total gold production reached 61 tonnes in 2006, against 52 tonnes in 2005. The development of economic activity came about in a context that was marked by the persistently high levels of world oil prices.

Table 2: Changes in GDP and growth rate

GDP and Growth	2002	2003	2004	2005	2006
GDP, in billions of FCFA	2,222.7	2,453.6.	2,632.1	2,8929.	3,205.8
GDP, in billions of USD	4.45	4.91	5.26	5.79	6.41
Actual growth rate, as %	4.4	7.7	2.8	6.1	5.3

Source: DNSI

Areas planted with maize, rice and fonio reduced significantly in 2004, with respective areas of 252,311 hectares, 314,915 hectares and 25,303 hectares, against 424,861 hectares for maize, 414,023 for rice, and 49,705 hectares for fonio in 2005. The total areas used for crops in the 2002−2007 period were: 7,611,138 hectares for millet; 3,983,980 hectares for sorghum; 1,724,500 hectares for maize 1,899,685 hectares for rice; 193,447 hectares for fonio; and 14,160 hectares for wheat/barley.

The total area sown for cereal crops in that same period was 15,739,910 hectares.

Table 3: Agricultural production indicators for 2002−2006

	Period	Millet	Sorghum	Maize	Rice	Fonio	Wheat /Barley
Area, in hectares	2002/03	1,557,590	923,403	318 161	356,611	34,757	2,548
	2003/04	1,888,889	822,331	316 683	405,641	37,910	2,328
	2004/05	1,184,607	577,021	252 311	314,915	25,303	3,535
	2005/06	1,484,190	744,172	424 861	414,023	49,705	2,184
	2006/07	1,495,862	917,053	412 484	408,495	45,772	3,565
Total	2002/07	7,611,138	3,983,980	1,724 500	1,899,685	193,447	14,160

	Period	Millet	Sorghum	Maize	Rice	Fonio	Wheat /Barley
Production, in tonnes	**2002/03**	**795,146**	**641,848**	**365,174**	**693,203**	**16,321**	**4,621**
	2003/04	1,260,498	727,632	454,758	938,217	22,437	5,701
	2004/05	974,673	664,083	459,463	718,086	19,655	8,942
	2005/06	1,157,810	629,127	634,464	945,824	26,598	4,805
	2006/07	1,128,773	769,681	706,737	1,053,236	26,247	8,565
Total	2002/07	5,316,900	3,432,371	2,620,596	4,348,566	111,258	32,634
Yields, in kg/ha	2002/03	510	695	1,148	1,944	470	1,814
	2003/04	667	885	1,436	2,313	592	2,449
	2004/05	823	1,151	1,821	2,280	777	2,530
	2005/06	780	845	1,493	2,284	535	2,200
	2006/07	755	839	1,713	2,578	573	2,403
Average	2002 / 07	707	883	1,522	2,280	589	2,779

Source: DNSI

The land potential suitable for irrigated crops is 2,200,000 hectares, of which around 566,000 hectares are irrigated from persistent surface water resources. Out of this total area, 295,791 hectares are currently benefiting from water monitoring. Of the 295,791 ha, 97,499 ha have full water control. Around 63 percent (61,000 ha) are medium sized and large irrigation perimeters in the *Office du Niger* (ON) area, of which 56,000 ha are planted annually with rice and 5,000 ha are used for sugar cane (the only sugar cane growing area in Mali).

Social Aspects

Mali's population was estimated at around 12 million in 2005, with an annual growth rate of around 2.4 percent. The population is relatively young, with 50 percent of people below the age of 15 years. Fifty-one percent of the population are women; 75 percent live in rural areas.

With 3.7 million urban citizens out of a population of 12 million, Mali has a low level of urbanisation compared to other countries in the region. Urbanisation is, however, proceeding apace, with a projected quasi-doubling of the proportion of urban dwellers by 2024. The importance of towns in the creation of the country's wealth is also an important factor: one-third of the population (the urban dwellers) produce around 50 percent of GDP. The poor represent some 30 percent of the urban population and poverty is intensifying in urban areas, especially as a result of the disappearance of traditional forms of solidarity and of difficulties in obtaining access to food, services and housing. The impact of economic growth on creation of employment has also been limited: only 9 percent of the population has stable employment in the formal economy. Lack of road infrastructure, drainage, and basic services (water, sewerage and electricity) is at the core of the problems and issues relating to Mali's urbanisation.

In 2006, the population's level of access to electricity nationally was 16.7 percent, against 15.0 percent in 2005. Access in rural areas was at only 1.3 percent, against 0.3 percent in 2005. Access to electricity amongst the urban population was 56.2 percent in 2006, against 49.8 percent in 2005. The number of customers supplied by *EDM.sa* (power company) went from 162,054 in 2005 to 174,152 in 2006; *AMADER* (agency for household and rural electrification) customers for electricity in rural areas went from 329 in 2005 to 6,910 in 2006, with a target of 40,000 for the 2005−2009 period.

The targets[1] set by the *Politique Energétique Nationale* (*PEN* − national energy policy) for the different energy sub-sectors are very clear. The specific aims are to: increase the country's level of electrification from 14 percent in 2004 to 45 percent by 2010 and to 55 percent in 2015; bring the rural electrification level from 1 percent in 2005 to 12 percent in 2010 and 55 percent in 2015; introduce sustainable management of traditional energy supplies, bringing the 321,000 ha currently under communal management to 1.5 million ha by 2010 and to 3 million ha by 2015; reduce the proportion of ligneous fuels in the country's overall energy consumption from 81 percent in 2004 to 70 percent in 2010 and 60 percent in 2015; increase the contribution from renewable sources in national electricity generating from 1 percent in 2004 to 6 percent in 2010 and 10 percent in 2015; and to develop the biofuels sector, especially pourghère technology, for a variety of uses (generating electricity, transport, mechanisation of agriculture, etc.). The degree to which the country's level of energy independence can be increased depends on meeting the above targets for renewable forms of energy.

Throughout the 2000s, Mali introduced a raft of regulations to open up the energy sector. This allowed the emergence of national companies in the hydrocarbons sub-sector which now dwarf the international firms (Shell, Total, etc.) in terms of volumes imported and distributed. In the electricity sub-sector, legislation allows independent operators to generate and sell electricity (mostly on a BOOT basis). Collection and selling of biomass has always been in the hands of private operators. This is also the case for rural electrification.

[1] PEN = Politique Energétique Nationale (national energy policy) document, adopted in March 2006

Advances on social issues have remained small. They concern access to drinking water, education and health care and attest to the scale of what remains to be accomplished if the Millennium Development Goals are to be achieved.

The main thrust of the strategies adopted in the area of health is to improve health indicators for Mali's population in general and for the poorest members in particular. Strategies specifically target:

- reduction in neonatal, infant and infant-juvenile mortality, by responding to the issues of ARI[2], diarrhoea, malaria, malnutrition and transmissible diseases such as HIV and tuberculosis; and,

- reduction in maternal morbidity and mortality by improving maternal care, prenatal care and obstetrics, as well as taking action on nutritional deficiencies and transmissible diseases.

As a result, the number of community health centres grew from went from 605 in 2002 to753 in 2005 to 785 in 2006. The proportion of the population living within a radius of 5 km from a health centre rose from 50 percent in 2005 to 51 percent in 2006, against 44 percent in 2002.

Figures from different national surveys, and particularly the 2001 *Enquête Démographique et de Santé* (*EDS*−national demographic and health survey) show that 40 percent of children under five years of age are underweight, 34 percent are undersized, 13 percent are emaciated and 18.6 percent suffer from diarrhoea. Infant mortality was 11.3 percent in 2001 and maternal mortality 582 in 100,000; both figures remain high.

Encouraging results have been obtained in the fight against HIV/AIDS, via prevention of transmission of the disease from mothers to children, antiretroviral (ARV) treatments, extension of places of treatment and strengthening of communication to bring about favourable changes in behaviour. Between 2005 and 2006, free treatment for HIV/AIDS increased the numbers of patients following ARV treatments from 6,500 to 11,508, a rise of 77 percent. The number of places where ARV treatment is available from 12 to 31, an increase of 158.3 percent; and the number of HIV/AIDS advice, voluntary and anonymous testing centres from 102 to 116, an increase of 13.7 percent.

Migration is also strongly linked to poverty, which is very prevalent in rural areas where a combination of climatic and man made conditions make development of activities very difficult. Sixty-four percent of the population was estimated to be affected by poverty in 2001. Unemployment is particularly prevalent amongst the young, who make up the vast majority of job seekers. This situation is even more cause for concern because most of these young people lack adequate professional qualifications and have a low level of enterprise culture.

Mali's basic laws set a clear orientation towards a just and equitable society and recognise equality between men and women before the law. This aspiration is given

[2] Acute Respiratory Infections

expression by the legal and regulatory framework in place. However, it must be recognised that custom continues to penalise women, despite the national legislation and international legal instruments to which Mali is a signatory. Introduction of a Family Code in the future should provide a solution to this problem.

Table 4: Basic statistical data

Basic statistics	Year	Unit
Physical area		
Area of country		1,241,000 km²
Total area used for cereal growing	2007	15,739,910 ha
Population		
Total population % of which is rural % of which is under 5 years old	2007	12.3 million 68 % 47.7%
Population density		11 inhabitants/km² (2 inhabitants in north of country + 25 inhabitants in south)
Economically active population % of population female male	2006	4,820,069 39% 32.37% 77.63%
Population economically active in agriculture (% of active population) female (%) male (%)	2006	78.67% 48% 52%
Economy and development		
Gross Domestic Product (GDP) value added in agriculture (% of GDP) GDP per capita	2006 2007 2006	USD6.41 billion 36.5 % of GDP USD521
Human Development Index (and ranking)	2005	0.380 (173 out of 177)
Human Poverty Index (and ranking)	2005	56.4 (107 out of 108 Least Developed Countries)
Environmental Sustainability Index		
GHG emissions	1990 2004	0.4 million tonnes (Mt) CO_2 0.6 Mt CO_2
Access to potable water (less than 500 metres)	2006	67.4 %
Infant mortality	2007	85 0/00
Literacy (over 15 yrs) as % of population female (%) male (%)	2005	24%

Basic statistics	Year	Unit
Literacy amongst adult females, as % of that of males, 2000−2006	2006	48%
Primary schooling and attendance by girls (as % of attendance by boys)	2006	80%
Secondary schooling and attendance by girls (as % of attendance by boys)	2006	73%

Mali's Key Vulnerabilities

Environmental

Mali depends mainly on biomass to meet the population's energy needs (see Table 5: Energy Balance 2007). Consumption of forestry sources is an aggravating factor for desertification and soil erosion. This situation affects use of land for the country's socio-economic activities (agriculture, livestock farming, housing, etc.).

Mali's energy systems have implications for the environment, for energy security, health and poverty. The high rate of population increase, extension of cultivated areas, increase in cash crops (especially rice and cotton) and progressive southward shift of pastoral activities, resulting from desertification, greatly amplify the pressure on arable lands and marginal soils. The area of cultivated land is increasing on average by 4.7 percent per year. This pressure manifests itself in terms of overexploitation of soils with a reduction in both the surface areas left fallow and the periods for which they are left, as well as increasing competition between crop farming and animal husbandry.

Amounts of dust carried on the air are influenced directly by global climate change. In the Sahara and Sahel, incidences of respiratory illness have increased dramatically over the past ten years. It is now established that higher ocean temperatures will reduce rainfall in the Sahara and Sahel.

Furthermore, global warming could increase the intensity and incidence of drought in this part of the world, as well as increasing the amounts of dust carried and illnesses linked to air pollution. This problem is aggravated if the soil ecology is disrupted and micro-organisms (bacteria and fungi) are carried by the wind. Several pathogenic bacteria, fungi and viruses are transported by dust, causing diseases such as tuberculosis, anthrax, aspergillosis and influenza. Dust is the prime transport vector for most fungal and viral diseases. In sub-Saharan Africa, the WHO has identified droughts and dust storms as the cause of regional outbreaks of meningitis and meningococcal disease[3].

[3] Joint FAST and United states Geological Survey (USGS) project. (Journal l'Essor, 20 March 2009)

Economic

Overexploitation of soils leads to their depletion and erosion, and to progressive encroachment of sand. The average yearly loss of agricultural income as a result of erosion is estimated at FCFA4,239/ha in the Sahelian area and as much as FCFA90,000/ha in the Sudanian area, depending on crop and slope of land. Soil degradation is a major factor in the pauperisation of rural populations.

Mali is a net importer of petroleum products and has no coast. The country's situation is therefore precarious and very sensitive to variations in oil prices on the international market. Consumption of petroleum products is increasing year on year.

Civic (governance & regulation)

The energy sector is faced with problems of supply of energy in all its forms (electricity, biomass, petroleum products). The constant increases in hydrocarbon prices seriously compromise the measures adopted by the Government of Mali (GoM).

Given the depth of the current crisis, GoM has made a critical analysis of the situation, considering both policy orientations and stakeholders in the sector. This work led, in March 2006, to the development of the *PEN* with the overarching aim of contributing to the country's sustainable development by making energy services accessible to the greatest possible proportion of the population and fostering promotion of socio-economic activities.

The main aims of the *PEN* are to:

1. Ensure consistency between the *PEN* and the strategic frameworks and orientations adopted by the government for the different sectors of the economy and society.

2. Improve effectiveness and implementation of energy policy.

3. Establish a direct link between availability of energy and the country's social and economic development.

4. Effectively orient the actions of public, para-public and private players in the energy sector to foster the country's rapid, balanced and viable development.

5. Favour symbiosis of the activities of the main players in the energy sector.

General Vulnerability Indicators

Environmental

Indicator 1: Changes in rainfall patterns

Year	Changes in rainfall patterns at Sikasso
1999	1,400
2004	1,300
Isohyets shifted 200 km south	

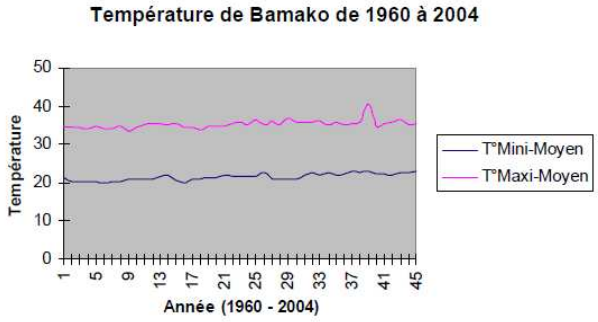
Analysis of data from the different meteorological stations (yearly averages) over the past 20 years shows that Sikasso is the city with the highest rainfall, at around 1,400 mm in 1998. Tessalit has the lowest rainfall, with 15 mm in 1990. From the rainfall data sets for the eight administrative regions and for the Bamako District for the 1999–2004 period, an overall reduction in annual averages is observed at Sikasso: from 1,400 to 1,300 mm. For the minimum, the average total rainfall was 60 mm in 2002 at Kidal. Alternating wet and dry periods were observed in the 1999–2004 period. However, rainfalls consistently lower than 1999 levels are observed in the north and lower than 2002 levels in the south. The most abundant rainfalls are in July, August and September.

Indicator 2: Temperature variations

Variations in average maximum and minimum temperature and relative humidity

Parameters	Variation
Average maximum temperature	33–38 °C
Average minimum temperature	19–24 °C
Maximum relative humidity	70–73%
Minimum relative humidity	9–10%

Figure 1: Variations in temperature at Bamako, 1960–2004



Température = Temperature; Année = Year; T°Mini-Moyen = Average min. temp.; T°Max.Moyen = Average max. temp.

Over the past twenty years the national average minimum temperature has been measured at Kayes: 19 °C in January 1997. The maximum was in April 1987, at Gao: 38 °C. On average the maximum temperature in the shade varies between 33 and 38 °C and the minimum between 19 and 24 °C. Maximum relative humidity is between 70 and 73 percent, the minimum between 9 and 10 percent. For more than a decade, the whole of Mali has been covered by a fine layer of dust from February to the end of March. This is due to sandstorms originating in the northerly parts of the country. Windspeeds are, normally, between 0.9 and 4 m/s.

Economic

Indicator 1: Proportion of households with access to electricity over the past two decades

EDM-SA level of service

	1990	1999	2001	2002	2003	2004	2005	2006	2007
EDM SA[4] centres		44.4%	46.9%	60.0%	64.4%	72.3%	74.4%	75.8%	79.6%
EDM SA[5] peripheral			38.7%	49.1%	52.7%	58.3%	61.4%	63.4%	66.7%
Urban		32.3%	33.9%	41.9%	43.9%	47.3%	48.7%	49.0%	50.5%
Rural		0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.4%	0.4%
Total	4%	8.9%	9.8%	12.4%	13.3%	14.8%	15.5%	16.2%	17.0%

In 2007, the national electrification level was 18 percent, geographical coverage 23 percent and the average service level 66 percent. In rural areas, the level of access went from 1 percent to 8 percent[6] in 2007. This level, one of the lowest in Africa, is ample demonstration of the scale of task that lies ahead in strengthening the production, transport and distribution of energy and of developing renewables.

Indicator 2: Increase in energy autonomy

Energy balance 2007

Energy sources	Biomass	Petroleum products	Electricity
Percentage in energy balance in 2007	82%	14%	4%
Energy balance 1990	89.9%	9.1%	0.9%

All of Mali's primary energy sources are national except for petroleum products, representing 14 percent of the total energy balance, and entirely imported from abroad.

[4] Localities electrified by EDM-SA (interconnected grid and isolated centres)
[5] EDM-SA perimeter authorised by concession contract (rural areas not concerned)
[6] Rural electrification level achieved by AMADER

Technical

Indicator 1: Changes in amounts of energy supplied from renewable sources

Share of hydro and thermal sources in generating of electricity

	1990[7]	2003	2004	2005	2006	2007	2008
Thermal	22.3%	6.0 %	9.2 %	9.8 %	12.8 %	33.0 %	25.1%
Hydro	77.7%	94.0 %	90.8 %	90.2 %	87.2 %	67.0 %	74.9%

The amount of energy supplied from renewable sources has varied in recent years. Hydroelectric generating grew, on average, by 16.72 percent between 2001 and 2006. The strongest growth was observed between 2002 and 2003. A progressive fall is observed afterwards as a result of reduced hydraulicity. Conversely, use of fuelwood, the country's main energy source, is growing continuously. There are no reliable statistics for solar photovoltaic (PV). However, a constant increase in the value of imports is noted: between 2002 and 2006, imports of renewable energy equipment increased on average by 19.9 percent; this level went from 12.28 percent in 2002 to 24.43 percent in 2006.

Indicator 2: Diversity of renewable energy sources and technologies

Use of renewable energy sources in Mali

Renewables	Application in the country
Hydroelectric	4 hydroelectric dams (3 in 1990)
Solar	Several thousand PV systems, solar water heaters and solar dryers
Wind	No significant use

The renewable energy sources in Mali are solar, hydroelectric, biomass and, to a lesser extent, wind. Efforts are being made to develop these sources. Use of biomass is traditional. Current efforts are focusing on solar energy (PV and thermal), wind and biofuels. The level of diversity of the different technologies is fairly high. Systems for pumping, lighting, refrigeration and electricity from solar PV (solar plants) are disseminated throughout Mali (several thousand systems); this is also the case for solar water heaters and dryers. Technologies such as solar cooking stoves are beginning to be introduced into the country. Improved biomass stoves are widely disseminated and there are two semi-industrial units producing briquettes.

Social

Indicator 1: Changes in prevalence of diseases

Changes in prevalence of diseases

	1990	2000	2001	2002	2003	2004	2005	2006
Cholera	61,636	1,885	67	18	1,455	2,839	1,178	7
Malaria	248,904	612,895	723,077	92,280,562	809,428			

[7] The Manantali dam, the largest hydroelectric scheme was not yet in operation

Incidences of diseases related to climate change are increasing each year. Malaria is now endemic to some regions of Mali from which it was absent a few years ago (cases of malaria went from 613,000 to 810,000 between 2000 and 2003).

Indicator 2: Changes in employment

Unemployment levels (2004)[8]

Age group	Formal sector	Informal sector
10−14 yr	12.1%	87.9%
15−24 yr	21.9%	78.1%
25−39 yr	50.3%	49.7%
Total	37.5%	62.5%
40 yrs and over	18.7%	81.3%
Overall total	16.0%	84.0%

Source: Doumbia and Traoré (2005) and OEF (2004)

From table above it can be seen that around 78 percent of young people between 15 and 24 years of age are active in the informal sector that is three young people out of four. This unstructured sector is therefore the prime provider of employment for the young. The informal sector—especially given the size of facilities and the educational level of their managers—is characterised by an almost total absence of proper contracts or other legal measures on social security and health.

According to the *Observatoire de l'Emploi et de la Formation* (*OEF* − employment and training observatory), unemployment is an essentially urban phenomenon (12.5 percent in urban areas against 1.1 percent in rural areas in 1997); young people and women are the groups most concerned. Young people are the most affected, 86 percent of the unemployed are aged between 14 and 39 years, young qualified people being the most numerous. It should be noted that around two young people out of three (65 percent) between the ages of 15 and 24 years in rural areas are occupied , at most, for six months of the year. The result is mass exodus of young people from those areas. The average absence of migrants is four months.

Governance: Developments in land rights[9]

Mali's current land rights issues are linked to the on-going process of decentralisation. Eight laws cover the creation of municipalities (conditions for free administration for local governments, local government codes of regulation, conditions and modalities of local provision of services no longer the responsibility of the central State, etc.). Rural populations have, in principle, to manage their assets and ensure access to land for everyone.

[8] This is the unemployment rate in the 'extended' ILO sense: ratio between the number of unemployed (including discouraged workers) and the extended economically active population (including the discouraged).

[9] The articles by B. Béridogo, S. Koné, Y.F. Koné and B. Kassibo were written within the *Groupe de recherche sur l'État, la décentralisation et le foncier* (*GREDEF* −research group on the State, decentralisation and land rights) financed by AIRE-Développement.

Energy Situation

Current Situation

Mali is a net importer of petroleum products. Its energy situation is characterised by the predominance of ligneous biomass, especially in meeting the needs of households for cooking, and by a very low level of electrification (16 percent). The issue for Mali in terms of social and economic development, and especially regarding the development of energy infrastructure, is the three-pronged challenge of over-exploitation of the nation's forests, high cost of conventional commercial forms of energy and low development and use of the country's renewable energy potential. The current situation is made worse by the continual increase in oil prices on the international markets.

To solve this somewhat complex equation, GoM adopted the *PEN* in March 2006 with the intention of taking up this challenge and recognising the following basic requirements:

1. The need to refocus the government's energy objectives and policy orientations in the light of the economic and social reforms introduced in the country in recent years.

2. The wide range of institutional, public and private players operating in the area of energy without a framework for convergence of their actions.

3. The low level of access to modern forms of energy, resulting from ineffectual policies and/or implementation.

Primary Energy Sources

All of Mali's primary energy sources are national except for petroleum products, for which the country is entirely dependent on imports.

Table 5: Energy balance, 2007

Year: 2007 (aggregated figures − ktoe)	Biomass	Petroleum products	Electricity	Total
Total primary energy supply	3,514.00	647.51	186.25	4,347.77
Final energy consumption	2,678.60	200.58	119.84	2,999.02
Total: industry sector		0.12	83.18	83.30
Total: transport sector		176.44		176.44
Total: other sectors	2,678.60	24.02	36.66	2,739.28
Percentage	82%	14%	4%	100%

Energy Demand

The national demand for biomass, mainly for household cooking purposes, is fairly well satisfied. Satisfying this demand is, however, to the detriment of the country's meagre forest resources which are subject to severe over-exploitation. Highest demand occurs in the urban centres. In rural areas, people gather their own supply, although it now appears that a trade in fuelwood is emerging in some rural parts.

Electricity demand is far from being satisfied in all areas of the country's economic and social life. Electricity demand increased progressively and regularly between 2001 and 2007. Low and medium voltage (LV and MV) consumption on the Interconnected Grid (IG) has grown by 9.7 percent in relation to 2006. Some major areas of demand remain unsatisfied, especially that of the mining companies whose consumption represents around 40 percent of the country's total consumption.

The total number of LV consumers on the IG has more than doubled in six years. The average annual rate of increase in the number of LV consumers over that period was 14.1 percent. The total number of IG LV consumers increased, on average, by 9.2 percent, resulting in an average annual increase in electricity consumption of 9.6 percent.

The grid's power peak also increased significantly over this period, going from around 75 MW in 2001 to more than 145 MW in 2007, an average of 9.9 percent per year. For Isolated Centres (IC) the annual average level of increase in consumption is 15.3 percent.

The total number of MV IC consumers increased by 50 percent over six years and electricity consumption doubled. Aggregated peak power for ICs experienced average growth of 14.8 percent per year in this period.

The demand for petroleum products is increasing at a constant rate (around 10 percent/year over the past five years). This is linked to development of the automobile fleet and to the emergence of major ‘self-generators’ such as the mining companies, not connected to the EDM-SA network.

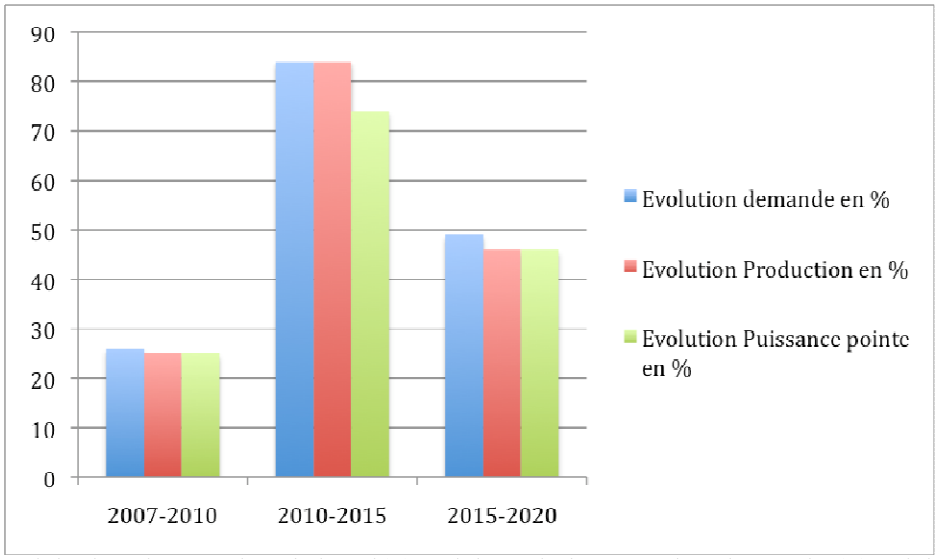
Energy Supply and Constraints

Electricity supply capacity falls far short of demand. Development in demand and generation required to meet that demand and peak power are presented below, according to three scenarios (basic, high and low)[10].

In the basic scenario, demand will increase by 26 percent between 2007 and 2010, by 84 percent between 2010 and 2015 and by 49 percent between 2015 and 2020. To meet this demand, generating capacity will have to increase by 25 percent between 2007 and 2010, by 84 percent between 2010 and 2015 and 46 percent between 2015 and 2020. For these same periods, peak power will have to increase by 25 percent, 74 percent and 46 percent. Figure 2, below, shows these basic scenario developments graphically.

[10] Study of demand and optimum investment plan for the electricity sector

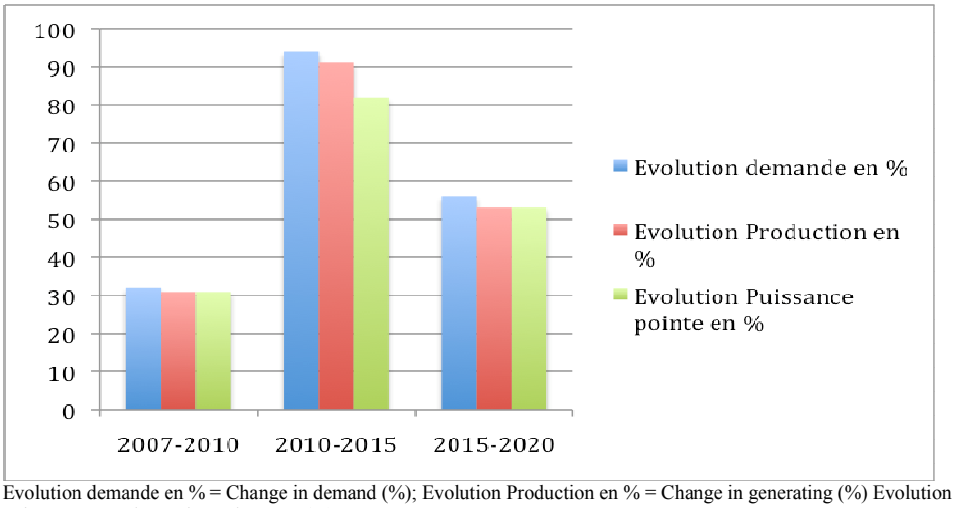
Figure 2: Developments in electricity demand, generating capacity and peak power for the periods 2007−2010, 2010−2015, 2015−2020 in the basic scenario



Evolution demande en % = Change in demand (%); Evolution Production en % = Change in generating (%) Evolution Puissance pointe en % = Change in peak power (%).

For the 'high' scenario for the same periods, demand will grow by 32 percent, 94 percent and 56 percent; generating by 31 percent, 91 percent and 53 percent and peak power by 31 percent, 82 percent and 53 percent. Figure 3, below, shows these 'high' scenario developments graphically.

Figure 3: Developments in electricity demand, generating capacity and peak power for the periods 2007−2010, 2010−2015, 2015−2020 in the 'high' scenario

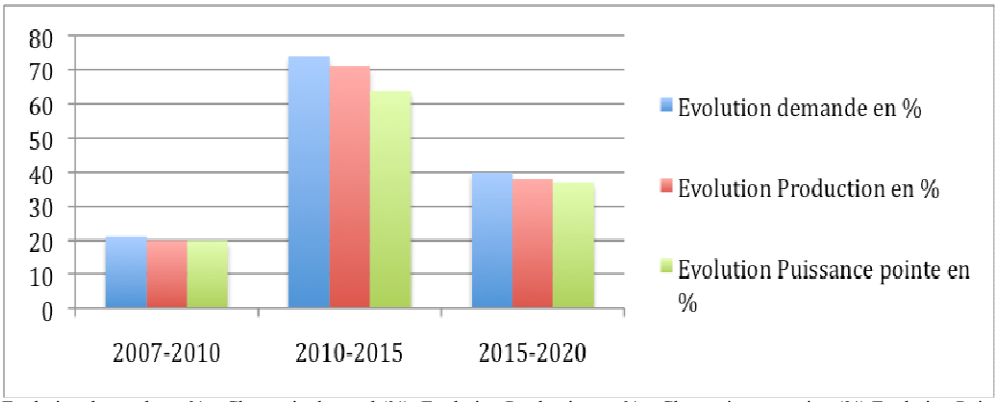


Evolution demande en % = Change in demand (%); Evolution Production en % = Change in generating (%) Evolution Puissance pointe en % = Change in peak power (%).

For the 'low' scenario, demand will increase by 21 percent, 74 percent and 40 percent; generating by 20 percent, 71 percent and 38 percent and peak power by 20 percent, 64 percent and 37 percent.

Figure 4, below, shows these 'low' scenario developments graphically.

Figure 4: Developments in electricity demand, generating capacity and peak power for the periods 2007−2010, 2010−2015, 2015−2020 in the 'low' scenario



Evolution demande en % = Change in demand (%); Evolution Production en % = Change in generating (%) Evolution Puissance pointe en % = Change in peak power (%).

Mali's electricity sub-sector is characterised by:

1. Strong growth in demand.
2. Relatively low generating capacity in relation to demand.
3. Relatively low level of access by the population.
4. High losses on the electricity grid.
5. Severe under-use of the national hydropower potential and renewable energy resources, and a utility company under great financial strain.

The national electricity sector has some major advantages and opportunities. Mali's hydroelectric potential is estimated at more than 1000 MW, spread over around twenty sites in the catchments of the Senegal (three-quarters of potential because of more rugged terrain) and Niger Rivers. Only one-quarter of this potential is used currently (Manantali + Sélingué + Sotuba = 250 MW).

The share of this potential for Mali is approximately 700 MW; 50 percent of the potential on the Senegal River would go to Senegal and Mauritania, within the *OMVS* (organisation responsible for thedevelopment of the Senegal River). The energy that could be generated for Mali would be around 3,000 GWh/yr which is at least 3.5 times the country's electricity demand in 2007.

Biomass supply is encountering difficulties in almost every part of the country and major constraints remain to be removed in the short and medium terms if a balanced and sustainable development is to be ensured for this sub-sector. Specifically, the following are observed:

1. Mismatch between wood tax regime and prices and the real costs of the ligneous resource.
2. Lack of control of forestry.
3. Fuelwood is disadvantaged because of the failure to apply real prices.
4. There is an unequal distribution of ligneous resources over the national territory. On the other hand, the outlook for consolidation of the achievements of projects

and programmes implemented and their extension throughout the country is good.

Obstacles hindering development of the hydrocarbon sub-sector mainly relate to:

- the difficulties inherent to the transport networks (rail and road);
- the high levels of taxes in some of the countries transited;
- the high level of price differences between some products; and,
- the absence of national security stocks.

However, renewables must play an increasingly important role in augmenting electricity supply. Despite considerable advances in the dissemination of these technologies and results obtained with bio-fuels, difficulties remain:

1. Lack of qualified human resources.
2. Lack of involvement of beneficiaries in the design of projects.
3. Absence of local units making and assembling renewable energy system components.
4. Lack of financial resources, both among the population and from the State.
5. Difficulties for promoters of renewable energy technologies (RETs) in obtaining loans.
6. Operators in the renewables sub-sector are under-equipped.
7. The small size of the national market.

Supply Difficulties

The pressure of exploitation of fuelwood in the woody savannah is pushing wood supplies farther and farther from the urban centres, where demand is the highest. Furthermore, wood cutters have increasing difficulty in finding especially if they do not have motorised transport. In the face of the high demand for wood, non-motorised transport such as by bicycle or cart is not always appropriate for meeting needs. In many parts of the country, the problem of distance of supply is further compounded by a reduction in available quantities.

Where petroleum products are concerned, the country's main difficulty is that Mali is a landlocked country—the nearest port is located several thousand kilometres from Bamako. Overcoming this difficulty would require the setting up of an efficient transport network.

The major difficulty for electricity is the lack of means for generating, transmission and distribution.

The Problems of Selling Firewood

The problem of selling fuelwood is one of distance from the demand rather than of lack of demand. In major urban centres, fuelwood (firewood and charcoal) is a high turnover product. Roadside vendors complain of a problem in selling because the demand is elsewhere, notably in urban centres which are often tens or even hundreds of kilometres from the place of production.

Only the organisation of transport—with improvements in means and facilitation of formalities required by the authorities controlling road haulage—would provide a solution to this difficulty.

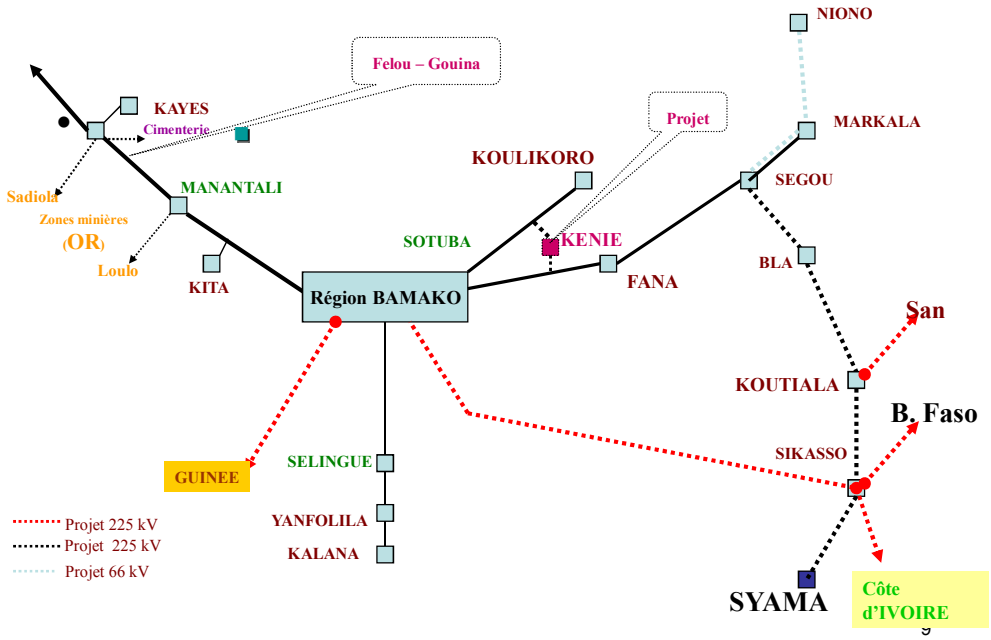
Bilateral and International Cooperation

Mali is a member of numerous sub-regional and international energy organisations:

- *Autorité du développement intégré de la région du Liptako-Gourma* (*ALG*−Liptako-Gourma integrated development authority);
- *Comité Inter-Etat de Lutte Contre la Désertification au Sahel* (*CILSS*−permanent inter-state committee for drought control in the Sahel);
- *Organisation pour la Mise en Valeur du fleuve Sénégal* (*OMVS*−Senegal river development organisation);
- *Union Economique et Monétaire Ouest Africaine (UEMOA*−West African economic and monetary union);
- *Autorité du Bassin du Niger* (*ABN*−Niger river basin authority);
- Economic Community of West African States (ECOWAS); and,
- the African Union (AU).

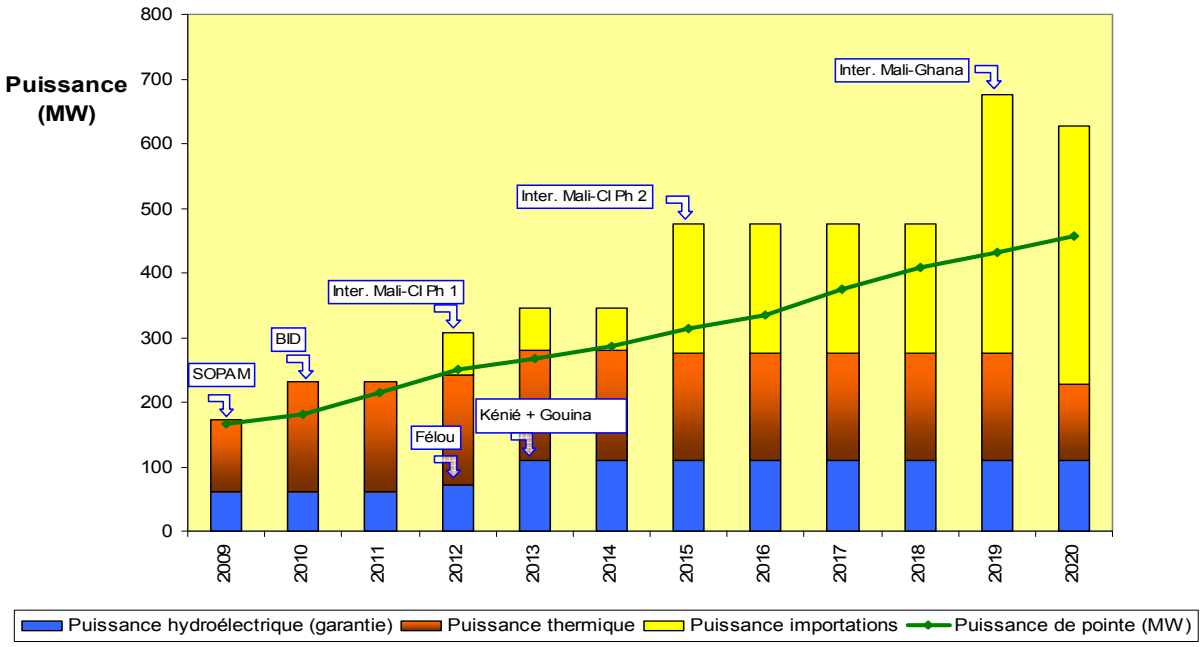
Numerous projects and programmes are under way or being prepared, of which the most notable are interconnection projects (Mali-RCI; Ghana-Burkina-Mali, the *Programme Energétique Communautaire* (community energy programme); second generation OMVS dams, etc.). These forms of cooperation are very useful in taking a comprehensive view of climate problems as they make it possible to think in terms of entire catchments when designing hydropower schemes and to therefore propose solutions extending over several countries.

Figure 5: Interconnected grid



Projet 225 kV = 225 kV project; Projet 66 kV = 66 kV project.

Figure 6: Interconnected grid generating plan



Puissance (MW) = Power MW
Puissance hydroélectrique (garantie) = Hydroelectric power (guaranteed); Puissance thermique = Thermal power; Puissance de pointe = Peak power (MW).

The generating plan for Mali's interconnected grid includes a progressive reduction in the share of thermal power plants and considerable increase in interconnections with Côte d'Ivoire and Ghana.

The National Energy System

The national energy system is made up as follows:

1. An electrical system consisting of an Interconnected Grid—supplied by hydroelectric and thermal power plants located mainly in the south-west of the country with a line to the centre of the country—and Isolated Centres with their own (thermal) generating units and local systems for distribution to places not connected to the Interconnected Grid.

2. Traditional energy sources, mainly fuelwood (firewood and charcoal) and corresponding, basically, to the following system: people working the forests (farmers or woodcutters and charcoal makers) who are producers located in the production areas; traders/hauliers who buy the produce and move it to the centres of consumption; and finally, vendors (wholesale and retail) who supply end users directly.

3. For hydrocarbons, the system is relatively simple: private operators (domestic or foreign) obtain supplies from the nearest maritime ports and distribute the products to supply stations located throughout the national territory.

All these systems involve a wide range of players and of fiscal regimes that are often inappropriate, as well as policies that have been incorrectly implemented.

Biomass System

The household sector is certainly the largest and most complex energy sector. This is explained by, amongst other things:

1. The importance of ligneous fuel sources in the national energy balance: more than 87 percent of final energy consumption.
2. The very large numbers of players in the sub-sector (woodcutters, charcoal makers, traders/hauliers, vendors, etc.).
3. The almost exclusive use of ligneous biomass for cooking and artisanal activities in rural areas.
4. The highly informal nature of the sub-sector.

To remove the main barriers in this sector, action is being taken to:

Control household energy demand by:

1. Reducing the amount of wood taken from the forests by disseminating improved cooking stoves, oil-burning stoves and agglomerated briquettes made from plant residues.
2. Reducing greenhouse gas (GHG) emissions.
3. Emergence of operational and financially independent Economic Interest Groups (EIG) dedicated especially to household energy in urban and rural areas.
4. Creation of operational and financially independent enterprises producing agglomerated briquettes and production of charcoal from agricultural and/or plant residues (cotton stalks, etc.).

Managing fuelwood sustainably, by introducing:

1. A properly enforced regulatory and fiscal framework for fuelwood, encouraging sustainable management of forests, and financing of actions in this area.
2. Rural markets ensuring effective sustainable management of forest resources in a critical part of the priority areas for intervention, as defined in the supply master plans for the country's major cities.
3. A modern fuelwood sector contributing to viable management, especially by making extensive use of improved carbonisation techniques.

And, improve management and information in the household energy sector, by:

1. Developing an appropriate institutional and organisational framework that allows for decentralisation.
2. Ensuring development, consolidation and long term viability of tools for planning, monitoring and assessment, etc.
3. Developing training, information and communication activities in the sub-sector.

GoM has being implementing projects and programmes to reduce this pressure for a number of years. The *Stratégie Energie Domestique* (household energy strategy, 1995–2002) and *AMADER* (since 2004) have developed technical instruments for rational management of supply and demand of ligneous fuels. Regulations and laws have been introduced in parallel, to govern the production and transport of fuelwood and to foster people's involvement in the management of their forest heritage.

Hydrocarbon System

Imports of petroleum products are rising constantly. Mali imported 614,073 tonnes in 2007, against 520,462 tonnes in 2004. These imports have a negative effect on the balance of payments. Increasing oil prices on international markets are aggravating the situation. This increased consumption is linked to the county's economic growth but also to the fact that virtually all of the mining and cotton ginning plants are self-generators, making use of the heat they produce. Consumption of butane gas as a substitute fuel for fuelwood has not encountered much success. Mali imported 6,423 tonnes of butane in 2007, against 3,428 tonnes in 2004—although the quantities imported have doubled the overall volume remains far from sufficient. GoM has opted for a popular subsidy on the gas to help make it accessible to the majority of the population. However, there are real difficulties in maintaining this subsidy with the gas supply operators.

Renewable energy

Mali has stated firmly its intention to promote renewable forms of energy, increasing the country’s share in its overall energy use from less than 1 percent in 2002 to 3 percent by 2007, 6 percent by 2010, 10 percent by 2015 and 15 percent by 2020. To achieve this goal, a *Stratégie Nationale pour le Développement des Energies Renouvelables* (national strategy for renewable energy development) was introduced in 2005, and a *Stratégie Nationale de Développement des Biocarburants* (national strategy for biofuels development) in 2008.

Both strategies spell out the essential ways and means required for development of renewables (solar, biomass, wind) throughout the national territory. Institutional, technical, financial, organisational and socio-economic aspects are fully addressed therein. More specifically, an *Agence Nationale de Développement des Biocarburants* (national biofuels development agency) has been recently created. The national strategy for biofuels development aims at a significant reduction of 35 percent of hydrocarbons imported between 2009 and 2022.

These targets correspond to annual production of pourghère oil estimated at 392 million litres by 2012, 56 million litres by 2017 and 84 million litres in 2022. This assumes intensification of production and will create employment both in agriculture and all along the oil production and consumption chain.

Electricity system

Mali's electricity system comprises 4 sub-systems:

1. The EDM SA's Interconnected Grid (IG), supplying principally Bamako and Ségou from hydraulic and thermal power plants.

2. The Manantali system operated by *SOGEM*, and *OMVS*, connected to the IG at the Kodialani sub-station in Bamako, supplying Bamako, Kayes and Kita *en route*.
3. EDM SA Isolated Centres (IC) supplied from diesel generators (with the exception of Kadiolo and Zégoua, supplied from Cote d' Ivoire).
4. Self-generators' diesel units (gold mines, *CMDT* − Mali textile development company) and sugar cane biomass plants.

Interconnected Grid
Key figures for the IG include:

- An installed generating base of hydro and thermal plants with a capacity of 230 MW, including two EDM hydro plants (Sélingué, 46 MW, and Sotuba, 5.7 MW), a SOGEM hydro plant (200 MW, of which 104 MW for Mali) and, mainly, EDm thermal plants at Bamako, Dar Salam (41.5 MW) and Balingué (32.5 MW).

- A 1,147 km transmission system (in 2007) comprising, mainly:
    - the 65 km EDM HV grid including 359 km of 150 kV lines (Bamako-Ségou and Bamako-Sélingué), 68.5 km at 66 kV (Sélingué-Kalana), 230.3 km at 30 kV and the associated sub-stations (324 MVA) and
    - the 225 kV Manantali grid (490 km from Kayes to Bamako).

- A 3,289 km distribution system (in 2007) comprising 1,032 km at 15 kV and 2,257 km of LV lines.

- Aggregated figures for the ICs are (2007 values):
    - An installed base of diesel generators with a total capacity of 43.6 MW;
    - 1,097 km of distribution grid with 283 km MV and 814 km LV.

Generating Capacity
Generating of electricity in 2007 was marked by a low level at Manantali following low water levels in 2006. This was compensated for by a large increase in production from thermal plants, especially off-grid Aggreko private facilities. These levels of production from thermal plants were the highest since 2001, the year in which Manantali came into service. The share of thermal plants in Mali's generation went from 23 percent in 2006 to 41 percent in 2007. This resulted in high costs for EDM because of high hydrocarbon prices.

The impacts of hydroelectric schemes are somewhat pernicious: the effect of a dam is to reduce the speed of flow of water entering the reservoir lake, thus allowing particles to settle out and fall to the bottom of the reservoir (causing it to silt up). Especially in dry ecosystems, slower flow also increases salinity of the water. If the water is to be used downstream for agriculture, this will contribute to sterility of the soil (physiological drought: the soil becomes hypertonic, plants dry out and die). In addition, as the water released from the dam is clear, it will seek to reconstitute its sediment load and therefore be more erosive. River erosion therefore increases downstream of dams (riverbed deepening and scouring of downstream banks and around structures). River erosion of the unprotected banks of the Senegal and Niger

rivers, caused by the Manantali and Sélingué dams, is a threat made all the greater because traditional flood recession agriculture is practiced along the banks.

The Sélingué dam compromised agricultural development in the Inner Niger Delta: it reduced the flooded area, thereby affecting two major rice growing projects (*Office du Niger* and Operation Rice for Ségou and Mopti) and livestock farming by reducing by 50 percent the production of 'bourgou', a sugary, aquatic grass. The 'bourgoutières' (plains where bourgou grows), afford excellent dry season grazing, have been severely degraded by overgrazing and drought.

Large impounded reservoirs are subject to loss of water by evaporation, thus increasing salt concentrations. Losses resulting from the new river-lake biotope are considerable. According to an estimate by Middleton (1995), water loss in lakes or in channels with 80 percent water hyacinth coverage is 2 to 6 times greater than uncovered surfaces.

In addition, the health of populations living near reservoirs suffers from recrudescence of water-related illnesses (urinary and/or intestinal bilharzia, onchocerciasis caused by releases of water, malaria, filariosis, trypanosomiasis, etc.) which weaken people and reduce their capacity to work.

Partial or total drying of beds greatly disrupts fish life: alternating dry periods and high water levels alter the hydraulic regime and create thermal shocks that kill young fish and the benthic fauna.

Energy System Vulnerability

Vulnerability Indicator	Calculation
Coal	
1. Number of coal mines located at less than 1 metre above seal level and within an area that could be flooded by a flood with a current recurrence period of 100 years *Mali has no coal mines.*	Not applicable
Oil and gas	
1. Share of offshore and oil and gas installations likely to be hit by a storm of more than 70 m/s gusts within the next 20 years (%) *Mali is a landlocked country and therefore has no offshore installation.*	Not applicable
2. Share/number of refineries likely to be hit by a storm of mire than 70 m/s gusts within the next 20 years (%) *Mali has no refineries. Oil exploration is under way in the north of the country and could discover large reserves.*	Not applicable

Vulnerability Indicator	Calculation
All fossil fuels	
1. Number or thermal (coal, oil and gas) power plants located at less than 1 metre above sea level and within an area that would be flooded by a flood with a current recurrence period of 100 years *Mali has no plants at less than 1 metre above sea level.Mali is a landlocked country.*	Not applicable
2. Additional information: Expected number of droughts that lead to a capacity decrease of thermal power plants of more than 10% within the next 30 years *Some thermal plants are water cooled. However, given their small size, the amounts of water required are not great.*	
Nuclear	
1. Number of nuclear power plants located at less than 1 metre above sea level and within an area that could be flooded by a flood with a current recurrence period of 100 years *There are no nuclear plants in the country.*	Not applicable
2. Number of incidents/accidents since the plant was built Describe the most significant incidents	Not applicable
Hydro	
1. Expected precipitation change over the next 20−50 years (%) **and/or** probability of floods in each watershed *River discharges and water availability will increase in the first half of this century according to meteorological specialists' analyses. Increase is estimated at between 10 and 40 percent by 2050 at high latitudes and in some wet areas. Conversely, levels will experience significant falls of between 10 to 30 percent in almost all of the mid-latitude and dry tropical areas. It should be borne in mind that some areas are already experiencing water stress.*	Between 10% and 40% increase in some areas Between 10% and 30% decrease in dry tropical areas

Vulnerability Indicator	Calculation
2. Number of multiple-use dams in the country today Volume of water (m^3) of each dam *The Sélingué dam on the Sankarani (tributary of Niger river) has a capacity of 2.17 km^3 producing energy. It is also used to regulate lower water discharge to a minimum of 75m^3/s at Markala.* *The Sotuba dam on the Niger supplying a small hydroelectric plant and the Baguineda canal for irrigation of around 3,000 ha.* *The Markala dam on the Niger, with a capacity of around 0.18 km^3, raising the river level and allowing supply of the Office du Niger canals via branches.* *The Manantali dam on the Bafing, regulating flow in the Senegal river; its capacity is around 11.27 km^3 and the water stored is shared by Senegal, Mauritania and Mali.*	5 Sélingué 2.17 km^3 Sotuba (run of river without reservoir) Markala 0.18 km^3 Manantali 11.27 km^3 Félou 1 (run of river dam)
a. Describe what % of the water is used for: Agriculture, Energy, Drinking *Current consumption for irrigation is around 5.9 km^3/yr, i.e. 90 percent of total extraction. This comes almost entirely from surface water resources and almost entirely over a six-month period: 1 June to 31 December.* *In 2000, water extraction for domestic uses was estimated at 590 million m^3/yr (9 percent of total), whereas industry used around 56 million m^3/yr (1 percent).*	Irrigation 90% Domestic use: 9% Industry: 1%
3. Additional information: Expected additional run-off from glacier melting (millions of m^3) *Mali is a Sahelian country, it has no glaciers.*	Not applicable
Transmission and distribution indicators	
1. Length of in-country, above-ground transmission and distribution lines (km) a. Distinguish between (2 sub-indicators): --High (transmission) --Middle + low voltage (distribution) b. Describe any trans-national lines	A transmission and distribution grid 4,436 km HV: 1,147 km (in 2007) 658 km EDM HV grid: 359 km of 150 kV lines, 68.5 km at 66 kV, 230.3 km at 30 kV associated sub-stations (324 MVA) Manantali 225 kV grid: 490 km Distribution grid of 3,289 km (in 2007) of 1,032 km at 15 kV and 2257 km at LV The Mali-RCI interconnection (225 KV) over more than 600 km

Vulnerability Indicator	Calculation
2. Number and length of power cuts (differentiate between failures due to weather or equipment failure and those cuts due to rationing) a. Average hours of interruption per year (hr/yr)	HV grid: Number of cuts: 2006 = 56 2007 =49 Duration of cuts: 2006 = 35 hours 2007 = 19 hours Number of cuts scheduled for works 2006 = 15 2007 = 19 MV grid: Number of cuts 2006 = 1251 2007 = 1134 Duration of cuts: 2006 = 1071 hours 2007 = 583 hours Number of cuts scheduled for works 2006 = 349 2007 = 486
3. Percentage of energy supply requiring regional transport over 50 km: *For electricity, the thermal power stations are in towns, especially in the isolated centres (town + power plant + distribution grid). Conversely, for the IG, the hydroelectric plants are relatively far from the centres of consumption. 22 percent of electricity supplied can therefore be considered as coming from more than 50 km away.* a. % that is transportation of fossil fuel. *For hydrocarbons, 100% of supply comes from more than 50 km as the country imports all of its oil and the supplying maritime ports are over 1000 km away.* b. % that is transportation of biomass. *Only major towns are supplied with biomass from more than 50 km away (mainly Bamako); 86 percent of fuelwood in Bamako comes from more than 60 km away; 70 percent for the town of Ségou. The geo-climatic situation of the towns varies greatly, this percentage can also vary considerably (higher for northern towns, lower for those in the south).*	22% 100% 86% for Bamako 70% for Ségou

Vulnerability Indicator	Calculation
Biomass	
1. Proportion of biomass used for energy purposes (%) in total biomass production *Biomass provides 97% of the country's energy needs. 78% of household energy needs are satisfied by biomass.*	97%
2. Expected precipitation change over next 20−50 years (%) *Mali's rainfall will decrease by more than 10 percent by 2100. This will result in a further southward shift of the isohyets*[11].	10% by 2100
3. Probability of a temperature increase beyond biological heat tolerance of key biomass crops within the next 20 years (%) *Simulations show that in 2025, crop yields will have dropped by 10 to 26 percent. This will be a consequence of a temperature increase of between 2.7 and 4.5 °C and a 10 percent decrease in rainfall in the areas for which simulations were made.*	10% - 20%
Wind	
1. Number of wind turbines less than 1 metre above sea level	Not applicable
Projected change of average windspeed in the next 20 years based on regional climate models (%)	
Solar	
1. Capacity of solar installations already in place (m^2) *Several hundred solar water heaters, solar driers and other systems installed. Several thousands of solar photovoltaic systems for lighting, pumping and telecommunications.*	More than 3 MW
2. Expected temperature increase in the next 20 years (°C) relevant for PV capacity	Not available
3. Projected change in rainfall and cloud cover over the next 20 years (%)	10%

[11] http://www.mae.gov.ml/revue_inner.php?id=320 ; TQI_N_91, Tuesday 13 May 2008

Energy System Resilience

Capacity Indicators	Calculation
Implementation indicators	
1. Domestic capital formation (millions of euros per year). *It is very difficult to estimate the domestic capital in general and per year. However, the global costs of some projects and programmes are available. Moreover, almost all of the major investments are of foreign capital.* *Major programmes currently under way in the energy sector:* *(i) Investment programme (until 2020): planned investments total €962 million, of which €424 million for transmission and €103 million for distribution.* *(ii) Investments planned under the PEDASB: €24 million and priority programmes under the rural electrification master plan: €6.8 million.* *(iii) Traditional energy sources: investments planned over the next five years: €5.3 million.* *(iv) Petroleum products: planned investment of €1.14 million by private operators, mainly for butane filling stations, and €7.2 million for the ONAP (national petroleum products office) for provision of storage capacities* *(v) Energy sector support programme: USD120 million.*	The contribution of domestic capital to various projects and programmes is estimated at €108 million
2. Domestic investment in renewable energy *Investments in renewable energy are difficult to evaluate at national level because of the multiplicity of players and sources of finance. However, the action plan from the national strategy for renewable energy development includes investments totalling FCFA 15,275 million over the next five years.*	€23.3 million over the next five years
3. Number of technical engineers graduating annually *There is a national engineering training school but figures on the numbers of engineers are not available.*	Several dozen per year
4. Availability of hazard maps for floods/droughts *The Action Plan for Wetlands, National Plan for Integrated Water Resources Management and many other projects and programmes have mapped areas subject to flooding in Mali. The main area is that of the Central Niger River Delta, extending over more than 30,000 km².*	Yes
5. Existence and enforcement of power plant siting and construction guidelines taking climate change into consideration *The electrical power plants are built according to international technical standards. Technical-economic feasibility studies and environmental and social impact assessments are essential for each plant.*	Yes

Capacity Indicators	Calculation
6. Existence of emergency plans to react to meteorological extreme events and availability of local emergency repair teams. *There are some sub-regional bodies such as the OMVS Early Warning and Communications System (management tool for exceptional or catastrophic floods − 90 monitoring stations set up). At the national level, these issues are managed by the ministry responsible for civil protection.*	Yes
7. Domestic availability of insurance schemes *Conventional insurance companies exist in the country. However, they concentrate more on the urban centres. The rural areas do not have the benefit of these services.* *The solution to this is the development of micro-financing in the rural areas. Important developments have been observed in the area of microfinance during the period. The number of neighbourhood organisations or service points has increased by almost 10 percent.* *One Malian out of six benefits from neighbourhood financial services and 35 percent of women are members of microfinance organisations. Despite the favourable developments observed, financial exclusion remains common (82 percent of the economically active population does not have access to financial services).* *More than 820,000 people nonetheless benefit from rural funds.*	Yes
8. Existence of citizens' users groups in the energy governance structure (enforcement of participatory decision-making) *Existence of several consumer groups and associations that are consulted before making of any major decision in the sector. Multi-sectoral committees bringing together all stakeholders are also set up for renewables.*	Yes
Wind	
1. Existence and enforcement of national regulations requiring storm proofing of wind power plants to withstand highest anticipated windspeed. *Wind turbines are built in accordance with current international standards. In Mali, they are also designed to withstand the country's wind regime. Measurement programmes are implemented to determine wind regime before any wind turbine installation.*	Yes
2. Existence of siting maps that detail projected changes in windspeed; floodplains; and areas impacted by sea level rise *Maps are being drawn up at the Centre National d'Energie et des Energies Renouvelables (CNESOLER − national centre for renewable energ).*	Yes

Capacity Indicators	Calculation
Solar	
1. Existence of siting map that details projected changes in cloud cover	No
2. Existence and enforcement of national regulation requiring storm proofing of concentrating solar power plants (CSP) to withstand the highest anticipated windspeed *Projects for building of solar thermal plants with a capacity of more than 100 MW are being prepared. Regulations in the area exist, covered by the energy policy document and other reference texts, notably those for rural electrification.*	Yes
Hydro	
1. Existence of a plan for optimised operation of hydro plants under projected flow regimes *Technical-economic feasibility studies and environmental impact assessment are pre-requisites for building of any hydroplant. These studies contain all of the possible scenarios. In general, there are low, medium and high scenarios for flow regimes on the rivers on which the schemes are located.*	Yes
2. Number of dams equipped with desilting gates and/or number of upstream land use management and water catchment plans for each hydropower installation *There are four hydroelectric dams in Mali (Félou I, Sotuba, Sélingué and Manantali). This number will increase in coming years with building of dams at Markala, Kénié, Taoussa, Félou II, Gouina, Koukoutamba and Gourbassi. Almost all of these will be multi-use dams. Developments are also planned for agriculture.*	4
Biomass	
1. Research, Development and Dissemination budget for heat and drought resistant crops *Research programmes on varieties suited to the Sahelian conditions are under way at national level and, above all, at sub-regional level.*	Yes
2. Supply of alternative fuels by private enterprises and cooperatives (% of total fuels) *The alternative fuels (biomass) supplied by private enterprises are, essentially, briquettes made from cotton stalks, typha autralis or wood charcoal dust. The quantities produced are very marginal.*	0
3. Dissemination of improved woodstoves (% of households) *Improved stoves are used widely in Mali. Penetration levels are very high, especially in urban centres (more than 50% on average).*	50%

Capacity Indicators	Calculation
Fuels from extractable resources	
1. Existence of maps showing mining deposits and electricity power plants taking account of areas where there is high risk of tropical storm, flood and drought	Yes
2. Implementation of national regulations to locate thermal power plants at places where there is a source of cooling water for the next 50 years	Yes

Recommendations and Suggestions for Policies and Measures

Mali has conducted a study of energy demand and an optimum investment plan for the next 20 years. The study indicates that, for Mali, hydroelectricity from national or regional schemes is currently the least costly way forward for energy production. This development would be accompanied by an increase in capacities for generating, transmitting and distributing energy.

A programme based on hydroelectric schemes presents a severe risk given the changes in climate that could occur, notably in terms of reduced rainfalls over relatively short or longer periods, and the ensuing low water levels in rivers. In the light of this, and in order to guarantee a secure energy supply, the following recommendations are made for the electricity sector:

Short -term

Develop scenarios for all plants to be built, including:

1. producible energy in dry years;
2. producible energy in average years (average rainfall); and,
3. producible energy in high rainfall years.

Such scenarios would allow planning for generating capacities from sources other than hydro in order to meet demand. For example, 2007 was marked by low production from the Manantali dam as a result of poor hydraulicity in 2006. This was compensated by a large increase in generating from thermal power plants, with the thermal share increasing from 23 percent in 2006 to 41 percent in 2007. This in turn led to high generating costs due to the high price of hydrocarbons. Increase in thermal plant generation leads inevitably to greater greenhouse gas emissions. Overall, the situation created difficulties for the electricity company and led to an increase in electricity prices. In addition, the country's economic performance took a down turn in 2007

Ensure security of electricity transmission systems. The current policy will lead to a substantial increase in electricity transmission lines (high voltage), going from the present few hundreds of kilometres to several thousands of kilometres in the near future. Even if the risk of a major storm is fairly remote for the country, the harshness of the climate (heat, sandstorms, soil erosion, etc.) can affect the lines mechanically. It is therefore recommended that the country be equipped to respond rapidly to incidents (building of capacities).

Secure the country's supply of petroleum products. The maritime ports the supply Mali are more than 1000 km away. To secure its supply, Mali has already introduced measures which need to be reinforced:

1. Reduce the country's isolation, both internal and to the exterior, by building of roads to countries that have coasts;
2. Build up of security stocks throughout national territory; and,
3. Diversify the supply of petroleum products.

Ensure flexibility in generating of electricity. A system based on just one or two sources is highly vulnerable. To ensure a high degree of flexibility, it is important to develop sources of renewable energy. The country has adequate potential for this. Current and future flexibility will, of necessity, require building of generating, transmission and distribution capacities for electrical energy by developing that potential and should include:

1. Creation of solar thermal power stations of several hundreds of MW, feeding into the Interconnected Grid. Solar thermal generating of electricity is now a mature technology and such power plants are already operating in several countries throughout the world. To achieve this, it would be necessary to:
    i. possess up-to-date maps of the solar resources;
    ii. establish standards for the building and operating of such power plants.
2. Systematic association of ecologically viable replanting with any exploitation of forest resources.

Promote of decentralised generating using RETs, especially in rural areas. This approach has already been developed by GoM with a focus on use of RETs to equip water supply points and for rural electrification to meet basic needs.

a. Involvement of communities in making decisions on energy services.
b. Making an inventory of all suitable mini and micro generating sites.
c. Promotion and dissemination of low-consumption equipment for traditional forms of energy and of substitute fuels for fuelwood (briquettes made from agricultural or agro-industry wastes).
d. Setting up of local systems for biofuel production to generate electricity and provide motive power for agriculture.

Long-term

Develop and implement proactive policies on energy saving and management by creating local and national energy efficiency centres able to issue enforceable standards and measures at national level to reduce peak demands and assist consumers in controlling their consumption: large-scale awareness raising campaign for low-consumption lamps and information and awareness raising to foster responsible consumer attitudes.

Introduce proactive monitoring of the electricity system supply-demand balance by applying economical and viable solutions, especially for thermal generating using heavy oil in an interim phase, building of new hydroelectric plants, establishing of electrical interconnections with countries in the sub-region and development of renewable resources.

Fuelwood, recommendations focus on intensifying:

a. development and updating of supply master plans for fuelwood in urban and peri-urban centres;
b. support for creation of rural fuelwood markets;
c. promotion of improved carbonisation techniques.

Promote the research and development and of training and management structures for groups of craftsmen, of SMEs in the sector, and of technology transfer, with a view to wide dissemination of appropriate RETs and local production of systems and components.

Improve energy governance by strengthening the main sectoral institutions to create a climate of discussion and investment favourable to increased private sector participation in energy service supply initiatives. Good governance in the energy sector will assist GoM in its efforts to restructure the sector and strengthen capacities for the emergence of an institutional, legal and regulatory environment that is attractive to private sector operators. It must also strengthen the capacity for planning, dissemination, monitoring and assessment of the environmental and social impacts of energy investments. And lastly, involvement of citizens is the best guarantee of success for energy policies that foster ecologically viable development that benefits everyone.

Increase the share of the national budget allocated to creation of energy infrastructure, to reduce the country's vulnerability to foreign investment in a context of global financial crisis that is affecting availability of foreign capital for the implementation of large-scale projects, including those in the area of energy.

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