# WORLD SMALL HYDROPOWER DEVELOPMENT REPORT 2013

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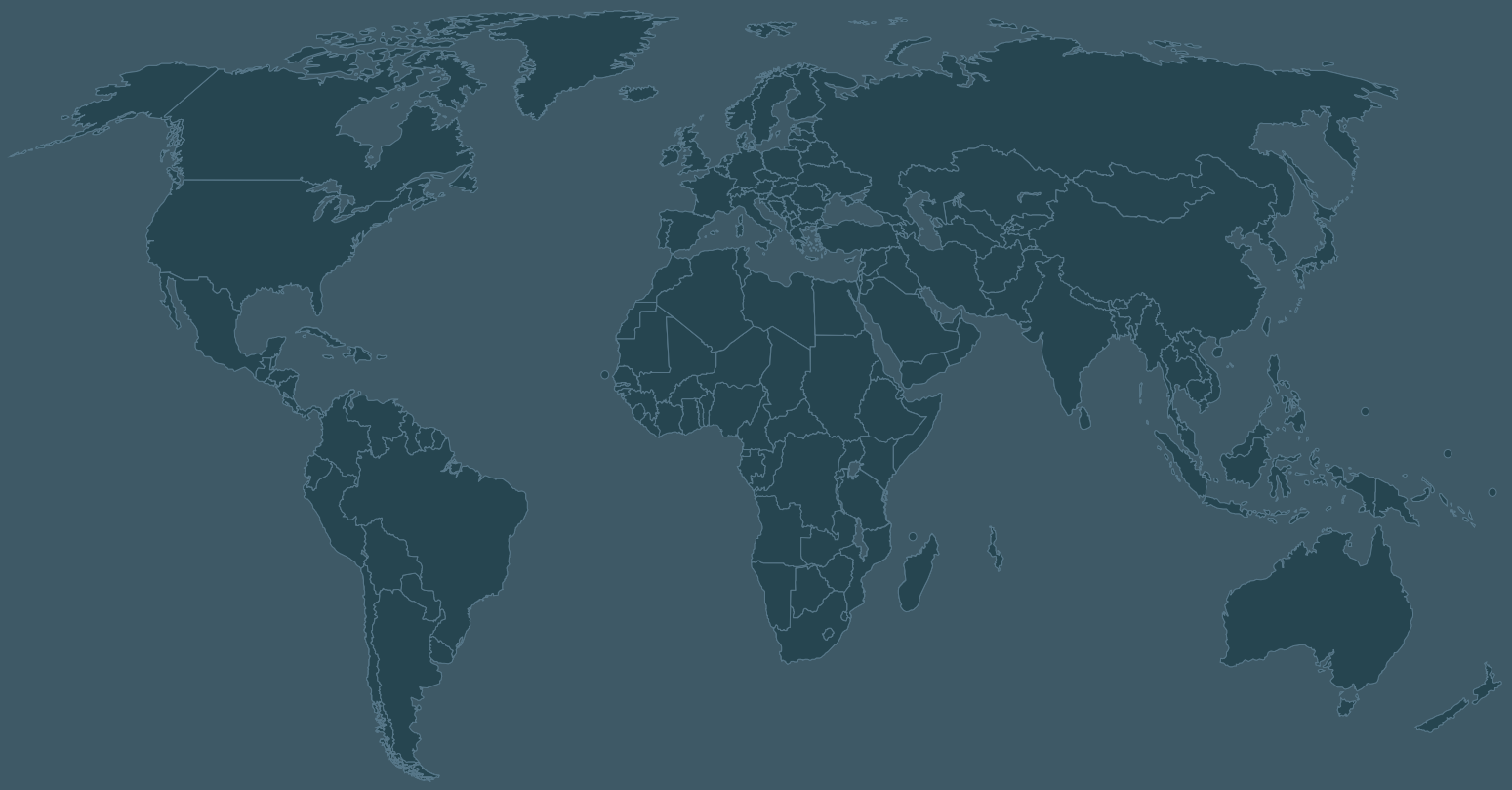
## WESTERN AFRICA



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# 1 Africa
# 1.5 Western Africa

A. A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa

**Introduction to Region**

Western Africa consists of 17 countries, of which 10 have operating small hydropower plants (table 1). Niger has no small hydropower plants, but shows some potential. Senegal has a flat topography, hence limiting its potential in developing small hydropower sites. Other countries in the region, such as Cape Verde, Gambia, Guinea Bissau, and Mauritania do not use small hydropower. All countries in West Africa region, except Mauritania, are part of the Economic Community of Western African States (ECOWAS).

From south to north, there are four climatic zones: the sub-equatorial zone, the Sudanese zone, the Sahelian zone and the Saharan zone. Precipitation is almost non-existent or negligible in the Saharan zone. Precipitation increases in the Sahelian zone (300-600 mm) and the Sudanese zone (600-1,100 mm), reaching 1,800–2,200 mm in the sub-equatorial zone. Strong variation in seasonal and daily temperatures is very pronounced in the Saharan and Sahelian zones (10°C to 45°C) but not nearly so in the southern zones featuring strong rains (22°C to 35°C). The vegetation varies from dense or scattered forest in the sub-equatorial zones to desert plains in the Saharan zones with savannahs featuring trees and shrubs in the Sudanese and Sahelian zones.

About 70 per cent of the 300 million people in West Africa live in rural areas with access to less than 10 per cent of modern energy services. Traditional biomass, in the form of charcoal and fuel wood is the major energy consumed. Access to other energy sources such as kerosene and natural gas are beyond their reach, as a result of their earning power. The absence of modern energy services contributes greatly to for example on-going poverty, illiteracy, health services access and a lack of access to potable water.

Table 1
**Overview of countries in Western Africa**

| *Country* | *Total population (million)* | *Rural population (%)* | *Electrification access (%)* | *Electrical installed capacity (MW)* | *Electricity generation (GWh/year)* | *Hydropower installed capacity (MW)* | *Hydropower generation (GWh/year)* |
|---|---|---|---|---|---|---|---|
| Benin[a] | 9.21 | 57 | 27.4 | 97 | 113 | - | 1 |
| Burkina Faso[a] | 16.30 | 84 | 14.6 | 252 | 620 | 32.0 | 117 |
| Côte d'Ivoire[a] | 21.60 | 49 | 47.4 | 1 391 | 5 877 | 604.0 | 1 618 |
| Ghana[a] | 24.33 | 85 | 72.0 | 2 170 | 11 200 | 1 180.0 | 6 200 |
| Guinea[ab] | 8.76 | 65 | 14.0 | 395 | 920 | 125.5 | 519 |
| Liberia[c] | 4.10 | 80 | .. | 23 | .. | .. | .. |
| Mali[ad] | 14.5 | 80 | .. | 327 | 1 213 | 156.5 | 692 |
| Nigeria[ae] | 158.42 | 64 | 50.6 | 8 702 | 76 231 | 1 938.0 | 7 104 |
| Sierra Leone[afg] | 5.08 | 62 | .. | 113 | 80 | 56.2 | 100 |
| Togo[fi] | 6.10 | 80 | 20.0 | 213 | 868 | 65.0 | 150 |
| **Total** | **268.4** | **-** | **-** | | **97 122** | **4 157.2** | **16 501** |

*Sources:*
a. World Atlas and Industry Guide[1]
b. Central Intelligence Agency[2]
c. World Bank[3]
d. Mali Direction Nationale de l'Energie)[4]
e. UNIDO Regional Center for Small Hydropower[5]
f. Mansaray[6]
g. ECOWAS Regional Centre for Renewable Energy and Energy Efficiency[7]
h. Togo Ministère des Mines et des l'Énergie/Direction Générale de l'Énergie[8]
i. Togo Energy Planning Department of Ministry of Mines and Energy[9]
*Notes:* The electrical capacity of Liberia prior to war was 412 MW.

Despite the growing gap and lack of investment capital, energy intensity in the countries remains high while energy is used in an inefficient way throughout all sectors. The estimated technical and commercial electricity losses in the electricity systems reach between 20 to 40 per cent in the West African sub-

region. Increasing fossil fuel import dependency, shortages and fluctuating fossil fuel prices are major concerns of the West African countries, requiring a diversification of energy sources.

The Economic Community Of West African States Renewable Energy Policy (EREP) aims to serve 25 per cent of the rural population by decentralized renewable energy solutions in 2030 (mini-grids and stand-alone systems) i.e. 60,000 mini-grid systems by 2020. Part of the mini grids could be powered by small-scale hydropower systems.[9]

**Small hydropower definition**

Small hydropower is defined as up to 10 MW or up to 30 MW in this region, with the exception of Ghana where it is up to 1 MW (table 2).

Table 2
**Classification of small hydropower in Western Africa**

| *Country* | *Small (MW)* | *Mini (MW)* | *Micro (kW)* |
|---|---|---|---|
| Benin[a] | 10-30 | 1-10 | 10-1000 |
| Ghana[b] | ≤ 1 | | |
| Mali | 1-10 | 0.1-1 | <100 |
| Nigéria | <10 | <1 | <500 |
| Sierra Leone[c] | 1-30 | 0.1-1 | <100 |
| ECOWAS[b] | 1-30 | 0.005-0.1 | < 5 |

*Notes:*
a. Benin Direction Générale de l'Energie[10]
b. ECREEE Baseline Report[7]
c. Sierra Leone Ministry of Energy and Water Resources[6]

**Regional overview**

Only 10 out of the 17 countries in the region have adopted small hydropower technology (table 1).

Estimations for the small-scale hydropower potential (up to 30 MW) in the Economic Community of West African States (ECOWAS) regions differ widely, ranging from 1,900-5,700 MW of feasible potential. The lower end takes into account the provided site data by the ECOWAS countries to the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) inventory during a workshop in April 2012. Applying a definition of up to 10 MW for small hydropower, installed regional capacity is estimated at around 82.5 MW and the approximate feasible potential at 743 MW.

No comprehensive study has been conducted to precisely determine the specific potential of small hydro in Niger. The only comprehensive hydropower study conducted by Lavalin International in the 1980s identified three sites ranging from 30-255 MW. It was noted, that an estimated four sites located on tributaries of the main river Niger, which is the main permanent river, may be of interest for the exploitation of micro hydro. However, this study is more than two decades old, therefore, taking into account all the effects of drought and climate change that occurred in the meantime, the potential of small hydropower resource would have to be re-quantified.[11]

Table 3
**Small hydropower in Western Africa**
(Megawatts)

| *Countries* | *Potential* | *Installed capacity* |
|---|---|---|
| Benin | 72.40 | 2.50 |
| Burkina Faso | 138.80 | 2.00 |
| Côte d'Ivoire | 11.90 | 5.00 |
| Ghana | 17.42 | 0.00 |
| Guinea | 60.70 | 10.31 |
| Liberia | 57.31 | 4.03 |
| Mali | 114.74 | 5.80 |
| Niger | 5.00 | 0.00 |
| Nigeria | 75.40 | 45.00 |
| Sierra Leone | 44.85 | 6.25 |
| Togo | 144.00 | 1.60 |
| **Total** | **742.52** | **82.49** |

*Sources:* See country reports

Small hydropower development has been slower than expected in the past, however, new initiatives are underway in many countries and the use of small hydropower has recently been increasing, specifically in Nigeria. International funds, such as African Development Bank (AfDB), Bank of Industry (BOI, Nigeria), World Bank, International Finance Corporation (IFC) are engaged. Short, medium and long term targets are being put in place by each country coupled with the removal of barriers, due to an increase in awareness, and with the trend of off-grid and decentralized electricity generation.

The small hydropower future seems promising in the Western Africa region. A sustained effort is required to achieve this position, which includes more feasibility studies where necessary, country level studies with small hydropower plans. Nigeria could be used as leader by virtue of the establishment of the UNIDO Regional Centre for Small Hydro Power in Africa, Abuja, and the success story so far. But the small hydropower developers in the Western Africa sub-region face many challenges.

For example, there is lack of hydrological data in the countries making it difficult to give comprehensive and updated overviews. Inventories established decades ago have never been updated. Gauging stations do not exist anymore. Resource assessments in the 1970s to 1990s were conducted by foreign consultants; therefore, regional expertise in hydro resource assessments is poor.[7]

In response to the challenges, governments of West African countries are already implementing some strategies, such as:

- Trust funds for renewable energy technologies (RET) and specifically for small hydropower projects in Ghana and Nigeria.
- Deregulation of the electricity sub-sector to allow independent power producers in Nigeria
- Establishment of Rural Electrification Agencies in Ghana, Nigeria and Liberia.
- Partnerships between public and private sector, e.g. ECOWAS Renewable Energy Facility
- Formulation of Strategies for RET development.
- Formulation of regulatory frameworks to facilitate feed-in-tariffs from RET to the national grid, e.g. Ghana and Nigeria in 2011.
- Establishment of UNIDO-Regional Center for Small Hydropower in Africa in Nigeria in 2006.
- Establishment of ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in Cape Verde in 2010.

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## 1.5.1 Benin

A.A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa, Nigeria; Lara Esser, International Center on Small Hydro Power

**Key facts**

| | |
|---|---|
| Population | 9,598,787[1] |
| Area | 112,622 km² |
| Climate | Tropical; hot, humid in south; semiarid in north.[1] Three climatic zones: in the South, the sub-equatorial zone with a bimodal rainfall pattern; in the centre the Sudanese Guinean transition zone between the Sudanese and sub-equatorial climates; in the far North the semi-arid Sudanese zone with uni-modal rainfall. Recorded temperatures vary between 27°C and 32°C. |
| Topography | Mostly flat to undulating plains; some hills and low mountains[1] |
| Rain Pattern | Two rainy and two dry seasons: principal rainy season April to late July; shorter less intense rainy period late September to November. Main dry season December to April; short cooler dry season late July to early September. Annual rainfall in the coastal area averages 3,600 mm.[2] Average annual rainfall varies between 800 mm and 1,200 mm depending on the year and the village. |

**Electricity sector overview**

The electricity sector in Benin is jointly governed by an international agreement between Benin and Togo and the Benin-Togo Code of Electricity since 1968. This code was revised in December 2003 to reflect the new requirements of development in the sector, especially in terms of openness to independent producers and single buyer status.[3]

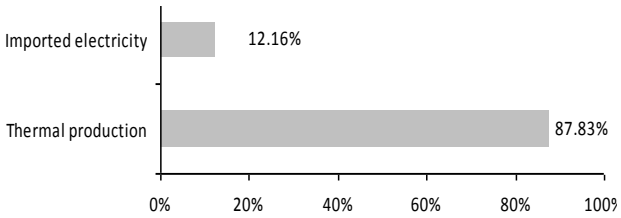


Figure 1 **Electricity generation in Benin**
*Source:* La direction générale du Trésor[4]

The national electrification rate of Benin was 27.4 per cent in 2010, but only 3.53 per cent in rural areas. Electricity production in Benin is managed by the company Communauté Électrique du Bénin (CEB), which is owned by Benin and Togo. Societé béninoise d'Energie électrique (SBEE) is responsible for electricity distribution. SBEE imports electricity directly from neighbouring countries such as Ghana, Ivory Coast and Nigeria. It also engages in its own electricity production using rented and owned diesel generation (figure 1).[5] In 2010 the country had a self-sufficiency rate of only 10 per cent.[6]

The stakeholder agency responsible for the electrification of rural areas is Agence Béninoise d'Électrification Rurale and de Maîtrise d'Énergie (ABERME).[7] Its electrification efforts are based on usage of hydropower, biomass, solar photovoltaic and wind.[3]

**Small hydropower sector overview and potential**

By 2009, micro-hydro plants with a total capacity of about 2 MW were completed.[3] The small hydropower plant of Yeripao, an installed capacity of 500 kW, is currently not in operation and requires maintenance.[6]

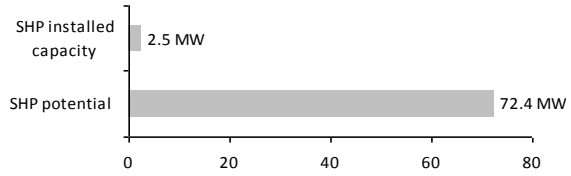


Figure 2 **Small hydropower capacities in Benin**
Source: Innovation Énergie Développement[3], ECOWAS Centre for Renewable Energy and Energy Efficiency[8]

The overall hydropower potential of Benin is not known, several sources indicate different potentials. According to a map issued by the Ministry of Mines, Energy and Water, there are nine sites, with capacities ranging between 2 MW and 9 MW and a total potential capacity of 42 MW, to be constructed.[6] There are three principal lists, two of which include hydropower sites with the capacity ≤10 MW:[8]

- List of 85 micro hydropower sites that includes potential sites <4.4 MW, with a total of almost 50 MW (200 GWh)
- List by ABERME based on work six sites by the Canadian Tecsult in 2009. Out of 20 potential sites, 6 were chosen for feasibility studies. The feasibility studies are available for six micro hydropower sites under 1,000 kW, with a total potential capacity of 1,240 kW.[3] [6]

The lists above are summarized in the *Baseline Report on Small-Scale Hydropower* in the Economic Community of West African States (ECOWAS) Region. There is a feasible potential of 305 MW and 99 sites in Benin for small-scale hydropower plants up to 30 MW and 88 sites with an unexplored potential capacity of 69.87 MW (applying up to 10 MW definition).[8]

According to a 2010 analysis for innovative energy development in Benin, there is potential for small hydropower deployment due to an abundant nationwide coverage of rivers, political support, including tax incentives and exemption of customs duties, as well as financing interest of some donors.[3]

**Renewable energy policy**

The Strategy for the Supply of Energy Necessary for Achieving the MDGs in Benin in 2006 mentioned solar PV, hydropower, biogas and wind as renewable energies available in the country.[9] It also concluded that several problems associated with the sub-sector of renewable energy, such as the lack of national energy policy as basis for developing a renewable energy strategy, lack of operational structures for the promotion of renewable energy and lack of a coherent policy for promoting renewable energy project implementation, especially in remote communities.

In April 2011, Benin's Minister of Energy announced that the Government intended to raise the rural electrification rate with renewable energy, from its present 3 per cent to 50 per cent by 2025.[7] A national agency for the development of renewable energy is under development.[8]

**Barriers to small hydropower development**

Several barriers to small hydropower development exist in Benin, including a lack of local hydropower equipment supply and an absence of local manufacturers. There is, however, potential for the establishment of a local hydropower manufacturing and reparation industry. It would need, however, institutional and regulatory framework that facilitates licenses, permits, authorizations and a buyback tariff.

In conjunction with the hydropower potential, problems of low flow and drying up of rivers need to be considered.[9]

While there is a Rural Electrification Fund in place and electricity production has been liberalized, independent power producers have not yet explored the option of small hydropower and there is no feed-in tariff for small hydropower in place.[8]

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## 1.5.2 Burkina Faso

A.A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa, Nigeria, Lara Esser, International Center on Small Hydro Power

**Key facts**

| | |
|---|---|
| Population | 17,275,115[1] |
| Area | 274,200 km² |
| Climate | Primarily tropical climate with two seasons (dry and rainy). There are three climatic areas: the Sudanian zone with extensive rainfalls during the rainy season; the Sudano-Sahelian zone, located in the center; and the Sahelian zone with a very short and moderate rainy season. The climatic situation of Burkina Faso includes long dry periods and therefore causes serious water supply issues.[2] |
| Topography | Mostly flat to dissected, undulating plains; hills in west and southeast[1] |
| Rain Pattern | The dry season lasts eight months in the North and six months in the South.[1] Irregular rainfall, 400 –1000 mm/year[3] |

**Electricity sector overview**

The national electricity company Societé Nationale d'Electricité du Burkina Faso (SONABEL) ensures electricity generation as the main vertically-integrated operator, with a national monopoly on the generation and distribution in the country's urban centres. Generation is based upon 24 thermal (diesel) plants and 4 hydropower plants (32 MW).[4] Forty-five per cent of the electricity is imported from neighbouring countries, especially Ivory Coast (figure 1).

The national electrification rate of Burkina Faso is 14.6 per cent.[5] Coopératives d'électricité (COOPEL) works with the rural electrification fund Fonds de développement de l'électrification (FDE) under the Electricity for All Programme. Local cooperatives produce and distribute electricity and are part of an umbrella organization, the National Union of Electric Cooperatives in Burkina Faso (Uncoopel / B).[6]

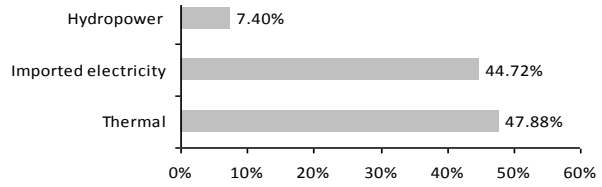


Figure 1 **Electricity generation in Burkina Faso**

*Note*: Data from 2012. The numbers do not include self-generation by private industrial companies (total capacity of 13.45 MW), mainly from thermal sources.[4]

**Small hydropower sector overview and potential**

In 1999, nine small hydropower sites with 36 MW were identified.[3] [7] Currently, two small hydropower plants exist: Tourni (0.5 MW) and Niofila (1.5 MW), which together produce about 1 GWh/year.[7] Both plants were built in 1996. Furthermore, there is a 2.5 MW small hydropower scheme to be implemented at Samendeni Dam which will produce 25 GWh/year, and two additional mini hydropower plants are planned, including Bonvale.[8]

A survey of hydropower sites was carried out within the Électricité de France SONABEL, National Centre of Hydraulic Equipment (Centre National d'Equipement Hydraulique). The study covers large-scale hydropower sites as well as small-scale installations. The capacities range between 65 kW and 550 kW, and 550 to 1,700 kW. The hydropower potential of rural areas is sufficient for decentralized electricity production. Some identified sites have estimated production costs between CFAF[i] 100 and 175 per kWh, several other sites have estimated costs of at least CFAF 200 per kWh.[2]

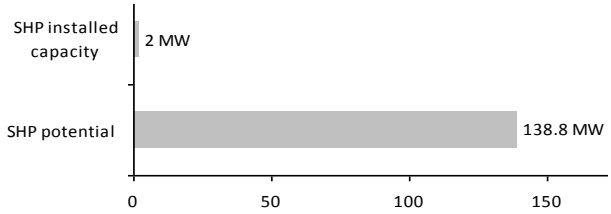


Figure 2 **Small hydropower capacities in Burkina Faso**
*Source:* Burkina Faso Ministere des Mines, des Carrieres et de l'Énergie[7]

All in all, 70 potential small hydropower sites have been identified with a total potential capacity of 138.8 MW (figure 2).[9]

**Renewable energy policy**

The Strategy for Rural Electrification supports solar energy for the electrification of rural areas currently lacking connection to the SONABEL grid. There are currently no policies or strategic directions for the use of renewable energy.[10]

**Barriers to small hydropower development**

Barriers to renewable energy include lack of local technical expertise and lack of financing, especially for capital-intensive technologies.[2] Apart from that, irregular rainfall pattern (400–1000 mm/year), the remoteness of the small hydropower sites to the sites of

consumption, as well as cost depreciation for rural small hydropower projects hinder development.[3]

**Note**

i. CFA stands for Communauté Financière d'Afrique (Financial Community of Africa) or Communauté Financière Africaine (African Financial Community). In several central African states, the Central African CFA franc, which is of equal value to the West African CFA franc, is in circulation. They are both the CFA franc.

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## 1.5.3 Côte d'Ivoire

A.A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa, Nigeria; Lara Esser, International Center on Small Hydro Power

**Key Facts**

| | |
|---|---|
| Population | 21,952,093[1] |
| Area | 322,462 km$^2$ |
| Climate | Four major climate zones, i.e. equatorial, semi-damp tropical, dry tropical and wet tropical/mountain climate.[2] Two air masses are influential: the Monsoon, a moist equatorial air mass, and the Harmattan, a dry tropical air mass coming along with a drying wind, with a saturation of 65-90%. |
| Topography | Mostly flat to undulating plains in the south; plateaus in the center, hills or hill chains with a height of 200-500m in the North, mountains in northwest.[1 2] |
| Rain pattern | Varying rainfall regimes exist, unimodal and bi-modal. The annual mean rainfall lies between a minimum of 900 mm and a maximum of 2,250 mm.[3] |

**Electricity sector overview**

The Electricity access rate is 47.3 per cent.[4] Table 1 shows energy sector objectives from the Poverty Strategy Paper (2009).[5]

Table 1
**Energy sector objectives in Côte d'Ivoire**
(Percentage)

| *Indicator* | *2008* | *2013* | *2015* |
|---|---|---|---|
| Proportion of electrified localities | 31 | 43 | 50 |
| Proportion of households with access to electricity | 17 | 35 | 55 |
| Proportion of share of new and renewable energies in the national energy consumption (excluding biomass) | 0 | 3 | 5 |

*Source:* Poverty Strategy Paper[5]

Electricity is exported from Côte d'Ivoire to Benin, Burkina Faso, Ghana, Mali and Togo.[6] Additional capacity development in the thermal and hydropower sector is planned.

Agence Nationale de Régulation (ANARE) is the National Regulatory Agency of the electricity sector. The Ivorian Electricity Company Compagnie Ivoirienne d'Electricité (CIE) has been granted concession and exploits electricity generation, conveyance and distribution facilities.[1]

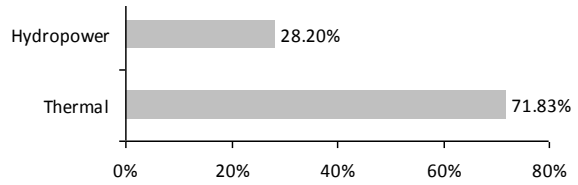


Figure 1 **Electricity generation in Côte d'Ivoire**
*Sources*: BIOVEA[7] and Ministry of Mines, Petroleum and Energy[10]
*Note:* Data from 2010.

Some 28 per cent of the electricity is derived from hydropower in Cote d'Ivoire.[9]

Table 2
**Installed hydropower capacities in Côte d'Ivoire**

| *Name* | *Installed capacity (MW)* | *Year constructed* |
|---|---|---|
| Ayamé | 20 | 1959 |
| Ayamé | 30 | 1961 |
| Kossou | 174 | 1972 |
| Taabo | 210 | 1979 |
| Buyo | 165 | 1980 |
| Grah | 5 | 1983 |
| **Total** | **604** | |

*Source:* German Agency for Technical Cooperation[1] and Koffi[9]

The economic potential of hydropower is 12 TWh. Hydropower sites with a potential of more than 1,300 MW were assessed by Électricité de France in the 1980s. Four large hydropower sites ranging from 5 MW to 290 MW have yet to be built, as well as several small hydropower sites with potentials up to 5 MW each.[1]

**Small hydropower sector overview and potential**

There is no specific classification for hydropower plants (small, micro, mini).[10] There is one existing small hydropower plant, Grah (5 MW), which was put into service in 1983 (figure 2).[10] Three small hydropower schemes are planned in the long term: Drou (1.6 MW, 2021), Aboissobia (5 MW, 2016) and Agnéby (0.3 MW, 2016).

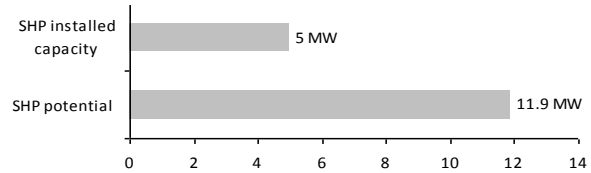


Figure 2 **Small hydropower capacities in Cote d'Ivoire**

**Renewable energy policy**

Société d'Opération Ivoirienne d'Électricité supervises the provision of facilities with focus on the implementation of the rural electrification programme.

Sustainable energy through developing renewable and other new energy sources is one of the areas of

activities of the 2011-2030 Strategic Development Plan of the Republic of Côte d'Ivoire.[8] The private sector should play an important role through investments. An assessment of national renewable energy potential is also planned. Furthermore, an increase in production capacities, both thermal and hydropower, is planned to match increasing electricity demand.

**Barriers to small hydropower development**

With the support of UNIDO and ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), Côte d'Ivoire plans to concentrate on the following activities to remove barriers preventing small hydropower development in the country:[10]

- Update old small hydropower studies.
- Establish a regulatory framework for the purchase of electricity.
- Adapt regulations on the use of waterways to avoid conflict between agriculture, fishing and electricity consumption.
- Provide training session for mapping.

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## 1.5.4. Ghana

Lara Esser, International Center on Small Hydro Power

**Key Facts**

| | |
|---|---|
| Population | 24,652,402[1] |
| Area | 238,535 km$^2$ |
| Climate | Tropical climate. Temperature is generally between 21°C and 32°C. |
| Topography | Mostly low plains with dissected plateau in south-central area[1] |
| Rain Pattern | Annual rainfall in the south averages 2,030 mm but varies greatly throughout the country, with the heaviest rainfall in the south western part. Two rainy seasons: March to July and September to October, separated by a short cool dry season in August and a relatively long dry season in the south from mid-October to March. |

**Electricity sector overview**

In 1989, the Ministry of Energy instituted the national electrification scheme (NES) as a principal policy to reach all parts of the country between 1990 and 2020. In 2010-2011, the national electricity access was 72 per cent and was expected to continue to increase.[2] Another report said that electricity access increased from 25 per cent in 1989 to 66 per cent in 2011, while rural access has increased from 5-40 per cent.[3]

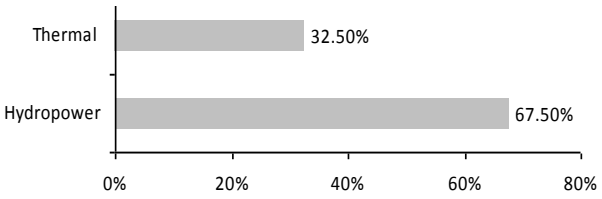


Figure 1 **Electricity generation in Ghana**
*Source*: Ghana Energy Commission[4]

In 2011, the total grid or public electricity generated in the country was 11,200 GWh. Two-third of electricity generated in Ghana comes from hydropower (figure 1).[5] There are two main large hydropower plants, Akosombo (1,020 MW) and Kpong (160 MW). For its dual-fuelled thermal plants, Ghana imports natural gas via the West Africa Gas Pipeline, for example, from Nigeria.[4]

The Energy Commission in 2006 published the Strategic National Energy Plan for Ghana (SNEP) for the period of 2006-2020. The Commission has been preparing annual energy demand and supply forecasts to provide a guide to the energy sector operators and potential investors.[4]

**Small hydropower sector overview and potential**

Ghana's definition of small-scale hydro is up to 1 MW, medium scale lies in the range of 1 MW to 10 MW and large-scale is 10 MW to 100 MW. There are no existing small hydropower plants in Ghana. The *Baseline Report for Small-Scale Hydropower* in the Economic Community of West *African States Region* reports a total of 85 potential sites of up to 30 MW, with a total potential capacity of 110 MW.[6] When considering only those up to 10 MW capacity, the 17.42 MW small hydropower potential comprises two sources: the Hydrological Service Department of Ministry of Works and Housing points out that this includes 69 sites (< 2MW) with a total potential of about 15.18 MW; and by the Energy Foundation, 12 sites (<1 MW) with a total potential of 2.24 MW.[6 7]

The feasibility study of the Randall Falls site (160 kW potential capacity) has been completed.[8] The Energy Commission has initiated actions to develop the country's renewable energy resources; particularly mini hydropower (table 2). The Energy Policy mentions that the mini hydropower potential is limited – 21 potential sites with generating capacities ranging between 4 kW and 325 kW.[8]

The Government has recognized the advantages of a more sustainable approach to agriculture, as a result, it created a policy to develop small hydropower and small scale irrigation facilities in order to boost agriculture in the rural areas. There are numerous rivers which have the potential for small hydropower development which could generate electricity with an installed capacity of between 4.5 MW to 42 MW (e.g. River Ankobra, Pra and Oti).[9]

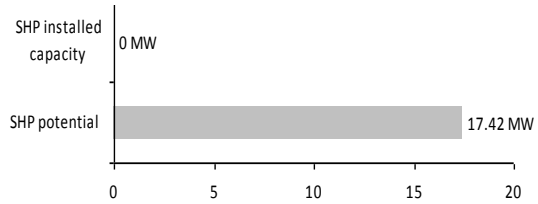


Figure 2 **Small hydropower capacities in Ghana**

**Renewable energy policy**

Ghana is endowed with abundant renewable energy resources such as solar energy, biomass, wind and small hydro. Therefore, it has a huge potential for electricity generation from these sources.[5] The Ghana Energy Commission has the mandate to ensure the adequate development and use of the country's indigenous energy sources. Since 2011, Ghana has a Renewable Energy Law, Act 832, which should create an enabling environment for the private sector to invest in

renewable energies.[4] The 2010 Energy Policy mentions mini hydropower in its policy direction and cites actions i.e. to create an appropriate fiscal and regulatory framework and to provide pricing incentives for small hydropower projects.[10]

**Barriers to small hydropower development**

Large hydropower plants are seen as cheap energy generators in Ghana. Most communities within the proximity of potential small hydropower sites are grid connected and therefore small hydropower deployment is not cost competitive. This is especially due to high capital costs (US$0.5million to US$2.0 million). Inadequate financing of civil works has already proven to lead to project abandonment (e.g. Likpe-Kukrantumi) which increases investment risks, especially in the case of unfavourable flow duration curves. In some cases, a particular site could be used to stimulate socio-economic activities other than power generation, for example irrigation, tourism, ecological education, religion which would avoid the displacement of people, animals and flooding.[11]

Another key issue is the absence of a regulatory and legal framework for development and use of renewable energy sources with little or no economic incentives in place to attract investors to small hydropower, although feed-in tariffs for renewables have been planned for 2013.[12] Another barrier is the limited local technical expertise.

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## 1.5.5 Guinea

Susanne Hughes, International Center on Small Hydropower

**Key facts**

| | |
|---|---|
| Population | 10,884,958[1] |
| Area | 245,857 km$^2$ |
| Climate | Generally hot and humid |
| Topography | Generally flat coastal plain, hilly to mountainous interior[1] |
| Rain pattern | Average annual precipitation is 4,418.5 mm. There are 160 days annually on which precipitation greater than 0.1 mm occur. Monsoonal-type rainy season: June to November (with southwesterly winds). Dry season: December to May (with northeastern Harmattan winds).[1] Driest month is February with 0.5 mm. Wettest month is July with 1,327 mm.[2] |

**Electricity sector overview**

The national electrification rate of Guinea is around 17 per cent, with 14 per cent of the population with access to electricity living in urban areas and 3 per cent in rural areas.[3] Another source reported that only about 10 per cent of the population in the capital, Conakry, and other small urban areas have access to electricity and water.[4] Hydropower accounts for 95 per cent of the total renewable electricity production, at 36 per cent (figure 1). Out of the total electricity generation, 90 per cent is consumed by 25 per cent of the country's population living in Conakry.[4] The provided electricity supply in Conakry and other urban areas remains insufficient.[4]

The Guinea Electrical Company (EDG), under the administration of the Ministry of Energy and Hydraulic, manages an installed power capacity of 150 MW.[4] About 50 per cent of all electricity generation is now privately owned.[5] The electricity is distributed via three interconnected grid-systems (Samou, Garafiri and Kinkon).

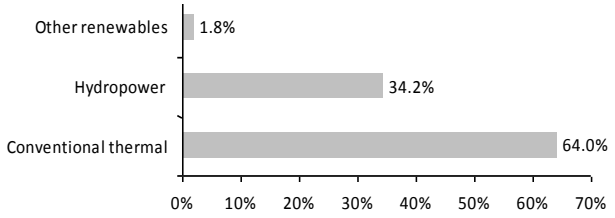


Figure 1 **Electricity generation in Guinea**
*Source:* World Atlas and Industry Guide[5]

A rural electrification project, partly financed by the African Development Bank, is being implemented (between 2011 and 2014), covering 31 localities, along the national interconnected grid. The Government has set an objective of raising the country's electrification rate to 36 per cent by the end of 2015.[6] It is estimated that electricity demand will increase by 10 per cent annually over the next decade.[5]

In 2010, the Kouroussa Corporation made a commitment to fight poverty through the construction of a hydropower dam on the Cogon River, supplying the villages of Boke, Kamsar and Sangaredi with electricity. This hydropower plant is estimated to add a power capacity of 80 MW within five years.[7] In 2011, the Prime Minister of the Guinean Government announced the news about the construction of a large hydropower plant at the Konkoure River (240.6 MW, 942 GWh) by the Chinese company China Water and Electric (CWE).[8] Once the citizens of Guinea are supplied with the required electricity, the Government plans to export this precious resource to the neighbouring countries through inter-connected electrical grids. CWE has proceeded with the construction of the dam as well as promised to achieve 70 km of paved roads, to supply two villages with electricity and to create an electricity transmission line of 147 km.[9]

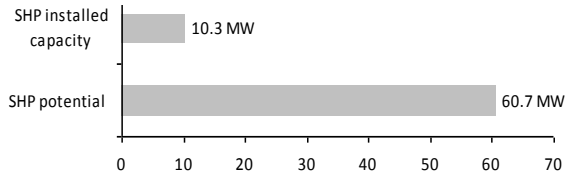


Figure 2 **Small hydropower capacities in Guinea**

**Small hydropower sector overview and potential**

There are seven small hydro plants with a total capacity of 10.31 MW in Guinea (figure 2). All of them need refurbishment. The following were recently reported to be operational: Kinkon (3.2 MW), Tinkisso (1.5 MW, 1967-1968) and Loffa (120 kW).[9] There were plans to upgrade the Loffa plant to 2.8 MW.[10]

In a recent report by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), the total hydropower potential (≤ 30 MW) is 107 MW (in 18 sites).[10] Out of those listed, 11 sites are < 10 MW and constitute a verifiable potential capacity of 24.668 MW.

Table 2
**Micro hydropower sites in Guinea**

| *Number* | *Site* | *River* | *Prefecture* | *Installed capacity (kW)* | *Energy production Gwh/year* |
|---|---|---|---|---|---|
| 1 | Tolo | Tolo | Mamou | 20 | 0.80 |
| 2 | Djoundé | Bouroundou | Boké | 30 | 1.80 |
| 3 | Goléya | Soguisogui | Kindia | 30 | 0.75 |
| 4 | Moussayah | Kassogny | Forécariah | 50 | 1.00 |
| 5 | Tamagaly | Konkoure | Mamou | 10 | 0.25 |
| 6 | Pike | Pike | Dalaba | 10 | 0.60 |
| 7 | Kansagui | Sonki | Telimele | 10 | 0.80 |
| 8 | Sagalé | Tominé | Lélouma | 10 | 0.30 |
| 9 | Kassira | Kassira | Mali | 60 | 0.36 |
| 10 | Nimbéli | Koela | Koubia | 60 | 0.38 |
| 11 | Nongoa | Mafissa | Gueckedou | 60 | 3.00 |
| 12 | Wantaguala | Kondékhouré | Dinguiraye | 28 | 1.68 |
| 13 | Dabadou | Konowa | Kérouané | 50 | 0.32 |
| 14 | Para-Marela | Mongo | Faranah | 20 | 0.14 |
| 15 | Kamba | Kouliyire | Forecariyah | 30 | 1.80 |
| 16 | Kabiéta | Huwoya | N'Zérékoré | 20 | 0.48 |
| 17 | Ouin ouin | Loffa | Macenta | 37 | 0.52 |
| 18 | Sonofilako | Kourayé | Beyla | 40 | 2.94 |
| 19 | Guibaya | Makona | Macenta | 30 | 1.00 |
| 20 | Tabouna | Santa | Kindia | 80 | 1.20 |
| 21 | Tonon | Gouan | Lola | 10 | 0.08 |
| 22 | Donghol | Petedji | Labe | 40 | 0.24 |
| 23 | Nila | Labatou | Pita | 10 | 0.06 |
| 24 | Souessou 2 | Souessou | Beyla | 10 | 0.08 |
| 25 | Lokoua | Loffa | N`Zerekore | 50 | 0.50 |
| 26 | Djounde | Bouroudou | Boke | 30 | 0.18 |
| 27 | Bossere | Doutou | Telimele | 50 | 0.36 |
| 28 | Banko | Bindibar | Dabola | 60 | 0.50 |
| 29 | Gountou | Gountouwol | Tougue | 80 | 0.48 |
| 30 | Pita | Lalia | Bambeta | 60 | 0.36 |

*Source:* N'Faly and Barry[11]

According to N'Faly and Barry (2006), there are 136 sites with potential capacities between 0.1 to 3 MW (total capacity 60.69 MW, 269.69 GWh). The priority lies with the small hydropower plants below 3 MW.[11]

Global Environmental Facility (GEF) is financing a project called Promoting Development of Multi-purpose Mini Hydropower Systems (2012-2016) that addresses existing barriers to renewable energy and plans to establish a total of 800 kW hydropower generation capacities. Three small hydropower sites have been identified and selected by the Ministry of Energy, i.e. Touba (Gaoual), Seredou (Macenta) and Keno. More detailed feasibility studies are needed, but due to budget limitations, it is likely that only one of the plants will be built as a pilot demonstration site.[12]

**Renewable energy policy**

There is no policy on the promotion and development of renewable energy projects in Guinea. It targets a renewable energy penetration rate of 2 to 6 per cent in 2013 and 8 to25 per cent in the long term (until 2019).[13]

***Legislation on small hydropower***

There is no established small hydropower legislation. In 1993, there was a regulating law initiative based on the Built Operate and Transfer (BOT) to favour the participation of private operators in the development of energy and hydropower, and a law established in 1998 to authorize private participation in financing, construction, development, maintenance and structural development in the energy and power sector.[4 5]

**Barriers to small hydropower development**

Small and large hydropower plants have been an important part of the electricity sector, justified by the importance of the development of the industry and mine sector. Guinea has a wide range of hydropower resources which can be developed in a sustainable manner to provide grid connected and non-connected areas with all the needed electricity supplies.[4] However, improvement must be made in areas as follows:

- Capacity building: The lack of adequate infrastructure for research and training of staff and supervisors of maintenance services of renewable

energy technologies in general and small hydropower in particular.[3]

- Developing the country's hydropower resources, in particular by promoting synergies between the mining and energy sectors, and continuing regional integration.[5]
- Upgrading the electricity grid to expand electricity access.
- Development of suitable and adapted legislation promoting the use of renewable energies including small hydropower as well as related implementation and creation of incentives.
- Further reforms in the electricity sector, with a view to achieving greater efficiency and encouraging private sector investment.[5]
- Financial mechanisms: Lack of financial resources due to the complex permitting and licensing process for renewable energy projects, with negative impact on the indices of development of renewable energy and on technology transfer.[3]

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## 1.5.6 Liberia

Lara Esser, International Center on Small Hydropower

**Key Facts**

| | |
|---|---|
| Population | 3,887,886[1] |
| Area | 111,370 km$^2$ |
| Climate | West African monsoon climate - tropical; hot and humid. Dry winters with hot days and cool to cold nights; Wet, cloudy summers with frequent heavy showers. Seasons are determined by the prevailing moisture-laden monsoon winds that come from the southwest. November to March, the dust-laden Harmattan wind blows in from the northwest producing a chilly and dry climate[2] |
| Topography | Four distinct relief zones: the coastal belt, rolling hills, plateaus and northern highlands |
| Rain Pattern | Dry Season: November to March. Rainy season: April to October. Average rainfall ranges between 4,770 mm along the coast and 2,030 mm in the interior.[2] |

**Electricity sector overview**

The Liberia Electricity Corporation is the state utility, with the mandate to provide adequate and reliable power to the nation at a reasonable tariff. All of its facilities (both hydropower and thermal plants) were looted and vandalized during the 14-year civil war from 1989 to 2003. Prior to the war, the total installed capacity was 412 MW (of which 200 MW operated by mining companies). A state-owned hydropower plant Mount Coffee (64 MW) was in operation at that time and is now being restored and expanded to 100 MW.

The installed capacity is approximately 24.6 MW and an Emergency Power Programme (EPP) including several diesel power plants is in operation. The estimated total electricity demand for 2010 was 36 - 37 MW.[3] More recent electricity production data is not available.

According to the Poverty Reduction Strategy (PRS), about 10 per cent of urban residents and less than 2 per cent of rural residents have electricity access. Liberia's rate of access to publicly provided electricity is close to zero.[3] Furthermore, an urban access rate can only be derived for the capital of Monrovia. Some 1,217 of an estimated 210,619 households are supplied with public electricity (as of late 2010), corresponding to 0.58 per cent of the capital's population. With the exception of a very limited municipal mini-grid in Gbarnga, Bong County, no publicly-supplied electricity service is available outside of the capital.[4] The remainder of the population depends on costly, inefficient and polluting resources such as small gasoline and diesel generators, firewood, charcoal, candles, kerosene and palm oil.[3]

In May 2010, the Rural and Renewable Energy Agency (RREA) started a number of pilot activities, including a pilot micro-hydropower project in Lofa county, and swapping kerosene lanterns with solar lanterns under Lighting One Million Lives in Liberia with the help of the Rural Energy Fund.[5]

A World Bank report estimates that by 2015, the electricity demand based on a slow-growth scenario will be 111.84 MW (36 MW on-grid, 75.84 MW off-grid) and by 2020 the demand will be 301.75 MW (103.49 MW on-grid, 198.26 MW off-grid).[3]

**Small hydropower sector overview and potential**

Liberia has an assessed hydropower potential of 2,000 MW. Prior to the war, there were 23 small hydropower plants. Now, only one privately-owned small hydropower plant (4 MW) is in operation.[6] Two small hydropower plants were damaged during the civil war and are in need of repair.[6 7]

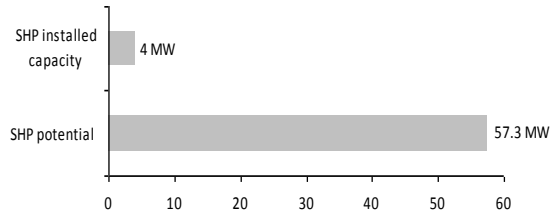


Figure 1 **Small hydropower capacities in Liberia**

A 30 kW small hydropower plant with an isolated grid was successfully operated and managed by the Yandohun community (Lofa county) in the 1980s. However, it was destroyed during the 14-year civil war. It was redesigned to 60 kW in 2009 through funding from the World Bank's Africa Renewable Energy Access Program. The rehabilitation works started in June 2011.[3] [9]

**Proposed small hydropower plants**

| | *Proposed plant* | *Potential capacity (MW)* |
|---|---|---|
| 1 | Lofa River Mini Hydro Plant | 2.5 |
| 2 | Zeliba River Mini Hydro Plant | 1.5 |
| 3 | St. John River Mini Hydro | 7.5 |
| 4 | Dougbe River Mini Hydro Plant | 0.6 |
| 5 | St. Paul Mini Hydro Plant | 5.5 |
| 6 | Ya Creek Mini Hydro Plant | 1.5 |
| | **Total** | **19.1** |

*Sources:* Sow[4], ECREEE[8]

The Baseline Report by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) indicates total potential of approximately 86 MW in Liberia based on two lists that combine 30 potential small hydro sites up to 30 MW each.[8] When considering sites up to 10 MW only, the 28 sites identified have a combined potential capacity of 57.31 MW (figure 1).

**Renewable energy policy**

Liberia has significant renewable energy resources including biomass, hydropower and solar energy. A draft Renewable Energy and Energy Efficiency Policy and Action Plan of the Ministry of Lands, Mines and Energy was published in 2007. Liberia has targeted to raise its share of renewable energy to 30 per cent of electricity production and 10 per cent of overall energy consumption by 2015.[10] A World Bank report *Options for the Development of Liberia's Energy Sector* considers various scenarios including renewable energy options in detail.[3] [10] A draft for the integrated water resource management is in process.[8]

**Barriers to small hydropower development**

Studies to assess Liberia's hydropower potential were conducted between 1976 and 1983, thus there is a great need to update these findings.[3] Higher education institutions do not have a small hydropower curriculum. An energy policy and a legal framework for the promotion of hydropower are not yet established (i.e. no policy, feed-in tariff or standard PPA).[8]

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## 1.5.7 Mali

Oumar Sidibe, Direction Nationale de l'Énergie, Mali

**Key facts**

| | |
|---|---|
| Population | 15,494,466[1] |
| Area | 1,240,192 km$^2$ |
| Climate | Subtropical to arid; hot and dry (February to June); rainy, humid, and mild (June to November); cool and dry (November to February)[1] |
| Topography | Mostly flat to rolling northern plains covered by sand; savannah in south, rugged hills in northeast[1] |
| Rain Pattern | Highly variable climate characterized by a long dry season and a rainy season averaging one month in the North (Timbuktu region) to five months in the South (Sikasso region). Rainfall ranging from 1,200 mm/year in the Sudano-Guinean zone to 200 mm/year in the Saharan zone[2] |

**Electricity overview**

The rate of access to electricity is 55.27 per cent in urban areas and 14.89 per cent in rural areas, leading to a national average of 27.08 per cent.

Some private sector operators provide the public service of electricity, the most important of which is the company Energy of Mali (Énergie du Mali EDM) as a contract-holder.

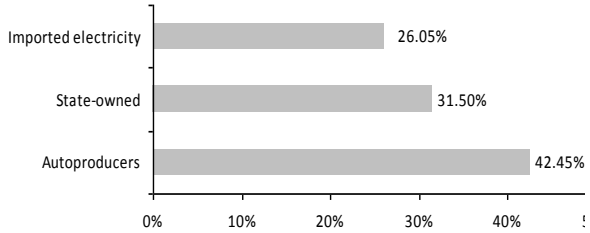


Figure 1 **Electricity generation in Mali**
*Source*: Mali Direction de l'Energy[3]

On the inter-connected grid, 57.3 per cent of the electricity is generated by hydropower plants and 42.7 per cent by thermal plants. The share of hydropower in the grid decreased from 80 per cent in 2004 to 57 per cent in 2010, because the constructions of key regional/national hydropower plants and regional interconnections were delayed, the Government had to increase costly thermal power supply in the short term.[2]

The total installed electricity generation capacity in Mali is 326.8 MW (excluding self-generation), distributed between hydropower (71.6 per cent) and thermal (28.4 per cent) power plants. About 20 hydropower sites of medium and large capacity with a total capacity of about 1,150 MW (an electricity production of about 5,600 GWh) were identified throughout the national territory. Only four of these sites are fitted out at the moment (representing approximately 25 per cent of the national potential), namely: Félou (0.6 MW, about 3 GWh/year), Sotuba (5.2 MW, about 40 GWh/year), Sélingué (44 MW, about 200 GWh/year) and Manantali (200 MW, about 800 GWh/year).

**Small hydropower sector overview and potential**

Since 1927, the inauguration year of the hydropower power station in Félou (600 kW, 3 GWh/year), no other small hydropower projects have been put into operation, except for one pico-hydropower station at Siraorobougou of 3 kW in 2008.

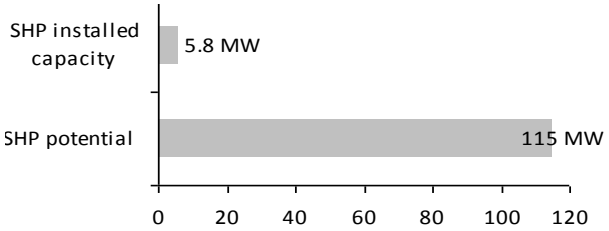


Figure 2 **Small hydropower capacities in Mali**

The country has a small hydropower potential, as demonstrated by the 1988 study of the German Technical Cooperation (GTZ), which inventoried and estimated briefly the sites of Farako (50- 250 kW), Kéniéba or Doundi (180-250 kW), Nimbougou (10-50 kW), Paparah (50-60 kW) and Missira. Other potential sites are identified in the regions of Kayes and Sikasso (at Sirakorobougou; 3 kW). Of all those sites, only Sirakorobougou is currently operational and Farako is part of a feasibility study, with technical and financial support from UNIDO.

Seven priority sites have been identified: three sites at Farako (Farako I, Farako II, Farako III), two sites at Waromi (Woroni I, Woroni II), Nimbougou and Doundi. The evaluation of a further 10 additional micro hydropower sites is planned within the framework of the Master Plan Study for Rural Electrification financed by the African Development Bank (AfDB).

**Renewable energy policy**

Mali's renewable energy penetration target for 2015 is 25 per cent.[4] [i] Renewable energies (solar, wind, micro/mini hydropower, etc.) are currently used at an insignificant level. The Government's vision and targets have been formulated in key policy papers, including the National Energy Policy (2006), the National Strategy for

the Development of Renewable Energies (2006), the National Strategy for the Development of Biofuels (2006) and the National Energy Sector Policy Letter (2009-2012).

Mali has been selected as one of the six countries to benefit from the Scaling-Up Renewable Energy Program in Low Income Countries (SREP), funded by the AfDB. The main objective is to demonstrate the economic, social and environmental viability of a low-carbon development path in selected countries, with a view to increasing energy access, by using renewable energy and creating new economic opportunities.

The SREP Mali Investment Plan has been prepared under the leadership of the Government of Mali, represented by the Ministry of Energy and Water, and by different specialized national agencies. It is therefore a country-led programme, in line with key strategies of the national energy sector, as well as with the main principles of its Growth and Poverty Reduction Strategy and the National Climate Change Strategy.

**Barriers for small hydropower development**

The main barriers in Mali for small hydropower are geo-climatic factors (see key facts above) as well as lack of financial resources to implement projects.

A legal and regulatory framework is needed in order to facilitate the construction of small hydropower plants in rural communities and in order to remove the barriers that small hydropower promoters in local communities and in the private sector encounter.

Tools are missing to build up local capacity for the design and implementation of mini- and micro-hydropower plants.[5] Lacking capacities in metal processing and manufacturing of key parts of small hydropower plants also pose a challenge.

**Note**

i. Another source reports the target of renewable energy contribution of 10 per cent of the total energy production by 2022.[5]

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## 1.5.8 Nigeria

Basheer Adekunle Kadejo, Nigeria; Kai Whiting and Lara Esser, International Center on Small Hydro Power

**Key facts**

| | |
|---|---|
| Population | 170,123,740[1] |
| Area | 923,766 km$^2$ |
| Climate | Varying climate; equatorial in south, tropical in center, arid in north[1] |
| Topography | Southern lowlands merge into central hills and plateaus; mountains in south-east, plains in north. The river Niger enters the country in the northwest and flows southward through tropical rain forests and swamps to its delta in the Gulf of Guinea.[1] |
| Rain Pattern | Rainfall has decreased from 1,350 mm (1941–1970) to 1,276 mm (1970–2002) annually. However, the coastal area is experiencing a light increase. Apart from the general southward shift in rainfall patterns, the intensity of rainy days has also decreased from 80-360 mm (year 1941 to 1970) to 40-280 mm (year 1970 to 2002). |

**Electricity sector overview**

The dominant sources of power generation in Nigeria are natural gas and hydropower. The estimated installed electricity generation capacity is 8,644 MW, while available capacity is approximately 3,200 MW.[2] With an estimated technically exploitable potential of 20,000 MW, the hydropower potential of Nigeria is high and hydropower currently accounts for about 32 per cent of the total installed commercial electrical power capacity.

Despite the country's abundance of petroleum and other natural resources, more than 60 per cent of the country's population has no access to electricity. The annual electricity consumption per capita of the remaining 40 per cent is about 109 kWh due to frequent power interruptions, load shedding and poor electricity infrastructure. This instability of the electricity system is seen as one of the causes for poor health services and poor economic growth.[3] [4] [5]

Electrification access stands at 50.6 per cent. As of 2009, only 10 per cent of rural inhabitants, which makes up 50 per cent of the total population, are connected to the national grid.[6]

The transmission network is overloaded with a wheeling capacity of less than 4,000 MW and has a poor voltage profile in most parts of the network, especially in the north part of the country where there is inadequate dispatch and control infrastructure, radial and fragile grid networks, frequent system collapses and exceedingly high transmission losses. Indeed, 40 per cent of the electricity generation is lost during transmission to the national grid.[7] According to Llugbo (2012), vandalism and theft of cables and other vital equipment are frequent, as well as accidental destruction of distribution lines and illegal connections, what often results in over-loading of the distribution lines, unannounced load shedding, and prolonged and intermittent outages. Consequently, many industrial outfits have resorted to generating their own off-grid electricity.[8] The African Development Bank (2009) has reported that instability in electricity supply is by far the most binding constraint to doing business in the country.

**Small hydropower sector overview and potential**

Nigeria adheres to the internationally accepted small hydropower definition (10 MW capacity limit). Plants with capacities up to 1 MW are considered mini hydropower in Nigeria, and those with capacity up to 500 kW are considered as micro hydropower.

With the set-up of the UNIDO Regional Centre for Small Hydro Power in Abuja in 2006, Nigeria is considered as one of the few places for systematic capacity development in small hydropower technology in Africa. It should serve not only for domestic needs but also for giving guidance to other countries in Africa.[9] Nigeria has a short term target of installing 100 MW of small hydropower capacity, and a medium target of 760 MW based on the renewable energy master plan (2006).[10] Please see following discussion on small hydropower potential.

There are various installed small hydropower plants reported for Nigeria. In 2011, it was reported that five small hydropower plants (up to 10 MW definition) exist in Nigeria (23.35 MW and 204.55 GWh/yr).[11] However, the *Baseline Report on Small-Scale Hydropower in the ECOWAS Region* lists 45 MW of existing small hydropower plants (up to 10 MW), 18 MW of which needs to be rehabilitated, as well as an additional 191 kW of micro capacity (figure 1).[12]

There is varying information on the potential of small hydropower in Nigeria. According to UNIDO Regional Centre on Small Hydropower, the gross small hydropower potential (for plants up to 10 MW) is 720 MW, the technically feasible potential is 605 MW and the economically feasible potential is 498.4 MW.[11] A study from 2006 identified 278 yet undeveloped sites

for small hydropower production with a total of 734.2 MW (with a definition of up to 30 MW).[13 14]

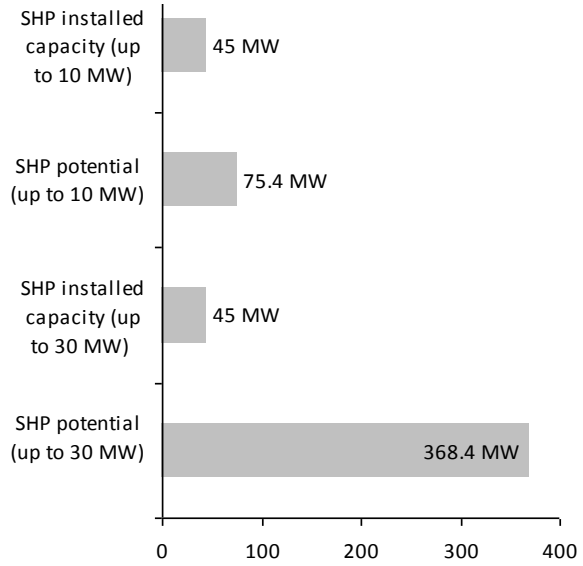


Figure 1 **Small hydropower capacities in Nigeria**
*Source:* Ecowas Centre for Renewable Energy and Energy Efficiency[12] and authors' calculation

Ongoing small hydropower activities are:

- 2x75 kW Waya Dam, Bauchi State plant completed (United Nations Industrial Development Organisation (UNIDO), Energy Commission of Nigeria (ECN), Bauchi State Government).
- 1x30 kW Ezioha-Mboro Dam small hydropower, Enugu (UNIDO, ECN).
- 2x200 kW Tunga Dam small hydropower, Taraba State (UNIDO)
- Capacity building in hydropower research and development at the National Centre for Hydropower Research and Development (NACHRED), University of ILORIN.

**Renewable energy policy**

In April 2010, the Federal Ministry of Power established a standing committee to work out ways of developing the country's capacity in the hydropower sector as part of its strategy to tackle its endemic problems.[9] So far there is no feed-in-tariff regulation in place.

Nigeria has a National Energy Policy that has been approved and launched in 2003, as well as a National Energy Master Plan and a Renewable Energy Master Plan in final draft.[15] Main targets are the expansion of electricity supply to 75 per cent of the population by 2025 and a stronger participation of the private sector. It also foresees a promotion of renewable energies and their incorporation in the national energy mix.[9] The goal is to generate 18 per cent of electricity from renewable energies by 2025, and 20 per cent by 2030, with broad objectives as follows:[16]

- To enhance energy security in the nation by diversifying the energy supply mix;
- To increaes energy access especially in the rural and semi-urban areas;
- To facilitate employment creation and empowerment;
- To protect the environment and to mitigate climate change.

**Barriers to small hydropower development**

As discussed in the previous sections, the issues of vandalism, theft and illegal connections to the grid make investment in electricity infrastructure difficult and limit business opportunities, with many firms struggling or failing to survive as an indirect result of electricity supply problems. However, small hydropower, particularly in its micro and pico forms, offers the possibility of energy security to rural areas. Due to the difficulties in the electricity infrastructure both people and businesses are ready to embrace small hydropower and other mini-grid solutions.[8] This provides a good springboard for small hydropower if it can overcome capacity building and technical barriers such as:

- Lack of small hydropower skills and information of the potential sites;
- Lack of feasibility studies;
- Need of information and awareness raising in rural areas;
- Energy infrastructure financing difficulties;
- Lack of energy service companies which can efficiently develop and operate the sites;
- Absence of local small hydropower research and development and small hydropower equipment manufacturing.[9]

Overlapping mandates and conflicts over responsibilities in Nigeria, including disagreements between the agencies responsible for water resources and those for power generation and distribution also affect small hydropower development.[10]

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## 1.5.9 Sierra Leone

Lara Esser and Kai Whiting, International Center on Small Hydro Power

**Key Facts**

| | |
|---|---|
| Population | 5,485,998[1] |
| Area | 71,740 km$^2$ |
| Climate | Tropical climate with two seasons: rainy season (May to October), and dry season (November to April). Humidity is high, about 85 per cent. |
| Topography | Mountainous range in the north-east which slopes down to the coastal swamps through an undulating grassland plain. The relief is drained by a system of rivers flowing through cataracts and waterfalls ideal for hydropower development, and providing water for the rural communities. |
| Rain Pattern | Average annual rainfall: 2,746 mm.[2] Three climatic belts: coast to 80 km inland (rainfall greater than 3,300 mm per annum), 80 to 190 km inland (average annual rainfall between 2,500 mm and 3,300 mm), 190 km to border areas (average annual rainfall between 1,900 mm and 2,500 mm).[3] |

**Electricity sector overview**

Sierra Leone is endowed with abundant energy resources, these include hydropower (estimated at 1,200 MW), solar, biomass, biogas/bagasse. However, these are not sufficiently developed yet to meet energy needs in the country. Most of the energy needs are met by petroleum products (e.g. petrol, diesel, kerosene), and traditional sources such as firewood, charcoal and other agricultural products. Only about 4.7 per cent of the hydropower potential in the country has been tapped so far.[4] Until the Bumbuna I hydropower station (50 MW) came on stream in 2010, generation relied mainly on costly fuel-based thermal generation (figure 1).[5]

The nation is still recovering from war and the electricity generation, transmission and distribution infrastructure is still poor. There is currently no national grid.

The national electrification rate is 10 per cent.[5] While Freetown has a relatively acceptable degree of electricity access, the rest of the towns are virtually in perpetual darkness, with only 1 per cent having access to an electric grid supply. In order to restore power to these areas, the Government has in principle repealed the act of parliament that empowers the National Power Authority (NPA) as the sole monopolist of electricity supply and now encourages private participation in electricity generation.[4] With the completion of the Bumbuna I hydropower facility in 2010, the country jumped from 13 MW to 63 MW of installed electricity generation capacity.[5]

The estimated hydropower potential in Sierra Leone is more than enough to supply Freetown and to export excess electricity to the neighbouring countries.[5]

Sierra Leone is part of the West African Power Pool (WAPP), a regional organization dedicated to fostering greater co-operation in the region's power sectors and interconnection between countries to enhance energy security. Currently Sierra Leone does not import electricity. By joining the WAPP, Sierra Leone has the potential to become both an importer and exporter of electricity and to compensate for seasonal variations in hydropower generation.[6]

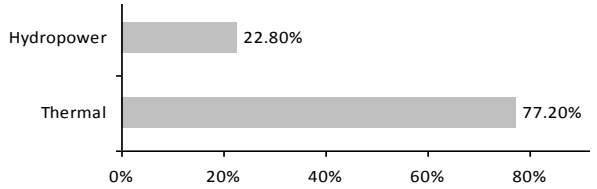


Figure 1 **Electricity generation in Sierra Leone**
*Source:* African Development Bank[7]
*Note:* Data from 2010.

**Small hydropower sector overview and potential**

Sierra Leone has a very high potential for small- and medium-hydropower generation. The new vision of the Sierra Leone Government is to develop all of its hydropower potentials, and to install thermal generation to complement the envisaged hydropower stations.[8] Nearly all the districts have one or more waterfalls which could be developed to generate small and/or medium hydropower.

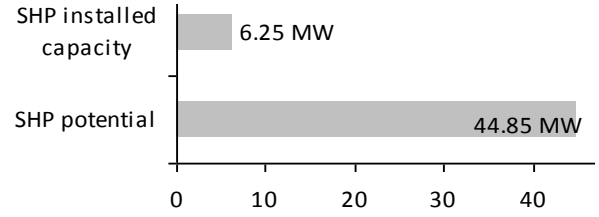


Figure 2 **Small hydropower capacities in Sierra Leone**
*Source*: ECOWAS Centre for Renewable Energy and Energy Efficiency[9]

The *Baseline Report on Small-Scale Hydropower in the ECOWAS Region* identified six potential small hydropower sites with a potential capacity of 38 MW.[9]

The only small hydropower station in the country is Dodo, with 6 MW capacity following a refurbishment.[4] A mini hydropower plant exists in Yele/Makali, with a total operating capacity of 250 kW in the northern part of Sierra Leone (figure 2).[9]

Since 2012, UNIDO has been working on a feasibility study for a 10-MW hydropower project linked to Njala University at the Moyamba district. Following an initial feasibility study, there are also further developments for a 1-MW mini hydropower scheme on River Banaksoka.[10]

Studies have been carried out in Charlotte, Freetown, with the aim to develop a 2.2-MW small hydropower plant. There has been limited information on the project, however the project is set to commence according to Kamara.[11]

Further possible development at Moyamba in the south of Sierra Leone (10 MW) still awaits contractual confirmation.[99] The project is proposed to receive Global Environmental Facility financing.[9]

**Renewable energy policy**

The main target of 2010 Energy Policy on electricity is to provide access to 35 per cent of the Sierra Leone population by 2015. There is no proposed contribution from renewable energy under the policy.[8]

The main objective of the national energy policy is to develop energy supply infrastructure countrywide, judiciously developing alternative sources of energy without adverse effect to the five pillars of the 25-year Development Plan, i.e. an environment for economic and social development, good governance, improvement of national security, employment creation, and poverty alleviation.

For the second and third stages of the energy expansion plan (by 2020 and 2025, respectively), two per cent renewable energy (non-hydro) is planned. For example, the target for 2020 is to reach a total installed capacity of 800 MW and an electricity production of 7,000 GWh per year.[8] Part of future renewable energy plans is grid-connected solar PV, solar thermal electricity production, generation from urban wastes and crop residues as well as low speed off-shore wind parks. However, feasibility studies are still required. Sierra Leone also aims to develop a rural electrification policy and strategy. The dominant institutional solutions considered are the establishment of a Rural Electrification Agency and the active deployment of off-grid technologies that make use of small-scale renewable energy sources, such as mini- or pico-hydro schemes, or solar technology.[5]

**Barriers to small hydropower development**

Eleven years of war has caused enormous damage to the national economy and severe destruction to the infrastructure. The country's electricity industry lags behind and needs upgrading. Barriers specific to small hydropower development are:

- Lack of local production of turbines and spare parts;[9]
- Lack of local consultancy capacity;[9]
- Lack of hydrology departments at universities and/or training institutes. However, a network of gauging stations for regular water level and runoff measurements and hydrological data collection is available at hydrological stations;[9]
- Lack of funding, which hinders the implementation of small hydropower projects.

There are also specific challenges in the electricity sector which hinder development. According to AfDB (2011) the country has one of the highest electricity tariffs in West Africa. There is also a lack of utility infrastructure and equipment. Capacity building for strategic planning, operation and maintenance of facilities is lacking, as are the financial means.[5]

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## 1.5.10 Togo

Lara Esser, International Center on Small Hydro Power

**Key facts**

| | |
|---|---|
| Population | 5,858,673[1] |
| Area | 5,017,000 km$^2$ |
| Climate | Tropical; hot, humid in south; semi-arid in north |
| Topography | Gently rolling savannah in north; central hills; southern plateau; low coastal plain with extensive lagoons and marshes[2] |
| Rain Pattern | In the North: one wet season (May to November) and one dry season (December to March, when the Harmattan wind blows north easterly). The South has two wet seasons: from March to July and a shorter wet season from September to November.[3] The northern and central regions receive 200-300 mm rain per month in the peak months of the wet season (July to September). Average annual rainfall in coastal areas is 950 mm.[4] |

**Electricity sector overview**

The national electrification rate in the Togolese Republic (Togo) is 22 per cent, with 18 per cent access in urban areas and 4 per cent access in rural areas.[5] An appropriate energy policy was previously lacking but is underway.

Electricity is supplied by two companies: the Compagnie Énergie Électrique du Togo (CEET), which has had a monopoly of electricity distribution and supply to end users since 2006; and the Communauté Électrique du Bénin (CEB), a joint venture with Benin for the purpose of purchasing electricity from the Volta River Authority hydropower facilities in Ghana. Togo depends on foreign sources for its electricity supply and is affected by multiple brownouts (an intentional or unintentional drop in voltage in an electrical power supply system).[1] According to the Clean Energy Portal-Reegle, 70 per cent of the electricity in Togo is imported (figure 1).

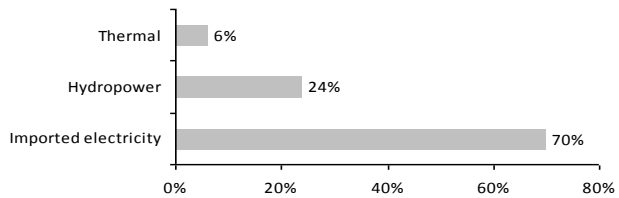


Figure 1 **Electricity generation in the Togolese Republic**
*Source:* Clean Energy Portal- Reegle[6]

**Small hydropower sector overview and potential**

There is a 48-year old small hydropower plant in the country, but it needs renovation. Its installed capacity is 1.6 MW, generating around 2.6 GWh/year. By 2015, up to 58 MW (more than 850 GWh/year) of small hydropower could be installed, however, funding is a major problem.[5]

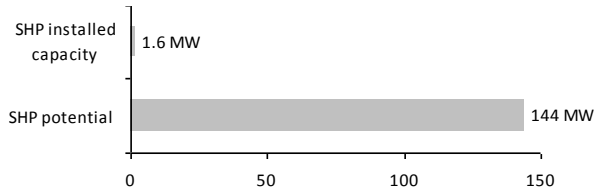


Figure 2 **Small hydropower capacities in Togolese Republic**
*Source*: Authors calculation based on Ecowas Centre for Renewable Energy and Energy Efficiency[8]

The last hydropower resource evaluation was conducted in 1984. It assessed a total technical potential of 224 MW (more than 850 GWh/year) on over 40 sites.[5] Fifteen of these 40 sites have potential capacities of up to 10 MW and a total potential of 81 MW (table).[7] The *Baseline Report on Small Hydropower in the ECOWAS Region* reports that the feasible potential of small-scale hydropower (defined as up to 30 MW) is 206 MW.[8] When applying 10 MW as the definition, the feasible potential in Togo is 144 MW, based on 35 sites (figure 2).

**Potential small hydropower sites in Togo**

| | | *Plant* | |
|---|---|---|---|
| *River* | *Village of site* | *Potential capacity (MW)* | *Estimated annual electricity generation (GWh)* |
| Amou | Gléï | 2 | 5 |
| Amou | Amou Oblo | 3 | 8 |
| Kara | Landa kpozanda | 5 | 13 |
| Mô | Banga (Bassar) | 6 | 16 |
| Domi | Tomégbé Akloa | 8 | 21 |
| Mono | kpéssi | 8 | 21 |
| Sin Sin | Route Atakpame-Badou | 2 | 5 |
| Kpaza | Parc Fazao | 3 | 7 |
| Assou Koko | Langabou | 5 | 13 |
| Keran | Route Kande-Mago | 5 | 13 |
| Mono | Dotecope | 9 | 24 |
| Mono | Sagada/Kpeteta | 8 | 21 |
| Koroon | Seregba | 9 | 24 |
| Gban Houn2 | Danye Konda | 5 | 13 |
| Mono | Landa Mono | 3 | 8 |
| **Total** | | **81** | **199** |

The African Development Bank (2011) mentions a need for diversification of energy supply sources by developing the country's hydropower potential.[1]

**Renewable energy policy**

One of the priority areas in the 2006-2008 Poverty Reduction Strategy of Togo is to develop infrastructure needed for growth, by developing energy resources. The priority measures include the decision and implementation of an energy policy, establishment of a national rural electrification agency, a rural electrification fund and a legislative and regulatory framework for developing renewable energies. However, due to the lack of financing, none of the objectives have been achieved.[9]

**Barriers to small hydropower development**

The hydro potential of small hydropower in Togo is highly seasonal and varies regionally.[8] Lack of funding is the principal barrier to developing small hydropower projects.[5] In addition, there is no feed-in-tariff for small hydropower.[8]

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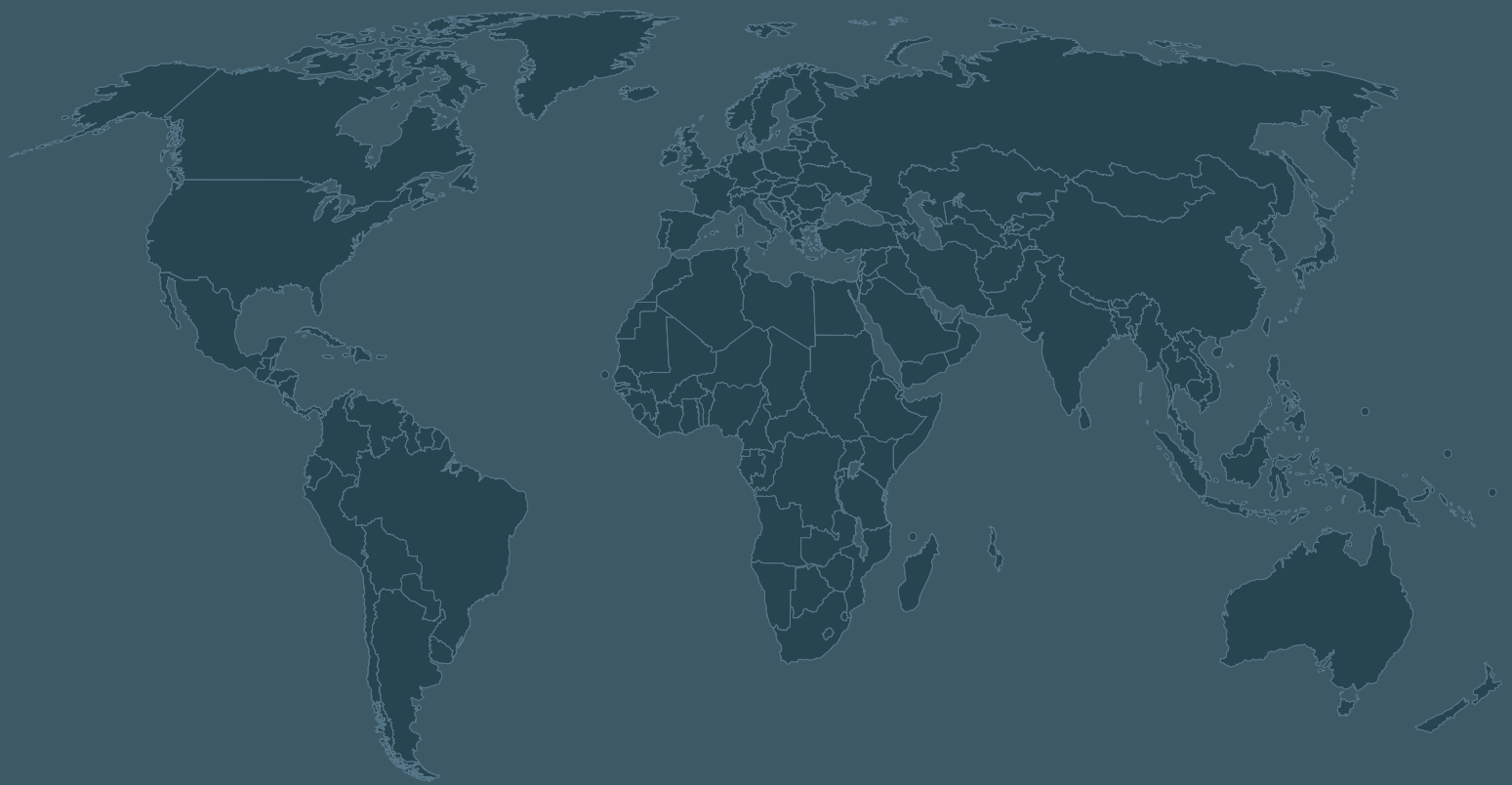
United Nations
Industrial Development Organization (UNIDO)
Wagramer Straße 2, 1220 Vienna
Austria

renewables@unido.org

International Center
on Small Hydro Power (ICSHP)
136 Nanshan Road, 310002 Hangzhou, Zhejiang
Province, China

report@icshp.org



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