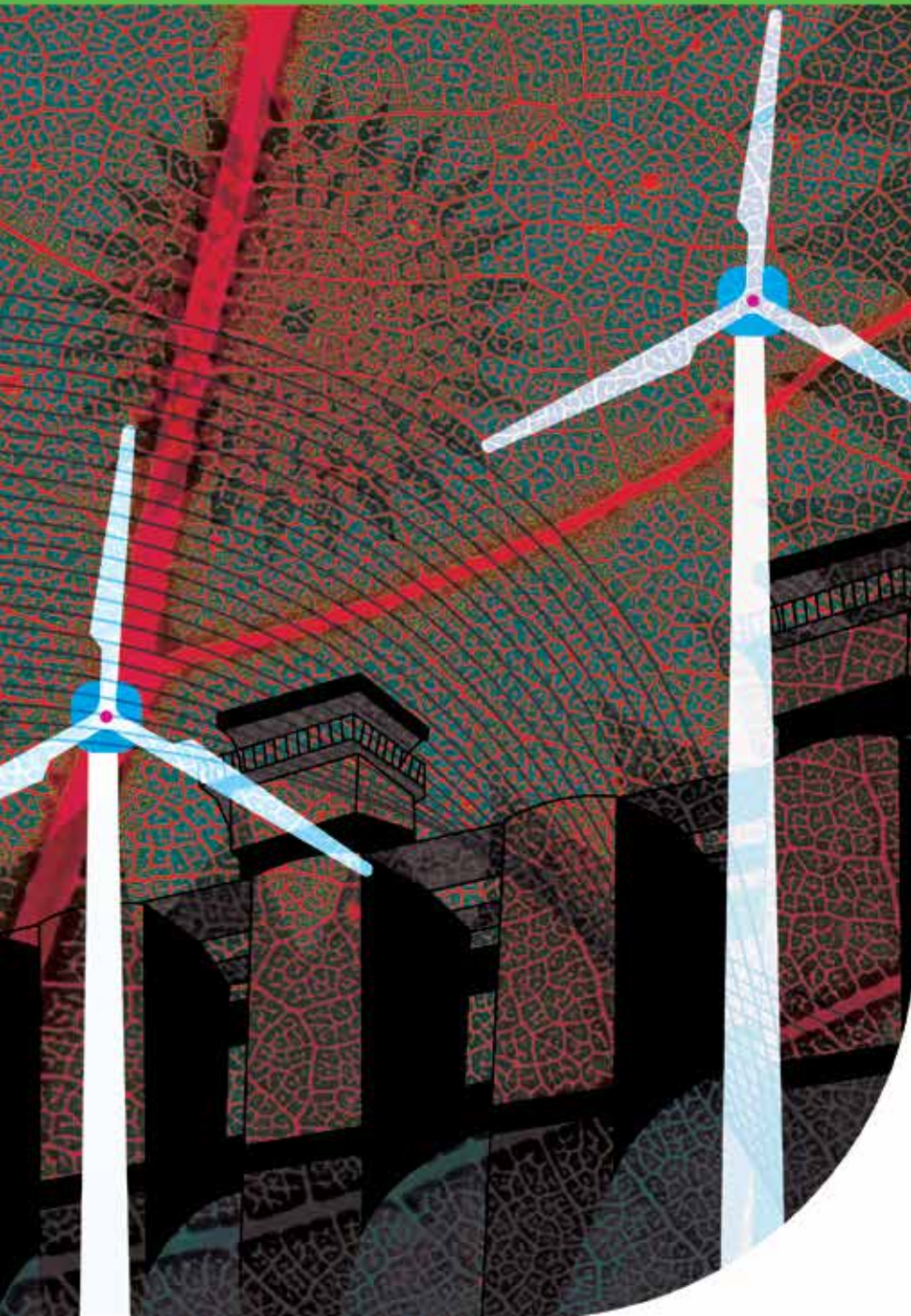
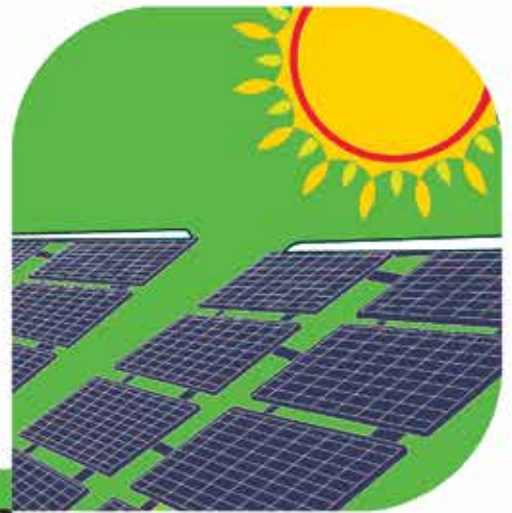


# RENEWABLES READINESS ASSESSMENT MALI



© IRENA 2019

Unless otherwise stated, material in this publication may be freely used, shared, copied, reproduced, printed and/or stored, provided that appropriate acknowledgement is given of IRENA as the source and copyright holder. Material in this publication that is attributed to third parties may be subject to separate terms of use and restrictions, and appropriate permissions from these third parties may need to be secured before any use of such material.

## About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that serves as the principal platform for co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. [www.irena.org](http://www.irena.org)

ISBN 978-92-9260-153-9

**Citation:** IRENA (2019), *Renewables Readiness Assessment: Mali*, International Renewable Energy Agency, Abu Dhabi

## About the RRA

A Renewables Readiness Assessment (RRA) is a holistic evaluation of a country's conditions that helps to identify the actions needed to overcome barriers to renewable energy deployment. This is a country-led process, with IRENA primarily providing technical support and expertise to facilitate consultations among different national stakeholders. While the RRA helps to shape appropriate policy and regulatory choices, each country determines the best mix of renewable energy sources and technologies to achieve national priorities. The RRA is a dynamic process that can be adapted to each country's circumstances and needs. IRENA has continually refined its methodology for the RRA process based on experience in a growing range of countries and regions.

For more information: [www.irena.org/rra](http://www.irena.org/rra)

## Acknowledgement

The report has benefited from the input of expert reviewers including, Haruna Kachalla Gujba (African Union), Yacob Mulugetta (UC London) and Kudakwashe Ndhlukula (SACREEE). IRENA colleagues Abdulmalik Oricha Ali, Gurbuz Gonul, Luis Janeiro, Rafael de Sá Ferreira, Elizabeth Njoki Wanjiru, Ali Yasir and Benson Zeyi provided valuable input. The comments of the IRENA policy team were also helpful.

**Contributing authors:** Nopenyo Esselasse Dabla (IRENA), Safiatou Alzouma Nouhou (former IRENA), Dr Souleymane Berthé (AER-Mali), Smail Khennas and Bagui Diarra (consultants)

Report available for download: [www.irena.org/publications](http://www.irena.org/publications)

For further information or to provide feedback: [publications@irena.org](mailto:publications@irena.org)

## Disclaimer

This publication and the material featured herein are provided "as is", for informational purposes.

All reasonable precautions have been taken by IRENA to verify the reliability of the material featured in this publication. Neither IRENA nor any of its officials, agents, data or other, third-party content providers or licensors provides any warranty, including as to the accuracy, completeness, or fitness for a particular purpose or use of such material, or regarding the non-infringement of third-party rights, and they accept no responsibility or liability with regard to the use of this publication and the material featured therein.

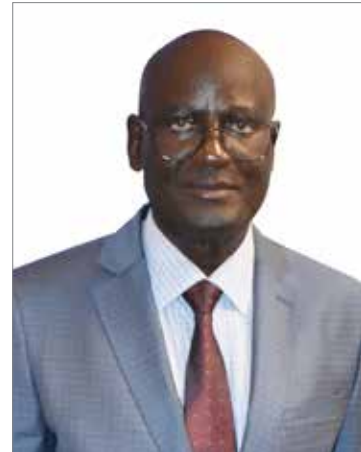
The information contained herein does not necessarily represent the views of the Members of IRENA, nor is it an endorsement of any project, product or service provider. The designations employed and the presentation of material herein do not imply the expression of any opinion on the part of IRENA concerning the legal status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

RENEWABLES  
READINESS ASSESSMENT

MALI

# FOREWORD

from the Minister of  
Energy and Water



Increased access to sustainable energy in households and economic sectors the country is at the heart of energy development prospects, with the ultimate ambition to support the government's commitment to reduce poverty and boost the national economy.

This strategic orientation is justified by low levels of access to energy services, still below national targets and indicators. In fact, energy access is mainly characterised by electrification rates, which are above 41% nationally but barely 17% in rural areas; cooking highly dependent on wood energy, albeit with encouraging penetration of alternative fuels and technologies; hydropower and solar resources that are not sufficiently utilised; expanding bioenergy use, which offers particular opportunities for rural communities; private investments in progress; energy demand growing rapidly, at about 15% yearly; and a singularly vulnerable living environment.

One can easily understand, then, the commitment of the Government of Mali to strengthening national policies and strategies, as well as specific laws and regulations, in the energy sector. The government's commitment has led to the ongoing revision of major framework documents, such as the National Energy Policy, the Rural Electrification Reference Framework, and the Presidential Ordinance of March 2000, on the organisation of the power sector.

Additionally, the development of an "Investor's Guide", standardised tender documentation and power purchase agreement (PPA) formats, and training for staff in the energy sector should help in implementing our national strategic energy guidelines. Through all these actions, the Government of Mali, through the Ministry of Energy and Water, aims to give national energy stakeholders a framework for the rapid development of sustainable energy projects and programmes.

The Ministry of Energy and Water will work to achieve the government's aims, including Mali's commitment to the regional energy framework of the Economic Community of West African States (ECOWAS), Nationally Determined Contributions (NDCs) stemming from the Paris Agreement, and other international agreements pertaining to energy.

The Ministry, working through the Mali Renewable Energy Agency (AER-Mali), has initiated a partnership with the International Renewable Energy Agency (IRENA) to assess Mali's readiness to scale up renewables. With the support of IRENA, AER-Mali and various national actors, carried out a rigorous and objective diagnosis of the development of the renewable energy subsector, with concrete recommendations that we can convert into action. This report will introduce you to the methodology, conclusions and recommendations of the assessment, including the identification of key "Resource-Service" pairs. Beyond that, I call on everyone to mobilise on these issues, so that bioenergy and other renewables become the engines for the energy sector to bloom, with the end-goal of a sustainable economic growth for Mali.

**His Excellency M. Sambou Wagué**  
Minister of Energy and Water, Mali

# FOREWORD

from the IRENA  
Director-General



Mali has vast resource potential for the development of renewable energy. Renewable-based technologies could strengthen agriculture, drive sustainable rural development and improve food security, as well as expanding energy access and boosting climate-resilience. By harnessing solar, wind and bioenergy resources in line with the National Renewable Energy Action Plan (PANER) for 2030, Mali could do much to reduce poverty and improve people's livelihoods, while setting a valuable example of sustainable energy development for all Sahel countries.

With less than one fifth of the rural population enjoying the benefits of electricity access, decentralised renewables have emerged as a crucial socio-economic development solution. Generation capacity from biomass could reach 2.2 gigawatts by 2030, while solar and wind power have the potential to contribute even more impressively in the long run.

This Renewables Readiness Assessment (RRA) presents clear and practical steps for Mali to make maximum use of renewables to drive sustainable economic growth. The assessment process underlined the need to adopt a broader range of renewable-based technologies and diversify the country's power supply through increased use of non-hydro options. The updated technology mix would create considerable socio-economic value, especially with climate change taken fully into account.

The report recommends policy and regulatory measures to encourage private-sector participation in renewable energy projects, both on and off the national grid. A grid code, meanwhile, must be adopted to encourage the integration of variable sources like solar and wind power. Alongside these technical considerations, meanwhile, the human factor will be of paramount importance. In addition to clear quality standards for renewable energy equipment, Mali would benefit from enhanced capacities to develop, appraise and finance bankable projects.

Since 2011, nearly 40 countries, spanning the Africa, the Middle East, Latin America and the Caribbean, Asia and the Pacific have undertaken RRAs, exchanging knowledge and fostering international co-operation to accelerate the deployment of renewables. Each process has been country-led, with IRENA providing technical expertise and highlighting regional and global insights, along with facilitating consultations among different national stakeholders.

IRENA is very grateful to the Malian authorities, and particularly the Ministry of Energy and Water and the Mali Renewable Energy Agency, for their commitment to this study. We appreciate the positive engagement and valuable input from multiple stakeholders. I am confident that the recommendations in this report will strengthen the pursuit of renewable energy solutions in Mali and across the region.

**Francesco La Camera**  
Director-General  
International Renewable Energy Agency



FIGURES	VII
TABLES	VII
ABBREVIATIONS	IX
EXECUTIVE SUMMARY	XI
<b>01 INTRODUCTION</b>	
1.1 Country background	01
1.2 Role of energy in development in Mali	02
1.3 Renewables Readiness Assessment in Mali	03
<b>02 ENERGY CONTEXT</b>	
2.1 Regional context	05
2.2 Energy supply and demand in Mali	07
2.3 Electricity generation, transmission and distribution	10
2.4 Renewable energy potential and use	14
2.5 Energy sector and climate change	18
2.6 Drivers for renewable energy deployment	20
<b>03 ENABLING ENVIRONMENT FOR RENEWABLE ENERGY</b>	
3.1 Key energy stakeholders and institutional structures	23
3.2 Energy policy and regulatory frameworks	24
3.3 Investment and finance	26
<b>04 EMERGING ISSUES AFFECTING RENEWABLE ENERGY DEPLOYMENT</b>	
4.1 On-grid renewables	31
4.2 Off-grid renewables	37
4.3 Institutional setup and skills reinforcement	40
<b>REFERENCES</b>	<b>43</b>



# FIGURES AND TABLES

## Figures

<b>Figure 1</b>	Mali's gross domestic product, 1970-2018 (USD, current prices)	01
<b>Figure 2</b>	Sectors and final energy consumption in 2014 (%)	02
<b>Figure 3</b>	West African Power Pool	06
<b>Figure 4</b>	Total primary energy supply in 2014 by energy sources (ktoe)	07
<b>Figure 5</b>	Residential energy consumption by energy forms in 2014 (ktoe)	08
<b>Figure 6</b>	Access to electricity across Mali 2001-15 (%)	09
<b>Figure 7</b>	Structure of Mali's energy sector	10
<b>Figure 8</b>	Mali's electricity generation by energy sources (gigawatt-hours)	11
<b>Figure 9</b>	Mali's national grid	12
<b>Figure 10</b>	Evolution of Energie du Mali's average production costs and low voltage and medium voltage tariffs	14
<b>Figure 11</b>	Solar map of Mali	17
<b>Figure 12</b>	Wind map of Mali	18
<b>Figure 13</b>	Greenhouse gas emissions in Mali's energy sector, 2007-14	18
<b>Figure 14</b>	Mali's sub-sector greenhouse gas emissions from energy consumption, 2012 (%)	19
<b>Figure 15</b>	Time series patterns of the observed drought indices (Standardized Precipitation Index and Standardized Precipitation and Evapotranspiration Index), as well as the Standardized Runoff Index, between 1961 and 2012: Niger River Basin	20
<b>Figure 16</b>	Aggregated installed capacity for Mali's emergency power generation (MW)	33
<b>Figure 17</b>	Suitability zones in southwestern Mali for utility-scale solar photovoltaic	33

## TABLES

<b>Table 1</b>	Mali's on-grid installed capacity	10
<b>Table 2</b>	Key characteristics of Mali's interconnected transmission grid and distribution network, 2016	12
<b>Table 3</b>	Mali's grid-connected pre-paid and post-paid tariffs	13
<b>Table 4</b>	Potential capacity and electricity generation from Mali's agricultural residues, 2010-50	14
<b>Table 5</b>	Mali's biofuel blending targets, 2010-30 (%)	15
<b>Table 6</b>	Status of Mali's hydropower potential	16
<b>Table 7</b>	Key energy institutional arrangement in 2016: Mali	23
<b>Table 8</b>	Mali's National Energy Policy: Renewable energy objectives and measures	24
<b>Table 9</b>	Targets for Mali's grid-connected renewables, 2010-30	25
<b>Table 10</b>	Targets for Mali's off-grid renewables, 2010-30	25
<b>Table 11</b>	Investment code and incentives for Mali's potential investors	26
<b>Table 12</b>	Institutional support of Mali's energy sector and areas of renewable energy concentration	27
<b>Table 13</b>	Potential private investment in Mali's renewable energy sub-sector	28
<b>Table 14</b>	Difference in electricity generation (average versus dry years) at Selingué, Sotuba and Manantali in Mali	32

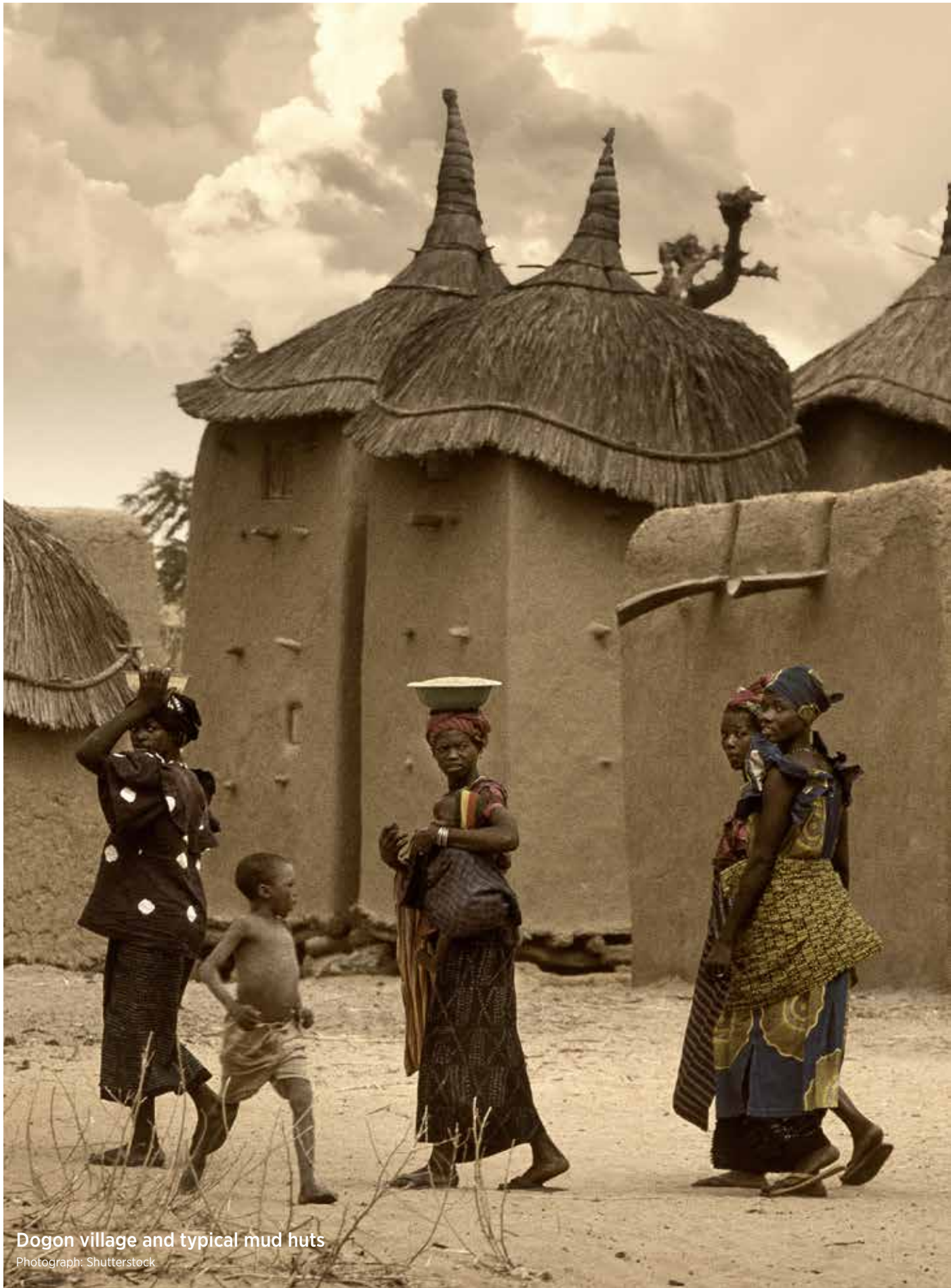


# ABBREVIATIONS

<b>AER-Mali</b>	Renewable Energy Agency of Mali (Agence des Energies Renouvelables du Mali)
<b>AMADER</b>	Malian Agency for Domestic Energy and Rural Electrification (Agence Malienne pour l’Energie Domestique et l’Electrification Rurale)
<b>ATI</b>	African Trade Insurance Agency
<b>DFI</b>	Development Finance Institution
<b>ECOWAS</b>	Economic Community of West African States
<b>ECREEE</b>	ECOWAS Centre for Renewable Energy and Energy Efficiency
<b>ECSES</b>	ECOWAS Certification for Sustainable Energy Skills
<b>EDM</b>	Energie du Mali SA (national water and electricity utility)
<b>EPP</b>	Emergency Power Producer
<b>GDP</b>	Gross Domestic Product
<b>GHG</b>	Greenhouse Gas
<b>GoM</b>	Government of Mali
<b>IPP</b>	Independent Power Producer
<b>IRENA</b>	International Renewable Energy Agency
<b>JTA</b>	Job Task Analysis
<b>LPG</b>	Liquefied Petroleum Gas
<b>NDC</b>	Nationally Determined Contribution
<b>NEP</b>	National Energy Policy
<b>OMVS</b>	Senegal River Basin Development Organization (Organisation pour la Mise en Valeur du Fleuve Sénégal)
<b>PPA</b>	Power Purchase Agreement
<b>PV</b>	Photovoltaic
<b>RMI</b>	Risk Mitigation Instrument
<b>RRA</b>	Renewable Readiness Assessment
<b>SPEI</b>	Standardized Precipitated and Evapotranspiration Index
<b>SPI</b>	Standardized Precipitation Index
<b>UEMOA</b>	West African Economic and Monetary Union (Union Economique et Monétaire Ouest Africain)
<b>WACEC</b>	West Africa Clean Energy Corridor
<b>WAPP</b>	West African Power Pool

## MEASUREMENTS

<b>GWh</b>	Gigawatt Hour
<b>km</b>	Kilometre
<b>kV</b>	Kilovolt
<b>MW</b>	Megawatt
<b>MWp</b>	Megawatt-peak



**Dogon village and typical mud huts**

Photograph: Shutterstock





# EXECUTIVE SUMMARY

Mali is a landlocked country and is one of the largest in Africa, with an area of 1 241 238 square kilometres and an estimated population of 19.6 million in 2018. The country has been experiencing high demographic growth at a 3.36% annual rate over the 2010-18 period (PopulationData.net, 2019).

Furthermore, there is an imbalance in the distribution of population between rural and urban areas, with more than 70% located in the former while those in the latter mainly concentrate in the regional capitals as well as the District of Bamako, a city of over 4.3 million inhabitants in 2018. Mali remains one of the poorest countries in the world, with a gross domestic product of USD 15.29 billion in 2017; that is, only USD 825 per capita. On average, agriculture and services account for approximately 80% of Mali's gross domestic product although final energy consumption for both sectors remains below 8%.

Mali is involved with the major regional political, financial and sectoral institutions. As a member of the Economic Community of West African States (ECOWAS), the country is part of the ECOWAS Energy Protocol, adopted in 2003. Mali also is part of the West African Economic and Monetary Union (Union Economique et Monétaire Ouest Africain, UEMOA) and the Permanent Interstate Committee for Drought Control in the Sahel (Comité Inter-état de Lutte contre la Sécheresse au Sahel, CILSS), which bring together ten countries within the Sudano-Sahelian zone.

In terms of electricity, Mali is a key member of the Senegal River Basin Development Organization shared by Guinea, Mali, Mauritania and Senegal. Within this organisation, Mali has participated in the construction and development of the Manantali and Félou hydropower plants. Mali is a member of the West African Power Pool, a specialised institution under ECOWAS whose aim is to integrate the operations of national power systems into a unified regional electricity block. In addition, the country belongs to the ECOWAS Regional Electricity Regulatory Authority responsible for cross-border electricity exchange regulation.

Mali depends entirely on imported petroleum products and wood fuel (wood energy) from its natural forests. The country also imports electricity from neighbouring countries. This negatively impacts Mali's environmental stability and the country's balance of payments. There are, nevertheless, unproven oil reserves that await extensive exploration in the northern and eastern parts of the country.

Access to electricity in Mali as in the majority of countries in the ECOWAS region is low, with sharp disparities across urban and rural areas. Only half of the urban population has access to electricity whereas in the rural areas, access is limited to only 16.7% of the population. As far as modern fuels for cooking are concerned, access is extremely low, at only 2% and 3% for rural and urban areas, respectively.

Mali's electricity system encompasses a national grid that is owned and operated by Energie du Mali SA (EDM SA) which supplies 35 towns, including Bamako. In addition to the national grid, EDM SA manages 30 isolated centres equipped with diesel generators and two centres supplied by Côte d'Ivoire. The Malian Agency for Domestic Energy and Rural Electrification (Agence Malienne pour le Développement de l'Énergie Domestique et de l'Électrification Rurale - AMADER) is in charge of rural electrification for schemes below 250 kW and is the regulator for rural electrification in accordance with the reference framework of rural electrification adopted in 2003.

Hydropower and thermal power stations are the main energy generation sources at the national level. Although hybrid (solar/diesel) and small-scale decentralised solar photovoltaic (PV) systems have been increasingly installed since 2011, the share of renewable energy, excluding large hydropower, remains low.

Mali continues to face major challenges in the electricity sector. Hydropower accounts for 51% of installed capacity; however, rainfall and hydrological changes have an impact on electricity generation and, as a result, Mali increasingly is resorting to oil-powered stations. Due to the high generation costs from thermal power stations and excessive technical and non-technical network losses, tariffs are particularly high apart from the social tariffs offered when consumption is below 50 kilowatt hours per month.

These challenges mean that other opportunities in renewables should be sought, particularly the options of on-grid and off-grid solar PV. Indeed, Mali is endowed with a large spectrum of renewables, including sustainable biomass if adequately managed. The national forest estate is estimated at 100 million hectares. The main challenge is to ensure the sustainable use of this resource to maintain pace with the natural productivity of forests. As for hydropower, although it already accounts for a significant share of electricity capacity and generation, there is still a considerable untapped potential, subject to further studies.

The impact of climate change, however, also must be taken into account to ensure a secure electricity supply over the long term. The International Renewable Energy Agency (IRENA) has carried out a comprehensive study on the planning and prospects for renewables in West Africa. Solar energy particularly solar PV has the most potential. Tapping only 2% of the solar PV potential was sufficient to cover total electricity supply in 2015.

The Malian National Renewable Energy Action Plan (NREAP) has set ambitious objectives for grid- and off-grid systems alike. For a connected system, installed capacity by 2030 for renewables, including large hydro, should reach 1416 megawatts (MW); that is, a nine-fold increase compared to 2010. For off-grid renewables, installed capacity should increase from 20 MW in 2010 to over 600 MW by 2030, a thirtyfold increase over the period. Ambitious targets have also been set for ethanol and biodiesel.

The findings of the Renewable Readiness Assessment (RRA) highlight the key bottlenecks that hinder the widespread deployment of renewables systems. They identify critical actions that could significantly impact the scale-up of RE in the short-to-medium term. In this context, Mali is offered various recommendations, highlighted below.

### **Diversify the power supply through increased penetration of non-hydropower renewables**

In its National Adaptation Programme of Action, Mali highlights the vulnerability of its energy sector to climate change by ranking it as the third most imperilled sector following agriculture and health. Indeed, given its heavy reliance on hydropower, the entire energy system is under the threat of climate change impact, suggesting the prioritisation and more accelerated deployment of renewable energy technologies beyond hydropower, such as solar and biomass.

Mali is therefore advised to develop a power sector master plan that captures, fully, cost-effective and sustainable renewable solutions. This should also be complemented by an assessment of various bioenergy resource potentials as well as an overall policy that takes into account other sectorial strategies. A thorough assessment of hydropower, including its current status and further development options in light of hydrological projections, is also advisable. The support of international partners, such as the Green Climate Fund and the Global Environment Facility, should be sought for the development and implementation of a long-term climate change resilience strategy.

### **Develop and adopt an electricity grid code**

Mali is still characterised by the absence of a grid code. Accommodating a large share of renewables in the near future implies developing and codifying operational procedures to respond to power generation forecasts as well as undertaking further studies regarding grid stability. It will also require a grid code to ensure procedures that are conducive to the technical integration of variable renewables (solar and wind) into the grid. This can take the form of a law or a directive that mandates compliance to a grid code by all generators.

### **Enhance the enabling framework for private renewable energy investments**

According to assessments conducted by the World Bank and other international institutions, Mali is thought to have a relatively weak supportive policy framework that deters international private investors that are often risk averse. The Malian government is thus advised to adopt stronger renewable energy policy support mechanisms. The national private sector, furthermore, is scarcely involved in the development of large-scale power plants. This mainly is due to an insufficiently incentivising framework and the mechanisms to effectively offset the risks taken by renewable energy investors. Adopting measures to mitigate off-taker risks is essential for the ramp up of mature renewable energy projects that already have been initiated by the private sector.

### **Adopt policies and regulations that support the growing mini-grid sector**

Rural electrification is a major challenge in Mali. The general principle is that electricity prices in rural areas are not regulated but capped to USD 0.51/kWh. As a result and despite AMADER's support to rural electrification electricity tariffs applied to the rural poor, who are not connected to the main grid or to isolated centres, are extremely high and range between USD 0.25/kWh and 0.51/kWh. This is largely due to the large share of thermal installations and represents an opportunity to for deployment of sustainable energy with the prospects of reduced production costs. Revising the tariff-setting mechanisms for rural electrification would, therefore, be pertinent. Price equalisation and support to the private sector must be considered to overcome this major challenge of high electricity tariffs in rural areas.

### **Develop a clear main grid arrival policy**

The RRA process highlighted that within the mini-grid sub-sector, there is great uncertainty as to what occurs to existing mini-grids when they are reached by grid extension campaigns. This uncertainty is generally linked to the inappropriate application of the provisions in force regarding takeover or retrocession between the State and private operators and constitutes a risk to private investors in rural electrification. Mali could learn from the best practices of other countries in order to apply the prevailing measures or adopt an appropriate model to mitigate that risk.

### **Implement quality control standards for renewable energy equipment and installers**

RRA discussions have highlighted the relative lack of standards and adequately qualified technicians for the sizing, design, instalment and maintenance of solar systems in the country. To sustain this effort, the Government of Mali may wish to consider equipping its Renewable Energy Agency (-AER-Mali) with the appropriate laboratory and other equipment to test locally manufactured and imported products. Mali could also benefit from the ECREEE-led and IRENA-supported ECOWAS Certification of Sustainable Energy Skills, as a way to equip the local market with high-quality technicians to curb the country's technical skills shortage.

### **Enhance technical capacities for a large-scale deployment of renewable power**

Technical and human capacities across the value chain, readiness of support institutions and grid infrastructure must be assessed to support Mali's preparedness for the integration of higher shares of variable renewable power. This assessment should ideally be followed by capacity-building efforts to bridge the gaps identified. Priority areas for capacity building should include streamlining existing institutional and regulatory frameworks as well as addressing the main bottlenecks, particularly the legal and technical issues that surround independent power producers, power purchase agreements, financing and guarantee mechanisms, certification and normalisation. Given the variability of renewables and possible disturbance on the grid, power generation forecasts and reliable and comprehensive renewable energy data are the other key areas to be prioritised to build capacities in the renewable energy sector.

### **Strengthen local capacities in the development, appraisal and financing of bankable renewable energy projects**

In addition to the policy and regulatory frameworks mentioned above, the current low level of local private sector involvement in renewable energy investments also relates to the lack of awareness of the local financial sector of the technicalities and business proposition in investing in renewables. This leads to the high-risk perception of renewable energy projects. Dedicated efforts should be channelled towards bringing potential players to the same level of knowledge, albeit by tailoring it to their specific needs.

### **Establish effective energy data collection and management processes to build capacities**

As in the case of most countries in sub-Saharan Africa, the quest for reliable, consistent and up-to-date data essential for understanding, not only the potential but also the energy situation in Mali, is often a daunting task. Statistical capacity-building activities are recommended to strengthen renewable energy data collection, processing and dissemination.





Mali's capital city, Bamako  
Photograph: Shutterstock





# I. INTRODUCTION

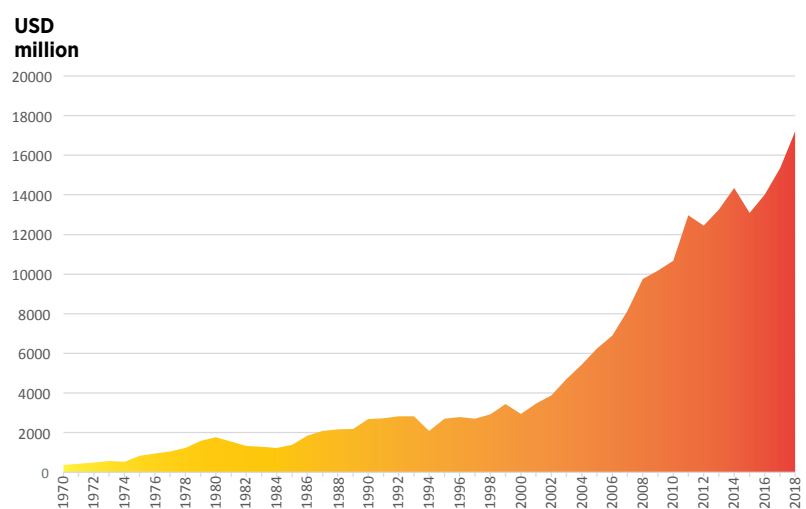
## 1.1 Country Background

Mali is a landlocked country with an area of 1241238 square kilometres and an estimated population of 19.6 million as of 2018. Two large rivers, the Senegal River (800 km) and the Niger River (1700 km), cross Mali. The country has been experiencing high demographic growth at 3.3% per annum. Furthermore, the population is unevenly distributed between rural and urban areas, with more than 70% located in the former. The urban population mainly concentrates in the regional capital as well as the District of Bamako which had over 4.3 million inhabitants in 2018.

The negative gross domestic product (GDP) growth experienced in 2012 (-0.8%) and low growth of 2.3% registered in 2013 have reversed, with GDP growth now recorded at approximately 5.97% and 5.8% in 2015 and 2016, respectively, although it slipped back to 5.4% in 2017.

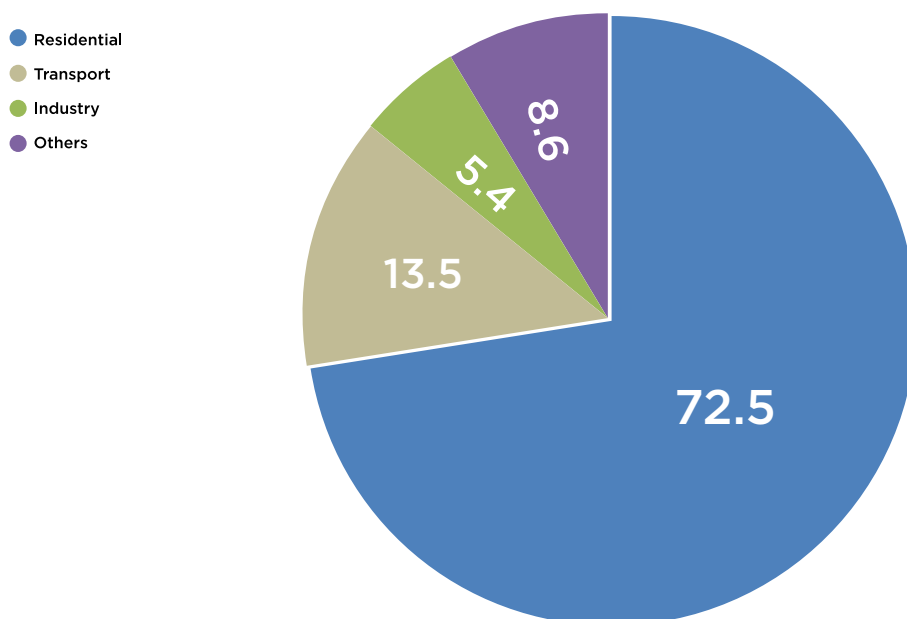
Mali remains one of the poorest countries in the world, with a GDP of USD 17.2 billion in 2017, indicating a GDP per capita of only USD 901.

**Figure 1. Mali's gross domestic product (USD, current prices)**



Adapted from World Bank online DataBank: available at <http://databank.worldbank.org/data>.

Figure 2. Breakdown of final energy consumption in 2014 (%)



Source: Adapted from SIE (2014).

## 1.2 Role of energy in the development of Mali

Energy is a key input in the economic and social development of all countries, as shown by the strong correlation between GDP, the Human Development Index and the energy demand historically witnessed in most economies. In Mali, energy consumption across the major economic sectors, notably the industrial sector, is low. As shown in Figure 2, the industrial sector accounted for only 5.4% of energy consumption in 2014, the bulk of which is concentrated within a few sub-sectors of the industrial sector, particularly that of mining.

Mali is a rural country that relies heavily on agriculture and services. Despite the predominance of traditional agriculture portrayed by the low level of energy consumption and the resulting low yields, for instance, agriculture contributes significantly to Mali's GDP. In 2017, the agriculture sector accounted for approximately 38.33% of GDP (World Bank, 2017a).

The low level of energy demand in Mali's agriculture sector is reflective of rain-fed agriculture practices, characterised by low outputs. This indicates that there exists potential to mechanise the sector, increase output and, therefore, contribute to sustainable economic growth and transformation. Mechanisation of the sector

in this manner would likely increase a demand for energy. In addition to agriculture, energy is a key enabler for improved health services, since access to electricity plays a critical role in the functionality of healthcare facilities. Energy also plays an important role in the quality, accessibility and reliability of health services delivered to rural communities, a major challenge in sub-Saharan Africa where one in four sub-Saharan health facilities do not have access to electricity (WHO, 2014).

---

## Energy is a key enabler for improved health services

---

### 1.3 Renewables Readiness Assessment process

The RRA process in Mali was led by the Renewable Energy Agency of Mali (Agence des Energies Renouvelables du Mali - AER-Mali) and the Ministry of Energy and Water (Ministère de l'Énergie et de l'Eau, MEE), with the support of IRENA and various international and national consultants. AER-Mali invited experts drawn by key institutions from the government, private sector and civil society. They were briefed on the nature and purpose of the RRA process and became a part of the Mali RRA country team.

A kick-off meeting was conducted in April 2017 and included the identification of renewable energy service-resource pairs, prioritisation criteria, and the completion of a set of templates for each renewable energy service-resource pair. A final RRA validation workshop, held in September 2017, concluded the study and drew the necessary actions to set the renewable energy sub-sectors in motion.

This report contains four chapters, the first of which includes a country background brief of Mali, the role of its energy sector in terms of development and its RRA process.

The second chapter presents an overview of the regional energy setting, contextualising Mali's national energy sector, the challenges it faces and the potential and use of renewables. It also provides an in-depth discussion of Mali's electricity sector.

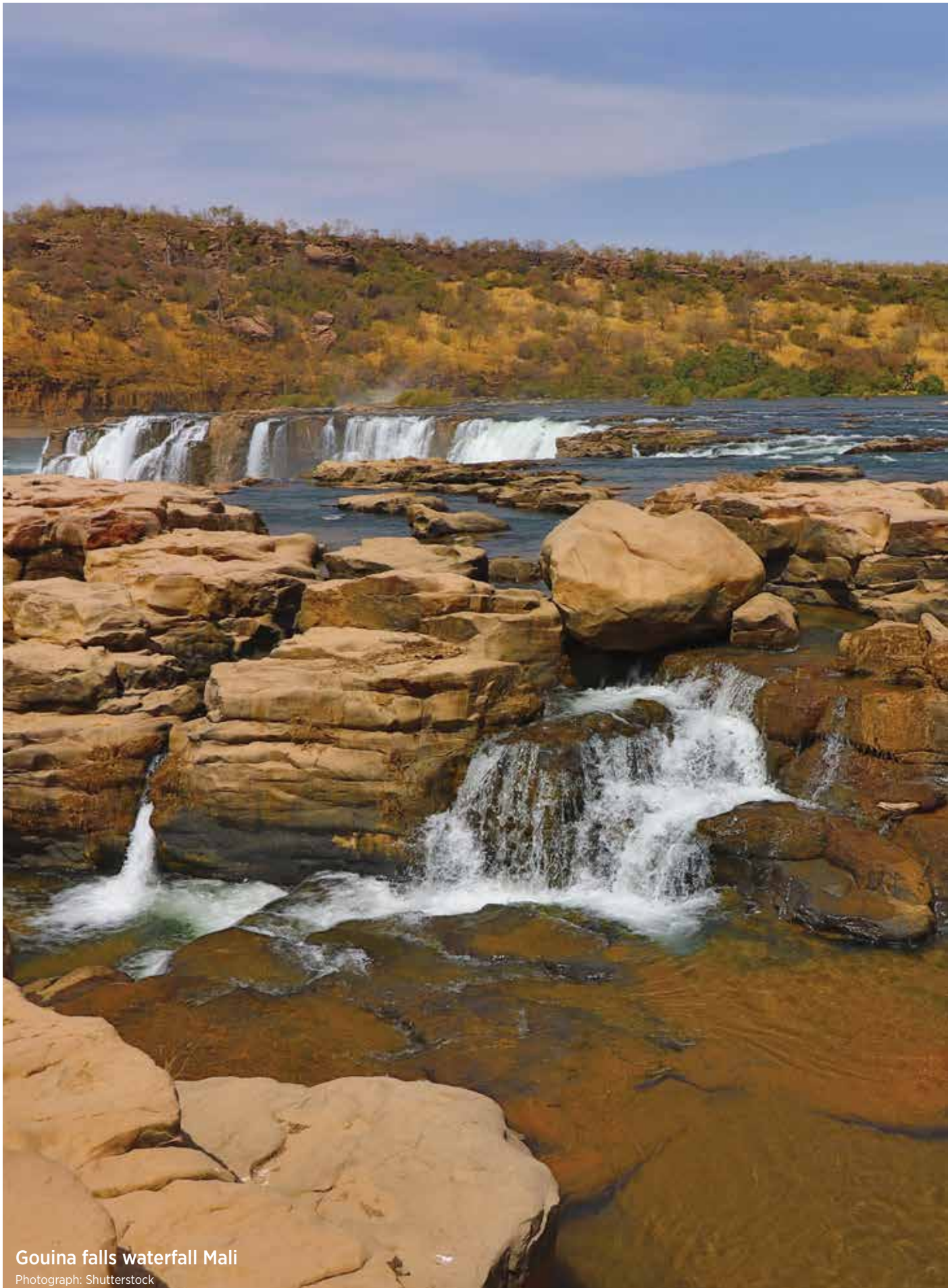
The third chapter lists the institutions that play a role in Mali's energy sector, defines key energy policies and regulatory frameworks and outlines the conditions for financing and investing in Mali.

The fourth and final chapter not only discusses the findings of the RRA process relating to the emerging concerns and conditions for scaling up the service-resource pairs that have been identified; it also sums up the relevant opportunities and constraints.



Photograph: Mali-Folkcenter Nyetaa





Gouina falls waterfall Mali  
Photograph: Shutterstock



## 2. ENERGY CONTEXT

### 2.1. Regional context

Mali is a member of the Economic Community of West African States (ECOWAS). The organisation works with its 15 member states<sup>1</sup> and international development partners on economic development in priority development areas, including the improvement of energy production, distribution and consumption within the region. Part of this mandate lies in increasing access to and reliability of energy services, in particular to support member states in their energy transition process.

As an ECOWAS member, Mali forms a part of the ECOWAS Energy Protocol that was adopted in 2003, a legal framework that aims to promote long-term co-operation based on building relationships that are mutually beneficial to increase energy sector investment in the region. In terms of trade, the ECOWAS Energy Protocol provides for, among its other principles, third-party access to the grid and a right to the transit of energy.

Mali also is a member of the West African Economic Monetary Union (Union Economique et Monétaire Ouest Africain, UEMOA), which encompasses eight West African countries.<sup>2</sup> UEMOA's objective is to reach 82% of electricity from renewables, including large hydropower by 2030. As far as the energy transition is concerned, UEMOA has carried out an installation study for large solar power plants, identifying five sites - which include Mali - for a total capacity of 574 megawatts (MW), to be commissioned by 2030. Given the limitation of the interconnected grid, however, the study recommends limiting capacity to approximately 22 megawatt-peak (MWp) per site.

Mali also forms part of the Permanent Interstate Committee for Drought Control in the Sahel (Comité Inter-état de Lutte contre la Sècheresse au Sahel, CILSS), which brings together 13 countries within the Sudano-Sahelian zone.<sup>3</sup> Under the regional solar programme of Permanent Interstate Committee, 151 solar water pumping and 33 solar home systems have been installed in Mali.

Mali is a member of the Senegal River Basin Development Organization (Organisation pour la Mise en Valeur du Fleuve Sénégal, OMVS) which also includes Guinea, Mauritania and Senegal. OMVS facilitates the regional management of water resources for electricity production in efforts to increase food security and reduce poverty, among other objectives, in alignment with the policies of its member countries. The OMVS has systematically implemented the principle of equitable sharing of economic resources in the Senegal River Basin among member states, including ownership of basin infrastructure and the benefits of water resources.

---

<sup>1</sup> Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, The Gambia, Togo

<sup>2</sup> Benin, Burkina Faso, Cote d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, Togo

<sup>3</sup> Benin, Burkina Faso, Cabo Verde, Chad, Cote d'Ivoire, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Senegal, The Gambia, Togo



Figure 3. West African Power Pool



Source: WAPP, 2017

Disclaimer: Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.

Within the OMVS, Mali participate in the construction and development of the Manantali and Félou hydropower plants, completed in 2001 and 2013, respectively. The Manantali hydropower plant has the potential to produce 800 gigawatt hours (GWh) a year and more than 1500 kilometres (km) of 225 kilovolt (kV) transmission lines, a key achievement in the energy field.

EDM S.A. is a member of the West African Power Pool (WAPP) (see Figure 3), a specialised ECOWAS institution established in 1999 with the aim of harmonising national electricity systems within the region and delivering power in a stable, reliable and cost-competitive manner. The rehabilitation of the 60 MW Félou hydropower plant to provide power to Senegal, Mali and Mauritania is one of various projects supported by WAPP.

Cross-border interconnection between Mali and Senegal enables the transmission of power from the Manantali hydro power plant, a multinational concern. In addition to completion of the 225 kV line between Mali and Côte d'Ivoire in 2012, further interconnections, such as Mali-Guinea, are planned in order to limit suppressed demand as well as reduce the average production cost of electricity. Given the region's hydropower potential, the share of renewables (mainly hydro, irrespective of size) in the energy mix could increase.

In order to support the creation of a regional power market in collaboration with the ECOWAS Regional Electricity Regulatory Authority; ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE); and WAPP, IRENA initiated the West Africa Clean Energy Corridor (WACEC) initiative. Building on current efforts

in the region, the WACEC promotes the development of utility-scale renewable power and its integration into West African power systems.

Energy Ministers at the Specialised Technical Committee on Transport, Transcontinental and Interregional Infrastructure, Energy and Tourism of the African Union recommended, in April 2019, that the Member States, Regional and Continental bodies to integrate the concept of the Clean Energy Corridors into their renewable energy and climate change agendas as well as in the design, implementation and update of regional and continental initiatives and programmes to support the Continent's transition to more sustainable, reliable and affordable energy systems.

Mali has established beneficial relationships with ECREEE, and in June 2016 AER-Mali, in partnership with ECREEE, provided capacity building to small- and medium-size enterprises and non-governmental organisations to enable them to produce and disseminate solutions for clean cooking relating to stoves and fuels. The effort encompassed all aspects of the clean-cooking value chain. With regard to rural electrification, ECREEE has supported Mali in undertaking pre-feasibility studies in 97 villages. In addition, ECREEE supported the Government of Mali in 2015 to develop a BOOT model tender for the development of grid-connected renewable energy projects.

Mali is a member of the ECOWAS Regional Electricity Regulatory Authority. This entity regulates the cross-border exchange of electricity and supports the national electricity regulators of member states.



## 2.2. Energy supply and demand in Mali

As in most sub-Saharan African countries, biomass (mainly in the form of firewood) provides the bulk of the energy supply (Figure 4). Mali has neither proven hydrocarbon resources nor a refinery; as a result, all petroleum products are imported through neighbouring coastal countries which impacts on the country's balance of payments.

Mali, as a landlocked country bordered by 7 countries, has to incur high transportation costs. Energy demand has been growing faster than its GDP and, if not reversed, the trend will result in a major constraint to energy supply and economic development.

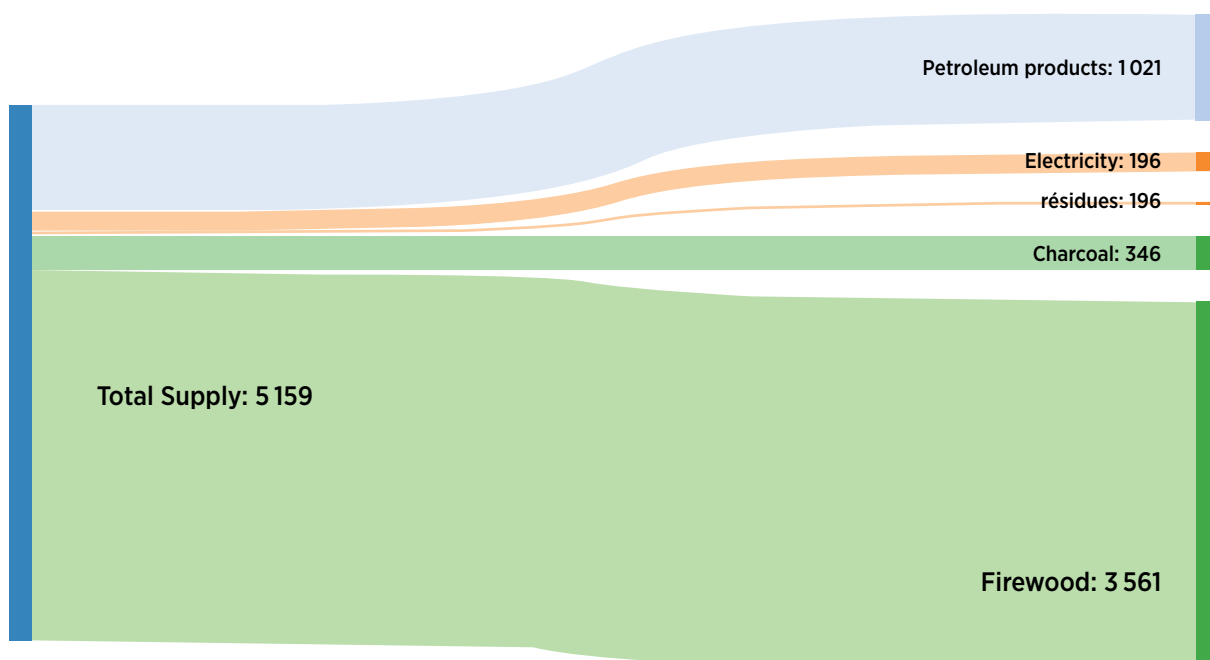
Mali's total primary energy supply in 2014 reached 5.1 million tonnes oil equivalent (Mtoe) out of which 3.6 Mtoe (69%) is from firewood and 7% from charcoal.<sup>4</sup> The share of other biomass is limited to residues (<0.5%), mainly from agriculture and forestry. Petroleum products accounted for 1.02 Mtoe (20%) mainly gasoline and diesel for the transport sector. The share of electricity, including imports, is only 3.8% of total energy supply.

Analyses of the total primary energy supply indicate dependence, to a large extent, on non-sustainable natural forests, imported petroleum products and, to a lesser extent, electricity imports from Côte d'Ivoire. With regard to energy consumption, the residential sector (72.5%) and the transport sector (13.5%) accounted for 86% of total demand in 2014 (Figure 2).

Total energy consumption by the residential sector is shown in Figure 5. Analyses of total household consumption evidence heavy reliance on biomass, primarily firewood (84%), a low contribution of charcoal (14%) and a significantly low contribution of electricity and modern fuels (e.g. liquid petroleum gas (LPG)). Use of traditional biomass leads to negative environmental and health impacts. Environmental issues that affect Mali, due to unsustainable harvesting of firewood, include desertification and deforestation.

Women and children, given that they are mainly involved in household chores, have a greater likelihood of suffering from infections caused by wood smoke. Mali, nevertheless, is one of the few countries that have deployed wood energy rural markets to limit the impact of deforestation and increase rural incomes. In the transport sector, diesel and gasoline account for the bulk of consumption.

**Figure 4. Total primary energy supply in 2014 by energy sources (ktoe)**

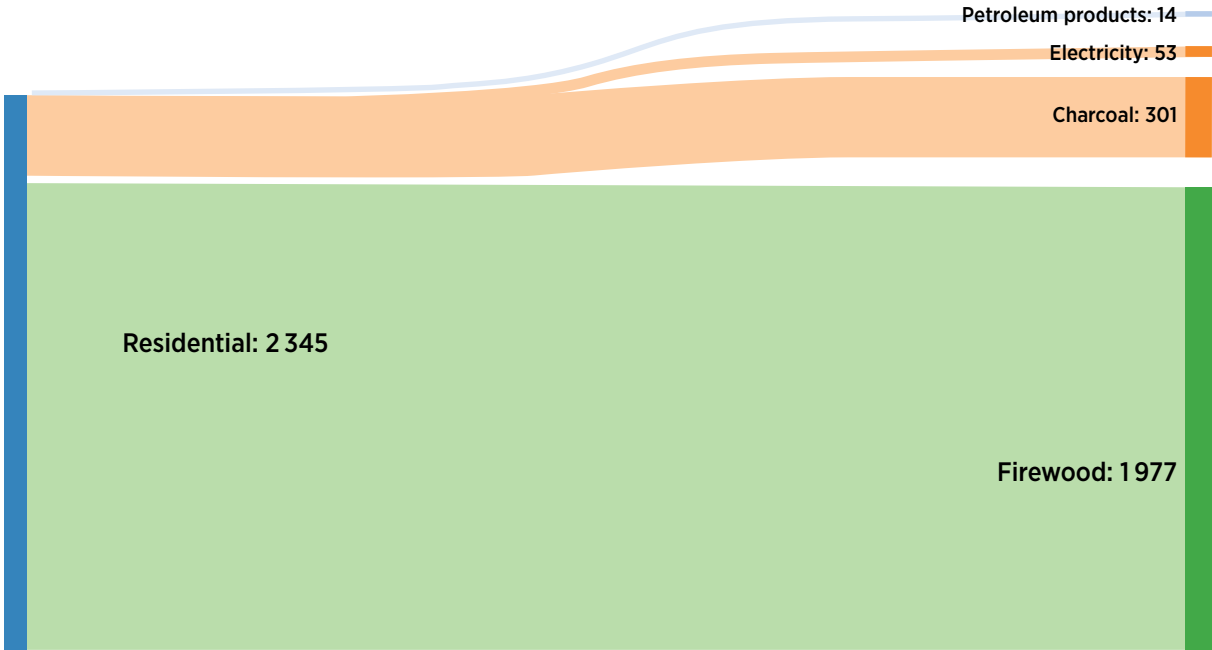


Based on the latest data available from Energy Information System (Système d'Information Énergétique) (2014); and Ministry Energy and Water/National Energy Directorate (Ministère de l'Énergie et de l'Eau/ Direction Nationale de l'Énergie).

ktoe = thousands of tonnes of oil equivalent

<sup>4</sup> Information regarding energy supply and demand in Mali is based on the last energy balance, available as of December 2016, published by Mali's Ministry of Energy.

Figure 5. Residential energy consumption by energy forms in 2014 (ktoe)

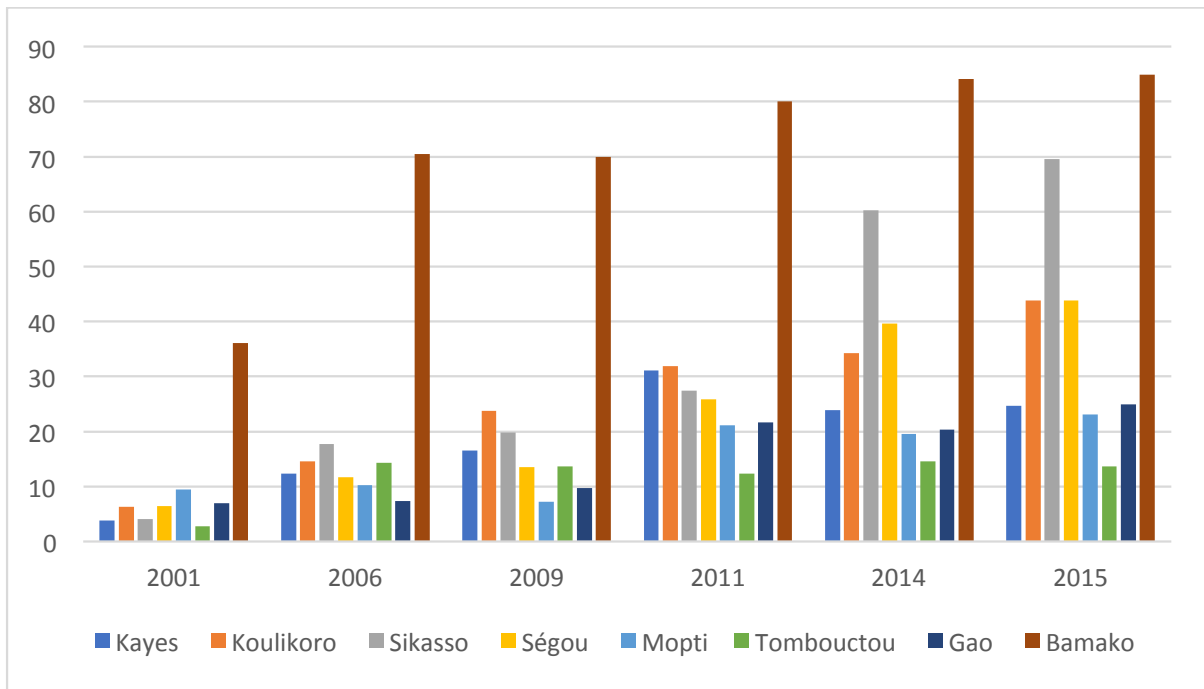


Based on the latest data available from Energy Information System (Système d'Information Energétique) (2014) and Ministry Energy and Water/National Energy Directorate (Ministère de l'Energie et de l'Eau/ Direction Nationale de l'Energie).  
ktoe = thousands of tonnes of oil equivalent



Photograph: Shutterstock

**Figure 6. Access to electricity across Mali 2001-15 (%)**



Sources: Mali's Poverty Assessment Survey (Enquête Malienne sur l'Evaluation de la Pauvreté, EMEP) (2001); Integrated Limited Household Survey (Enquête Légère Intégrée, ELIM) (2006); Multiple Cluster Indicator Survey/Light Household Integrated Survey (Enquêtes par Grappes à Indicateurs Multiples/Enquête Légère Intégrée auprès des Ménages, MICS-ELIM) (2009); Permanent Modular Household Survey (Enquête Modulaire et Permanente auprès des Ménages, EMOP) (2011); EMOP (2015) and National Statistics Institute (Institut nationale de la statistique, INSAT) (May 2016).

Access to electricity is paramount in the effort to alleviate poverty, and it is a major input to increasing economic productivity. Access in Mali is one of the lowest in the world, with sharp disparities across urban and rural areas and regions (Figure 6).

In 2015, the nationwide electricity access rate was 41% (IEA, 2017), fourfold higher than in 2001. In Bamako, it was approximately 85%, although it remained below 50% in the regions of Kayes and Timbuktu, where this figure lies at 25% and 13%, respectively. Low access to electricity in regions not yet connected to the national grid offers positive opportunities for the large-scale deployment of renewables.

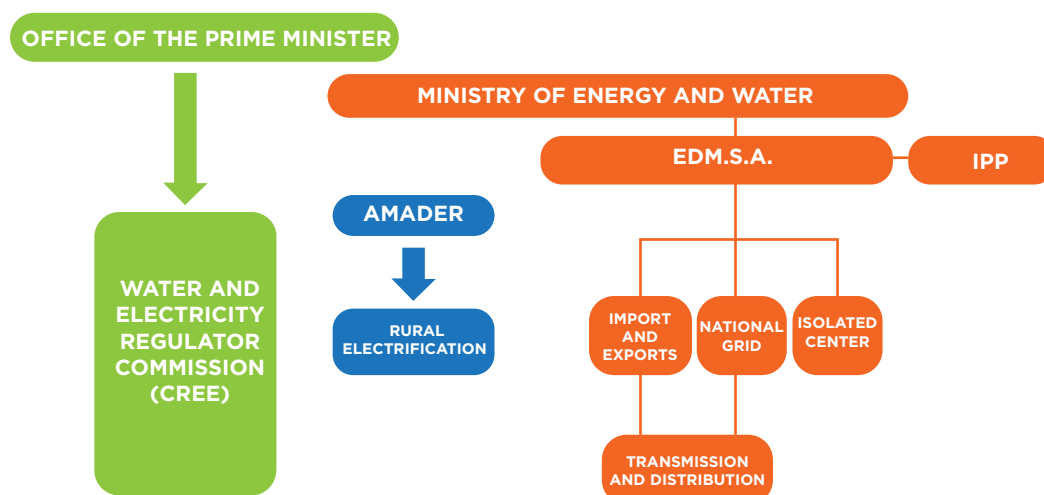
In terms of modern fuels for cooking, access is extremely low at only 2% and 3% in rural and urban areas, respectively, the key reasons being poverty, the relatively low price of biomass and the high price of LPG. This pattern of consumption is a major threat to the sustainability of biomass resources.

Furthermore, this sector is characterised by inefficiencies along the entire supply chain (i.e. production, transformation, transport, consumption) which increase the unsustainable exploitation of natural forest resources.

LPG consumption per capita in West Africa is among the lowest in the world, and consumption in absolute values has not significantly increased since 2009. This translates into a diminishing trend of consumption per capita during this period, given demographic growth.



Figure 7: Structure of Mali's energy sector



### 2.3. Electricity generation, transmission and distribution

From 1960 to 1999, the state-owned electricity utility, EDM S.A., had a de jure monopoly on the generation, transmission and distribution of electricity. EDM's capital was shared by the Malian State (nearly 98%) and France's utility, Électricité de France (nearly 2%).

From 1998 to 2000, the GoM undertook a major reform of the electricity sub-sector in a key effort to remedy the persistent under-performance of the sub-sector. In 2000, EDM was partially privatised to form a consortium that included France's SAUR (a subsidiary of Bouygues S.A.) (47%) and Industrial Promotion Services (a subsidiary of the Aga Khan Fund for Economic Development) (13%). The hydropower plants, however, were kept under state ownership. In 2005, SAUR sold its shares in EDM to other parties, and the state regained 66% control (AfDB, 2015). The remaining shares were owned by Industrial Promotion Services West Africa. In July 2018, the state regained full control of the utility.

Mali's power system encompasses an interconnected grid that is owned by EDM, supplying 35 towns including Bamako. EDM S.A. also manages 31 isolated production centres that are powered with diesel generators and two centres supplied by Côte d'Ivoire's medium-voltage grid.<sup>5</sup> EDM is responsible for cross-border electricity trade (export and import) as well as power purchases from independent producers.

The Malian Agency for Domestic Energy and Rural Electrification (Agence Malienne pour l'Energie Domestique et l'Electrification Rurale, AMADER) oversees the rural electrification of schemes below 250 kilowatts and acts as de facto regulator for rural electrification (Figure 7).

#### Electricity generation

Hydropower and thermal<sup>6</sup> power stations are the main power generation plants. Despite the presence of various hybrid systems (e.g. solar and diesel), the share of renewables excluding large hydropower remains low.

Table 1. Mali's on-grid installed capacity

HYDROPOWER				THERMAL POWER PLANT		
Plant	Capacity (MW)	Reservoir Capacity (m <sup>3</sup> )	Ownership/Operator	Plant	Capacity (MW)	Ownership/Operator
Sélingué	47	2.6 billion	EDM	Darsalam	36.6	EDM
Sotuba	5.7	Run of river	EDM	Balingué	24.32	EDM
Manantali <sup>7</sup> (52% share)	104*	11.3 billion	SOGEM	IDB (Baligué)	71.6	EDM
Felou (45% share)	27*	Run of river	SOGEM	SOPAM	56	SOPAM (IPP)
<b>Total</b>	<b>183.7</b>				<b>176.5</b>	

Notes : SOGEM = Société de Gestion de l'Energie de Manantali; IDB = Islamic Development Bank; and IPP = Independent Power Producer.

<sup>5</sup> In the context of the Malian power system, isolated centres refer to power systems in large urban areas not covered by the national grid but which are still managed by the national power utility, EDM.

<sup>6</sup> Diesel and Heavy Fuel Oil.

<sup>7</sup> Manantali is a multinationally shared power station with a capacity of 200 MW, from which 104 MW is Mali's share. Félou is a shared power station with a capacity of 60 MW, from which 27 MW is Mali's share.

Mali benefits from a 30 MW minimum guaranteed capacity from Côte d'Ivoire which has been raised to 50 MW based on an agreement (EDM, 2017). In 2017, imports from Côte d'Ivoire reached 333.18 GWh; that is, 16% in excess of total electricity generated to supply the national grid. With regard to the isolated centres, total installed capacity stood at only 70 MW in 2015, a drop from 75 MW in 2014 due to the decommissioning of various diesel power plants. The electricity of isolated centres comes from small generators (0.74-14.5 MW), accounting for approximately 7.6% of EDM's total generation.

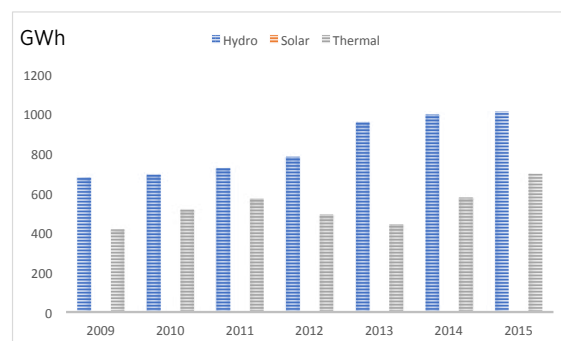
Access by the rural population to electricity remains extremely low. In 2015, only an estimated 16.7% had access to power, including street lighting (PANER, 2015). The share of renewables and hybrid systems is estimated at 4.3%. Decentralised renewable or hybrid solutions may offer the least cost option for rural electrification.

The World Bank, through AMADER, has initiated the Rural Electrification Hybrid System Project to expand access to modern energy services in rural areas. This project aims to increase renewable-based generation capacity in existing rural power stations that supply rural mini-grids and to expand those with approximately 4.8 MWp of capacity through hybrid systems, including PV panels, inverters, batteries and control electronics, as well as mini-grid extension and densification (World Bank, 2017c).

Given the limits of the interconnected grid, the isolated centres and many enterprises, mainly in the mining sector, generate their own electricity. Diesel is the principal fuel for electricity self-generation. The production cost of diesel generators is particularly high, which may offer opportunities for decentralised renewables. Approximately 56 GWh was generated in 2014 by self-producers, from which 4.5 GWh was from waste and or agricultural residues (SIE, 2014).

The electricity generation mix, which consists of a large share of thermal power (see Figure 8), is pushing production costs upwards due to fuel price fluctuations, while hydro power is impacted by climate change. Other renewable energy sources for electricity generation are limited to small PV systems, although major grid-connected PV power plants are under construction in the Kita District (Box 1).

**Figure 8: Mali's electricity generation by energy sources**



Source: EDM (2016)

#### Box 1: Kita 50 MW solar power plant

- Investment: USD 89.2 million
- Mechanism: BOOT scheme
- Shareholders: Akuo Energy, R20
- Technical details: 76 gigawatt-hours/year; 186 000 photovoltaic modules
- Employment: 450 direct jobs throughout project
- Avoided CO<sub>2</sub> emissions: 51 700 tonnes/year
- Completion: Planned for October 2019

BOOT = Build, Own, Operate, Transfer

Source: (GlobalData, 2019)

#### Transmission and distribution

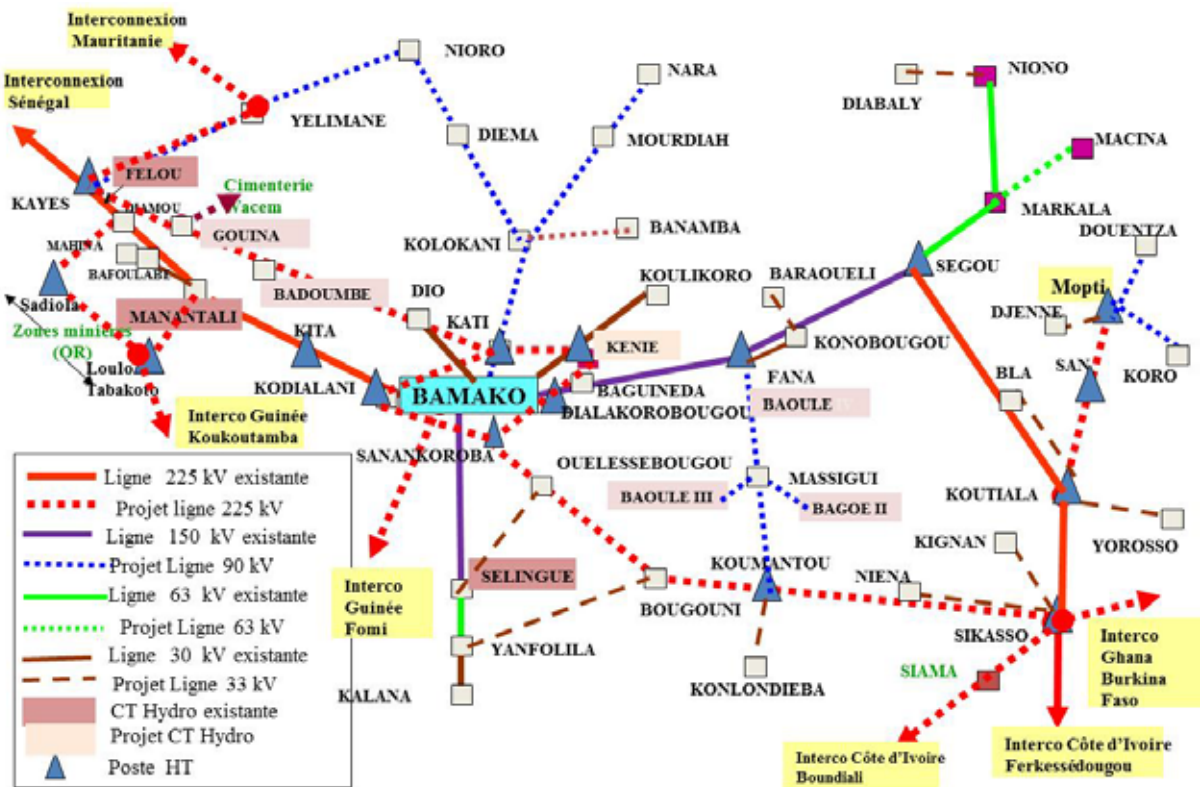
The existing grid (see Table 2) consists mainly of a 150 kV line that links Bamako to Fana and Ségou in the east from the Sélingué hydropower plant; a 63 kV line that connects the towns of Ségou and Niono; and a 225 kV line (operated by the Energy Management Company of Manantali (Société de Gestion de l'Energie de Manantali – SOGEM) from the Manantali hydropower plant that also connects Bamako with the towns of Kayes and Kita). A second 225 kV line from the town of Ferkessédougou, as part of the interconnection with Côte d'Ivoire, has extended Mali's grid to the towns of Koutiala and Sikasso by connecting them to the 150 kV Bamako-Fana-Ségou line in Ségou (See Figure 9).

Total technical and non-technical losses in the electricity sector remain high. They stood at approximately 20% over the 2010-14 period (DNE, 2016).

**Table 2:** Key characteristics of Mali's interconnected transmission grid and distribution network, 2016

Towns/centres connected	Grid voltage	Connection
35	225 kilovolts (kV)	Côte d'Ivoire-Sikasso-Koutiala-Ségou: 389 kilometres (km)
	225 kV	Bamako-Kita-Kayes
	150 kV	Bamako-Fana-Segou: 376 km
	66 kV and 63 kV	Segou-Niono
	30 kV	392 km
<b>Distribution (low voltage)</b>	<b>6 808 km</b>	

**Figure 9.** Mali's national grid



Source: Energie du Mali S.A. (2019).

**Table 3: Mali's grid-connected pre-paid and post-paid tariffs**

Pre-paid tariffs			
Single phase 5 Amps			
Band 1	Band 2	Band 3	Band 4
1-50 kWh/month	51-100 kWh/month	101-200 kWh/month	>201 kWh/month
USD 0.11/kWh	USD 0.18/kWh	USD 0.21/kWh	USD 0.25/kWh
Single Phase 10-60 Amps			
kVA	Band 1	Band 2	
	101-200 kWh/month	> 200 kWh/month	
2.2-13.2	USD 0.21-0.22/kWh	USD 0.21-0.25/kWh	
Triple Phase 10-30 Amps			
kVA	Band 1	Band 2	
	101-200 kWh/month	> 200 kWh/month	
6.6-19.8	USD 0.21-0.23/kWh	USD 0.25-0.27/kWh	
Post-Paid Tariffs			
Social Tariffs (2 wires 5 Amps)			
Band 1*	Band 2*	Band 3	Band 4
1-50 kWh/month	51-100 kWh/month	101-200 kWh/month	>201 kWh/month
USD 0.11/kWh	USD 0.18/kWh	USD 0.20/kWh	USD 0.24/kWh
Normal Tariffs (2 Wires > 5 Amps and 4 Wires Meters)			
Band 1	Band 2		
1-200 kWh/month	> 201 kWh/month		
USD 0.20/kWh	USD 0.24/kWh		

Source: EDM S.A. (2018)

\*Bands 1 and 2 for social tariffs do not pay value added tax.

Notes: Amp = ampere; kWh = kilowatt hour; kVA = kilovolt-ampere. Apart from the social tariffs and consumption below 50 kWh/month, tariffs are particularly high in Mali given the high generation costs from thermal power stations and, to some extent, management issues resulting in significant technical and non-technical losses.

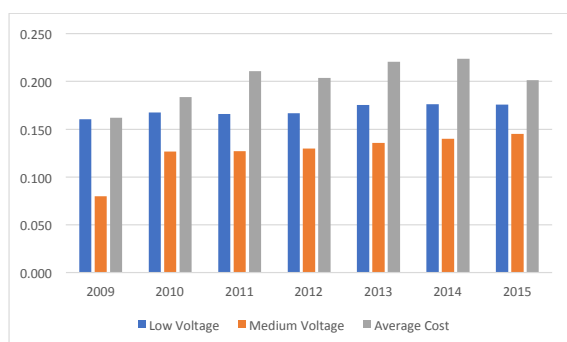


## Tariffs

Further to the penetration of pre-paid meters, EDM has two broad categories of tariffs, pre-paid and post-paid. Tariffs depend on several parameters (e.g. consumption, voltage and subscribed power) for each category. Table 3, below, gives an overview of the EDM's electricity tariff.

In 2014 and 2015, average production costs per kWh reached USD 0.23 and USD 0.20, respectively, which is significantly high (See Figure 10). Average selling prices also are excessive, although they remain far below average production costs for low, medium and high voltage. The fuel used for the generation of power and end-user tariffs alike are subsidised by the GoM. In 2015, the total subsidy received by EDM amounted to USD 106.7 million in 2014; 2014, USD 78.5 million in 2015 and USD 62.9 million in 2016. High tariffs offer opportunities for renewables and explain, to a large extent, the development of solar PV projects.

**Figure 10.** Evolution of EDM's average production costs and low voltage and medium voltage tariffs (USD/kWh)



Source: adapted from EDM Annual reports  
Note: kWh = kilowatt hour.

**Table 4.** Potential capacity and electricity generation from Mali's agricultural residues, 2010-50

	2010	2020	2030	2040	2050
Harvesting residue (metric tonnes)	10.8	13.7	17.4	21	25.3
Processing residue (tonnes)	1.5	2	2.5	3.0	3.6
Residue demand for livestock (metric tonnes)	2.5	3.0	3.6	4.6	5.9
Residue available for bioenergy (metric tonnes)	9.9	12.7	16.3	19.4	23.0
Residue available for bioenergy (quadrillion joules - primary @ 15 megajoules/kilogramme)	148	190	245	291	345
Power generation (gigawatt hour @ 25% conversion efficiency)	10 627	13 185	16 988	20 189	23 960
Installed capacity (gigawatt @ 90% capacity factor)	1.3	1.7	2.2	2.6	3.0

Based on IRENA estimates

Notably, this is the theoretical potential for electricity installed capacity and generation. Further analyses must be carried out to identify agricultural residues that could be tapped sustainably and cost effectively.

## 2.4. Renewable energy potential and use

### Biomass

Biomass derives from forest resources and agricultural residues, among others. In terms of the former, Mali's ecological diversity includes forest situations that vary from shrub savannahs in the north; the tiger bush that covers 25% of the South; and the forests of the Sudan-Guinean zone in the west. The national forest area is estimated at 100 million hectares (ha), from which approximately 32 million ha comprise the bulk of woody resources. The area under controlled exploitation is in excess of 350 000 ha. Forest areas and their productivity are in perpetual decline, mainly as a result of wood fuel consumption, pastoralism and forest clearance for agriculture (SIE, 2014).

According to Mali Forest Information and Data, the exploitation of wood fuel and charcoal, the main sources of household energy, is estimated at 5 million tonnes a year (i.e. exploitation of 400 000 ha). These figures are expected to exceed 7 million tonnes, or 560 000 ha, in the near future. The main challenge is to ensure the sustainable use of this resource which should include partial fuel switching to modern energy sources to keep pace with the productivity of natural forests.

With regard to agricultural residues, IRENA's database provide figures for these in terms of capacity and electricity generation potential throughout the country (See Table 4). These are based on energy conversion, capacity factor and harvest growth assumptions until 2050.

## Biofuels

In Mali, biofuels encompass bio-ethanol from the sugarcane industry as well as jatropha oil. Deployment targets for both products are highlighted in Table 5.

Expectations from biofuels, particularly with regard to jatropha are being called into question at the national level for a series of reasons, notably their vulnerability to market externalities as well as low yields which have compromised the cost effectiveness of the entire value chain. Furthermore, the overall reduction in oil price levels since 2013 has affected the competitiveness of biofuels as an alternative.

## Lower oil prices have affected the competitiveness of biofuels

**Table 5.** Mali's biofuel blending targets, 2010-30 (%)

	2010	2020	2030	2040	2050
Ethanol share in gasoline consumption	0.19	10.83	11	21	25.3
Biodiesel share in diesel and distillate diesel oil	0.02	4	5.4	3.0	3.6



## Hydropower

Hydropower currently accounts for a significant share of installed capacity and electricity generation. There remains, however, considerable untapped potential, some of which require further assessment while others are in the process of being developed. Hydroelectric potential capacity is estimated at 1050 MW, with an annual average energy generation of approximately 5 000 GWh. The following table summarises the status of Mali's hydro power potential.

Considerable  
hydropower potential  
remains untapped

**Table 6. Status of Mali's hydropower potential**

CURRENTLY UNDER DEVELOPMENT			
Hydropower Plant	Capacity (megawatt)	Generation (gigawatt hour)	Reservoir Capacity (cubic metres)
Taoussa	20	100	3 150 000
Sotuba II	6	20-30	Run-of-river
Markala	10	45	175 000 000
Kénié	42	188	Run-of-river
Gouina	140	320	Run-of-river
<b>Total</b>	<b>218</b>	<b>673-683</b>	
PRE-FEASIBILITY			
Hydropower Plant	Capacity (MW)	Generation (GWh)	
Labezanga	14-84	67	
Gourbassi	13	104	
Moussala	30	160	
Galougo	285	1 520	
<b>Total</b>	<b>342-412</b>	<b>1 851</b>	
UNDER INVESTIGATION			
Hydropower Plant	Capacity (megawatt)	Generation (gigawatt hour)	
Toubani	35	134	
Baoulé II	30	124	
Bakoye II	45	193	
Salambougou	10	40	
<b>Total</b>	<b>120</b>	<b>491</b>	

## Solar power

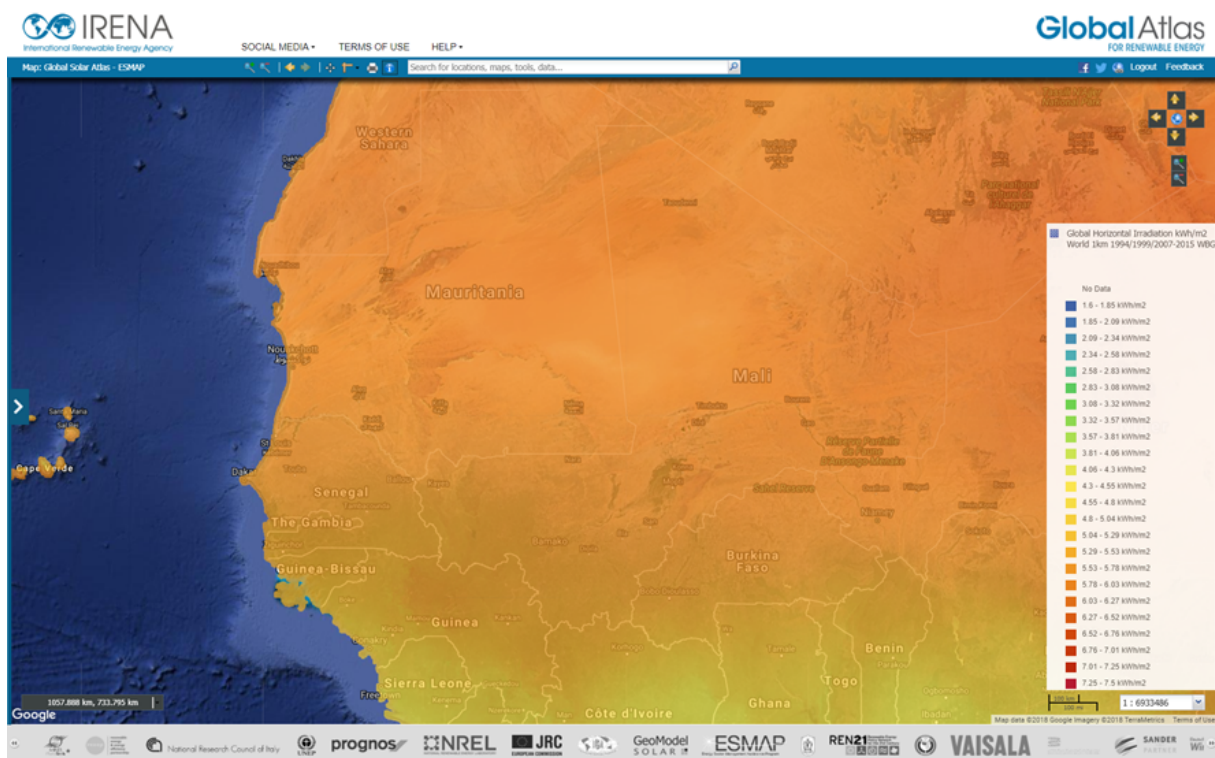
The values in Figure 11 indicate that there is substantial variation between north and south due to the seasonal differences in cloud cover and the position of the sun. In the south, however, where most activities and the population are located, average solar radiation data collected over a long period shows that the average solar daily radiation is above 5.5 kWh/square metre/day, which is sufficient to deploy solar applications that are cost effective.

IRENA has carried out a comprehensive study on the prospects for renewables in West Africa (IRENA, 2018b) to assess the energy potential. Beyond maps, the findings of the study highlight the future capacity and/or production of Mali's renewables.

Solar energy is disaggregated according to key technologies; that is, concentrated solar power and PV, whereby the former reflects 36.2 terawatt hours and the latter, 79.1 terawatt hours.

As expected, solar energy – particularly solar PV – has the most significant potential. According to the most reliable data (AER-Mali and National Energy Directorate (Direction Nationale de l'Énergie, DNE), total installed capacity in 2014 did not exceed 17 MW. This scenario, however, could dramatically change based on the global trend in the generation of solar PV.

Figure 11: Solar map of Mali

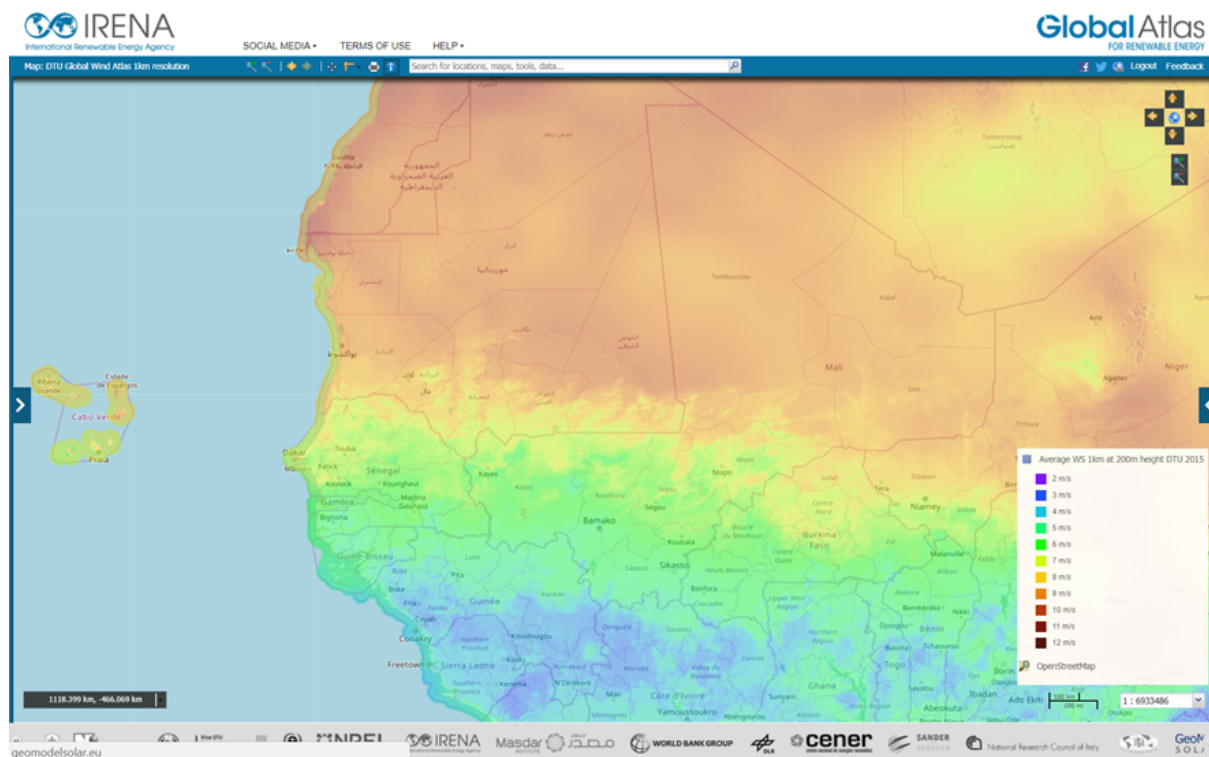


Source: IRENA: Global Atlas, Solar Irradiation Map of Mali, 'World Bank ESMAP 2018', Base layer 'Google Satellite Map 2018'.

Disclaimer: Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.



Figure 12: Wind map of Mali



Source: IRENA: Global Atlas, Average Wind Speed Map 1km at 200m height: 'DTU 2018', Base layer 'OpenStreetMap contributors 2018'  
 Disclaimer: Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.

### Wind power

Wind energy resources, particularly in the south, are not as promising as solar (See Figure 12). Wind speeds of 5 metres/second are generally considered to be the lower limit for the economically feasible exploitation of wind resources.

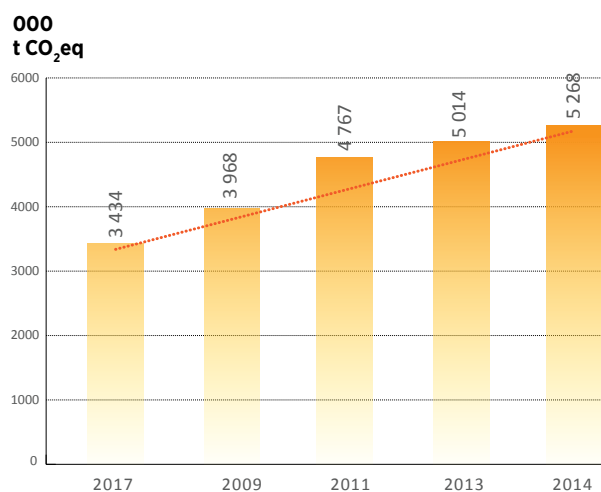
Wind speeds greater than 5 metres/second prevail in the northern part of the country at above 16 degrees' latitude, including in the towns of Timbuktu and Gao. Due to the low population density in those areas, however, demand will be low. Moreover, the critical political and security situation affecting the north of Mali will be a determining factor in the development of wind projects.

## 2.5. Energy sector and climate change

Mali has committed to address climate change by having become, in 1994, a signatory to the United Nations Framework Convention on Climate Change and, in 1999, the Kyoto Protocol. Mali's total greenhouse gas (GHG) emissions, expressed in CO<sub>2</sub>eq, remain rather low, amounting to 0.06% share of world total emissions (GoM, 2015). Within the framework of the three national communications of Mali on climate change (GoM, 2000; MEA, 2011; GoM, 2015), detailed calculations for GHG emissions were carried out according to the methodology of the Intergovernmental Panel on Climate Change.

These three communications, together with Mali's Nationally Determined Contribution (NDC) (GoM, 2016), establish that energy is the sector with the highest GHG emissions and increasing. Over the 2007-14 period, emissions from energy production and consumption have increased from 3.43 million tonnes CO<sub>2</sub>eq to 5.26 million tonnes CO<sub>2</sub>eq, averaging a 6.4% annual increase (Figure 13).

Figure 13: Greenhouse gas emissions in Mali's energy sector, 2007-14

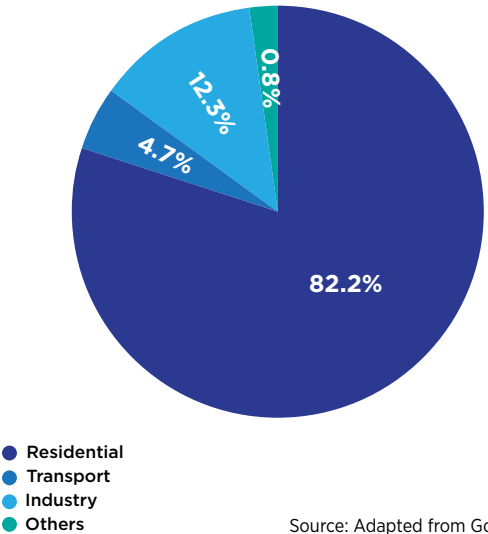


Adapted from GoM (2015).

Over the 2007-14 period, GHG emissions have risen sharply, mainly as a result of the increase in energy consumption. GHG emissions per capita, however, remain relatively low compared with many other African countries. Owing to its forest cover, Mali is a key net carbon sink and as such, the sustainable development of forest resources is vital for the nation to maintain its positive contribution in carbon sequestration.

With regard to energy sources, biomass accounts for the bulk of Mali’s total primary energy supply. Furthermore, this sub-sector is characterised by significantly low efficiency for energy transformation (wood to charcoal) and use. As a result, the residential sector - and main consumer of biomass - is responsible for over 82.2% of GHG emissions in the energy sector. Emissions from energy industries, particularly the power sector, account for less than 5% (Figure 14). Managing the future carbon footprint of the energy sector with a higher penetration of renewables in the electricity mix and the sustainable use of biomass would limit the increase of GHG emissions in Mali.

**Figure 14: Breakdown of Mali’s greenhouse gas emissions from energy consumption (%)**



Source: Adapted from GoM (2015).

In terms of power generation, Mali still relies heavily on hydropower due to its substantial potential,<sup>8</sup> already partially tapped. To cope with increasing electricity demand, feasibility studies have been undertaken to further utilise hydro potential. As shown in Table 6, a total of 218 MW of generation capacity is currently being developed, while 342-412 MW is at the pre-feasibility stage. This cumulative generation will add up to 2 504 GWh to the country’s electricity generation, thereby meeting over two-thirds of incremental electricity demand, estimated to grow by 3 777 GWh between 2017 and 2030 (IRENA, 2018b).

This strong focus on hydropower, nevertheless, fails to take into consideration key features and factors that have an impact on the development of this source of energy, such as the hydrological trends in the Niger Basin which continue to impact the performance of the hydropower installations it hosts. Historical data collected in Koulikoro (Upper Niger)<sup>9</sup> and in the upstream basins shows a high inter-annual flow variability that has occurred since 1907, as well as a strong decrease since 1970. In addition, this trend is coupled with a decrease in the groundwater level of tributary rivers, resulting in a runoff deficit (Mahé et al., 2011).

The Niger Basin is located in a region that is prone to droughts at four to six-year intervals, as evidenced from the close correlation between the Standardized Precipitation Index (SPI),<sup>10</sup> Standardized Precipitated and Evapotranspiration Index (SPEI)<sup>11</sup> and Standardized Runoff Index<sup>12</sup> shown in Figure 15. These indices track the evolution between 1961 and 2012.

<sup>8</sup> Mali is home to two river basins, the Niger River and the Senegal River. For this study, however, only data from the Niger River has been largely considered, since it crosses the country from west to east for a length of 1 700 km. Information has been more readily available from the Niger Basin Authority.

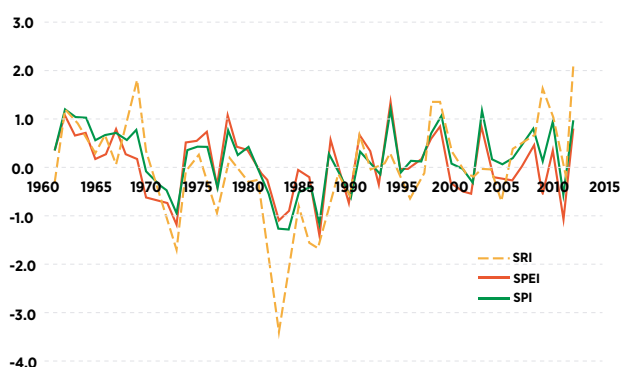
<sup>9</sup> The Niger River Basin comprises four distinct sections; these are the Upper Niger, Inner Delta, Middle Niger and Lower Niger.

<sup>10</sup> SPI is an index characterising meteorological drought on a range of timescales. On a short timescale, the SPI closely relates to soil moisture, while at longer timescales, it relates to groundwater and reservoir storage.

<sup>11</sup> The SPEI is an extension of the SPI, taking into account precipitation and potential evapotranspiration (a combination of evaporation and crop transpiration) in determining drought. Thus, unlike the SPI, the SPEI captures the main impact of increased temperatures on water demand.

<sup>12</sup> The SRI is a hydrological drought indicator, based on an assessment of the runoff (or streamflow) of a given basin, usually spreading over a specific period of time.

**Figure 15: Drought patterns based on observed indices between 1961 and 2012**



Source: Oguntunde et al. (2017).

Moreover, the level of rainfall (SPI) is projected to decrease until at least the year 2100. For example, the region of Sikasso, the region receiving most rainfall in the country, will experience a reduction in average rainfall per annum from 1 000 millimetres in the 1960-90 period to 850 millimetres in 2100 (DNM, 2007).

## 2.6. Drivers for renewable energy deployment

In light of the energy context described in previous chapters, many drivers exist to stimulate actors to support the deployment of renewable energy technologies in Mali. Aspects such as improved access to modern energy services, improved energy supply reliability, climate change mitigation and adaptation and the creation of local economic value and jobs are few examples. In fact, Sustainable Development Goal 7 which aims to “Ensure access to affordable, reliable, sustainable and modern energy for all”, has proved to have strong linkages with other SDGs; and “increasing substantially the share of renewable energy in the global energy mix by 2030” also is one of its targets. Mali’s National Renewable Energy and Energy Efficiency Action Plan highlights the country’s ambition to decrease its reliance on fossil fuels and to put the country on a low-carbon development pathway.

### Improved access to modern energy services

In Mali, less than half of the population has access to electricity, whereas in rural areas access is limited to only 16.7% of the population. In terms of modern fuels, access is extremely low, at only 2% and 3% for rural and urban areas, respectively. Energy access is widely recognised as essential to improve economic welfare.

Access to reliable, cost-effective and environmentally sustainable energy through renewable energy technologies can have a multiplier effect on development, such as reduced health effects, improved livelihoods, poverty alleviation, job creation, gender equality and enhanced access to water and food. These crosscutting impacts of renewables are also at the heart of efforts to achieve the Sustainable Development Goals. Renewable energy has proven its case in providing reliable and sustainable access to power to over 146 million people through off-grid systems by 2016.

### Electricity supply diversification and reliability

At present, thermal and large-scale hydropower plants are the main sources of electricity supply on the national grid. Renewable energy could provide the most competitive form of power in Mali due to today’s advanced technological reliability, declining technology costs and high resource potential. As explained earlier, the strong level of climate vulnerability of Mali’s hydropower-based power supply system also emphasises the need for diversification in the power supply. As shown in Box 2, with the examples of Brazil and Colombia, non-hydro renewables can play a strong role in adapting to climate-induced hydrologic fluctuations that affect power systems that comprise a large share of installed hydropower capacity.

### Socio-economic value creation

With 11 million jobs created worldwide so far, renewable energy is a catalyser for new employment opportunities. This is especially true in a country traditionally dominated by conventional sources of energy supply. It provides new avenues for technological innovation and the opening of new sectors for economic value creation.

### Low-carbon development

The combustion of fossil fuels and traditional use of bioenergy is a major source of local air pollution, with sulphur dioxide, nitric oxide and microparticles as some of the main pollutants. These pollutants can cause adverse human health effects, although they also can reduce agricultural yields, devastate forests and fisheries (acid rain) and damage buildings and infrastructure. The majority of adverse impacts, however, are evident on human health. Renewables also offer the most prominent low-carbon solution to meeting Mali’s climate targets. The country has committed to reducing its GHG emissions by 35% by 2030 compared to the 1990 base year in the NDC under the Paris Agreement. The NDC already emphasises use of alternative and renewable energy sources to achieve this target.



**Box 2: Diversification towards non-hydro renewables for climate change adaption in the power sector: Brazil and Colombia**

South American countries with high shares of hydropower in their electricity mix have been dealing with the concept of diversification of primary energy sources in recent years. The examples of Brazil and Colombia, where hydropower has accounted in each for over two-thirds\* of total grid-connected installed power generation capacity in 2018, illustrate how non-hydro renewables contribute to electricity supply security and affordability in light of changing hydrologic behaviour.

Among the four interconnected subsystems in which the Brazilian power system is divided, the northeast best illustrates the role of diversification towards non-hydro renewables in the context of changing hydrologic behaviour. The figure below indicates the decreasing trend in water inflows to the hydropower plants of the northeastern sub-system since late 2012. Although scientific discussions continues in Brazil on whether or not these decrements can be traced to climate change or to long-term climatic cycles, one thing is certain: the increase in wind power production (and, more recently, solar power output) in the northeast has contributed decisively to the local balance between load and generation. In its absence, production costs and emissions associated with local thermal generation would have risen further.

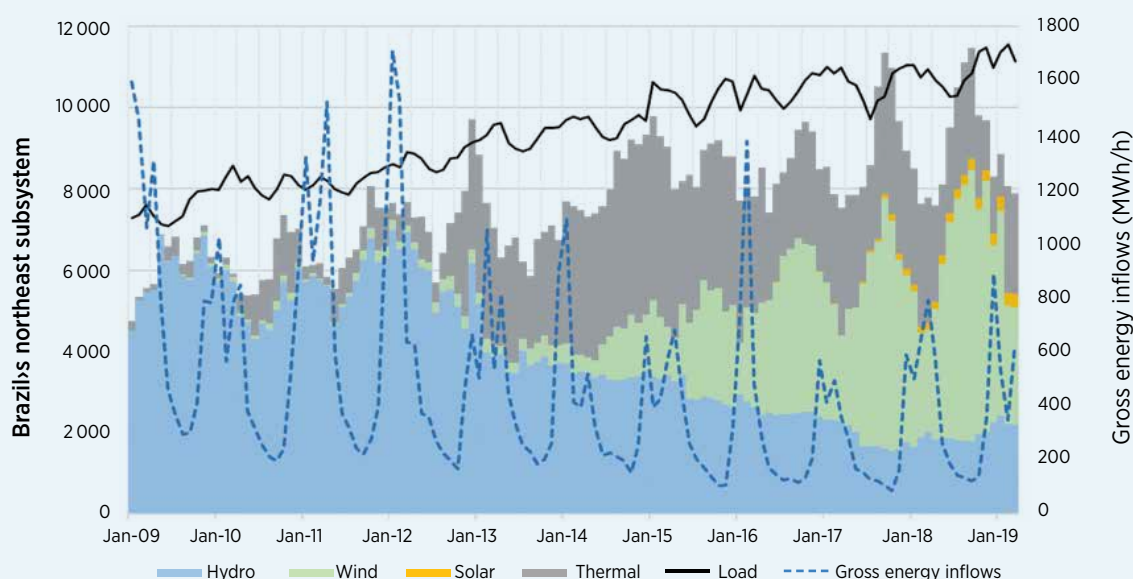
Other complementarity mechanisms between hydropower and renewables are also essential to Brazil's northeast sub-system. The above scenario clearly depicts the partial seasonal complementarity between wind power output and water inflow to reservoirs in the region, with average monthly wind power output peaking in September and October – not among the most humid months.

While not visible in the graph, the flexible output of hydropower also plays a role in counteracting the short-term variability of wind and solar power resources in the northeast. Local resources and imports from Brazil's southeastern system account for the largest share of installed hydropower capacity in the country.

In Colombia, the matter of diversification of primary resources for electricity generation as an adaptation strategy against climate change has caught the attention of governmental institutions, at least since 2013. Colombia's Energy Mining Planning Unit (Unidad de Planeación Minero Energética, UPME), the governmental executing agency for planning studies relating to the energy sector, issued its first assessment on the subject that same year. Other adaptation measures assessed in the study target demand-side management and the conservation of river basins.

Colombia has come a long way since the first studies were published. In the following year, in 2014, the government issued Law #1715 establishing guidelines for the deployment of renewable energy in the Colombian power system. This legal instrument explicitly points to diversification of energy supply as one of the diversification drivers towards other renewable energy sources. The process culminated in March 2018 with the issuance of Decree #570/2018 by the Ministry of Mines and Energy (Ministerio de Minas y Energía, MME). This decree, de facto, establishes auctions aimed at contracting wind and solar power projects in Colombia, while listing the “resiliency of the electricity generation matrix to climate change and climate variability” as one of the reasons for doing so.

\* Including small-scale hydropower plants, 67.5% in Brazil by late 2018; 68.3% in Colombia by early 2019



Source: Prepared by IRENA with data from the National Electricity System Operator (Operador Nacional do Sistema Eléctrico), Brazil.



Photograph: Shutterstock



# 3. ENABLING ENVIRONMENT FOR RENEWABLE ENERGY

## 3.1. Key energy stakeholders and institutional structures

Institutions involved in the management of the energy sector include Mali's Ministry of Energy and Water and its affiliated entities. Table 7 summarises the key institutions and their main tasks.

**Table 7: Key energy institutional arrangement in 2016: Mali**

Institution	Key task	Remarks
Ministère de l'Énergie et de l'Eau	Responsible for policy formulation, promotion, co-ordination, monitoring and evaluation	Main structures : Direction Nationale de l'Énergie ; Direction Nationale de l'Hydraulique
Agence Malienne pour l'Énergie Domestique et l'Électrification Rurale	Responsible for rural electrification	Off-grid energy service provider, regulating generation systems below 250 kilowatts
Agence des Énergies Renouvelables du Mali	Promotes widespread use of renewable energy in the country to enable sustainable socio-economic development	Created from a redefinition of the mandate of the former National Center for Solar and Renewable Energy.
Agence Nationale de Développement des Biocarburants	Formulates and implements national biofuels policy	Ensures the regulation of the bioenergy sub-sector
Commission de Régulation de l'Électricité et de l'Eau	Regulates electricity and water sectors	Independent from government operators, with juridical powers and financial autonomy. Under the supervision of the Prime Minister's Office.
Agence pour la promotion des investissements au Mali	One-stop shop for all procedures to setting up companies, assisting investors and issuing approvals relating to the Mali Investment Code	Its institutional footing changed in 2019 when it moved from the Ministry of Investment to the Prime Minister's Office
Agence de l'Environnement et du Développement Durable	Focuses on biodiversity preservation, fights against desertification and climate change	Home to the Mali Green Fund and a key player in the elaboration and implementation of the Nationally Determined Contribution.

## 3.2. Energy policy and regulatory frameworks

Mali's National Energy Policy (NEP) dates back to 2006 and aims to contribute to its overall sustainable development through the provision of cheap and reliable energy services, in order to increase electricity access and to promote its underlying socio-economic benefits. Centred around the guiding principles of decentralisation, liberalisation, competitiveness and public-private partnerships, its key objectives are (i) to meet energy needs at the most adequate quality, quantity and cost; (ii) to ensure protection against the risks of inadequate energy services; (iii) to strengthen the capacities of the relevant stakeholders of the energy sector at the levels of policy, operations and monitoring; and (iv) to strengthen international co-operation in the energy sector. Table 8 gives an overview of renewable energy objectives and measures contained in the NEP.

The NEP was supplemented in 2009 by the National Energy Sector Policy Letter, which specified further the objectives of the policy, notably through measures such as restructure of the national power utility and tariff reforms; development of additional hydropower and thermal capacity; and reinforcement of the power system's overall infrastructure with, in particular, the strengthening of interconnections with neighbouring countries,

At the sub-sector level, a National Strategy for the Development of Renewable Energies (2006) and a National Strategy for the Development of Biofuels (2008) have been formulated. These embody the strong political will to develop indigenous energy sources. The NEP and the previously mentioned national energy sector strategies in Mali are being updated to incorporate any specific innovative approaches that support the rapid development of the sector.

**Table 8: Mali's National Energy Policy: Renewable energy objectives and measures**

<b>OBJECTIVES</b>
1. Promote the widespread use of renewable energy technologies and equipment to increase the national share in electricity generation from less than 1% in 2004 to 6% in 2010 and 10% in 2015
2. Develop the biofuel sector, particularly in terms of jatropha, for various end uses
3. Create the best conditions for the sustainability of renewable energy services
4. Adapt sustainable financing mechanisms to renewable energy
<b>MEASURES</b>
1. Measure and develop national renewable energy resource potential
2. Disseminate extensively solar energy equipment in rural community centres
3. Promote biomass (e.g. briquettes, biogas, vegetable oil, alcohol) in agricultural and agro-industrial areas
4. Promote local content in projects, including the use of locally manufactured and assembled components
5. Promote research and development for non-mature renewable energy technologies
6. Ensure the systematic coupling of renewable energy programmes and projects with income-generating activities
7. Improve access to local, national and international financial institutions
8. Support local initiatives that promote the renewable energy sector
9. Develop local skills for small- and medium-size enterprises in the renewable energy sub-sector
10. Develop efficient systems to operate and maintain renewable energy equipment in rural and peri-urban areas
11. Decentralise, geographically, entities responsible for sales and after-sale services of renewable energy equipment
12. Adopt policy instruments to promote renewable energy, such as tax and customs incentives
13. Promote the exchange of experience with other countries and become involved in regional energy programmes.

Source: National Energy Policy



The Authority of ECOWAS Heads of State and Government, in July 2013, expressed its commitment to provide access to sustainable energy services in West Africa by adopting a ground-breaking policy, the ECOWAS Renewable Energy Policy. This policy aims to increase the share of renewable energy in the region's overall electricity generation mix to 23% by 2020 and 31% by 2030 (ECREEE, 2013).

This was later translated into the National Renewable Energy Action Plan (NREAP) for the 15 member states. The objectives of the NREAPs fed later into the formulation of Sustainability for All (SEforALL) Action Agendas. In Mali's case, the NREAP was developed in 2015, building on the NEP's guiding principles. This action plan (GoM and ECOWAS, 2015) details the targets and measures for grid and off-grid renewable energy, as well as efficient cookstoves. Milestones are set for 2020 and 2030, beginning from a 2010 baseline. Table 9 summarises the NREAP's key targets for grid-connected renewables.

In Mali, a decline is expected in the relative value of the share of renewables in the electricity mix due to an increase of electricity imports (generated from non-renewable sources) from the regional market (Côte d'Ivoire, Ghana, Guinea and Nigeria). For non-grid connected renewables, systems are broken down into mini-grids, including hybrid and other systems, as summarised in Table 10.

With regard to Mali's regulatory framework, the electricity sector is governed by Order No.00-019/P-RM of 15 March 2000 and its amended Implementing Decree No. 00-184 /P-RM of 14 April 2000, which liberalises the power sector. It also defines the following guidelines, among others:

- general pricing;
- tendering processes;
- procedures for terminating concessions and
- authorisations of permit holders;
- definition of technical and financial management
- ratios; and
- grid connection fees.

The tendering process guidelines, described in the abovementioned order, were reinforced by Law No. 2011-084 of 29 December 2011. Furthermore, Decree No. 2014-0816/PRM of 27 October 2014 suspending the import levy of VAT, fees and taxes on solar equipment and renewable energy, comes to an end and should be subject to extension for a new five-year period.

**Table 9: Targets for Mali's grid-connected renewables, 2010-30**

	2010	2020	2030
Installed capacity for non-hydro RE (MW)	6.3	150.7	201.8
Non-hydro RE* of total installed capacity (%)	2.3	13.8	8.3
Installed capacity for all RE targets including hydro** (MW)	156.5	660.40	1 416
RE targets, including hydro** of total installed capacity (%)	57.71	61.44	58.25
Non-hydro RE* production in the electricity mix (%)	3.12	12.11	8.63
RE targets, including hydro** production in the electricity mix (%)	65.09	49.35	36.88

Source: Adapted from GoM and ECOWAS (2015).  
RE = renewable energy; MW = megawatts

\* RE targets, excluding small and large hydro (> 30 megawatts).  
\*\* RE targets, including small and large hydro.

**Table 10: Targets for Mali's off-grid renewables, 2010-30**

	2010	2020	2030
Mini-grids, renewable and hybrid (megawatt)	0.094	8.063	8.063
Total Installed capacity for all other systems (megawatt)	20.27	234.72	605.01
Rural population with electricity access from renewables (mini-grid and isolated systems) (%)	1.7	36.9	66.64

Source: Adapted from GoM and ECOWAS (2015).

### 3.3. Investment and finance

Financing the renewable energy sector is a key challenge in most sub-Saharan African countries as, while the initial investment may be high, operating costs are low. In least-developed countries such as Mali, the public sector often lacks sufficient financial means to invest in energy generation.

To attract investment mainly from outside the country, Mali has adopted an investment code in 2012,<sup>13</sup> which provides a number of benefits to private investors to develop the electricity sector, such as the waiving of minimum investment threshold requirements. Investment authorisation requests for approval are now processed through a single online database that processes the documents within five days. In addition, further incentives are granted, as follows:

- Non-discrimination: Foreign investors will benefit from the same rights and privileges as do local investors.
- Repatriation of funds: Repatriation of the entire capital and profits by individuals and companies.
- Foreign property: Foreign companies are able to maintain the entire capital
- Dispute resolution: Mali is a member of the International Centre for Settlement of Investment Disputes Investments, the Common Court for Justice and Arbitration (CCJA), and the Organisation for the Harmonization of Corporate Law in Africa (OHADA)

- Investment guarantee: Investments are guaranteed by Article 15 of the treaty that establishes the Multilateral Investment Guarantee Agency.

In addition, investors will be able to benefit from reduced customs tax, value added tax, and taxes that relate to investments above USD 500 000 (Table 11).

Although Mali is overall ranked at the 145th place in 2019 (143 in 2016) in the Ease of Doing Business report, a significant progress was achieved to register a company. For this indicator, Mali is ranked at the 110th place in 2019 compared to 172th in 2016 (World Bank, 2017b). To register a company, the applicants submit all documents and forms at the API's one-stop shop. It takes only five days to complete the procedure. Since March 2015, the database regularly publishes a notice of incorporation of new companies on its website. The cost of the publication is included in the notary fee. In terms of renewables, the agency publishes investment data that relates to energy service companies tapping into Mali's energy potential.

Budget allocation and investment in the renewable energy sector, nevertheless, remains low compared with the country's needs and potential. The budget allocated by the Government of Mali (GoM) to the renewable energy sub-sector rose from USD 6.7 million in 2010<sup>14</sup> to USD 21.2 million in 2018. This is projected to rise further to approximately USD 70 million by 2020 (MEF, 2018). Despite the increase, the budget remains modest especially when considering that it takes into account the staff wages of those public institutions involved in renewable energy.

**Table 11: Investment code and incentives for Mali's potential investors**

Investment category	Investment amount (USD)	Customs exemption	Local value added tax exemption	25% reduction tax	Exemption from minimum lump sum tax
A	25 000 ≤ Investment ≤ 500 000	6.3	150.7	201.8	5 years
B	500 000 < investment < 2 000 000	2.3	13.8	8.3	8 years
C	≥ 2 000 000	156.5	660.40	1 416	10 years

Source : Agence pour la Promotion des Investissements, Mali.

<sup>13</sup> Law No. 2012-016 of 27 February 2012. This is the sixth investment code; the first goes back to 1991, currently being updated under the leadership of API-Mali

<sup>14</sup> Budget allocated to the former National Centre for Solar Energy and Renewable Energies (Centre National de l'Énergie Solaire et des Énergies Renouvelables, CNESOLER) and the National Agency for Development of Biofuels (Agence Nationale de Développement des Biocarburants, ANADEB) (Ministère de l'Économie et des Finances, 2018)

Most projects that previously were undertaken have been financed by various donors such as multi-lateral and bilateral development and co-operation organisations (e.g. African Development Bank, European Union, United Nations Development Programme and World Bank), as well as national and international non-government organisations (e.g. Mali Folkecenter, SNV Netherlands). By and large, the financial and technical support that is provided by each organisation has targeted specific areas (Table 12).

Apart from the technical and financial support provided by the bilateral and multilateral organisations, the GoM has set up mechanisms and incentives to speed up the deployment of renewables. A key incentive has been issuance of Decree No. 2014-0816/P-RM of 27 October 2014 that suspends, for five years, until 2019, value added tax on renewable energy equipment imports.

With regard to rural electrification, a major incentive aside from the support from AMADER is Mali's Rural Electrification Fund (REF) that was created in 2000 under Decree 00-019/P-RM.

The fund aims to promote the country's rural electrification agenda through various pilot projects, communication and awareness-raising campaigns. More specifically, it provides financial support, among others, for feasibility studies, subsidies to upfront investment costs, and guarantees for rural electrification schemes. Resources of the Rural Electrification Fund are provided by grants from development partners, donors, loans and from the renewal of grant authorisations from AMADER. In terms of mechanisms, AMADER only allocates investment subsidies and, as far as possible, complies with the principles of competition relating to grant awards. Projects below 50 kW, however, are not subject to competition, given their small size.

On the basis of the BOOT (build, own, operate and transfer) schemes and the procurement activities already under way, an additional PV capacity of 158 MW could be added in the short- to mid-term for an approximate investment of USD 182 million. Apart from solar PV, three BOOT schemes have been signed to deploy 61 MW of hydropower capacity on three sites for a total investment of USD 210 million.

**Table 12: Institutional support of Mali's energy sector and areas of renewable energy concentration**

AREAS	INSTITUTIONS	TYPE OF SUPPORT
Energy sector reform	African Development Bank, European Union, World Bank,	Scaling Up Renewable Energy Programme
Renewable energy potential	DANIDA	Mapping renewable energy potential
Solar energy	United Nations Development Programme	Transition from fossil multifunctional to solar
Solar and hybrid	World Bank	Rural electrification
Solar energy	West African Economic and Monetary Union	Subsidy of more than USD 5 million for implementation of a photovoltaic electrification programme (Phase 1); construction of hybrid solar/diesel power stations supplying mini-grids in 13 rural communities (Phase 2)
Energy efficiency	West African Development Bank	Financing of large-scale dissemination of improved stoves through carbon funds*

Although solar PV projects are at various stages of development, a sharp discrepancy in cost per installed megawatt has occurred between projects (e.g. USD 1.6m/MW in the case of Scatec Solar and USD 2.1m/MW for Akuo Energy). For ongoing procurement activities, however, investment per installed capacity is much lower and is in line with international downward price trends. With regard to Scatec Solar, it is not a new entrant into Mali. Scatec prepared an initial feasibility study in May 2011 for a 10 MWp PV power plant in Mopti.

The construction of Mali's utility-scale projects has yet to begin, despite the fact no licences were issued and power purchase agreements (PPAs) signed for several years. A major challenge lies in the provision of credit guarantees, the shortage of which has, to a large extent, limited the funding of renewables projects in sub-Saharan Africa to large bilateral and multilateral financial institutions.

This is because foreign private actors primarily rely on their own funds and those of their financial partners to secure investment capital.

Banks are reluctant to provide loans to independent power producers (IPP) for fear they will not be serviced according to schedule if IPPs are no longer paid on time for the power they deliver. To overcome the financial constraint, lenders usually require a letter of credit to back payment obligations under a PPA to complement the host government's guarantees.

In most cases, however, the bank that provides the letter of credit will request up to 100% cash as collateral, usually provided by the utility. Most IPP projects are still pending since this liquidity requirement cannot be met by the utilities, given their financial situation. Innovative financing mechanisms must therefore be designed to speed up the implementation of mature renewable energy projects (Table 13).

**Table 13: Potential private investment in Mali's renewable energy sub-sector**

PLANT	TECHNOLOGY	CAPACITY (MEGAWATT)	INVESTMENT (MILLIONS OF USD)	STATUS
Scatec solar (Ségou region)	Solar photovoltaic (PV)	33	55	BOOT signed 2015
Akuo Energy	Solar PV	50	105	BOOT signed 2015
Sikasso area	Solar PV	50	55*	Procurement ongoing
Koutiala area	Solar PV	25	27*	Procurement ongoing
Markala	Hydro	13	35	BOOT signed 2010
Kénié	Hydro	42	120	BOOT signed 2015
Sotuba II	Hydro	6	30	BOOT signed 2015

Source : Agence pour la promotion des investissements au Mali (February 2017).

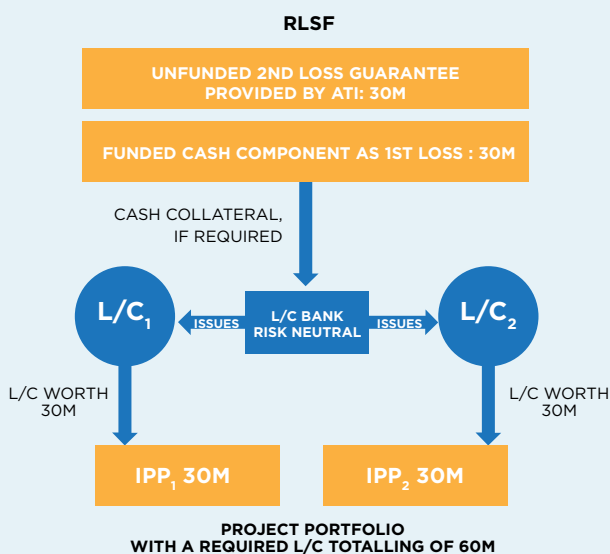
\*Estimate.

Note: BOOT = build, own, operate, transfer.



### Box 3: Regional Liquidity Support Facility

Initiated by Germany's KfW Development Bank, implemented by the African Trade Insurance Agency (ATI) and funded by the German Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, BMZ), the Regional Liquidity Support Facility (RLSF) enables a sustainable financing approach by providing utilities and commercial banks the collateral they require for power purchase agreements.



Sources: KfW (2017) and ATI (2016).

The facility's shareholders are 13 African member countries plus the African Development Bank. ATI is a multilateral insurer of trade credit and political risk investment (ATI, 2016). ATI issues a letter of credit to select banks for the IPPs that have been approved and backed by the facility. ATI also assesses each transaction to ensure that the project is fully supported by the utility and host government. The relevant mechanisms are illustrated in the figure below.

#### Eligible projects must comply with the following criteria:

- Installed capacity up to 50 megawatts (up to 100 megawatts in exceptional cases).
- Supported technologies that include solar photovoltaic, hydro, onshore wind, geothermal, biomass (i.e. waste-to-energy), co-generation (i.e. renewable feedstock).
- Sufficient support of the host government and utility.

The bank that issues the letter of credit is protected by the cash component that serves as a first-loss buffer. The second loss guarantee is provided by ATI and matches the component. When an independent power producer experiences payment delays, it can draw immediately from the letter of credit, thus enabling it to continue its debt repayment to its lenders.



Innovative financing mechanisms must be designed to speed up the implementation of mature renewable energy projects



Photograph: Mali-Folkcenter Nyetaa





## 4. EMERGING ISSUES AFFECTING RENEWABLE ENERGY DEPLOYMENT

Development of the renewable energy market is largely subject to Mali's natural resource assets and corresponding technologies to convert energy sources into services, as well as its regulatory environment in relation to the private sector. This chapter not only identifies the challenges and opportunities faced by Mali's renewable energy sector; it also covers the various resources, policy and regulatory frameworks, private sector involvement, and human capacities and skills necessary to develop current renewable energy technologies. The status of each subsector is reviewed, followed by the issues that need confronting.

The key issues are based on an initial analysis that follows the drafting of a background paper. They also arose from the exchange of information at the initial meeting on IRENA's Renewable Readiness Assessment (RRA) and from various bilateral meetings held in Mali with key local stakeholders.

### 4.1. On-grid renewables

Reliable, sustainable and affordable electricity is a prerequisite for transformative development. The grid remains essential to reach large numbers of people in a cost-effective way. To extend the national power grid is, by far, the most effective method to provide communities with power. Moreover, Mali's geographical location offers significant opportunities to enable it to play a key role in developing a regional power market.

The RRA process identified hydro, solar and biomass as the key sources for grid-connected power. There remain, however, fundamental issues that should be examined in terms of developing large-scale hydropower, such as the variability of the water regime in the river basins, as well as the effects of climate change. These can be addressed by deploying non-hydro renewable energy and overcoming the technical, institutional, resource and financial barriers that prevent the establishment of a stable and resilient power infrastructure.

#### **Diversify power supply through increased penetration of non-hydropower renewables**

As highlighted earlier, the power produced by Mali's energy sector accounts for a negligible portion of total GHG emissions. Despite this, however, the sector is threatened by the impact of climate change based on its heavy reliance on hydro. This makes it more compelling to prioritise and accelerate the deployment of renewable energy resources beyond that of hydropower.

Mali has identified, in its National Adaptation Programme of Action, the vulnerability to climate change of its energy sector. It ranks the sector as the third most vulnerable, following agriculture and health (DNM, 2007). Indeed, recent history evidences sharp differences in the generation of electricity due to variations in the rainfall between the average and dry years, as illustrated Table 14.

A 1% decrease in water flow results in an estimated 1.3 million kWh decrease in the generation of hydropower (NDE, 2011). At present, the deficit of hydropower generation installations is covered by an emergency thermal power supply, which have been playing an increasingly important role in the country's electricity supply mix, reaching up to 21.59% in 2014 (EDM, 2018), as shown by Figure 17.

The increasing use of Emergency Power Producers in the power mix results in an added financial burden on the public sector due to the heavy subsidisation of the fossil fuels as well as the end user tariff.

Emergency power producers (EPP) represented over 21% of the power generation mix in 2014, a time when the subsidy level exceeded USD 106 million. This compares with USD 63 million in 2016 when EPPs represented roughly 18% of the generation mix (EDM, 2016; EDM, 2017).

Furthermore, and despite their relatively short lead time, EPPs significantly contribute to GHG emissions.

In light of these challenges in developing and exploiting hydropower, as well as the presence of backup options that rely only on EPPs, the GoM has to consider alternative renewable energy technologies that will represent far more sustainable and cost-effective options (e.g. solar PV).

At a capacity factor of 18%,<sup>16</sup> an estimated 118 MW<sup>17</sup> of solar generation will be required to compensate for the Selingué, Sotuba and Manantali deficit of hydropower generation in the dry years. This is evident in light of the country's ever-increasing demand for electricity.

The investment cost of PV systems is rapidly declining. Driven by an 81% drop in the price of solar PV modules since the end of 2009 and a reduction in system costs, the global weighted average levelised cost of electricity of utility-scale solar PV has fallen 73% between 2010 and 2017 (IRENA, 2018a).

These reductions imply that residential and commercial grid-connected systems have significantly increased in attractiveness and that grid parity (i.e. parity between the cost of PV for these two systems and the retail price for household electricity) has been achieved - or is approaching achievement.

From an assessment undertaken by IRENA of the viability of solar as a backup capacity versus diesel-based emergency power generation, it was established that the southwestern region of Mali has the most suitable zones for solar power in terms of existing potential, grid infrastructure and load centres, among others. IRENA has calculated that only in that part of the country lies the opportunity to install up to 53 gigawatts of grid-connected solar capacity.<sup>18</sup>

**Table 14: Difference in electricity generation (average versus dry years) at Selingué, Sotuba and Manantali<sup>15</sup>**

	YEAR OF COMMISSIONING	AVERAGE YEAR GENERATION (GIGAWATT)	DRY YEAR GENERATION (GIGAWATT)	DIFFERENCE (GIGAWATT)	DIFFERENCE (%)
Sélingué	1980	224.7	198	26.7	-11.88
Sotuba	1966	38.6	37	1.6	-4.15
Manantali	2001	420	260	160	-38.10
Total		683.3	495	188.3	-27.56

Source: Senegal River Basin Development Organization (Organisation pour la Mise en Valeur du Fleuve Sénégal).

<sup>15</sup> Unlike Sélingué and Sotuba, the Manantali Dam is not located in the Niger River Basin; rather, it lies on the Senegal River. It has been added to this analysis because of the similarities of the climate change impacts across the two basins.

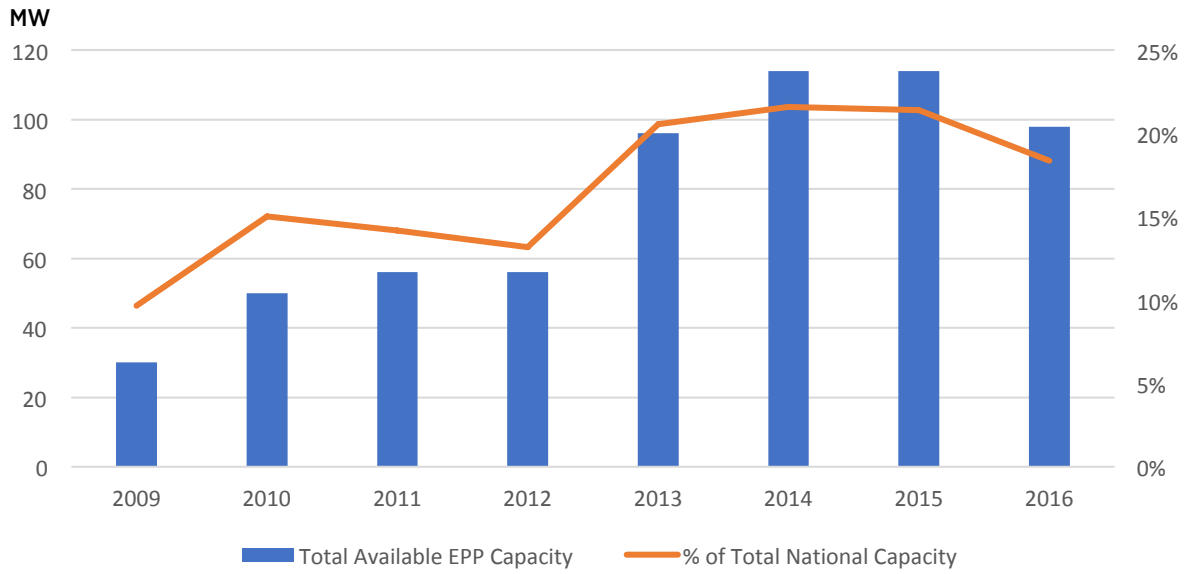
<sup>16</sup> Average capacity factor of the Ségou solar power plant (AfDB, 2016).

<sup>17</sup> Based on own calculation by dividing the difference in output of 118.3 GWh by the product of the average capacity factor and the number of hours in a year, which was converted into MW.

<sup>18</sup> In these calculations, 1% of the total suitable area up to 30 km from a transmission was assumed to be used for solar power generation.



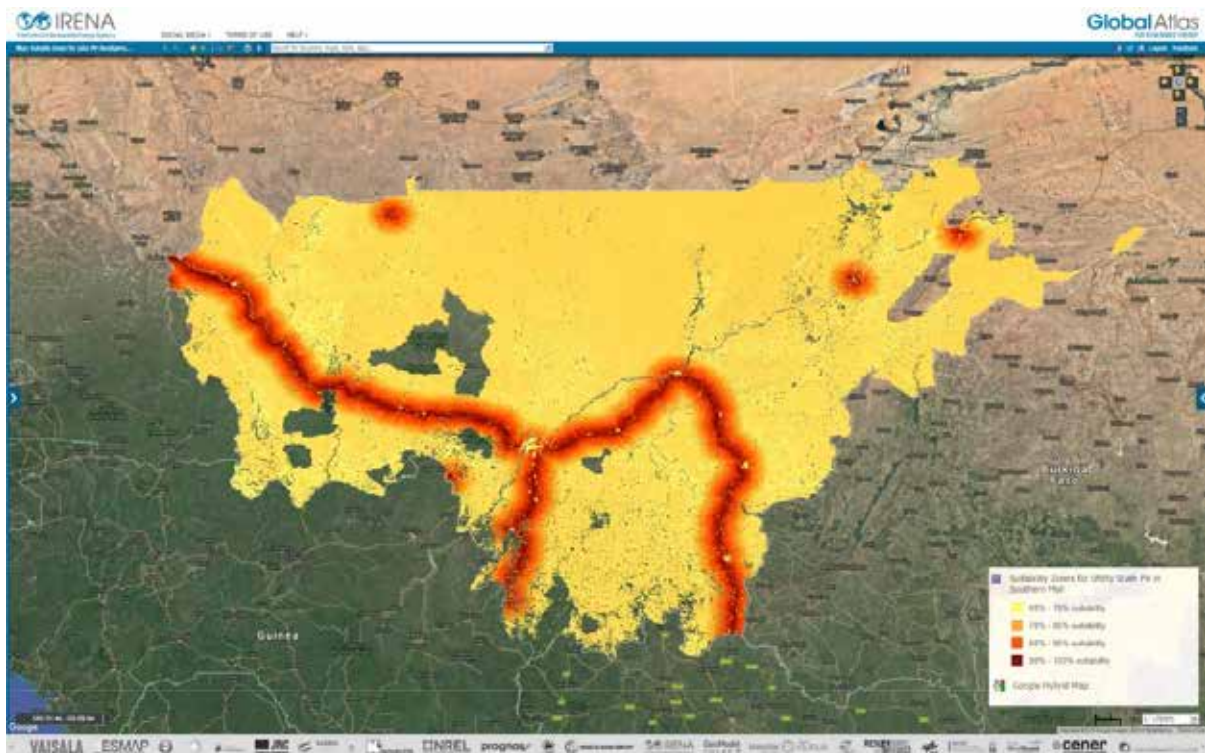
**Figure 16:** Aggregated installed capacity for Mali's emergency power generation (MW)



Source: EDM (2018).

Note: EPP = emergency power producer.

**Figure 17:** Suitability zones in southwestern Mali for utility-scale solar photovoltaic



Source: IRENA: Global Atlas, Suitability scoring and areas: 'IRENA 2018', Base layer, 'Google Hybrid Map 2018'.

Disclaimer: Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.



With regard to costing, IRENA has assessed the financial viability<sup>19</sup> of 11 solar sites located in the southwestern region of Mali, including Sélingué where there is a hydropower station.<sup>20</sup> The results of the Sélingué appraisal indicate that at a capital cost of 13% - comparable to prevailing regional market rates - a project would be achievable at a cost of approximately USD 217.96/MWh with a 90% confidence level in annual energy generation. Even if the confidence level were at 50%, the tariff would drop down to USD 195/MWh.

These cost figures are substantially lower than those of EDM's average generation at USD 280/MWh. They are also less than the cost of diesel-powered EPPs in Mali, which can be as high as USD 331/MWh.

#### Promote utility-scale solar photovoltaic

In light of the decline in costs and Mali's resilience to climate change, the government could well consider the rapid deployment of solar power. For that to occur, however, there are various recommendations offered.

- Conduct a thorough assessment of the current status and further development of hydropower resources in light of the hydrological projections of and water regime changes in the Niger Basin and Senegal Basins, its effects on the vulnerable economic sectors such as agriculture (food security) and health as well as the projections for electricity demand in the medium-to-long; and develop a hydropower development roadmap accordingly.

- Develop a power sector master plan that adequately captures sustainable and cost-effective renewable energy options, in line with the National Renewable Energy and Energy Efficiency Action Plans as well as the energy components of the 2014-2035 Optimal Investments Master Plan

- With the support of international partners such as the Green Climate Fund, Global Environment Facility and Sustainable Development Mechanism, develop and implement a long-term climate change resilience strategy that takes into account Mali's energy sector.

<sup>19</sup> IRENA's site assessment focuses on appraising the financial viability of solar and wind projects earmarked for development, in order to establish a benchmark fee for a bidding process in relation to the various sites. This will help local authorities and project developers alike to understand their economic rationale and the investment potential and return. The assessment is based on inputs from countries, such as the cost of capital, grid availability, geographic co-ordinates, income tax and installed capacity.

<sup>20</sup> Site selection is based on an official request from the GoM to IRENA.

### Untap the bio-energy potential for power generation

As highlighted in Chapter 2, Section 2.1, Mali has significant bio-energy resources that can lead to a paradigm shift in the structure of the power supply system. A country-wide, in-depth assessment of bio-energy resources and a policy framework are among the key initial steps toward better utilisation of resources.

### Assess the potential of various bio-energy resources

There has been neither a detailed appraisal of the country's bio-energy potential nor an assessment undertaken of the cotton and sugar industries to date. Such analyses, including the generation of energy, have been conducted only in relation to rice residues by Denmark's DANIDA. Such assessments should include a mapping of the various potential sources of bio-energy across the country, as well as a robust framework to support its use, especially in relation to power generation and, in particular, through the cogeneration of and waste-to-energy plants.

### Develop an overall bio-energy policy that takes into account other sectorial strategies

For power generation at a utility scale, an in-depth evaluation is required of the processing facilities for Mali's biomass feedstock (i.e. bagasse from sugar production and waste, used Mali's strong cotton industry). The example of N'Sukula - a sugar factory that applies bagasse to generate power for its own consumption as well as for the EDM grid - could be scaled up by adopting policies and incentives to the use of this resource.

In summary, an overall policy framework is required to support the mid- and long-term strategies of the agriculture and industry sectors, with a view to streamlining their approach towards modernising the use of forest resources and potentially creating a market for sugar and cotton residues and energy crops. Moreover, a bio-energy strategy and master plan should be developed that take into account an in-depth assessment of the potential for a sustainable supply of feedstock to generate power.

### Develop and adopt an electricity grid code

A grid code is a critical element in the management and operation of a power system. As renewable power requires flexible conditions for adequate integration, The grid code must take account of options that would allow renewable power integration without jeopardising the grid safety and stability (IRENA, 2016a).

Following RRA discussions, it was recommended that Mali develop and adopt a grid connection code that will, among others, permit third-party access to the grid in the case of IPPs. Mali also should provide guidelines and standards to accommodate renewable-based electricity.

Consultation with relevant stakeholders is crucial, since grid connection codes impact on all those involved in the power system. By engaging the relevant parties, codes will be able to be implemented without placing the system in jeopardy. At the same time, responsibilities can be fairly shared between the stakeholders. Furthermore, best practices should be drawn from frontrunner countries in terms of how to integrate a high share of variable renewable energy into power systems.

Another country's grid codes cannot simply be copied without first considering the local context. This includes the size of the national power system (e.g. capacity, generation, consumption, assets, load profile) and its flexibility and distribution of generation and load; level of interconnection; voltage-level requirements; policy instruments that are in place to boost penetration of variable renewable energy; characteristics of conventional generators (e.g., fuel, technology, operational flexibility); and energy planning and power system operational practices (IRENA, 2016a).

Further to adopting a grid code, establishing a revision process that is predictable will increase system reliability and security so that changes in technology and operational practices are easily adopted. This also will facilitate future system planning. A comprehensive guide to develop grid connection codes for the integration of renewables is available in *Scaling Up Variable Renewable Power: The Role of Grid Codes* (IRENA, 2016a)

### Enhance the enabling framework for private renewable energy investments and adopt robust renewable energy policies and regulatory schemes

The Regulatory Indicators for Sustainable Energy, a tool designed by the World Bank to assess national policy frameworks in order to promote access to modern energy services, energy efficiency and renewables, is a benchmark to establish the readiness of a country to support investments in sustainable energy. The most recent version of the tool scores Mali a 21 (“Few or no elements of a supportive policy framework have been enacted”) (ESMAP, 2018).

In its annual assessment of the global status of renewables deployment, REN21 highlights that although Mali has a renewable energy policy in place, there are yet to be regulatory instruments that support implementation. These should include feed-in tariffs and payment premiums; standards for electric utility quotas and renewables; net metering and billing; bio-fuel blend obligations/mandate; renewable heat obligations and mandate; tradable renewable energy credits; and tendering processes (REN21, 2019). REN21 also notes the presence of tax incentives, as well as public loans and subsidies.

At the time of the RRA, public loan schemes targeting renewable energy deployment and policy in Mali were limited to the Renewable Energy Loan Project, supported by the World Bank. The project focused on the financing by local banks of solar home systems in an off-grid context, based on a government credit line. This innovative project, which has currently been put on hold, needs to be resumed upon the completion of an evaluation of its impacts. This initiative by itself is not sufficient to overcome the challenges Mali’s renewable energy sector faces, however, a successful implementation will be a driver for an uptake of renewable energy technologies.

In order for Mali to fulfil its renewable energy ambition, an overarching enabling policy framework is required that goes beyond the technology context and covers not only policies that facilitate access to finance, but also those to support the deployment of renewable (e.g. regulatory approaches such as feed-in policies or mandates and obligations; education and training; development of infrastructure). Other factors, such as the high level of political and economic risk in Mali, make private investment in renewables somewhat challenging. To be effective, policies require a stable regulatory environment - an issue that goes beyond the energy sector.

### Provide risk mitigating solutions and promoting blended finance

In addition to the political and macroeconomic risks, Mali’s power utilities and traditional off-takers - as in most countries in sub-Saharan Africa - face serious obstacles in fulfilling payment obligations in a timely and reliable manner, based on their PPAs. As a result, banks shy away from providing loans to IPPs due to concerns that the debt will not be serviced according to schedule if IPPs are not paid on time for the power they deliver. Risk mitigation instruments (RMI) and initiatives (e.g. RLSF) should, therefore, be designed to speed up implementation of mature renewable energy projects. This can be achieved, for example, by reputable banks issuing standby letters of credit and providing the necessary collateral so that an IPP is able to operate for six months in the event of not being paid by the utility.

Other risk-mitigating solutions include political risk coverage (e.g. guarantees, insurance), interest rate and currency risk (e.g. interest rate and currency forwards, swaps) and resource risk, among others. These are offered by development finance institutions (DFI), insurers, export credit agencies and others, such as the Multilateral Investment Guarantee Agency, Overseas Private Investment Corporation, Africa Trade Insurance Agency, Currency Exchange Fund, Agence Française de Développement, African Development Bank and GuarantCo, to name a few. Provision of RMIs is often a key to making renewable energy projects bankable and thus attracting private sector capital.

To understand and to facilitate access to such instruments, IRENA aims to launch an online platform for sector stakeholders (i.e. developers, lenders and other investors) to collect RMI data that relate to renewables, while at the same time providing a comprehensive overview of those RMIs that are available and information on how such instruments work.

In tandem with efforts to de-risk renewable energy projects, blended finance transactions should be encouraged to bring in local private capital into Mali’s renewable energy market, alongside institutions such as DFIs. Such transactions can take the form of syndications, on-lending and co-lending,<sup>21</sup> and build the experience of local capital providers (to benefit from the experience of development banks in terms of renewable energy project finance), lower the cost of financing and distribute risks among a broader group of lenders (IRENA, 2016b).

---

<sup>21</sup> On-lending occurs when public finance institutions use their high credit rating to borrow debt at low rates, ultimately on-lending such debt to local institutions by way of low-interest credit lines. Co-lending (or syndication) is when multiple financiers provide capital for a project. As such, local institutions will be able to use the experience of DFIs, drawn from RE project financing, or avoid taking risks that they cannot carry.



## 4.2. Off-grid renewables

Off-grid renewable solutions are crucial to achieve universal access to electricity, particularly in a country such as Mali where less than 20% of the rural population has access to power. Off-grid renewables will create opportunities and benefits beyond basic lighting and communication for rural communities, thus contributing to several development needs - most critically, an improvement in rural health services.

Based on the resource availability across Mali, the RRA process has identified hydropower, solar and bio-energy as suitable options. These are able to provide electrification and other energy services in remote areas.

Going beyond enabling policies and effective regulatory frameworks, RRA discussions have focused on core priority areas. These include tariff regulations and main grid arrival policies, as well as quality control.

### Adopt policies and regulations that support the growing mini-grid sector

Mali's current rural electrification strategy relies on a decentralised mini-grid approach, co-ordinated by AMADER and funded through the various budgetary allocations and development programmes of international partners. There is an increased effort to convert most of the existing mini-grids - traditionally diesel-powered to hybrid systems and by limiting the issuance of new rural electrification permits to hybrid installations. permits.



The current rural electrification approach has increased the electrification rate from 1% in 1999 to 17% in 2018. Despite this progress, two main areas of concern for private mini-grid investors are (i) to what extent does the type of support mechanism available for such investments apply over time and (ii) what regulatory framework is conducive for the sub-sector?

From an operational perspective, AMADER's support to private operators ceases at the investment stage (with a subsidy of up to 80% of capital expenditure), leaving operators to navigate through the complex environment with no support. For most installations, imported diesel represents a significant portion of the expenses for private hybrid system operators.

Coupling this with a low revenue stream, there will be many instances whereby the monthly revenue will cover only one week's provision of diesel, thus worsening the financial situation and, eventually, leading to the bankruptcy of many private operators. (due to bankruptcy, the number of private rural electrification operators have declined considerably from over 300 to only 47 at present.) Such insolvency affects the business case for Mali's rural electrification.

Moreover, electricity is supplied for a maximum of 12 hours a day (often for less) in order to minimise operator losses, given the high cost of fuel. Such limited electricity supply limits the economic activity in these remote, rural communities. If, however, approaches and business models for rural electrifications were to be consumer driven, an increase in electricity may well stimulate more consumption from mid- to high-power consumers, thus creating a deeper socio-economic impact and increase in the income of private operators.

On the revenue side, AMADER has instituted a fixed tariff regime to unify tariffs across rural areas. The tariffs in rural areas are driven by production costs, and are excessive (approximately USD 0.48-55/kWh) compared to those in urban areas (as low as USD 0.17/kWh). A fixed unified tariff that is not cost-reflective arguably will weaken the viability of current and prospective rural electrification projects in the country.

Given that this is the main concern of private operators, policies and support schemes should be tailored and sufficiently dynamic to effectively support a growing market. Moreover, effective regulation is essential, especially in the mini-grid sector. It should include flexible tariff setting for mini-grid projects to enable commercial viability; encourage innovation in the design and financing of technology and business models to reduce costs; establish quality control mechanisms for equipment; and improve efficiency.

### Develop a clear grid-arrival policy

In Mali, the untimely arrival of the national grid generates significant uncertainty in terms of the long-term viability of mini-grids, given that there are no concrete regulatory provisions (through interconnection and compensation mechanisms) for when the grid arrives.

This risk has for long been one of the main challenges faced by private mini-grid operation worldwide, and several options to mitigate it have been proposed or issued by policymakers and regulators in recent years.

A recent ESMAP study (Tenenbaum et al., 2018) highlights five of the most common options.

- conversion to a main grid-connected SPP (Small Power Producer)
- conversion to an SPD (Small Power Distributor);
- conversion to serve as a main-grid SPP + SPD;
- allowing the mini-grid developer to serve customers, side by side to the main grid, but without interconnection; and
- ensuring that the mini-grid receives compensation and the main-grid operator takes over responsibility.

Mali is advised to adopt either of these options to mitigate the risks faced by the private mini-grid operators as far as grid-arrival is concerned.

#### Box 4: What happens when the grid arrives? Country experiences

Conversion of mini-grids to (main) grid-connected small power producers has happened in various countries (e.g., Indonesia, Sri Lanka and the United Republic of Tanzania), whereby the main-grid operator then purchases the electricity produced from the mini-grid(s). A review of key success factors for such conversions highlights a combination of regulatory measures and social and economic motivators.

For instance, in Indonesia, a ministerial decree on Small Distributed Power Generation Using Renewable Energy requires the main grid operator to purchase electricity from mini-grids located near the main grid, as long as they were generating power from renewable energy sources.

Similarly, the United Republic of Tanzania's newly revised small power producer framework outlines standardised power purchase tariffs and small power purchase agreements to enable mini-grids to sell electricity to the main grid or isolated grids that are owned by the national utility (Odorno et al., 2017).

Cambodia's success with converting a record 250 mini-grids to small power distributors exemplifies the effectiveness of this strategy option for mini-grid survival. The study undertaken by the Energy Sector Management Assistance Program (ESMAP) highlights that Cambodia's approach to incentivise mini-grid investors to standardise distribution infrastructure is through tariff top-ups, largely attributing to its success (Tenenbaum et al., 2018).



### Develop quality control standards for renewable energy equipment and installers

In the Malian context, the market for rural electrification also should be leveraged to promote the local production of parts. An example is Horonya Solaire, a manufacturing company for the assembly of solar panels that employs approximately 30 people and has the capacity to produce up to 150 panels a day for national and regional markets. A larger and more dynamic market would boost the local industry by the manufacture of parts for solar installations, although this may require some co-ordination across the ECOWAS region in terms of synergy and complementarity. Such a stimulus, however, would raise the issue of quality control standards, which would require agreement at the national and regional levels, a topic that is currently being debated.

To sustain this effort, the GoM may consider equipping AER-Mali with the necessary laboratory and other equipment to test locally manufactured and imported products with a view to setting equipment norms and standards that will sustain the market for renewable energy products. For a market to be sustainable, however, quality assurance is essential at various levels. Quality renewable energy equipment will provide the services expected only if systems are designed, installed and maintained by individuals who are highly qualified.

RRA discussions have emphasised the relative lack of highly qualified technicians for the sizing, design, installation and maintenance of solar systems in Mali. This being a common regional issue, IRENA is working with regional counterparts to establish a regional certification scheme (Box 5) for solar PV installers. Mali also could benefit from this scheme as a way in which to equip the local market with high-quality technicians to curb its technical skills shortage.

#### Box 5: Regional certification scheme for solar photovoltaic installers: West Africa

The International Renewable Energy Agency (IRENA) supports the Centre for Renewable Energy and Energy Efficiency (ECREEE) of the Economic Community of West African States (ECOWAS) in the establishment and piloting of a regionally harmonised scheme to build the human capacity of renewable energy resources in ECOWAS member states. The programme, Certification for Sustainable Energy Skills (ECSES), improves the of renewable energy workers, including off-grid solar photovoltaic (PV) technicians. The aim of the scheme is to support the development of renewable energy markets in ECOWAS countries. ECREEE serves as the governing body of the ECSES programme, with IRENA playing an advisory role until such time when a separate legal entity is established. The initiative also is supported by Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) GmbH.

The ECSES scheme requires technicians to undertake regionally agreed examinations based on a Job Task Analysis (JTA) to ensure a uniform competency level across the region. At present, the JTA for off-grid solar PV technicians, as well as operational processes and procedures, examination content and procedures, have been developed in English and French with the support of IRENA and have been approved by ECOWAS members.

The ECSES scheme has been successfully piloted with practical and written examinations having been held at the Ecole Supérieure Polytechnique in Dakar, Senegal in January 2019 and at the Kwame Nkrumah University of Science and Technology in June 2019 in Kumasi, Ghana. The scheme is being rolled out in other ECOWAS countries, with examinations scheduled in Burkina Faso, Cabo Verde and Nigeria during the third quarter of 2019, while work has commenced on the development of JTAs for additional competencies, such as those for grid-connected solar PV, solar PV mini-grids and solar PV inspectors.



### 4.3. Institutional setup and skills reinforcement

#### Strengthen institutional processes

A more streamlined approach to institutional processes is essential for the effective uptake of renewables in Mali. The issue of overlapping institutional mandates has often been underscored, making it difficult to create synergy to meet their mandates.

In line with this, the Project Supporting the Promotion of Renewable Energies in Mali (Projet d'Appui à la Promotion des Energies Renouvelables au Mali, PAPERM), led by the Climate Investment Funds, aims to reform and streamline the energy sector by undertaken an in-depth analysis of the overall institutional and regulatory framework. This would enable the relevant institutions to assess policies and activities, as well as address, the shortcomings of Mali's energy sector - in particular the shortage of skills - in a coherent manner.

#### Enhance technical capacities for large-scale deployment of renewable power

Assessing and improving the technical capabilities in terms of the availability of necessary human capacities across the value chain and the readiness, of support institutions, the grid infrastructure, etc. would increase the country's readiness for integration of higher shares of variable renewable power. A tailor-made, capacity-building programme would improve the skills of key stakeholders, boosting the national and regional renewable energy planning systems and the regional power market. In this context, Mali, as a WAPP member, is able to benefit from IRENA's capacity-building programme under the West Africa Clean Energy Corridor (WACEC) initiative that places emphasis not only on technical training in the planning and operation of grids with a higher share of renewable power, but also on study visits to a country that has substantial experience in the integration of variable renewable energy into its national grid.

A further constraint in the deployment of grid-connected renewable power projects is the negotiation of PPAs. Thus far, PPAs in Mali are drawn up on a case-by-case basis and have been concluded only for hydro- and fossil fuel-based generation. Attracting investment for variable renewable-based power in the grid would be possible if the bankability of PPAs were strengthened.

Mali should engage, therefore, in consultations to develop a standardised PPA to increase the bankability of renewable power projects. IRENA and Terrawatt Initiative are focusing on this particular challenge in collaboration with various working groups (e.g., law firms, financial institutions and other core industry stakeholders). Together, they have launched Open Solar Contracts, an initiative to standardise the key documents required in solar PV projects, including those relating to PPAs, operations and maintenance agreements, supply agreements, fit and commissioning agreements and finance facility agreements, as well as project development and implementation guidelines.

#### Strengthen local capacities in the development, appraisal and financing of bankable renewable energy projects

In addition to the policy and regulatory frameworks mentioned above, the current low level of private sector involvement in renewable energy investments in Mali also relates to a lack of awareness by the local financial sector on the technicalities and business propositions around renewables investment, leading to a perception that renewable energy projects are of high risk. As such, limited access by the various stakeholders to quality sector information and the lack of knowledge of the relevant risk allocation and mitigation methods of renewable energy projects are important factors. In an effort to foster an energy market that is private-sector inclusive, potential actors must be brought to the same level of knowledge, particularly specific to their needs.

Support for the private sector should also take the form of reinforcing local capabilities in terms of project preparation, development, financing and implementation. This would be essential for off-grid market operators, and would require international development partners that support bankable renewable energy projects.

Awareness campaigns in the form of training should be provided to local financial institutions to raise their level of understanding of renewable energy technologies in addition to building their capacity to develop financing lines for renewable energy projects. Given that Mali is involved in many regional political, financial and sectoral institutions, these capacity reinforcement efforts should be complemented by the World Bank's Regional Off-Grid Electrification Project (ROGEP, implemented by ECREEE) that includes, among its components, the option of credit lines for several local commercial banks to enable them to support local entrepreneurs. This would provide an opportunity for the Malian private sector to access more financing from local commercial banks.





## Establish an effective energy data collection and management process, and build required capacities

As is the case in most sub-Saharan countries, the quest for reliable, consistent and up-to-date data on Mali's energy situation and potential is daunting. Countries in West Africa have differing definitions and assumptions for basic indicators (e.g. rate of access to electricity, rate of coverage), as well as differing mechanisms for the collection and processing of statistical data. This leads to discrepancies between country data, despite field conditions being similar throughout the region. There is urgent need standardise indicator definitions across the region to the benefit of all countries.

Furthermore, sub-Saharan Africa should overcome its shortage of institutional and human resources necessary to gather accurate and timely energy and renewable energy statistics.

It should also address the lack of guidance to capture not only the emerging methodological challenges associated with renewable energy statistics, but also the rapid evolution in the production and consumption of renewable energy, often not reflected in a timely manner in official statistics.

Mali's RRA process has faced various obstacles due to the lack of readily available statistical data to enable an assessment of critical energy sector indicators (e.g. total primary energy supply, energy consumption per sector, rural electrification rate). This is attributed to the absence of energy statistics training in ministries and governmental agencies, lack of funding and inadequate budgetary allocations for timely surveys and censuses, as well as an inability of statistics entities to retain qualified staff. Statistical capacity-building activities relating to the collection, processing and dissemination of renewable energy data will assist not only Mali but also West Africa, in general, to develop a systematic and effective data management process.

### Box 6: IRENA tools and services to reduce project costs and nurture the renewable energy market

**Site Appraisals Service:** For a country to effectively support an accelerated deployment of renewables, it needs to identify suitable project sites that are not only rich in resources but also financially viable. IRENA thus has developed its Site Appraisals Service to assess the financial pre-feasibility of wind and solar sites. The output of this assessment tool is a tariff that can act as a benchmark against comparable projects to assist countries in their power sector planning and project negotiation process. The service tool covers utility-scale wind and solar, solar storage systems and solar-diesel hybrid systems.

The site appraisals service tool is an innovative and cost-effective approach to screen prospective sites for solar and wind development in a specific country. It consists of two linked models for resource assessment and power generation and one as a simplified financial model. These serve to indicate the technical and economic feasibility of prospective solar and wind projects sites.

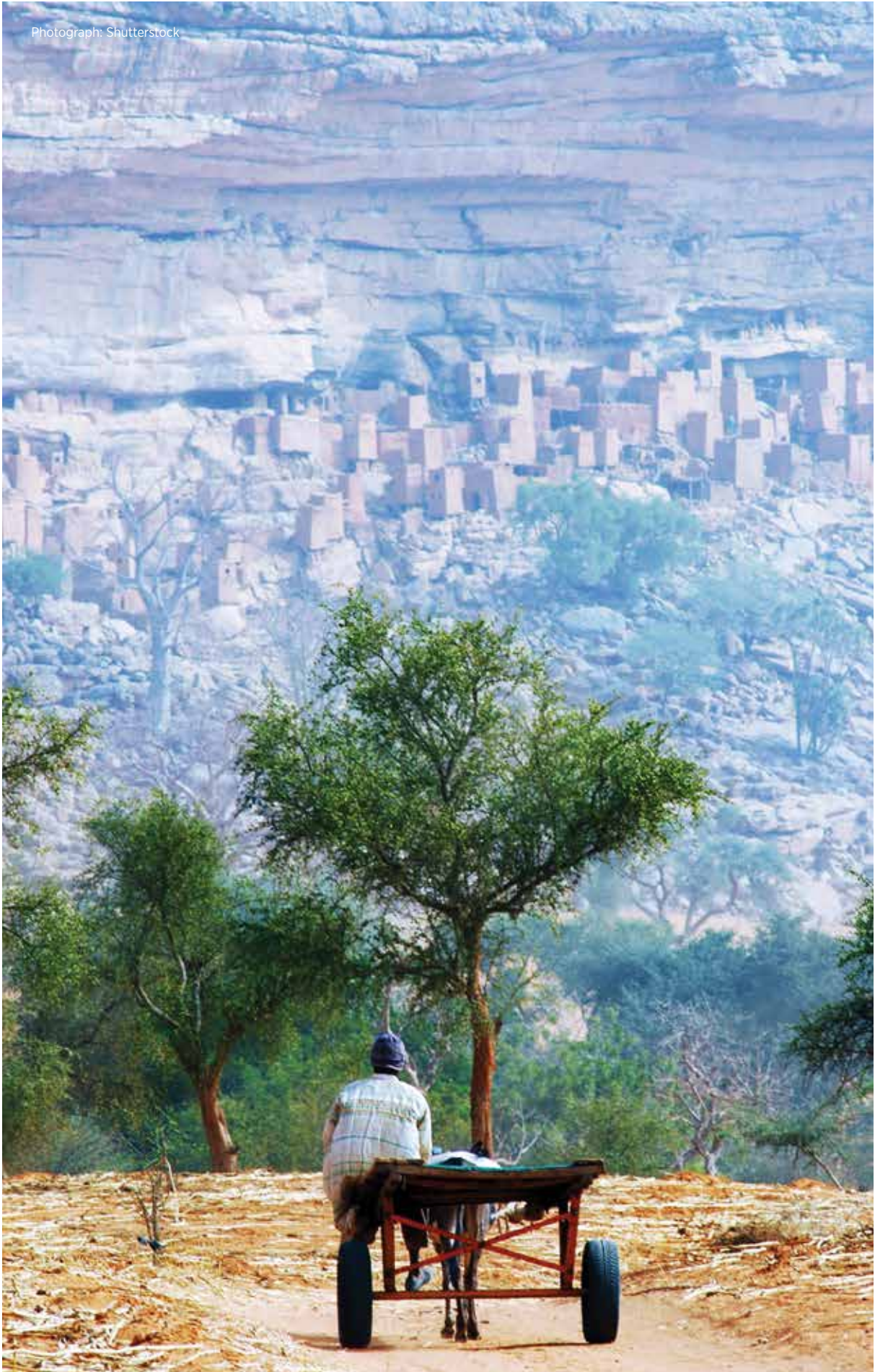
The service enables ministries and government entities to increase their chances of success, either by screening a list of potential wind or solar sites to select the most promising or by identifying, from relatively high-priority areas, those sites that are economically feasible as a precursor to carrying out further in-depth ground measurements.

Site appraisals can also be used by local authorities in negotiation with prospective independent developers.

**Project Navigator:** This online platform provides comprehensive and practical information, as well as guidance, for the development of bankable renewable energy projects. The tool includes a project lifecycle process that is structured in various distinct phases, designed to support the progressive development of renewable energy projects. At this stage, technical concept guidelines are available for on-shore wind, solar photovoltaic, woody biomass, small hydro, mini-grids and solar home systems.

**Sustainable Energy Marketplace:** This online platform connects project owners, financiers/investors, service providers and technology suppliers to bring projects to fruition. At the African hub of the Sustainable Energy Marketplace, IRENA conducts project assessments and provides an understanding of project requirements in the region. This data is then applied when matching and linking projects to financial institutions and other relevant stakeholders, depending on the project.

Photograph: Shutterstock





# REFERENCES

- AfDB (African Development Bank) (2016)**, *Scaling-Up Renewable Energy Program In Low-Income Countries - Mali: Segou Solar PV Project*, African Development Bank, Abidjan, [www.climateinvestmentfunds.org/sites/default/files/meeting-documents/srep\\_set\\_aside - segou solar pv project - appraisal\\_report - afdb\\_final.pdf](http://www.climateinvestmentfunds.org/sites/default/files/meeting-documents/srep_set_aside_-_segou_solar_pv_project_-_appraisal_report_-_afdb_final.pdf).
- AfDB (African Development Bank) (2015)**, *Renewable Energy in Africa: Mali Country Profile*, African Development Bank, Abidjan, [www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Profil\\_ER\\_Mal\\_Web\\_light.pdf](http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Profil_ER_Mal_Web_light.pdf).
- ATI (African Trade Insurance Agency) (2016)**, *Annual Report and Accounts*, ATI, Nairobi. [www.ati-aca.org/wp-content/uploads/2017/11/2016-Annual-Report-English.pdf](http://www.ati-aca.org/wp-content/uploads/2017/11/2016-Annual-Report-English.pdf).
- DNE (2016)**, "Opportunités d'Investissement dans le Secteur de l'Énergie au Mali", presentation at the 18th Africa Energy Forum, [www.energynet.co.uk/webfm\\_send/1611](http://www.energynet.co.uk/webfm_send/1611).
- DNM (Direction Nationale de la Météorologie) (2007)**, *Programme d'Action National d'Adaptation aux Changements Climatiques*, Ministère de l'Équipement et des Transports; Direction Nationale de la Météorologie, Bamako, [www.adaptation-undp.org/sites/default/files/downloads/mali\\_napa.pdf](http://www.adaptation-undp.org/sites/default/files/downloads/mali_napa.pdf).
- ECREEE (2013)**, *ECOWAS Renewable Energy Policy*, ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), Praia, [www.ecreee.org/page/ecowas-renewable-energy-policy-erep](http://www.ecreee.org/page/ecowas-renewable-energy-policy-erep).
- EDM (Électricité du Mali S.A.) (2019)**, *Caractéristiques du Système Électrique EDM-SA*, [www.edm-sa.com.ml/index.php/2014-05-27-14-05-11](http://www.edm-sa.com.ml/index.php/2014-05-27-14-05-11). Accessed on 16 July 2019.
- EDM (2018)**, "EDM en chiffres". [www.edm-sa.com.ml/index.php/2014-06-27-10-06-12](http://www.edm-sa.com.ml/index.php/2014-06-27-10-06-12). accessed on July 20, 2019
- EDM (2017)**, *Rapport Annuel d'Activités Volume 2/2 Compte Rendu Financier, Exercice 2016*. Énergie du Mali, S.A., Bamako, [www.edm-sa.com.ml/images/EDM%20SA%20rapport%20annuel%20d%27activit%C3%A9s%202016%20CRF%20vsc%2023082017vCLF.pdf](http://www.edm-sa.com.ml/images/EDM%20SA%20rapport%20annuel%20d%27activit%C3%A9s%202016%20CRF%20vsc%2023082017vCLF.pdf).
- EDM (2016)**, *Rapport Annuel d'Activités Volume 2/2 Compte Rendu Financier, Exercice 2015*. Énergie du Mali, Bamako, <https://docplayer.fr/111459280-Energie-du-mali-sa-rapport-annuel-d-activites-volume-2-2-compte-rendu-financier.html>.
- ESMAP (2018)**, *Regulatory Indicators for Sustainable Energy*, ESMAP Report. World Bank, Washington, D.C. <http://documents.worldbank.org/curated/en/553071544206394642/pdf/132782-replacement-PUBLIC-RiseReport-HighRes.pdf>
- GoM and ECOWAS (Government of Mali and Economic Community of West African States) (2015)**, *Plan d'Action National d'Énergies Renouvelables (PANER), période 2015-2020/2030*, Ministère de l'Énergie et de l'Eau, Bamako, [www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country\\_PANER/Mali\\_Plan\\_d\\_Actions\\_National\\_pour\\_les\\_Energies\\_Renouvelables\\_.pdf](http://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANER/Mali_Plan_d_Actions_National_pour_les_Energies_Renouvelables_.pdf).
- GlobalData (2019)**, *Kita Solar PV Park*, <https://power.globaldata.com/PowerPlants/PlantDetails?PlantType=SolarPV&AssetId=56170>, accessed on 03 September 2019.
- IEA (International Energy Agency) (2017)**, *Energy Access Outlook 2017: From Poverty to Prosperity*, World Energy Outlook Special Report, International Energy Agency, Paris, [www.iea.org/publications/freepublications/publication/WEO2017SpecialReport\\_EnergyAccessOutlook.pdf](http://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf).
- IRENA (n.d.)**, *Global Atlas for Renewable Energy: Solar Irradiation Map of Mali*, 'World Bank ESMAP 2018', Base layer 'Google Satellite Map 2018'.
- IRENA (n.d.)**, *Global Atlas for Renewable Energy: Average Wind Speed Map 1km at 200m height: 'DTU 2018'*, Base layer 'OpenStreetMap contributors 2018'.
- IRENA (n.d.)**, *Global Atlas for Renewable Energy: Suitability scoring and areas: 'IRENA 2018'*, Base layer, 'Google Hybrid Map 2018'.
- IRENA (2018a)**, *Renewable Power Generation Costs in 2017*, International Renewable Energy Agency, Abu Dhabi, [www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA\\_2017\\_Power\\_Costs\\_2018.pdf](http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf).
- IRENA (2018b)**, *West African Power Pool: Planning and Prospects for Renewable Energy 2016/17 Update*, IRENA, Abu Dhabi.
- IRENA (2016a)**, *Scaling up Variable Renewable Power: The Role of Grid Codes*, International Renewable Energy Agency, Abu Dhabi, [www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA\\_Grid\\_Codes\\_2016.pdf](http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Grid_Codes_2016.pdf).

**IRENA (2016b)**, *Unlocking Renewable Energy Investment: The Role of Risk Mitigation and Structured Finance*. International Renewable Energy Agency, Abu Dhabi, [www.irena.org/documentdownloads/publications/irena\\_risk\\_mitigation\\_and\\_structured\\_finance\\_2016.pdf](http://www.irena.org/documentdownloads/publications/irena_risk_mitigation_and_structured_finance_2016.pdf).

**KfW (2017)**, "Regional Liquidity Support Facility", (Online.) KfW, Frankfurt am Main. [www.kfw-entwicklungsbank.de/ipfz/Projektdatenbank%20/Regional-Liquidity-Support-Facility-36394.htm](http://www.kfw-entwicklungsbank.de/ipfz/Projektdatenbank%20/Regional-Liquidity-Support-Facility-36394.htm).

**Mahé G., et al. (2011)**, "Le fleuve Niger et le changement climatique au cours des 100 dernières années". *Hydro-Climatology: Variability and Change*, Proceedings of symposium J-H02 held during IUGG2011 in Melbourne, Australia, July 2011, [www.researchgate.net/publication/229112040\\_Le\\_fleuve\\_Niger\\_et\\_le\\_changement\\_climatique\\_au\\_cours\\_des\\_100\\_dernieres\\_annees](http://www.researchgate.net/publication/229112040_Le_fleuve_Niger_et_le_changement_climatique_au_cours_des_100_dernieres_annees).

**MEA (Ministère de l'Environnement et de l'Assainissement) (2011)**, *Seconde communication nationale du Mali sur les changements climatiques*. Bamako, <https://unfccc.int/resource/docs/natc/mlinc2.pdf>

**Ministère de l'Economie et des Finances (2018)**, *Projet de Loi de Finances 2018 – Document de Programmation Pluriannuelle des Dépenses et Projet Annuel de Performance (DPPD-PAP) 2018 – 2020*, Ministère de l'Economie et des Finances, Bamako, [www.finances.gouv.ml/sites/default/files/DPPD-PAP\\_Version%20AN%20du\\_29-09-17.pdf](http://www.finances.gouv.ml/sites/default/files/DPPD-PAP_Version%20AN%20du_29-09-17.pdf).

**NDE (National Directorate of Energy) (2011)**, *SREP MALI – Investment Plan: Scaling up Renewable Energy*, Ministry of Energy and Water, Bamako, [www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/SREP-Mali\\_IP\\_Volume1\\_EN\\_21Sept%20\(2\).pdf](http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/SREP-Mali_IP_Volume1_EN_21Sept%20(2).pdf).

**Odarno, L., et al. (2017)**, *Accelerating Mini-grid Deployment In sub-Saharan Africa: Lessons from Tanzania*, World Resources Institute, Washington, D.C. <http://documents.worldbank.org/curated/en/532751512396163620/pdf/WP-acceleratingminiGRID-deploymentsubaharanafrica-PUBLIC.pdf>.

**Oguntunde, P.G., et al. (2017)**, "Impacts of climate variability and change on drought characteristics in the Niger River Basin, West Africa", *Stochastic Environmental Research and Risk Assessment* 32(4): 1017-1034, <https://link.springer.com/article/10.1007/s00477-017-1484-y>.

**PANER (Plan d'Action National d'Energies Renouvelables) (2015)**, Bamako, [www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country\\_PANER/Mali\\_Plan\\_d\\_Actions\\_National\\_pour\\_les\\_Energies\\_Renouvelables.pdf](http://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANER/Mali_Plan_d_Actions_National_pour_les_Energies_Renouvelables.pdf)

**PopulationData.net (2019)**, "Mali", (database), [www.populationdata.net/pays/mali/](http://www.populationdata.net/pays/mali/), accessed on 26 February 2019. **REN21 (2019)**, *Renewables 2019 Global Status Report*, Paris. **REN21 Secretariat**, [www.ren21.net/wp-content/uploads/2019/05/gsr\\_2019\\_full\\_report\\_en.pdf](http://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf).

**SIE (Système d'Information Energétique) (2014)**, <http://sieuemoa.org/index.php/statistique/pub/MA>. Accessed on July 20, 2019

**Tenenbaum, B., C. Greacen and D. Vaghela (2018.)** *Mini Grids and the Arrival of the Main Grid: Lessons from Cambodia, Sri Lanka, and Indonesia*. Energy Sector Management Assistance Program (ESMAP) Technical Report 013/18. Washington, DC: World Bank.

**West African Power Pool (2017)**. Brief Presentation on the WAPP at the IRENA-WAPP Meeting. Abu Dhabi, 12 June 2017.

**World Bank (2019)**, *Doing Business 2019: Training for Reform*. World Bank, Washington, D.C. [https://espanol.doingbusiness.org/content/dam/doingBusiness/media/Annual-Reports/English/DB2019-report\\_web-version.pdf](https://espanol.doingbusiness.org/content/dam/doingBusiness/media/Annual-Reports/English/DB2019-report_web-version.pdf).

**World Bank (2018)**, *Mini Grids and the Arrival of the Main Grid: Lessons from Cambodia, Sri Lanka and Indonesia*. ESMAP Technical Report 013/18, World Bank, Washington, D.C., <https://openknowledge.worldbank.org/bitstream/handle/10986/29018/134326.pdf?sequence=6&isAllowed=y>.

**World Bank (2017a)**, *Agriculture, forestry, and fishing, value added (% of GDP)*; available at <https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=ML>.

**World Bank (2017b)**, *Doing Business 2017*, World Bank, Washington, D.C., [www.doingbusiness.org/data/exploreeconomies/mali#starting-a-business](http://www.doingbusiness.org/data/exploreeconomies/mali#starting-a-business).

**World Bank (2017c)**, *Mali Rural Electrification Hybrid System Project* <http://projects.worldbank.org/P131084?lang=en>

**WHO (World Health Organization) (2014)**, [www.who.int/sustainable-development/health-sector/health-risks/energy-access/en/](http://www.who.int/sustainable-development/health-sector/health-risks/energy-access/en/); Accessed on July 20, 2019







P.O. Box 236  
Abu Dhabi, United Arab Emirates  
Tel: +971 2 4179000  
[www.irena.org](http://www.irena.org)

Copyright © IRENA 2019