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Decentralised renewable energy for powering agri-food value chains in the Republic of Guinea

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Abbreviations

AFD	*Agence Française de Developpement* (French Development Agency)
AfDB	African Development Bank
AGER	*Agence Guinéen de l'électrification Rurale* (Guinean Agency for Rural Electrification)
APER-GUINEE	*Association de Professionnel en Energie Renouvelable de Guinée* (Association of Renewable Energy Professionals of Guinea)
CAGR	compound annual growth rate
CNOPG	*Confédération Nationale des Organisations Paysannes de Guinée* (National Confederation of Farmer Organisations of Guinea)
CRG	*Crédit Rurale de Guinée* (Rural Credit of Guinea)
DRE	decentralised renewable energy
EDG	*Electricité de Guinée* (Guinea Electricity)
FEPAF-BG	*Fédération des Planteurs de la Filière Fruit de la Basse Guinée* (Federation of Fruit Planters of Lower Guinea)
GDP	gross domestic product
GHG	greenhouse gas
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit* (German Development Corporation)
hp	horsepower
IOM	International Organization of Migration
IPP	independent power producer
IRENA	International Renewable Energy Agency
kg	kilogramme
km²	square kilometre
kVA	kilovolt amp
kWh	kilowatt hour
LDC	least developed countries
MAGEL	*Ministère de l'Agriculture et de l'Elevage* (Ministry of Agriculture and Livestock)
MEF	*Ministère de l'Economie et des Finances* (Ministry of Economy and Finance)
MEHH	*Ministère de l'Energie de l'Hydraulique et des Hydrocarbures Guinée* (Ministry of Energy, Hydraulics and Hydrocarbons)
MFI	microfinance institution
mm	millimetre
MSME	micro, small and medium-sized enterprise
MW	megawatt

NDC	Nationally Determined Contribution
NGO	non-governmental organisation
PAYG	pay-as-you-go
PNDA	*Politique National de Développement Agricole* (National Agriculture Development Policy)
PNDES	*Plan National de Développement Economique et Sociale* (National Plan for Economic and Social Development)
PNIASAN	*Plan National d'Investissements Agricoles et de Sécurité Alimentaire et Nutritionnelle* (National Agricultural Investment and Food and Nutrition Security Plan)
PRI	*Programme de Référence Intérimaire* (Interim Reference Programme)
PUE	productive use of energy
PV	photovoltaic
R&D	research and development
RBF	results-based finance
RNAE	*Recensement National de l'Agriculture et de l'Élevage* (National Census of Agriculture and Livestock)
SDG	Sustainable Development Goal
SHF	smallholder farmer
UNDP	United Nations Development Programme
USD	United States dollar
WB	World Bank
WTB	willingness-to-buy
WTP	willingness-to-pay

Executive summary

For nearly 80% of Guinea's population, agriculture is the main livelihood. In 2022, the sector also contributed 31% of the country's gross domestic product (GDP). Agriculture is therefore a key strategic sector for the Guinean government in its drive to alleviate poverty and guarantee food security. This drive has been outlined in Guinea's Plan National de Développement Economique et Sociale (PNDES) or National Plan for Economic and Social Development, as well as in the country's Programme de Référence Intérimaire 2023-2025 (PRI) or Interim Reference Programme, 2023-2025. It has also been outlined in Vision Guinée 2040, or Guinea Vision 2040. All of these plans envision the transformation of the agricultural sector in driving the country's sustainable socio-economic development.

Known as the "water tower of West Africa," Guinea has some of the most significant agricultural potential in the region. Yet, despite favourable natural conditions for agriculture, yields per hectare are low. These yields also remain well below the level needed to make agriculture the main driver of economic development in the country.

Among the constraints limiting the development of the agricultural sector are: poor farming techniques; a heavy reliance on seasonal rains; poor access to land (especially for women, who represent 53% of the agricultural workforce); poor infrastructure, such as limited road networks and access to electricity in rural areas; and lack of access to concessional financing for smallholder farmers (SHFs) and micro, small and medium-sized enterprises (MSMEs). In parallel, climate change threatens food security in Guinea through its impact on water availability, soil degradation and crop loss.

A critical factor in establishing a robust and transformative agricultural sector is ensuring access to modern energy services. Guinea's current electricity infrastructure is limited in its reach and capacity to supply power to rural, or peri-urban communities, hindering mechanised agricultural activities. In 2022, an estimated 48% of the total population had electricity access, with wide access disparities between the urban areas (91% access rate) and rural areas (21% access rate). SHFs and MSMEs in rural areas often resort to diesel generators to meet their energy needs for agricultural production and processing.

Decentralised renewable energy (DRE) solutions have the potential to transform Guinea's agriculture sector, enhancing productivity and sustainability, while contributing to the achievement of the country's Nationally Determined Contributions (NDCs). These aim for 80% of electricity generation to come from renewable sources by 2030, while also putting the agricultural sector on a carbon-neutral path by 2050.

Within the overarching framework of IRENA's Empowering Lives and Livelihoods Initiative, this study assesses the market potential for the integration of DRE solutions in powering Guinea's agri-food value chain. The methodology used in the assessment was designed to focus on commercially viable DRE technologies that specifically target commercial SHFs. It follows a country-led participative and inclusive approach in selecting three agricultural value chains, each of which is in line with Guinea's strategic priorities. These are rice, maize and vegetables, as these are the crops most cultivated by Guinea's SHFs. They also represent significant market value and have potential in bolstering the country's food security.

In conducting this study, a series of consultative engagements was undertaken with key stakeholders in the energy and agriculture sectors. This was done to map existing policy, regulatory, finance and other market support interventions. These consultations were followed by in-field quantitative and qualitative data collection at the farm and agro-processing business levels.

Based on this data, the study employed a chain-ratio method to estimate addressable market potential for solar photovoltaic (PV) water pumping, solar PV milling and solar PV cold storage. These have been identified as the most suitable DRE entry points to support the development of the country's rice, maize and vegetables value chains. This identification was informed by the maturity levels and accessibility of these technologies observed in-country.

The key findings of the study can be summarised as follows:

- **Access to electricity:**

  For SHFs in rural areas, access to electricity is limited. Only 6% of the farmers surveyed had access, mainly through diesel gensets and solar home systems.

- **Access to credit:**

  For SHFs and MSMEs in Guinea, there is limited access to commercial credit. The percentage of SHFs surveyed who reported having had access to commercial credit was only 1%.

- **Agricultural production and access to land:**

  The most cultivated crops in the agricultural zones surveyed were rice, vegetables and maize. Female SHFs accounted for 40% of the workforce in maize production, 35% in horticulture production and 23% in rice farming. In terms of access to land, 30% of surveyed SHFs owned the land they farmed, 50% borrowed land from other SHFs, and 20% rented the land on a short-term basis. Land preparation was overwhelmingly done manually.

- **Access to energy technologies for agricultural production and processing:**

  Solar water pumps: Only 1% of the farmers surveyed had access to water pumps for irrigation, with these almost exclusively diesel-powered. Access to solar PV pumps was very limited, due to low awareness of solar PV technologies and high capital costs. Up to 70% of SHFs without water pumps reported high costs as the primary deterrent. Notwithstanding this, 88% of SHFs said they were willing to acquire solar water pumps, with 86% of these SHFs willing to pay – in United States dollar (USD) terms – between USD 100 and USD 300 for a pump. Up to 82% of the surveyed SHFs indicated a willingness to take out a loan to finance a solar water pump.

  Solar refrigeration units: Only 1% of the SHFs surveyed owned a refrigerator (capacities ranged between 50 litres and 100 litres). These were mostly genset-powered, with a few powered by solar PV. While high capital costs and low awareness were cited as the key deterrents, 81% of the SHFs interviewed were willing to acquire a solar refrigeration unit, with 79% of these farmers willing to pay between USD 100 and USD 300.

  Solar PV milling: Up to 82% of the milling service businesses surveyed were diesel-powered. While awareness of solar PV-powered milling technologies was low, 86% of the milling businesses showed a willingness to acquire this technology, with a willingness to pay between USD 500 and USD 1 000 towards this. Up to 92% of the businesses surveyed were willing to take out a loan to cover the full cost of the solar PV milling technology to replace diesel-based mills.

- **The addressable market potential of DRE solutions:**

  The estimated total addressable market potential for solar water pumps in Guinea was USD 60.4 million. For solar refrigeration units, it was USD 50.7 million, and for solar milling equipment, USD 13.4 million, at baseline willingness-to-buy levels of 88%, 81% and 86%, respectively. A sensitivity analysis shows that the maximum addressable market potential for solar water pumps is approximately USD 90 million, which considers the maximum willingness-to-pay of USD 300 per commercial SHF. Putting in place policies, regulations and facilitating access to appropriate financial mechanisms is key to accelerating the potential penetration of solar water pumps in Guinea's agriculture sector.

  For solar refrigeration units in the vegetables value chain, the estimated market potential ranged from USD 25 million to USD 76 million at the baseline willingness-to-pay of 81% of surveyed commercial farmers. The actual market potential for solar refrigeration units may eventually be bigger, however, as corner shops and boutiques were not considered in the analysis, due to data limitations.

  For MSMEs, the estimated market potential for solar PV milling equipment ranged between USD 8.9 million and USD 17.8 million at the baseline willingness-to-buy of 86%.

Barriers to DRE penetration in Guinea

The great interest in DRE solutions shown by the SHFs and agro-processing businesses surveyed indicates there is strong market potential for these in Guinea. Yet, the study also found several barriers limiting the penetration and widespread adoption of such technologies, especially in rural areas. These barriers can be broadly categorised into four areas, as illustrated below:

Demand side	Supply side	Enabling environment (policy regulation)	Finance
Limited abilito to pay	Limited commercial viability	Limited co-ordination beteween actors	Limited capital flow and high interest rates
Lack of DRE knowledge	Distortive effect of handout model	Limited political commitment to support DRE	Limited access to consumer credit
Economic insecurity	“Last mile” infrastructure deficit	Limited experience and capacity	Limited research and development grants
Gender gap	Lack of knowledge on agric. value chains	Limited incentives for DRE	Limited results-based finance mechanisms
Limited access to services	Informal market competition		
Disparity in socio-economic conditions			

Recommendations for boosting DRE uptake in Guinea’s agriculture sector

Drawing on the findings of the study, this report presents several key, recommended priority actions. These are to be implemented in the short-to-medium term in order to accelerate the integration of DRE into Guinea’s agri-food value chains. The recommendations are categorised into three areas, as follows:

Market development actions:

- Develop a programme plan for a results-based finance (RBF) subsidy delivery mechanism for DRE focusing on solar water pumps for SHFs and solar refrigeration units for the storage of perishable products.
- Develop a plan for a research and development (R&D) mechanism in the delivery of grants in support of the development of fee-for-service DRE business models. These include walk-in-cold-rooms and small-sized solar milling services.
- Design and deliver a demand stimulation campaign, with events, exhibitions, media campaigns and roadshows.
- Enhance the capacity and skills of the off-grid sector for all involved players through training, education and awareness raising.

Policy actions:

- Co-host multi-stakeholder engagement with the private sector and government stakeholders.
- Establish an inter-ministerial platform, including joint delivery and the co-ordination of efforts between the *Ministère de l'Energie de l'Hydraulique et des Hydrocarbures* (MEHH), or Ministry of Energy, Hydraulics and Hydrocarbons, and the *Ministère de l'Agriculture et de l'Elevage* (Ministry of Agriculture and Livestock).
- Support the *Ministère de l'Economie et des Finances* (Ministry of Economy and Finance) in setting up financial incentives and exemptions for DRE companies.
- Support the MEHH in designing and establishing a DRE strategy within the existing national electrification strategy.
- Formulate a long-term strategy that combines access to DRE appliances with agriculture programming.
- Integrate gender considerations in order to recognise the different forms of discrimination that impact the energy needs and aspirations of women (*i.e.* RBF design and targeted mechanisms, and training and capacity building for women).

Stakeholder collaboration actions:

- Identify channels of collaboration with microfinance institutions (MFIs), including new financing opportunities that address the shortage of capital.
- Define co-ordination mechanisms between actors in the agriculture and energy sectors and in overall management roles.
- Establish a partnership facility with DRE private sector companies.

1. Introduction

The agricultural potential of the Republic of Guinea is among the most significant in West Africa, owing to the country's abundant water resources and vast stretches of arable land. Despite this potential, however, agricultural productivity remains low. This is due to a dependency on rain-fed agriculture, traditional farming techniques and inadequate infrastructure. At the same time, approximately 80% of the population relies on the agricultural sector for its livelihood – either directly or indirectly – while the sector also contributed 31% of gross domestic product (GDP) in 2022. Creating favourable market conditions to boost production and value added in the sector is therefore crucial in driving national economic growth.

Given this economic significance and the sector's considerable untapped potential, agriculture requires intervention, if its development and expansion is to be sustainably supported. A crucial aspect in establishing a robust and transformative agricultural sector is ensuring access to modern energy services to power various agricultural activities. These include: land preparation, planting, irrigation, harvesting, processing, storage and the commercialisation of products. In Guinea, most agricultural activities are carried out by smallholder farmers (SHFs) manually, or with animal power, while commercial farmers often rely on diesel-based equipment.

Guinea's current electricity infrastructure is limited in its reach and ability to supply power to rural or peri-urban communities. This hinders mechanised agricultural activity and the development of productive uses of energy (PUE) by businesses. Many SHFs and businesses in remote areas resort to diesel generators to meet their energy needs. This not only proves costly, but also contributes to greenhouse gas emissions (GHG). Yet Guinea possesses abundant renewable energy resources – primarily hydro, biomass and solar. This makes the country well-suited for the adoption of decentralised renewable energy (DRE) in support of its productive sectors – and of agriculture, in particular.

Transitioning to renewable energy sources could allow Guinea to capitalise on its agricultural potential, leading to increased production and value addition. This aligns with the government's objective of achieving food self-sufficiency and improving the lives and livelihoods of SHFs. There is growing recognition, too, that simply providing access to electricity through renewables is not enough; energy needs to be leveraged for productive purposes – especially for driving socio-economic development in rural areas.

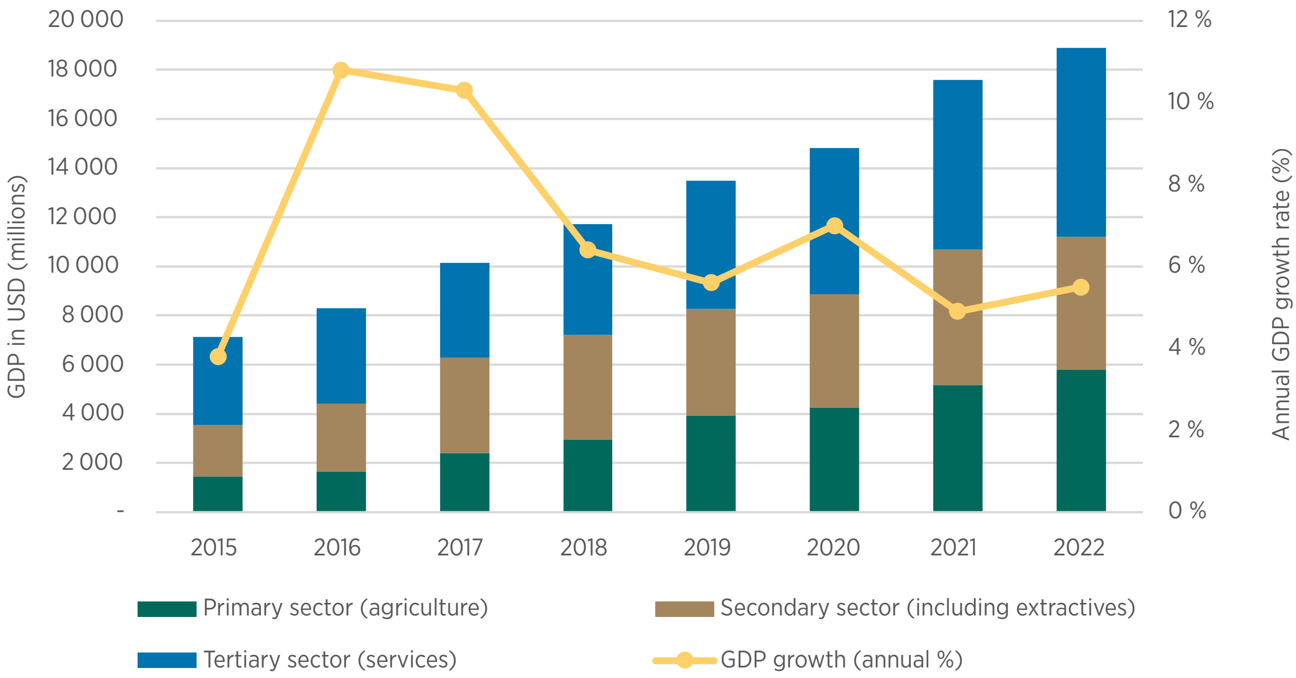
This market assessment report highlights the opportunities for incorporating DRE into specific stages of Guinea's rice, maize and vegetable value chains. These food chains have been identified by the government of Guinea as crucial to the country's food supply and demand. This report identifies the most suitable DRE solutions and entry points within each value chain, as well as the barriers hindering widespread adoption of DRE in Guinea's agriculture sector. It also recommends priority interventions to overcome these obstacles and enhance the country's DRE ecosystem. The analysis presented in this report seeks to establish a foundation for the development of a country investment programme aimed at integrating DRE solutions into Guinea's agriculture sector. It also highlights areas for more in-depth analysis. This work aligns with Guinea's National Socio-economic Development Plan (2021-2025), Interim Reference Programme (2023-2025) and Guinea Vision 2040, which all envision transforming the agriculture sector in order to drive sustainable socio-economic development.

1.1 Socio-economic context

Located in West Africa, Guinea has a total surface area of 245 857 square kilometres (km^2). The country borders six others: Guinea Bissau and Senegal to the north, Liberia and Sierra Leone to the south, and Côte d'Ivoire and Mali to the south-east and north-east, respectively. In 2023, Guinea had an estimated population of 14.2 million (World Bank, 2024), with this growing at an annual average rate of 2.7%. The country is also one of the most demographically heterogenous in the region, owing to its cultural diversity and distinct ecological characteristics. The population aged between 15 and 49 years old represents 46% of the total, signifying a strong human capital resource to drive economic growth in the country. Guinea's rural population represents around 63% of the overall total, with these rural dwellers deriving more than 75% of their income from the agricultural sector and its allied activities.

The economy of Guinea is mainly comprised of three sectors: services, extractives and agriculture. In 2022, these represented 40%, 29% and 31% of total GDP, respectively (Figure 1). In terms of exports, the extractives sector contributed 93% of total export receipts in 2022. In United States dollars (USD) terms, this represented USD 6.9 billion, mainly generated by gold and bauxite exports. Agricultural exports contributed 2.45%, valued at USD 182 million (INS, 2023). Between 2019 and 2023, Guinea's annual GDP growth was robust, averaging 5.4%, driven mainly by the extractives sector and the recovery of the agricultural and services sectors from the effects of the COVID-19 pandemic. In terms of mineral resources, Guinea holds the largest estimated bauxite reserves in the world, with approximately 23% of total global reserves (USGS, 2023). Guinea is also the only country in the world where mineral and metal resources exceed 15% of the country's total wealth (World Bank, 2021). To capitalise on this, Guinea's strategic vision – as enshrined in its forward-looking *Guinée Vision 2040* (Guinea Vision 2040) strategy – is to graduate from its least-developed country (LDC) status to an emerging economy by 2040. The pathway for this is seen as via industrialisation of the agricultural and extractive sectors.

Figure 1 Evolution of contribution to GDP by sector and annual GDP growth rates



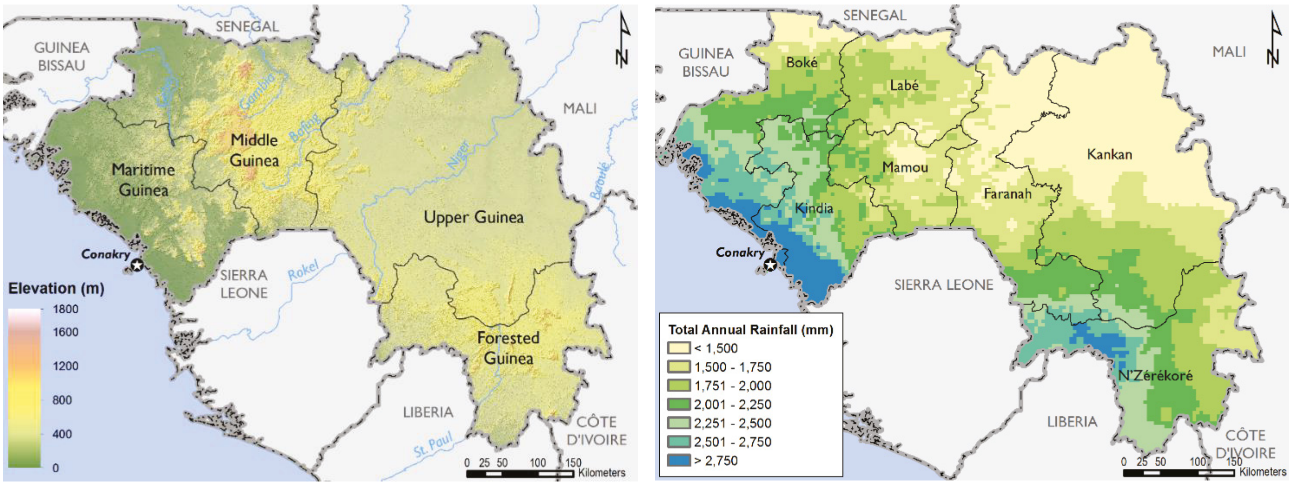
Source: (INS, 2023).

Note: GDP = gross domestic product; USD = United States dollar.

1.2 Agro-ecological characteristics

Geographically, Guinea is divided into four natural regions (Figure 2; left), each with a distinct economic potential and agro-ecological characteristics. Rainfall is abundant, ranging between 1 000 millimetres (mm) and 4 000 mm per year (Figure 2; right). Known as the "water tower of West Africa", Guinea has an extensive hydrographic network, with this stretching around 6 500 km. Based on combined analysis of topographical, soil, climatic and land use data, Guinea's arable land is estimated to total 13.7 million hectares (*i.e.* 56% of the national territory – see Table 1), of which only 10% is cultivated annually. Estimates show that irrigable land with total or partial water control could reach 751 563 hectares, of which only 69 868 hectares (9.3%) has been developed (Government of Guinea, 2017a). This potential presents an opportunity to guarantee food self-sufficiency, empower livelihoods – particularly through large-scale commercial farming of cash crops – and generate significant export receipts.

Figure 2 Elevation and natural regions (left) and average annual rainfall (right)



Source: (USAID, 2017).

Notes: m = metres; mm = millimetres.

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Table 1 Potential agricultural land

Available potential		Surface (hectares)	%
Potential land available for agriculture	High suitability	**8 398 870**	**34.16%**
	Average suitability		
	Marginal suitability	**5 319 017**	**21.63%**
	Not suitable	**8 455 510**	**34.39%**
	Permanently unsuitable	**152 215**	**0.62%**
Surface area of other types of multi-purpose land (excluding nature parks and classified forests)	Man-made lands (artificial)	175 439	0.71%
	Conservation forests	448 854	1.83%
	Mangroves and other sensitive ecosystems	133 780	0.54%
	Open spaces with little or no vegetation	160 449	0.65%
	Mines	11 630	0.05%
	Marine wetlands and water resources	186 380	0.76%
Nature parks (reserves) and classified forests		1 086 544	4.42%
No information		57 012	0.23%
Total surface area of Guinea		**24 585 700**	**100%**

Distribution of available potential land for agriculture by natural region			% total surface	% available potential
In Guinea		**13 717 887 ha**	**56%**	**100%**
By natural region	Upper Guinea	6 033 991 ha	25%	44%
	Forested Guinea	3 337 430 ha	14%	24%
	Middle Guinea	2 625 032 ha	11%	19%
	Maritime/lower Guinea	1 721 435 ha	7%	13%

Source: (ANASA, 2020).
Note: ha = hectare.

1.3 Overview of the agriculture sector

Agriculture is the main source of sustenance and income for nearly 80% of the population of Guinea, with this dominated by subsistence-level farming. Despite favourable natural conditions for agriculture, yields per hectare are low and remain well below the level needed to make agriculture the main driver of the country's economic development. Among the constraints limiting the development of the sector are: poor farming techniques; heavy reliance on seasonal rains; poor access to land (especially for women); poor infrastructure, including limited road networks and access to electricity, especially in rural areas; and lack of access to concessional financing for SHFs and micro, small and medium enterprises (MSMEs).

In parallel, climate change threatens Guinea's food security and nutrition. It does this through its impact on water availability, land degradation and the functioning of the ecological ecosystem as a whole. Particularly vulnerable to the impacts of climate change are SHFs who depend on these agricultural resources for sustenance.

In terms of agricultural production, rice is by far the most important staple in Guinea, grown practically throughout the country. Between 2015 and 2022, rice production steadily increased, from 2 million tonnes in 2015 to over 3 million tonnes in 2022, yielding 2.4 tonnes/hectare (Table 2). However, domestic production is insufficient to cater for local demand, requiring Guinea to import 865 000 tonnes of rice in 2023. This represented 29% of the total rice consumed (FAO, 2024).

Other important food crops include maize, cassava, groundnuts and vegetables. While cassava is among the most important staples in Guinea, maize production and consumption has seen a steady increase and is considered in some areas as a common substitute for rice. Agricultural processing is localised and small-scale, as the industrial agro-processing sub-sector is yet to develop.

All these factors make agriculture a strategic sector for the government in its drive to alleviate poverty and guarantee food security for the country (see Box 1). In 2022, the sector also attracted approximately USD 98 million in external financing for public investment projects (INS, 2023).

Table 2 Evolution of main food crop production (tonnes)

Crop	2015	2016	2017	2018	2019	2020	2021	2022
Rice	2 015 476	2 149 030	2 291 434	2 443 274	2 605 176	2 777 806	2 961 875	3 158 141
Maize	719 284	739 118	759 499	780 443	801 963	824 077	846 801	870 152
Fonio	479 029	485 019	491 083	497 223	503 439	509 734	516 107	522 560
Millet	262 240	266 127	270 071	274 074	278 136	282 258	286 442	292 121
Sorghum	72 991	74 041	75 106	76 186	77 282	78 394	79 522	82 386
Groundnut	200 791	275 539	378 113	518 873	712 033	977 101	1 340 845	1 839 999
Cassava	1 247 808	1 401 643	1 574 444	1 768 548	1 986 582	2 231 496	2 506 603	2 815 628
Sweet potato	402 346	406 214	410 120	414 064	418 045	422 065	426 123	430 221
Yam	101 619	122 045	146 576	176 038	211 421	253 917	304 954	366 250
Potato	56 313	74 924	99 687	132 633	176 468	234 791	312 390	415 634
Taro	101 166	105 415	109 843	114 456	119 263	124 272	129 492	134 930

Source: (INS, 2023).

Box 1 Government policy and strategy for agricultural development in Guinea

The *Plan National de Développement Economique et Sociale 2016-2020* (PNDES), or National Socio-economic Development Plan, provides the overarching framework for Guinea's socio-economic development. Under this, the government has put special emphasis on the agriculture sector. In 2017, the government also adopted the *Politique National de Développement Agricole* (PNDA), or National Agriculture Development Policy, which outlines the vision and objectives for creating a modern, sustainable, productive and competitive agricultural sector. The operationalisation of the PNDA is based on the *Plan National d'Investissements Agricoles et de Sécurité Alimentaire et Nutritionnelle 2018-2025* (PNIASAN), or National Agricultural Investment and Food and Nutrition Security Plan 2018-2025.

Strategic vision for agricultural development and food security in Guinea

Production	Processing	Markets	Products / export	Investments
• Water management & farm mechanisation • Improvement of seed quality & agricultural practices • Reduction of post-harvest losses	• Creation of processing and packaging centres	• Prioritisation of strategic infrastructure investments (roads, rails, storage facilities • Access to appropriate financing	• Introduction of high yield products and value addition • Focus on products of strong regional and international demand	• Development of air and port infrastructures • Implementation of reforms to attract and protect investors

The government's vision for the sector has been further strengthened by the *Programme de Référence Intérimaire* (PRI), or Interim Reference Programme, adopted in 2022 for a three-year transition period (PRI, 2022-2025). The PRI aims to achieve the following strategic objectives by 2025:

- Support youth and women through a loan mechanism for the cultivation of rice, maize and vegetable crops.
- Develop 2 000 hectares of maize.
- Develop of 2 000 hectares of rice.
- Develop/rehabilitate 3 000 hectares of agricultural land.

The private sector is expected to play a key role in achieving these objectives, particularly in the areas of agricultural supply, production, marketing and service offerings.

Sources: (Government of Guinea, 2017a, 2017b, 2022a).

1.4 Gender and agriculture in Guinea

Worldwide, agri-food systems are major providers of employment and important sources of livelihood for women (FAO, 2023). In Guinea, women account for 53.3% of the agricultural workforce and are active throughout the agricultural value chain, from production to transformation, trading and marketing (Government of Guinea, 2018).

Despite their strong contribution to the agriculture sector, however, women have limited access to resources such as land, credit, inputs and mechanised farm equipment. This limits their level of participation in agricultural activities. During the rainy season, women are mostly engaged in land preparation and crop maintenance in both lowland and upland fields, where staple crops (such as rice) are cultivated. In the rice value chain in particular, women are involved as helpers in production activities. These include sowing and winnowing paddy and in processing (rice parboiling) and marketing.

Ensuring access to energy is critical in enabling women to reach their full potential in agricultural activities. This necessitates the integration of gender considerations into programmed interventions in the agriculture sector in order to remove the barriers impacting women.

In cognisance of the critical role played by women in agri-food value chains, the Guinean government is set to develop the human capital and empowerment of young people and rural women in the sector. It is doing this through vocational training and entrepreneurial support, which are key components of the PNIASAN 2018-2025.

1.5 Overview of the energy sector

The Guinean energy sector is at a turning point after years of precarity in electricity caused by: insufficient generation capacity; limited transmission and distribution infrastructure; high technical and commercial losses; and a poor financial performance by the national electricity utility, *Electricité de Guinée* (EDG) or Guinea Electricity. In recent years, considerable investments by the government, with support from development partners such as the World Bank (WB), the *Agence Française de Developpement* (AFD), or French Development Agency, and the African Development Bank (AfDB) have transformed the sector, in terms of generation capacity and access to electricity.

Guinea has significant hydroelectric potential, estimated by the WB at 6 233 megawatts (MW) (World Bank and AECOM, 2018), of which only about 13% is currently exploited. Nonetheless, the electricity supply situation has been improved by these hydropower sources, with the commissioning of the Kaleta Hydropower Plant (240 MW) in 2015 and the Souapiti Hydropower Plant (450 MW) in 2021, as well as the rehabilitation of existing hydropower plants.

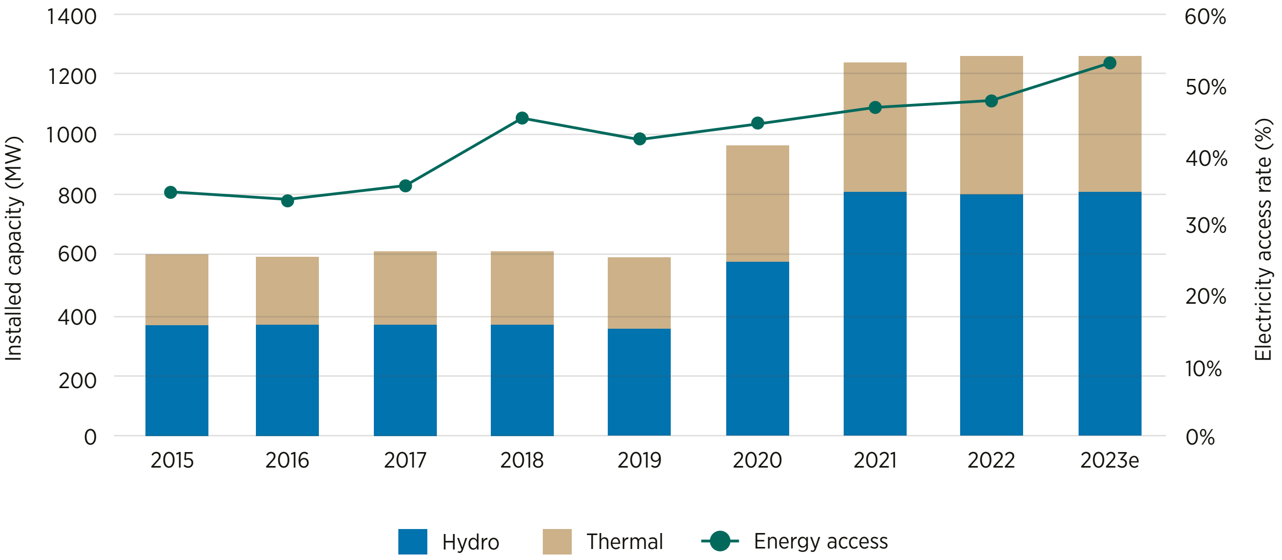
Box 2 Government policy and strategic objectives for the energy sector

The National Energy Policy, adopted in 2012, is geared towards the following objectives:

- Guarantee the security of the energy supply through diversification of the energy mix. This is being done in order to: contribute to national energy autonomy; reduce dependence on fossil or oil-based energy; and export energy products. To this end, support for hydroelectric production and multi-purpose dams is a government priority. Key policy objectives put forward include: the promotion of domestic gas to curb the abusive exploitation of wood and charcoal; the promotion of renewable energies; the ensuring of environmental, ecosystem and human health protection.
- With a view to promoting the country's economic competitiveness, growth and sustainable development, the plan aims to: stimulate energy efficiency and energy saving programmes for all categories of users; control operational, maintenance and investment costs; and control the prices and quality of energy inputs and products.

The National Energy Policy reaffirms the government's determination to stimulate the private sector to achieve these objectives, in particular for hydroelectric production and the provision of electricity services.

Figure 3 Installed capacity and electricity access rate in Guinea



Source: (INS, 2023; IEA *et al.* 2024).

Notes: e = estimated; MW = megawatts.

Despite its strong potential for energy self-sufficiency and, indeed, to become a net energy exporter to neighbouring countries in West Africa, just 48% of the total population of Guinea had access to electricity in 2022 (IRENA, 2024a). There was a wide access gap between the urban and rural areas that year, with urban areas showing a 91% access rate in 2022, compared to just 21% in rural areas (IEA *et al.* 2024).

While 90% of total electricity generation was produced by hydroelectric sources in 2022, the remaining 10% was generated by thermal power plants (INS, 2023). Total installed capacity also grew steadily between 2019 and 2022, up from 589 MW to 1 260 MW (INS, 2023), of which 66% was renewable energy capacity (IRENA, 2024b). Between 2020 and 2022, total energy demand grew at a compound annual growth rate (CAGR) of 9%. This rate is expected to increase with the on-going expansion of the national grid to key growth centres in the interior of the country.

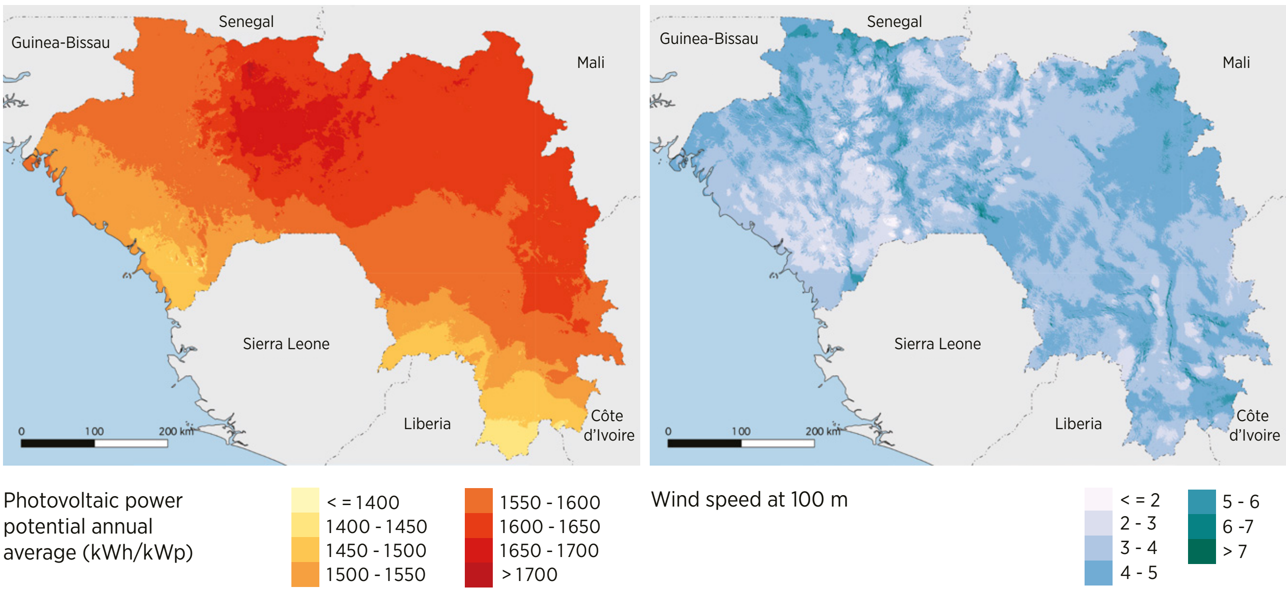
Key government priorities for the sector include expanding access, increasing the share of renewable energy in the energy mix, improving energy efficiency and lowering electricity tariffs.

While Guinea's national electrification strategy mostly relies on grid extension, off-grid solutions still have a critical role to play, both as a "pre-electrification" strategy, anticipating the arrival of the national grid, and as a way of reaching last-mile connections in remote areas of the country. Development partners such as the United Nations Development Programme (UNDP), the WB and the AfDB are already supporting the government of Guinea in expanding electricity access through mini-grids. Several mini-grid pilot projects were launched in 2020, and many more are on the horizon, with the aim of accelerating the electrification of hard-to-reach remote areas.

In addition to its hydroelectric potential, Guinea has high solar irradiation, complemented by modest wind resources for electricity generation (Figure 4). In 2023, off-grid solar photovoltaic (PV) accounted for 2% of the country's total renewable capacity (IRENA, 2024b).

In 2021, as part of the diversification of Guinea's energy mix, a 40 MW solar PV independent power producer (IPP) project – the Khoumagueli Solar PV Park – was begun, with this expected to be commissioned in 2025. In the long term, the government is planning to add 600 MW of solar energy (AfDB, 2021). These large-scale renewable energy developments can position Guinea as a net exporter of renewable electricity to the sub-region, while also contributing to Guinea's climate commitments under the Paris Agreement. According to the updated Nationally Determined Contribution (NDC) adopted in 2021, Guinea has committed to produce 80% of its electricity from renewable sources by 2030 and aims to transition the agricultural sector to a carbon-neutral pathway by 2050 (see Box 3).

Figure 4 Solar resource map (left) and wind resource map (right)



Notes: kWh/kWp = kilowatt hours per kilowatt power; m = metres.

Disclaimer: These maps are provided for illustration purposes only. Boundaries and names shown do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Box 3 Guinea's climate commitments

Globally, around 30% of GHGs emanate from the different stages of the agri-food sector's processes. These include production, processing, transportation, marketing and consumption (FAO, 2022).

In Guinea, the agriculture sector is the largest contributor to GHG emissions, emitting an estimated 21 million tonnes in 2020 – a figure which accounted for 51% of the country's total emissions (Ritchie *et al.* 2024). The country is also grappling with the impacts of an ever-changing climate, including increasing numbers of extreme weather events (floods, droughts *etc.*) which impact many aspects of people's livelihoods and the agri-food sector.

In 2021, the country updated its NDCs under the Paris Agreement. It now aims to reduce GHG emissions by 9.7% (unconditional) and 16.9% (conditional) by 2030, compared to the business-as-usual scenario. Emissions reduction efforts are being focused on several priority sectors, including mining, agriculture, energy and land use, land use change and forestry. Guinea's NDC implementation is expected to cost USD 13.9 billion, with the agriculture sector (including livestock) requiring USD 550 million for climate adaptation. The renewed ambitions on adaptation and mitigation actions are highlighted below:

1.1 Adaptation objectives and commitments:

Commitment 1:	To preserve the quality and quantity of surface water resources through the effective implementation of the National Water Policy.
Commitment 2:	To protect, conserve and manage ecosystems, revitalise economic activities and the resilience of populations in the country's coastal zone.
Commitment 3:	To support the adaptation of rural communities through the development of agro-sylvo-pastoral techniques that enable a continuation of their activities and preservation of resources.
Total cost:	**USD 1 billion (7.5%)**

1.2 Mitigation objectives and commitments:

Commitment 1:	To reach 80% of electricity production from renewable sources by 2030.
Commitment 2:	To modernise the wood-energy sector and put responses to heat on a renewable trajectory.
Commitment 3:	To urgently curb deforestation through sustainable forest management and increasing protected areas.
Commitment 4:	To set the mining sector on a net-zero emissions trajectory by 2040.
Commitment 5:	To improve the efficiency of the national transport system.
Commitment 6:	To collect and recycle urban waste.
Commitment 7:	To set the agricultural sector on a carbon-neutral path by 2050.
Total cost:	**USD 12.9 billion (92.5%)**

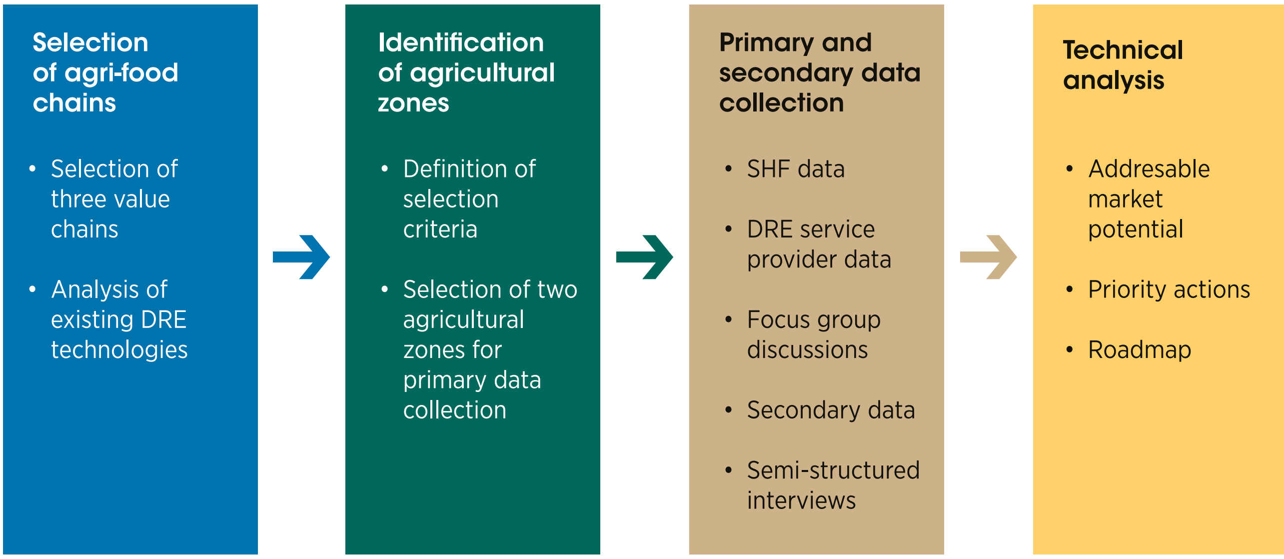
Source: (Government of Guinea, 2022b).

2. Methodology

The methodology used in this assessment has been designed to identify commercially viable DRE technologies that can be specifically targeted at commercial SHFs who may have the financial means to afford and acquire these technologies and services. In selecting three agricultural value chains in line with Guinea's strategic interests and priorities, the methodology also follows a country-led participative and inclusive approach. The rice, maize and vegetables value chains are the most cultivated by SHFs in Guinea, possess significant market value, and have the potential to bolster food security in the country.

This chapter also presents the analytical steps and underlying assumptions made in estimating the market potential of DRE in Guinea's agriculture sector, based on collected field data. Figure 5 illustrates the methodology and approach of the study, described in detail in the succeeding sections.

Figure 5 Approach and methodology of the study



2.1 Selection of agricultural value chains

The selection criteria for agri-food chains in this study encompassed several factors: the current national production volume; the extent of representation of the value chain within the country; the potential direct added-value to smallholder farmers resulting from the deployment of DRE technologies; and the market value of the crop. In Guinea, rice and maize are the most cultivated staple crops, significantly contributing to the national food balance sheet. Additionally, vegetable production plays a crucial role in ensuring food security and in meeting the subsistence needs of rural farming households. Table 3 provides detailed information on the selection criteria employed.

Table 3 Value chain selection matrix

	Agriculture value chain		
	1. Rice	2. Maize	3. Vegetables
Current national production volume	High	Medium	High
Level of representation across the national territory	High	High	High
Improvement of added value for smallholder farmers, if gaining access to DRE solutions	Medium	Medium	High
Market value of crops at GDP national scale	Medium	High	Low
Most suitable DRE technology attached to the crop	*Irrigation*	*Milling*	*Irrigation/ cold storage*

Note: DRE = decentralised renewable energy; GDP = gross domestic product.

For each of the rice, maize and vegetable food chains, the most suitable stage for deployment of DRE technology has been identified, in line with the priorities of the government. For example, solar PV water pumping, especially during the dry season, has the potential to enable SHFs to significantly boost their production, thereby reducing food insecurity and increasing their income. Post-harvest agro-processing technologies such as milling – as well as cooling technologies like solar refrigeration units or walk-in cold rooms – can effectively prolong the shelf life of produce, thereby enhancing the value addition of agricultural products.

2.2 Identification of agricultural zones for primary data gathering

In collaboration with government stakeholders led by the *Ministère de l'Agriculture et de l'Elevage Guinée* (MAGEL), or Ministry of Agriculture and Livestock, two agricultural zones – Kegneko, in the Mamou region, and Linsan, in the Labé region – were chosen for the collection of quantitative and qualitative data from SHFs and productive-use service providers. This selection was based on the predetermined criteria outlined in Table 4. These two regions exhibit distinct agroecological characteristics and socio-economic profiles, representing the diversity of the country. By incorporating these nuances into the analysis, the study aims to achieve greater representativeness in the data gathered.

Table 4 Criteria for selection of agricultural zones

Criteria	Description
Proximity to commercial centres	Proximity to major towns provides SHFs with greater access to agricultural markets, allowing them to sell their produce more easily and offering increased opportunities to obtain agricultural inputs. PUE services such as milling and refrigeration are usually more accessible in these areas.
Crop production levels	Various factors are considered, such as the market value and demand for crops in both local and international markets.
Access to water all-year around	The availability of permanent water resources (*e.g.* rivers or lakes) is a crucial factor in ensuring the effective utilisation of DRE for agricultural production, especially in the case of off-grid solar PV pumping. Agricultural areas with permanent access to water resources are prioritised to optimise DRE-powered irrigation.
Distance from national grid	The proximity of agricultural settings to the national grid is a determining factor in assessing the suitability of deploying DRE solutions in these areas. Agricultural zones that are distant from the national grid are prioritised in this study, as they are more likely to benefit from the deployment of DRE solutions.

Notes: DRE = decentralised renewable energy; PV = photovoltaic; SHF = smallholder farmer.

2.3 Primary data collection

To gain a comprehensive understanding of the socio-economic and energy-use profile of SHFs and productive-use providers in Guinea, both quantitative and qualitative data were collected from the field by a local team of enumerators. For the quantitative data, a total of 775 SHFs (24% of the respondents being women) and 45 productive-use service providers (comprising 31% women) were surveyed using questionnaires. These covered a wide range of socio-economic, energy, finance, and technology-related subjects. Meanwhile, qualitative data gathering through four focus discussion groups with SHFs helped to triangulate information and provide a more substantive and context-specific analysis for DRE use in Guinea.

In addition, over a dozen semi-structured interviews were conducted. These covered development partners, such as the UNDP, WB, the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ), or German Development Corporation, and the AFD. They also covered government agencies, such as the *Agence Guinéenne d'Électrification Rurale* (AGER), or Guinean Agency for Rural Electrification, private sector companies, such as renewable energy equipment suppliers and agro-input dealers, and local agriculture federation and co-operative groups, including the *Confédération Nationale des Organisations Paysannes de Guinée* (CNOPG), or National Confederation of Farmer Organisations of Guinea, and the *Fédération des Planteurs de la Filière Fruit de la Basse Guinée* (FEPAF-BG), or Federation of Fruit Planters of Lower Guinea.

2.4 Analysis of DRE market potential for agriculture in Guinea

This study employs a chain-ratio method[1] to estimate the addressable market potential for DRE in specific stages of the rice, maize and vegetables value chains. The target beneficiaries are classified into two groups, as follows:

- Commercial SHFs with the capacity to acquire individual solar-powered irrigation pumps and refrigeration units. The number of SHF households in Guinea that cultivate the three value chains is presented in Table 5.
- Productive-uses service providers offering milling and refrigeration services.

Table 5 SHF households engaged in rice, maize and vegetable cultivation

Value chains	Rice	Maize	Vegetables
Total SHFs in Guinea per selected value chain (in 2021)	928 846	933 062	894 534
Estimated commercial SHFs	325 096	326 572	313 087
Estimated subsistence SHFs	603 750	606 490	581 447

Source: (ANASA, 2023).

For commercial SHFs, the addressable market potential for solar water pumps and solar refrigeration units has been estimated using the following variables:

- Level of interest in acquiring the specific DRE technology
- Availability of permanent and superficial sources of water for solar water pumps
- Willingness to pay by potential customers
- Number of commercial SHF cultivating the target crops

For PUE service providers, the addressable market potential for solar-powered milling and refrigeration services has been estimated by employing the following variables:

- Willingness to buy solar powered mills and refrigeration equipment to replace diesel-based equipment
- Willingness to pay for specific DRE technologies
- Estimated number of milling businesses in Guinea. The study considers that every district in Guinea has an average of five milling services

2.5 Sensitivity analysis of estimated market potential

The estimated market potential of the different DRE technologies is directly correlated to the willingness-to-buy (WTB) and willingness-to-pay (WTP) of target commercial SHFs and PUE service providers. Variations in these two important parameters can greatly influence the estimated market potential. Based on the survey results, a sensitivity analysis of the WTB and WTP has therefore also been considered in this study.

For WTB, the sensitivity analysis considered four levels, while for WTP, the analysis considered three levels among the surveyed commercial SHFs and three among PUE service providers (Table 6).

1 A method of calculating total market demand for a product/service in which a base number, such as the prospective users, is multiplied by several delimiting factors in order to arrive at a rough estimate of the potential market for the particular product/service.

Table 6 Sensitivity analysis of willingness to buy and willingness to pay on estimated market potential

WTB	Rate (%)	Notes
Low WTB	25%	Based on low penetration of DRE in the agriculture sector in Guinea.
Median WTB	50%	Assuming average penetration of DRE.
High WTB	75%	Assuming high penetration of DRE in Guinea.
Universal WTB	100%	This provides the total addressable market – *i.e.* that in which 100% of target SHFs are willing to buy DRE.
WTP among commercial SHFs	**Amount (USD)**	**Notes**
Low WTP	100	These values are based on survey results. On average, 81% of commercial SHFs are willing to pay between USD 100 and USD 300.
Median WTP	200	
High WTP	300	
WTP among PUE service providers	**Amount (USD)**	**Notes**
Low WTP	500	These values are based on survey results. On average, 86% of the businesses are willing to pay between USD 500 and USD 1 000 to acquire DRE technologies.
Median WTP	750	
High WTP	1 000	

Notes: DRE = decentralised renewable energy; SHF = smallholder farmer; WTB = willingness-to-buy; WTP = willingness-to-pay.

2.6 Limitations of the estimated market potential methodology

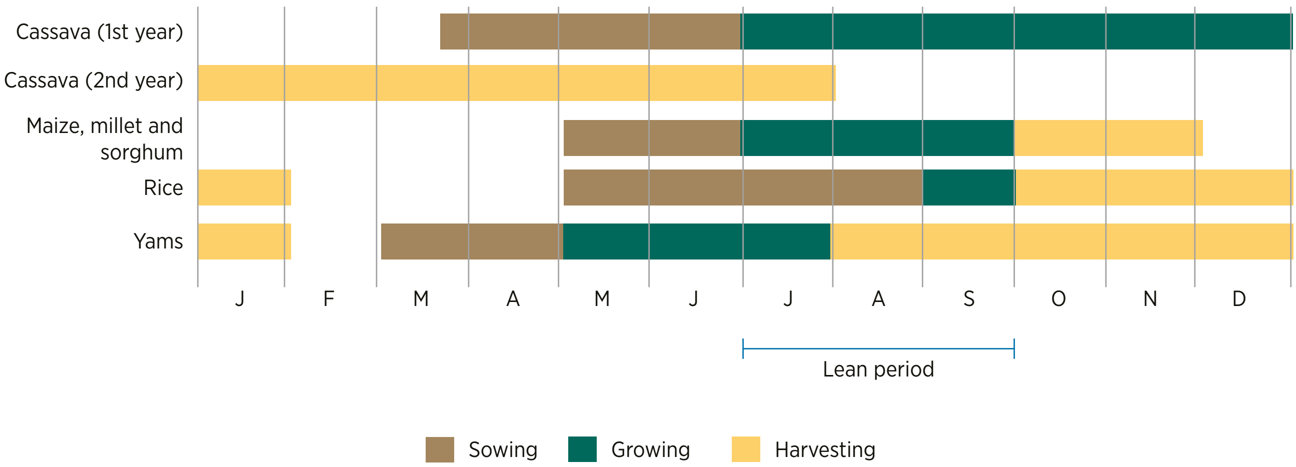
In this study, the quantitative data collected from the two agricultural zones has been complemented by the results of the *Recensement National de l'Agriculture et de l'Élevage* (RNAE), or National Census of Agriculture and Livestock (ANASA, 2023). While the two agricultural zones are considered mostly representative of Guinea's agricultural setting, the authors acknowledge that the scaling approach may introduce inherent errors and potential bias due to the sample size. The assumption of a linear relationship between the sample data and overall national farmer population does not take into account potential non-linear factors, such as seasonality (temporal considerations), farming practices and market dynamics which could vary significantly between agricultural zones. Therefore, the estimated market potential for DRE solutions presented in the report should be taken as preliminary analysis for Guinea. To support robust policy planning and investment programming for DRE integration in the country's agriculture sector, a more in-depth and expansive market assessment should be conducted, potentially building on the results of the present study.

3. Agricultural value chains in Guinea

The agriculture system in Guinea is predominantly subsistence based and conducted by SHFs who rely on traditional cropping methods. These farmers also have restricted access to agricultural inputs, mechanised equipment and low-cost financing.

Generally, the cropping season begins between March and May, with the onset of the rainy season (Figure 6). The harvesting period is between October and January for most crops, particularly rice and maize. Typically, SHF households face challenges during the lean period, when food stocks are depleted and prices reach their peaks. This chapter presents the rice, maize and vegetables value chains in terms of activities, actors and the greatest entry points for the integration of DRE.

Figure 6 Cropping calendar for major crops in Guinea



Source: (FAO, 2024).

3.1 The rice value chain

In Guinea, rice is the most important agricultural commodity and rice production is strategic to the country's development. Nationwide, rice accounts for 47% of the cropped area and more than 50% of total cereal production (FAO, 2024). In 2023, the per capita consumption of rice was 147 kilogrammes per year (kg/yr). Making it the most consumed staple in Guinea (FAO, 2024).

Rice is also the largest import commodity in the country, with an import value averaging USD 142 million between 2018 and 2022 (INS, 2023). Between 2016 and 2022, rice production increased by more than half, from 2 million tonnes to over 3 million tonnes (Table 7). While yields have improved in recent years – rising from 1.3 tonnes/hectare in 2016 to 2.4 tonnes/hectare in 2022 – they are still below the global average yield of 4.2 tonnes/hectare (World Bank, 2023). The government has set a production target of 4.6 million tonnes by 2025, with a yield level of 3 tonnes/hectare (Government of Guinea, 2018). By 2030, the cultivated area for rice is projected to reach 2.4 million hectares, requiring a capital investment of USD 272 million (IFAD, 2021).

Table 7 Production, cultivated area and yield levels for rice in Guinea, 2016-2022

Year	Production (tonnes)	Area (hectares)	Yield (tonnes/hectare)
2016	2 149 030	1 708 551	1.3
2017	2 291 434	1 661 371	1.4
2018	2 443 274	1 615 493	1.5
2019	2 605 176	1 570 883	1.7
2020	2 777 806	1 527 504	1.8
2021	2 961 875	1 485 323	2.0
2022	3 158 141	1 336 383	2.4

Source: (INS, 2023).

Government policies and strategies for the development of the rice value chain aim to address three major challenges: food security, rural poverty and a negative balance of trade in food. Recent policy and strategic directions for rice development have also been set down in three main documents: the *Strategie Nationale de Developpement de la Riziculture en Guinee, 2019* (SNDR), or National Strategy for the Development of Rice Production, 2019; the PNDA, 2016-2025; and the PNIASAN, 2018-2025.

Rain-fed rice, upland rice, lowland rice and mangrove rice farming are the four main rice production systems in Guinea (Government of Guinea, 2019). Of these, the rain-fed system is by far the most widespread, accounting for 65% of the area under rice cultivation. Cultivation is done manually and without the use of fertilisers, with yields varying between 500 kg per hectare and 900 kg per hectare.

The lowland system represents 10% of the rice area and is predominantly in the region known as Forested Guinea. This production system yields between 1.5 tonnes per hectare and 2.5 tonnes per hectare. The upland rice farming system accounts for 9% of the land area and is mainly practiced in Upper Guinea, with yields between 0.5 tonnes and 2 tonnes per hectare, depending on the flooding of the rivers and their tributaries. Mangrove rice farming is predominantly practiced in the coastal plains of Lower Guinea and accounts for 16% of the rice cultivated area, with yields ranging between 1.5 tonnes and 3.5 tonnes per hectare.

Figure 7 Mapping the rice value chain in Guinea

Stage	Activities	Actors	DRE entry points
Production	Land, preparation, irrigation, harvesting	Farmers, input suppliers	Solar, wind-based pumping, mini-grids
Collection	Aggregating, paddy selling	Collectors, aggregators	Solar powered theshing
Processing	Parboiling, drying, miling, storage	Community services, millers	Solar drying, solar miling, mini-grids
Marketing	Transport, storage, packing	Wholesalers, retailers	Electric transport
Consuption	Cooking	Consumers	Renewable energy based electric cooking

Rice cultivation is highly labour-intensive in Guinea, where most rice production is still undertaken manually, or with animal traction (USAID, 2015). Modern mechanical means of rice production are only significantly deployed in the Kankan region (51%), the country's largest and most mechanised rice cultivation area. Most of this mechanisation involves using walk-behind-tillers and tractors.

Almost all harvesting and threshing is done by hand, which invariably results in a high level of broken grains. Post-harvest losses are indeed common, due to inadequate storage and handling capabilities, insufficient infrastructure and a lack of processing equipment. The most common methods for processing paddy rice are manual threshing, parboiling and simple mechanical milling. The most energy-intensive processes in the rice value chain are irrigation and processing.

Different commercially viable and near-to-market DRE technologies currently exist that could be employed to power different stages of the rice value chain, as illustrated in Figure 7. This assessment focuses on solar water pumping for the irrigation of rice fields. This is done in order to increase production, which constitutes the greatest priority of the government, as well as being the source of highest energy demand.

3.2 The maize value chain

In Guinea, maize is the second most commonly grown cereal consumed, after rice. In recent years, demand for maize has been rising, particularly in urban areas, where it is commonly used as a substitute for rice. It also has other uses, including as an animal feed (USAID, 2017). Maize production is predominantly rainfed, with limited input usage, and is usually intercropped with other commodities such as groundnuts. Maize is currently cultivated by over 933 062 SHFs (ANASA, 2023).

Between 2016 and 2022, the country's maize production grew by nearly 3% per year. Over the same period, average maize yields increased by 285 kg per hectare. In 2022, over 870 000 tonnes of maize were cultivated, giving a record yield of 3.2 tonnes per hectare (INS, 2023). The government has set a production target of 1.3 million tonnes by 2025, with a yield level of 3 tonnes per hectare (Government of Guinea, 2018). The cultivated area for maize is projected to reach 518 000 hectares by 2030, requiring a capital investment of USD 78 million (IFAD, 2021).

Table 8 Production, cultivated area and yield levels for maize in Guinea, 2016-2022

Year	Production (tonnes)	Area (hectares)	Yield (tonnes/hectare)
2016	739 118	620 559	1.2
2017	759 499	539 773	1.4
2018	780 443	469 504	1.7
2019	801 963	408 383	2.0
2020	824 077	355 218	2.3
2021	846 801	308 975	2.7
2022	870 152	266 175	3.2

Source: (INS, 2023).

Figure 8 Mapping the maize value chain in Guinea

Stage	Activities	Actors	DRE entry points
Production	Land, preparation, irrigation, harvesting	Farmers, input suppliers	Solar, wind-based pumping, mini-grids
Collection	Aggregating	Collectors, aggregators	Solar powered theshing
Processing	Dehusking, drying, miling, storage	Community services, millers	Solar drying, solar miling, mini-grids
Marketing	Transport, storage, packing	Wholesalers, retailers	Electric transport
Consuption	Conusumption	Consumers, animal farmers	Renewable energy based electric cooking

Note: DRE = decentralised renewable energy.

Medium-sized and large-scale maize producers do exist in Guinea, but only in small numbers. Post-harvest processing of maize usually takes place in local milling businesses owned by co-operatives, federations and women's groups. Large-scale processing facilities for maize are limited, except for some medium-scale processors in Conakry and Kindia. Although the government has provided direct purchasing and distribution of diesel-based milling machines in the past (INS, 2020), this falls short of the vast needs the country is facing. Similar to rice, women engage more in maize production and harvesting, while men are more active in post-harvesting and retailing.

3.3 The vegetables value chain

The main vegetables produced and consumed in Guinea are aubergines, tomatoes, onions, okra, cucumbers and peppers. Together, 3.3 million tonnes of these vegetables were produced in 2022, with aubergines and tomatoes representing more than 52% of the total (Table 9).

The main regions for vegetable cultivation are in Maritime and Middle Guinea. While the adoption of intensive and specialised production methods has risen in recent years, most vegetable production is still carried out by small-scale producers (mainly women) using traditional farming techniques. Harvests are sold directly at local markets in high consumption peri-urban and urban areas.

Post-harvest processing of vegetables depends on the type of product. While tomatoes usually do not need refrigeration at the farm gates (as they are usually picked unripe), other crops, such as lettuce, need refrigeration services to maintain freshness. Due to the perishable nature of vegetables, provision of drying and refrigeration services are a critical part of the vegetable value chain.

Table 9 Production of Guinea's principal vegetable crops, 2015-2022 (tonnes)

Crops	2015	2016	2017	2018	2019	2020	2021	2022
Aubergine	774 702	792 480	810 666	829 270	848 300	867 767	887 681	908 052
Okra	487 000	495 566	504 283	513 153	522 180	531 365	540 711	550 222
Pepper	274 335	284 463	294 964	305 853	317 144	328 852	340 992	353 581
Tomato	558 886	593 534	630 329	669 406	710 905	754 976	801 780	851 486
Onion	447 890	473 710	501 019	529 901	560 449	592 758	626 930	663 071
Lettuce	85 871	86 108	86 346	86 584	86 823	87 063	87 303	87 544

Source: (INS, 2023).

Figure 9 Mapping the vegetables value chain in Guinea

Stage	Activities	Actors	DRE entry points
Production	Irrigation, harvesting	Farmers, input suppliers	Solar, wind-based pumping, mini-grids
Collection	Aggregating, cooling	Collectors, aggregators	Solar powered theshing
Processing	Drying, grading, storage	Community services, SMEs	Solar drying, solar miling, mini-grids
Marketing	Transport, storage, packing	Retailers	Electric transport
Consuption	Conusumption	Consumers	Renewable energy based electric cooking

Note: DRE = decentralised renewable energy.

In Guinea, vegetable production faces two major challenges: lack of adequate water irrigation systems; and food losses resulting from insufficient cold storage, handling, and processing infrastructure. Food loss is estimated at between 30% and 40%, according to the field data gathered in this study. There is minimal to no post-harvest processing of vegetables in Guinea. However, vegetables such as peppers and tomatoes are sun-dried to extend their shelf life, enabling trade in markets over longer distances. Sun drying of vegetables is done manually, typically on large soil surfaces and during the dry seasons. In addition to reducing spoilage, drying can improve product diversification and create new jobs – especially for women – in the drying process, packaging, logistics and marketing.

4. Current DRE trends in Guinea's agricultural sector

DRE technologies and the business models associated with their deployment enable a range of benefits. These include access to irrigation – which boosts agricultural production – and the powering of small and medium-scale agro-processing enterprises and their equipment. Solar refrigeration units enable the preservation of agricultural produce, reducing food losses. These are currently estimated at 30% for the sub-Saharan Africa region (E4A, 2019). Emerging technologies, such as walk-in cold rooms or agro-milling machinery can boost income generation and value addition, opening new market opportunities for SHFs. The addressable market potential for DRE-powered water pumping, cooling and processing in sub-Saharan Africa is estimated at USD 11 billion (World Bank, 2019).

4.1 State of the DRE market and operational business models in Guinea

In Guinea, the DRE segment of the energy sector is still very nascent, with only a few private companies operating in the solar off-grid industry. The majority of these private actors commercialise and install off-grid solutions for individual households, with few deployments of DRE for commercial and industrial applications. As of 2023, the *Association des Professionnels des Énergies Renouvelables de Guinée* (APER-GUINEE), or Association of Renewable Energy Professionals of Guinea, consisted of 25 companies offering renewable energy (solar, wind, or biogas) supply and installation services. The majority of APER-GUINEE members are off-grid solutions importers and distributors. At least two DRE companies are engaged in the design and installation of solar PV water pumps for mid- and large-scale commercial farmers, or for rural water supply under non-governmental organisation (NGO) and humanitarian-based funded projects.

During stakeholder consultations and engagements undertaken as part of this study, APER-GUINEE identified the following as the main challenges for the DRE sector in Guinea:

- **A lack of access to capital to grow operations:** Commercial banks are not fully aware of the potential of DRE technologies. Highly capitalised banks do not yet offer any tailored credit line to DRE companies. There are micro-finance institutions (MFIs), such as the *Crédit Rural de Guinée* (CRG), or Rural Credit of Guinea, that provide agriculture and equipment loans, but these are typically at high interest rates – around 18% – with short repayment periods.
- **The absence of a clear regulatory framework for renewable energy:** While there is government willingness to support the growth of DRE companies, there are no clear and supportive policies and regulations in place.
- **A lack of incentives:** There is no streamlined tax exemption process for DRE products and technologies, hampering importation processes and increasing costs at points of sale. Tax exemptions are provided only on a project-to-project basis.

Almost all DRE companies in Guinea operate under an up-front cash sales business model, with only Orange Energy offering solar home systems sold on a pay-as-you-go (PAYG) basis. The highest demand for DRE appliances appears to be portable solar lighting and solar home systems. To date, there are no DRE companies offering solar PV milling machines, walk-in cold rooms, or mobile surface water pumps. However, one DRE company (Alpha Technologies) plans to pilot the first off-grid solar walk-in cold room. By far, solar PV water pumping is the most mature DRE technology in Guinea, yet its low level of deployment leaves a lot of room for expansion.

With the support of its development partners, the Guinean government is currently promoting the deployment of private solar PV mini-grids, or the hybridisation of existing mini-hydro or diesel-based mini-grids in rural areas, through its rural electrification agency, AGER. The UNDP, for example, has financed the hybridisation of a 60 kilovolt amp (kVA) mini-hydro power plant in Bolodou with 20 kilowatt peak (kWp) solar PV and 35 kilowatt hour (kWh) battery storage. It has also financed the installation of a 102 kWp solar PV plant with 175 kWh battery storage in Thianguel Bori. The AfDB, meanwhile, has been supporting the implementation 12 solar PV/diesel hybrid mini-grids, in collaboration with the World Bank. These two organisations have also been supporting the carrying out of socio-economic feasibility studies into new mini-grids for 45 rural communities across Guinea. These mini-grid interventions have great potential in supporting anchor loads, such as water pumping for agriculture and agro-processing by agri-enterprises.

4.2 Decentralised renewables in agri-food chains

The application of DRE technologies and services in agri-food chains has emerged rapidly over the last decade. This has been driven mainly by the falling cost and the improved efficiency of solar PV. Other DRE technologies that have been demonstrated in places such as Nepal and India include micro-hydro, biogas, or wind systems (IRENA, 2016). In the recent past, evidence shows off-grid appliances and products have been critical in enabling income generation, improving quality of life, creating employment, and building climate resilience among vulnerable rural communities (GOGLA, 2023).

The economics of DRE technologies are highly favourable for SHFs, as well as MSMEs, with payback periods ranging from one to six years (World Bank, 2022). This is particularly true when replacing diesel-based systems with DRE solutions, but the economics are also good for farmers transitioning from rainfed farming to solar irrigation farming, due to the potential increase in yields. Off-grid solutions like solar water pumps, for example, can boost agricultural productivity by up to 30%, while solar-powered cold storage facilities located at the farm level can reduce post-harvest losses by between 30% and 40% (E4A, 2019, 2022).

DRE technologies are characterised in Table 10 by their level of market maturity, which ranges from concept stage to commercial stage. Table 11 shows the maturity levels of different DRE technologies and most common business models in Guinea's agriculture sector.

Table 10 Stages of product development and technical and market maturity levels

Stages of product development and maturity levels	Concept	Horizon	Emerging	Near-to-market	Commercial market
Technical level	Product prototype exists	Product being piloted	Minimum viable product exists	High rates of design and manufacturing, innovation, and cost reduction	Incremental changes in cost, performance, and efficiency
Market level	Nascent	Business models being piloted	First sales from a few early adopters	Growing sales and new entrants in the market	Products sold at volume by many players. Market 'ecosystem' of supporting inputs and services exists

Adapted from: (World Bank *et al.* 2022).

Table 11 DRE technologies by application, business model and maturity in Guinea

Sector	Application	Technology	Business model	Maturity stage
Agriculture	Irrigation	Solar water pumps	Cash upfront/PAYG	Near-to-market
	DRE-powered cooling	Walk-in cold rooms	Fee-for-service	Emerging
		Refrigerators	Cash upfront/PAYG	Near-to-market
		Freezers	Cash upfront/PAYG	Emerging
		Milk chillers	Cash upfront/PAYG	Horizon
		Ice makers	Cash upfront/PAYG	Emerging
	DRE-powered agro-processing	Mills	Fee-for-service	Horizon
		Threshers	Fee-for-service	Horizon
		De-huskers	Fee-for-service	Horizon
		Oil presses	Fee-for-service	Emerging
		Dryers (solar-powered)	Fee-for-service	Horizon
	Transportation	E-mobility	Fee-for-service	Emerging

Notes: DRE = decentralised renewable energy; PAYG = pay-as-you-go.

The field work conducted in this study unveiled the most prominent DRE technology entry-points for the selected agri-food chains in Guinea. These are shown in Table 12 and then described below.

Table 12 Initial cross-cutting between DRE solutions and selected value chains

	DRE technology entry point		
	Solar PV cold storage	Solar powered irrigation	Solar milling/ processing
Availability of DRE technologies/ business models in Guinea	Low	**Medium**	Low
Availability of DRE technologies/business models elsewhere in sub-Saharan Africa	High	High	**Medium**
Availability of local private sector with technical capacity	**Medium**	**Medium**	Low

Note: DRE = decentralised renewable energy; PV = photovoltaic.

- **Solar water pumping:** Solar water pumping means communities have greater control over their agriculture and are more resilient in the face of negative climate effects. Solar water pumping means increased yields via irrigation, while it also decreases the likelihood of food and water insecurity.
- **Solar agro-processing, focused on milling:** This includes a broad category of DRE technologies, but typically refers to equipment or devices that add value to agricultural products, such as cereal mills, threshers, de-huskers, dryers *etc*. These are typically employed by farmers and MSMEs to add value to their produce prior to commercialisation.
- **Solar refrigeration:** Cold storage (walk-in cold rooms or individual solar refrigerators) add value in multiple ways. First, they can reduce post-harvest losses by up to 40% and second, market access can be increased, as cold storage extends the lifespan of perishable goods. Lastly, cold chains can open up new local business opportunities, such as local fish or meat sales.

5. DRE market potential for agriculture in Guinea

This chapter presents an analysis of the energy needs and market potential of Guinea's SHFs. It gives a profile of these farmers based on the findings of a study that examined their access to credit, their agricultural production and their current use of energy technologies in production and agro-processing.

The chapter also estimates the market potential of several DRE technologies in powering Guinea's agricultural sector. Those technologies are solar water pumps, solar refrigeration and solar milling. Importantly, the chapter conducts a sensitivity analysis to assess how the estimated market potential is influenced by the WTB and WTP factors of both SHFs and PUE service providers. This approach offers valuable insights into the current state of energy access and opportunities for expanding renewable energy solutions in support of commercial smallholder farming in Guinea.

5.1 Profile of SHFs in Guinea

The farmers surveyed were males aged between 30 and 60 years old, with household sizes ranging between four and ten members. A quarter of the farm households interviewed were headed by women,[2] 59% of whom worked in the primary agricultural labour force, while 24% provided productive end-use services and 17% generated revenues from other businesses. This is in line with the national average of female-headed agricultural households in Guinea, which were estimated to account for 18.4% of the total by the 2020-2022 national census (ANASA, 2023).

SHFs in Guinea can be broadly categorised into two groups:

- **Subsistence SHFs:** These have a low level of production that is mainly for household consumption. They also have limited access to land and low-income generation. They are typically in rural and isolated regions, far from any road access and basic services.
- **Commercial SHFs:** These have higher productive capacity, access to bigger plots of land and agricultural inputs, and higher income generation than subsistence SHFs. They are typically located in regions with primary and secondary road access that connects to urban areas.

In terms of geographical distribution, survey data shows commercial SHFs are typically based in better-off areas, while subsistence SHFs are more often found in remote areas (see Table 13).

2 According to the International Organization for Migration (IOM), women-headed households "are households where either no adult men are present, owing to divorce, separation, migration, non-marriage, or widowhood; or where the men, although present, do not contribute to the household income because of illness or disability, old age, alcoholism or similar incapacity (but not because of unemployment)"(IOM, 2023). Most of the cases in this survey related to migration or widowhood.

Table 13 Characterisation of SHFs by income, agricultural production and land access

Category	Income generation	Agricultural production	Land access	Location
Subsistence SHF	• Low-income generation (USD 0.20/day-USD 0.55/day)	• Practice subsistence agriculture mainly for household consumption • 50-100 kg of produce for each season	• Typically, 0-2 hectares per SHF • Lower quality of land	• In remote communities, 77.9% of surveyed SHFs were subsistence farmers • In peri-urban areas, 51.7% of survey SHFs were subsistence farmers
Commercial SHF	• Relatively higher income generation (USD 2.0/day-USD 2.7/day)	• Large production and commercialisation in local markets. • 500-1 000 kg of produce for each season	• Typically, 2-5 hectares per SHF, with some below 2 hectares • Better land quality	• In remote communities, 22.1% of surveyed SHFs were commercial farmers • In peri-urban areas, 48.3% of survey SHFs were commercial farmers

The sub-headings below summarise the main findings of the field surveys and focus group discussions conducted. These characterise the majority of SHFs in Guinea:

Access to electricity: Only 6% of the SHFs surveyed had access to electricity, mainly through diesel gensets and solar home systems. At the household level, the majority of solar home system customers pay cash up front and usually purchase from local retailers, contracting local non-professional technicians to install the systems. The age of these systems ranges between one and five years, with most having been installed in just the last two years. This suggests that solar off-grid technologies are only beginning to penetrate rural Guinea.

Access to credit: The percentage of the SHFs surveyed who reported having had access to commercial credit was only 1%. The main barriers included: the remoteness of banking offices to them; collateral requirements; and high levels of interest. The utilisation of mobile money services in rural areas was limited, with only 2% of the SHFs surveyed having access to it.

In terms of direct government financial support, the majority of SHFs interviewed reported that they had rarely received direct support from the government. Only 3% of SHFs had received some sort of government support. This had come in the form of food assistance (through the World Food Programme), agricultural inputs (such as seeds and fertilisers), or some form of subsidy to purchase agricultural equipment (such as a tractor).

Agricultural production and access to land: The most cultivated crops in the agricultural zones surveyed were rice, vegetables and maize, in descending order. Female SHFs accounted for 40% of the workforce in maize production, 35% in horticultural production and 23% in rice farming. However, for the rice value chain, women accounted for more than half the workforce in post-harvest activities such as threshing and de-husking.

While rice was the most cultivated value chain, SHFs tended to cultivate maize, vegetables or other crops alongside it. Around 15% of the SHFs surveyed annually cultivated the three value chains (*i.e.* rice, maize and vegetables). In addition to these crops, 87% of the SHFs surveyed produced groundnuts, while 20%, 6% and 2% cultivated fonio, cassava and fruits (banana and mango), respectively.

In terms of access to land, 30% of the SHFs surveyed owned the land they farmed on. In addition, 50% worked land borrowed from other SHFs, while 20% rented land on a short-term basis. Land preparation was overwhelmingly done manually, with maize production apparently using more animal traction and tractors than the other two value chains. This could be explained by the fact that maize was most often cultivated as a cash crop, hence done by more mechanised farmers.

In terms of the cropping calendar, 82% of the SHFs surveyed cultivated only during the rainy season, due to a lack of irrigation systems, while 12% irrigated their crops during the dry season. Only 5% practiced all year-round farming. While 94% of rice and 88% of maize fields were only cultivated during the rainy season, vegetables were typically cultivated all-year round, with approximately 58% of production in the rainy season and the remainder in the dry season (usually irrigated using hand-held watering cans).

In terms of production and sales, 63% of the SHFs surveyed sold less than 100 kg of produce every season, while 36% of SHFs sold over 500 kg per season locally, representing a group with higher income capacity and larger agricultural land sizes.

Access to energy technologies for production and processing: Only 1% of the farmers surveyed had access to water pumps for irrigation. These were almost exclusively diesel-powered and typically 2 horsepower (hp), using between 5 litres and 15 litres of diesel per day. Access to solar PV pumps is very limited, due to low awareness of solar PV technologies and their high capital costs. Indeed, up to 70% of those SHFs surveyed who did not have water pumps reported high costs as the primary deterrent. There was, however, great interest in solar PV water pumps among the SHFs surveyed, with 88% of those SHFs willing to acquire this technology. In terms of WTP, 86% of the SHFs surveyed would be willing to pay between USD 100 and USD 300, covering around 30%-40% of the cost of a portable solar PV water pump. Up to 82% of the SHFs surveyed indicated a willingness to take a loan out to finance the solar water pump. There is great potential for such pumps in Guinea, too, especially during the dry season. Some 91% of the SHFs surveyed were located near a permanent water source, with 56% of these farmers having access to fresh river water all year round, while 35% had access to boreholes and water wells.

The use of solar refrigeration by SHFs is quite limited. Only 1% of the SHFs interviewed owned a refrigerator, with capacities typically ranging between 50 litres and 100 litres. The refrigerators were mostly diesel-genset powered, with a few working on solar PV. While high capital costs and low awareness were cited as the key deterrents, 81% of the SHFs interviewed were willing to acquire a solar refrigerator, typically of between 25 litres and 50 litres in size. In terms of WTP, 79% of the SHFs interviewed would be willing to pay between USD 100 and USD 300 to acquire a solar refrigerator, with 73% willing to take out an asset-financing loan for this. Interestingly, 77% of the SHFs would be open to pay fee-for-cooling-services, if such were available in their areas.

In terms of the processing of agricultural produce, 69% of farmers processed their produce using milling and drying services, while 31% marketed their produce unprocessed. Most of the milling is done manually, while 37% of SHFs outsource the milling process to productive service providers, typically community based MSMEs. In Guinea, farmers generally dry their produce themselves by spreading it across a plain, open-to-sun surface in their households. There were no existing private or public drying services in the surveyed agriculture zones, with 78% of the SHFs interviewed expressing unwillingness to pay for drying services, even if they were available in the area.

No significant differences were found between subsistence SHFs and commercial SHFs in terms of demographic information, or access to energy technologies and services, such as irrigation or agro-processing. Due to their higher income levels, the affordability of energy services tended to be greater for commercial SHFs than for subsistence SHFs. Overall, the vast majority of SHFs in rural Guinea did not have access to solar water pumps or solar refrigeration units, despite high levels of interest.

5.2 Access to energy technologies for PUE service providers in Guinea

The survey results showed that the most-used agro-processing service in Guinea was milling. Up to 82% of the milling service businesses surveyed used diesel engines for power, with these consuming an average of between 5 litres and 20 litres of diesel per day. While awareness of solar PV-powered milling technologies was low (93% of the milling business owners were not aware of the solar PV milling technologies on the market), 86% of the milling businesses surveyed showed a willingness to acquire solar PV milling technologies. In terms of WTP, this was between USD 500 and USD 1 000, with 92% of the businesses surveyed willing to take out a loan to cover the full cost of solar PV milling technology.

Yet, while there was this high level of interest among milling businesses to shift to solar PV, a lack of awareness, financial barriers and access to commercial credit were found to be the main challenges to this transition.

In terms of solar PV refrigeration, 69% of the businesses interviewed were not aware of solar PV refrigeration units. However, 83% of businesses were willing to acquire a solar PV refrigerator, while 79% were found to be open to offers of fee-for-cooling services for SHFs to store their perishable produce.

The study also showed that commercial SHFs and PUE service providers – such as milling services – would have a much greater chance of obtaining DRE technologies, if these were available in rural areas and access to credit was tailored to the needs of such customers. Most DRE companies operate in the capital city, with commercial credit for end-users – including PAYG credit services – typically offered by DRE energy service providers. Today, these do not exist in rural Guinea.

Considering the current socio-economic profile of the country's SHFs and PUE service providers, the most suitable DRE technologies identified for improving agricultural production and value-addition for Guinea's SHFs are presented in Table 14 below.

Table 14 Appropriate DRE technologies for selected agri-food chains in Guinea

Value chain	Food chain stage	DRE technology	Technology description	Indicative price range
Rice and vegetables	Production	Solar water pumping	Off-grid solar water pumps enhance irrigation and prolong the growing season for SHFs in rural areas. Typically, portable appliances have power capacities up to 1 kW.	USD 550-USD 1 300
Vegetables	Aggregation and storage	Solar refrigeration unit	Off-grid refrigeration units help minimise the risk of food contamination while preserving perishable goods and beverages in rural, off-grid communities. Typically, these units have capacities of up to 300 litres.	USD 600-USD 2 000
		Walk-in cold-room	Solar-powered cold storage solutions allow for larger-scale preservation of fruits, vegetables, meat and dairy products. Typically, these are between 300 litres and 500 litres in volume. Agricultural produce can be conserved for 12 weeks at 8°C.	USD 5 000-USD 60 000
Rice and maize	Processing	Solar milling	Small-sized solar milling device for off-grid communities, adapted to cereals such as rice and maize. Average throughput is 30 kg/hour-60 kg/hour. Typical Power Ratings are 1.5-2 kW.	USD 1 000-USD 1 500

Based on: (NEFCO, 2023).

Notes: kg = kilogramme; kW = kilowatt; SHF = smallholder farmer; USD = United States dollar.

5.3 Estimated DRE market potential for agriculture in Guinea

In this study, the market potential for DRE in powering specific stages of the agricultural value chain have been estimated based on quantitative and qualitative first-hand data, the typologies of SHFs and the types of PUE service providers identified and analysed. This should be taken as a preliminary market potential analysis for DRE in Guinea, however. It provides a basis for a more in-depth and representative assessment of the DRE market – one that would benefit from a more representative socio-economic survey and more granular field data.

This study focuses on the market potential for solar water pumps, solar refrigeration units and solar milling, with the estimated results presented below.

Estimated market potential for solar water pumps

The addressable market potential for solar water pumps in Guinea has been estimated considering the following variables and delimiting factors (see Table 15):

- The estimated number of commercial SHFs, with this based on primary field data and the 2020-2022 national census (ANASA, 2023).
- The average WTP of the commercial SHFs surveyed in a solar water pump.
- The proportion of SHFs with permanent access to superficial water resources all year round.
- The level of interest in acquiring a solar water pump.

In addition, commercial SHFs tend to cultivate two or more crops on the same field. Therefore, every commercial SHF with access to a solar water pump can irrigate different crops at the same time. In practice, this reduces the number of solar water pumps per SHF required.

Table 15 Addressable market potential for solar water pumps

Market potential of solar water pumps	
Estimated number of commercial SHFs cultivating one or more crops in the same field	612 776
Percentage of SHFs with permanent access to superficial water resources, all year long	56%
WTB a solar water pump	88%
WTP for a solar water pump	USD 200
Total addressable market potential for solar water pumps	**USD 60 395 180**

Notes: SHF = smallholder farm; WTB = willingness to buy; WTP = willingness to pay; USD = United States dollar.

The estimated market potential for solar water pumps of USD 60.4 million takes into account multi-cropping, which invariably reduces the number of solar water pumps required by a particular SHF to irrigate the same plot of farmland. Field surveys showed 87% of commercial SHFs cultivated at least two crops in the same fields for effective land and water resources management to enhance yields and increase profit. Commercial SHFs cultivating maize and rice represented the biggest market segment.

Estimated market potential for solar refrigeration units

The addressable market potential for solar refrigeration units in Guinea has been estimated considering the following variables and delimiting factors (Table 16):

- The estimated number of commercial SHFs that cultivate vegetables, with this based on primary field data and the 2020-2022 national census (ANASA, 2023).
- The average WTP for a solar refrigeration unit by the commercial SHFs surveyed.
- The WTB of a solar refrigeration unit by the commercial SHFs surveyed.

In addition, only commercial SHFs cultivating vegetables were considered by the analysis. Solar refrigeration units are critical to maintain the freshness of vegetables and to reduce post-harvest losses.

Table 16 Addressable market potential for solar refrigeration units

Market potential of solar refrigeration units for the vegetables value chain	
Estimated number of commercial SHFs that cultivate vegetables in Guinea	313 087
WTB a solar refrigeration unit	81%
WTP for a solar refrigeration unit	USD 200
Total addressable market potential for solar refrigeration units	**USD 50 720 077**

Notes: USD = United States dollar; WTB = willingness to buy; WTP = willingness to pay.

Estimated market potential for solar mills

Analysis of the market potential for solar mills for PUE service providers has proved to be more complex than for commercial SHFs. This is due to limited information on the number of milling businesses in operation. Field data shows that there are an average of five diesel-based milling businesses per district. Similar to solar water pumps and solar refrigeration units, the addressable market potential for small-sized solar PV milling systems in Guinea has been estimated considering the following variables and delimiting factors:

- the level of interest (%) of the MSMEs surveyed in buying solar-powered mills
- the average WTP of those MSMEs in a solar mill
- an estimation of five milling business per district, based on field data.

On this basis, the total addressable market potential for small-sized solar milling services in Guinea has been estimated at USD 13.4 million, given the surveyed MSMEs' average WTP of USD 750.

Table 17 Addressable market potential for productive uses of energy service providers

Market potential of solar PV mills	
WTB a solar mill	86%
WTP for a solar mill	USD 750
Number of districts/quarters in Guinea	4 142
Estimated number of milling businesses in Guinea	20 710
Total addressable market potential for small-sized solar PV milling	**USD 13 357 950**

Notes: PV = photovoltaic; USD = United States dollar; WTB = willingness to buy; WTP = willingness to pay.

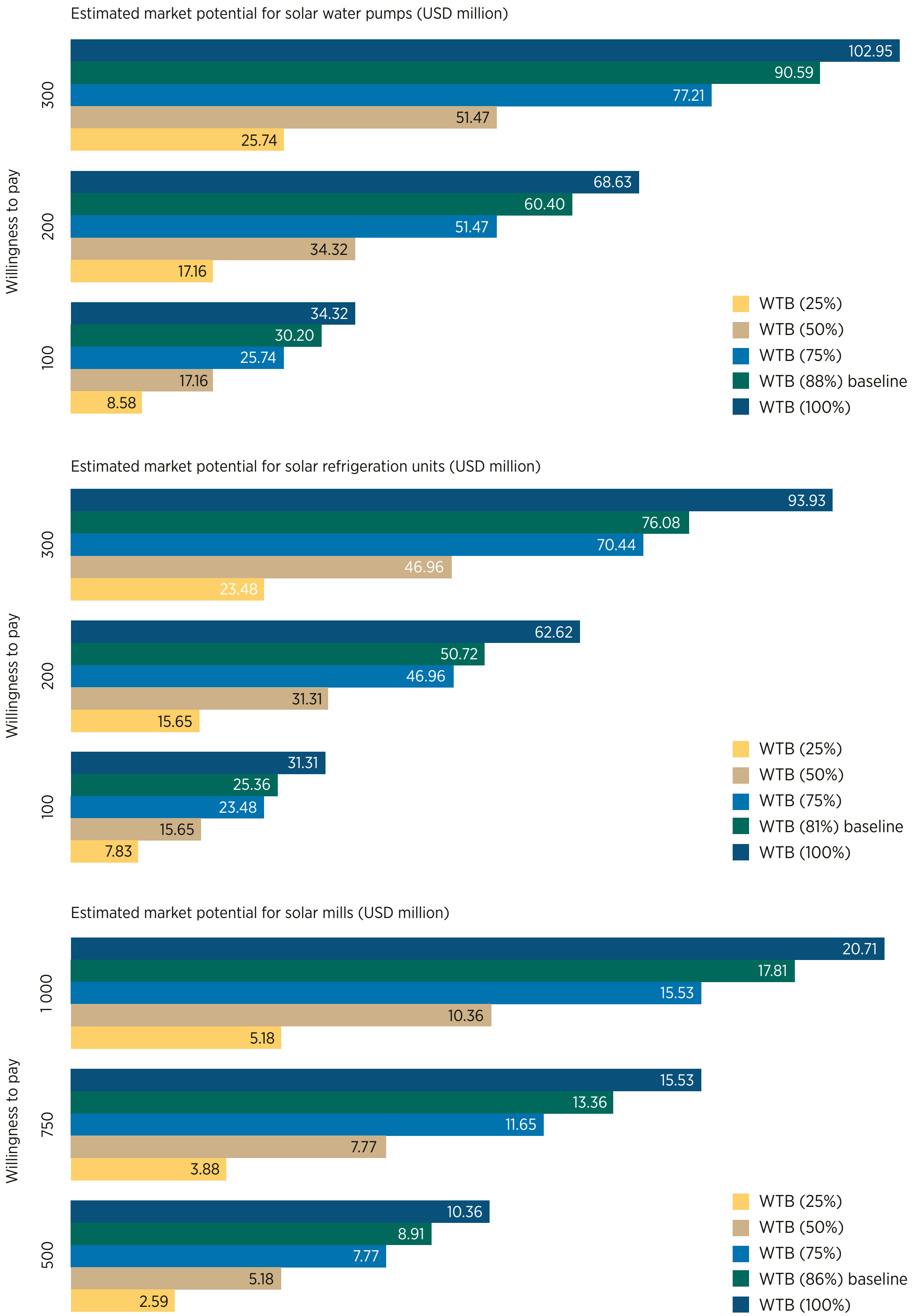
5.4 Sensitivity analysis of estimated market potential

To understand the sensitivity of the market potential estimated above, this study also provides an analysis of the different levels of WTB and WTP of SHFs and MSMEs, based on the survey results. This helps us understand the different market segments taken by each DRE technology.

While all the commercial SHFs surveyed that were willing to buy solar water pumps were deemed able to pay at least USD 100 toward the cost of the equipment, not all of them would be willing or able to pay the higher amount of USD 300 (see Chapter 2). At a WTP of USD 300 per commercial SHF, the analysis demonstrated that the maximum addressable market potential for solar water pumps was approximately USD 90 million, with a baseline WTB of 88%. Establishing the right enabling environment would therefore potentially allow for the market to expand. Putting in place policies and regulations that facilitate access to appropriate financial mechanisms would therefore be key to accelerating the potential penetration of solar water pumps in Guinea's agriculture sector.

For solar refrigeration units, the estimated market potential ranges from USD 25 million to USD 76 million at the baseline WTB of 81% of the commercial farmers surveyed. The actual market potential for solar refrigeration units may eventually be bigger, given that corner shops that provide cooling-for-fee services were not considered in the analysis, due to data limitations. For MSMEs, the estimated market potential for solar PV milling equipment ranges between USD 8.9 million and USD 17.8 million at the baseline WTB of 86%.

Figure 10 Market potential of DRE solutions at different sensitivity levels of WTB and WTP



Notes: USD = United States dollar; WTB = willingness to buy.

6. Barriers to DRE penetration in Guinea's agriculture sector

As this study shows, there is considerable market potential for solar water pumps, solar refrigeration and solar milling in Guinea, with uses ranging from irrigation to produce preservation and value addition. This would help enable the transformation of the agriculture sector.

Yet, several barriers limit the penetration and widespread adoption of these technologies, especially in rural areas, where most of the SHFs are located. These barriers can be broadly categorised into four areas: demand and supply side bottlenecks; the lack of an adequate enabling environment; and limited access to finance (Figure 11).

Figure 11 Barriers to DRE entry in Guinea's agriculture sector

Demand side	Supply side	Enabling environment (policy regulation)	Finance
Limited abilito to pay	Limited commercial viability	Limited co-ordination beteween actors	Limited capital flow and high interest rates
Lack of DRE knowledge	Distortive effect of handout model	Limited political commitment to support DRE	Limited access to consumer credit
Economic insecurity	"Last mile" infrastructure deficit	Limited experience and capacity	Limited research and development grants
Gender gap	Lack of knowledge on agric. value chains	Limited incentives for DRE	Limited results-based finance mechanisms
Limited access to services	Informal market competition		
Disparity in socio-economic conditions			

Note: DRE = decentralised renewable energy.

6.1 Demand side

While the DRE market remains attractive for future investments and the number of potential agricultural and business customers is significant – around 88% of the SHFs surveyed were willing to acquire DRE solutions – the local DRE market remains nascent. Demand side barriers include: low consumer awareness; sociocultural resistance to new technologies; the inaccessibility of technologies in rural areas; and low affordability, due to high up-front costs.

DRE technologies such as solar water pumps are costlier than regular solar home appliances such as solar lighting kits. They are therefore regarded as potentially risky investments by SHFs and PUE service providers. The affordability gap is a major barrier to SHFs acquiring DRE technologies for agricultural activities, given the low incomes of rural farmers in Guinea. DRE technologies could help SHFs move up the income bracket, however, through increased agricultural productivity and output.

Anchor customers – which include PUE service providers, such as milling businesses – currently expend significant amounts of money in operating oversized diesel generators. Despite their willingness to acquire DRE technologies as an alternative, however, their real ability to pay is not strong enough for up-front payments. Along with the capital costs of these technologies, which tend to be higher than diesel-based appliances (although they are much more economic in the long run) access to credit is a big barrier. Only 1% of the SHFs surveyed reported having had access to commercial credit. Financial products for solar refrigeration units or solar water pumps do not yet exist in Guinea, also limiting the potential expansion of these systems. Nonetheless, many of the commercial SHFs and PUE service providers could afford to service asset-based loans, if such tailored and affordable financing mechanisms were available.

Customer awareness of DRE technologies also remains a big barrier for SHFs and PUE service providers in accessing DRE technologies. Just 7% of the SHFs surveyed were aware of solar powered milling alternatives. There is a significant gap in technical expertise and knowledge among local farmers, impeding the adoption and maintenance of these systems. Currently, no exhibitions and road shows are being implemented that reach out to rural communities to raise awareness of new technologies and support services. Radio is often overlooked as a potential outreach tool. Farmer's organisations, such as the *Confédération Nationale des Organisations Paysannes de Guinée* (CNOP-G), or National Confederation of Farmer's Organisations of Guinea, have piloted some DRE technologies (*i.e.* solar water pumps), but they have limited technical knowledge of these technologies and business models.

6.2 Supply side

Most DRE suppliers operate in the capital city and do not offer end-users commercial credit or PAYG services. While these companies have significant capacity to generate sales, they often lack the experience needed to expand their operations, with limited agricultural distribution networks and very nascent business models that are typically limited to up-front cash sales. Globally, the distribution networks established by DRE companies for selling solar-powered appliances and products are typically located in densely populated urban areas, making them inaccessible to rural customers. This is particularly true for Guinea, where companies barely have any rural presence and experience in the DRE market. Meanwhile, those with experience are obliged to undertake significant costs in customer education to help shift SHFs towards a longer-term mindset, substantially increasing the cost of retail, administrative and logistics expenses.

Among the commercially viable DRE applications in Guinea is solar-powered water pumping. However, only two DRE companies are known to be capable of distributing and installing quality equipment in this technology. For solar milling and solar refrigeration, there is no retailing company available in Guinea that has the capacity to commercialise or install such technologies, despite the existence of a very attractive local market and demand for these products.

There is also a lack of technical capacity in most DRE companies when it comes to undertaking the design and installation of these systems. This impacts the business development potential of these companies, especially in relation to the new opportunities offered by these new technologies. In the DRE sector, there is a lack of user data and limited aggregation of annual sales. There are thus insufficient benchmarks for measuring company performance.

6.3 Enabling environment (policy and regulations)

The off-grid segment has traditionally received little attention from the government, due to its focus on grid extension as the principal approach to electrification. This has stalled the development of an enabling environment for decentralised renewables and the reinforcement of capacities to key institutions such as AGER and the *Ministère de l'Energie de l'Hydraulique et des Hydrocarbures Guinée* (MEHH), or Ministry of Energy, Hydraulics and Hydrocarbons, to fully deliver policies and plans to boost the off-grid sector. There is also limited inter-agency co-ordination between key institutions, such as EDG and AGER, limiting the pace of deployment of off-grid systems. Plans to prioritise grid-expansion first, leaving off-grid DRE provision for a later stage, also limits the pace of rural development and the transformation of rural Guinea.

Overall, data and statistics are limited, with this particularly affecting off-grid energy access and PUE, for which data is broadly lacking. Water availability data from MEHH (for groundwater and superficial water) is key over the long-term. As available water pumps (*i.e.* diesel and solar PV) grow in number and power, data will be critical in improving water usage efficiency and management for the long-term sustainability of these interventions.

Multi-stakeholder engagement and co-ordination between government actors and the private sector is lacking. A more industry-wide engagement with professional private sector umbrella bodies should be fostered between the government and the private sector. This would support the development of tailored policy frameworks for off-grid energy.

With the government assessing all DRE technologies that address rural electrification on a strictly case-by-case basis, tax exemption processes for renewable energy technologies have not been streamlined, reducing the effectiveness of such policy instruments.

The absence of technical quality standards or regulations governing the import and sale of DRE products also hinders the sector' growth. The prevalence of counterfeit DRE products in Guinea undermines the trust and confidence of potential customers, due to the poor quality of this equipment.

6.4 Finance

Capital investment in DRE is extremely limited for companies in Guinea, hampering the growth of off-grid companies and their expansion into the countryside. Unlike traditional off-grid appliances (*e.g.* solar kits), the commercialisation of DRE technologies for agriculture requires more working capital, guarantees, insurance and other de-risking mechanisms to support the development of the country's DRE market.

A lack of targeted subsidies, grants offered by the government or development partners also hampers the leveraging of potential customers in rural areas, such as commercial SHFs or PUE service providers. Current government tendering processes for the provision of agricultural equipment and DRE technologies in rural areas do not integrate the need of DRE companies to grow and expand. This is necessary, if sustainable DRE markets are to be built.

Commercial banks and MFIs are not present in rural areas and do not offer tailored loans for SHFs. The interest rates charged by commercial banks are high and credit lines for DRE companies are almost non-existent. For example, only 1% of the farmers surveyed had had access to commercial credit lines. Farmers reported high interest payments, short loan tenures and insupportable collateral requirements as the main deterrents. Existing DRE companies do not offer PAYG credit to customers, with the exception of one company (Orange Energy). Overcoming these financial barriers is critical in realising the full potential of DRE technologies in powering sustainable agricultural development in Guinea.

7. Recommendations

The penetration of DRE solutions in the energy market has been slow and limited due to regulatory bottlenecks, policy lapses and supply chain constraints. Based on the barriers to DRE penetration identified by the study, this chapter presents some tailored recommendations for the acceleration of DRE integration in agri-food value chains for the Guinean government's consideration.

As there is no "one-size fits all" solution, the report recommends key interventions in pursuing a market-based approach to the provision of DRE technologies in the Guinean agriculture sector. In particular, these are in the areas of demand, supply, finance and the enabling environment. In practice, a combination of the recommended actions can potentially be implemented under the framework of a national programme for the integration of DRE in the Guinean agriculture sector, with support from technical and financial partners.

7.1 Recommended priority interventions

Given the low penetration of DRE technologies in the sector, the report presents key recommended priority actions for the short-to-medium term. These cover business models and delivery mechanisms, policy and regulatory frameworks, risk mitigation, technical capacity and skills development, as well as gender considerations. The proposed interventions are grouped into three areas:

- **Market development actions:** These go beyond the specific programming of energy activities to be implemented. They concern strategies for the development of the enabling environment from a market perspective.
- **Policy actions:** These are similar to market transformation and aim to create a supportive set of public strategies, policies, regulations and spaces to enable engagement with other stakeholders. Some of these are critical and preconditional in accelerating DRE access in Guinea's agriculture sector.
- **Stakeholder collaboration actions:** These aim to facilitate the nexus between energy access programming and the agricultural sector.

Specific recommended actions have been placed on a priority scale, ranging from low to high. This is considered more relevant, and it is deliberately non-time-specific. Instead, the scale tries to link actions to their relative importance and inter-dependency. High priority actions should be targeted in one-to-two years, medium priority actions in two-to-five years, and low priority actions in periods longer than five years. Annex A elaborates on these recommendations.

1. Market development actions

These actions are crucial to effectively integrate DRE technologies into Guinea's agriculture sector. This includes initiatives to enhance the availability and affordability of DRE solutions, such as solar-powered cold storage units, irrigation and milling systems. Key market development actions include: developing a market for DRE products and services; facilitating access to financing options and opportunities; and raising DRE technology awareness among SHFs in order to stimulate demand.

By implementing the following actions, Guinea can create a vibrant market for DRE technologies, making them more accessible and affordable for SHFs and agri-businesses:

Table 18 Recommended market development actions and their level of priority

Recommended actions	Priority
Develop a programme for a **DRE results-based finance (RBF) subsidy delivery mechanism** for solar water pumps and refrigeration units for SHFs and retail outlets.	High
Develop a plan for research and development (R&D) into the delivery of a grants mechanism that will **support the development of fee-for-service DRE business models**. These include walk-in-cold-rooms and small-sized solar milling services.	High
Design and deliver a demand stimulation campaign, with events, exhibitions, media campaigns and roadshows.	High
Enhance the capacity and skills of the off-grid sector through training, education and awareness raising among all involved parties.	High
Provide guidelines for guarantees and de-risking mechanisms for both market actors in the primary chain and providers of finance, logistics and other services.	Medium
Establish a robust certification programme to promote the adoption of quality standards for DRE products. This could be Verasol, or any other acceptable regional standard.	Medium

Notes: DRE = decentralised renewable energy; RBF = results-based finance; R&D = research and development; SHF = smallholder farmer.

2. Policy actions

Effective policy actions are essential in creating an enabling environment for the adoption of DRE technologies in Guinea's agriculture sector. A robust policy and regulatory framework helps to build the confidence of market players, such as DRE suppliers and end-users. Key policy interventions include: incorporating DRE integration into agricultural policies, strategies and programmes; establishing a clear regulatory framework for DRE; and providing incentives and exemptions to encourage farmers, agri-businesses and DRE suppliers. By implementing the following policy actions, Guinea can create a supportive regulatory environment that fosters the growth of DRE technologies in the agricultural sector:

Table 19 Recommended policy actions and their level of priority

Recommended actions	Priority
Co-host **multi-stakeholder engagement** with the private sector and government agencies.	High
Establish an inter-ministerial platform that includes joint delivery and co-ordination of efforts between the MEHH and the *Ministère de l'Agriculture et de l'Elevage* (Ministry of Agriculture and Livestock).	High
Support the *Ministère de l'Economie et des Finances* (MEF), or Ministry of Economy and Finance, in setting up **financial incentives and exemptions** for DRE companies.	High
Support the energy ministry **in designing and establishing a DRE strategy** within the existing national electrification strategy.	High
Formulate a **long-term strategy** that combines access to DRE appliances within agricultural programming.	High
Integrate **gender considerations** in order to recognise the different forms of discrimination that impact the energy needs and aspirations of women (*e.g.* in RBF design and targeted mechanisms, training and capacity building for women).	Medium

Notes: MEHH = Ministry of Energy, Hydraulics and Hydrocarbons; DRE = decentralised renewable energy; RBF = results-based finance.

3. Stakeholder collaboration actions

Realising the full potential and sustainability of DRE integration in agriculture requires a collaborative approach. This would involve governments, financial institutions, technology providers and communities. Key stakeholder actions include fostering collaboration between SHFs in local communities, private sector companies, government institutions and development partners to promote knowledge sharing and best practices. Guinea can build a strong support network to ensure the successful integration of DRE technologies into the agricultural sector by fostering stakeholder collaboration through the implementation of the actions listed in the table below.

Table 20 Recommended stakeholder collaboration actions and their level of priority

Recommended actions	Priority
Identify channels of collaboration with MFIs, including new financing opportunities that address the shortage of capital.	**High**
Define co-ordination mechanisms between actors in the agriculture and energy sectors and overall management roles.	**High**
Establish a partnership facility with DRE private sector companies represented by APER-GUINEE and agro-input dealers.	**Medium**
Support the creation of a national database for the monitoring of the energy needs of SHFs and DRE service providers.	**Medium**
Capitalise on the lessons learnt and disseminate these at national, regional and international levels.	**Low**

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ANNEX A: Recommended actions to stimulate DRE uptake in Guinea's agricultural sector

Table 21 Recommended actions for stimulating DRE demand

Recommended actions to stimulate DRE demand	Barriers addressed by recommended action: Limited ability to pay	DRE knowledge gap	Economic insecurity	Gender gap	Difficult to access services	Description of action item
Develop awareness raising programme on DRE (through roadshows, exhibitions, and media).	☐	☑	☐	☐	☑	Delivery of DRE exhibitions and roadshows in different regions of the country and radio/social media campaigns.
Creation/mobilisation of savings groups and farmer co-operatives to provide financial assistance to the most vulnerable SHFs.	☑	☐	☑	☑	☑	Savings groups may work best in areas where population income is low. They are suitable for providing financial services to groups (*e.g.* female-headed households) who may lack the collateral to receive loans or any other financial services.
(Gender-appropriate) training and capacity building as a measure for employment generation (*e.g.* in DRE distribution and installation).	☐	☐	☑	☑	☐	Applicable to all, as well as where women's organisations are more established. Minimum participation of women in capacity and training must be ensured (30% or above). For distribution, operation and maintenance training, a focus on government entities with a willingness to increase the capacity of rural, local personnel, along with DRE companies.
Partnerships with MFIs to offer government, or development partner-backed loans to SHFs to finance DRE technologies on a concessional basis.	☐	☐	☐	☑	☑	Interest rates applied by MFIs are not tailored to SHFs. They remain high and collateral may be a problem. Not all users may be eligible for a loan with MFIs. Female-headed SHFs are particularly vulnerable to a lack of access to credit.
Subsidy programme to cover female-headed households or households with vulnerable members.	☑	☐	☐	☑	☐	Government subsidy schemes able to reach low-income, subsistence SHFs in rural areas – and particularly female headed households and households with vulnerable members.

Table 22 Recommended actions for stimulating DRE supply

Recommended actions to stimulate DRE supply	Barriers addressed by recommended action					Description of action item
	Limited viability	Market distortions	Infrastructure deficit	Lack of knowledge of agricultural value chains	Market competition	
Develop RBF instruments to promote near-to-market DRE technologies.	☑	☐	☑	☐	☑	RBF could be targeted on addressing differences across market segments (*i.e.* on inclusivity and targeting the gender gap). Such instruments should be designed to cover at least 50%-60% of the cost of the DRE technology, integrating voluntary quality standards as a prerequisite in accessing RBF funding.
Leveraging secure storage and the distribution networks of delivery partners.	☑	☐	☑	☐	☐	Access to secure storage and distribution networks is likely to be a significant challenge to companies, which will face high costs in establishing their own logistics.
Phasing out of the handout model for DRE energy solutions, to be replaced with RBF that is targeted and conditional on the purchase of certain quality DRE appliances.	☐	☑	☐	☐	☐	Relevant across all market segments and aiming to change the behaviour of certain government agencies.
Piloting of DRE technologies that are not yet available in Guinea.	☑	☐	☑	☐	☐	This includes delivering challenge R&D funds to deliver innovative fee-for-service business models, such as small-sized solar PV milling or solar PV, along with technical assistance for DRE entrepreneurs.
Establish a national DRE database for the monitoring of agricultural energy needs.	☐	☐	☐	☑	☑	Data and information on energy demand by SHFs and PUE service providers in rural areas should be built.
Build partnerships with agro-input dealers.	☐	☐	☑	☐	☐	By involving agro-input dealers, DRE companies can get access to established distribution networks in rural Guinea. There are over 10 such companies in Guinea. These have a vested interest in commercialising new DRE technologies and have access to local networks of agents operating in all regions of the country.

Table 23 Recommended actions for stimulating the DRE enabling environment

Recommended actions to create an enabling environment	Barriers addressed by recommended action: Limited co-ordination	Lack of capital flow	Limited access to consumer credit	Political commitment	Limited technical capacity	Detail of the action item
Mechanisms to shift the mode of the tendering process towards market-based, energy-led interventions.	☑	☐	☐	☑	☐	This includes integrating support for private sector companies and innovative business models in tendering processes – including agricultural tenders – and pursuing the growth of such companies' operations in order for them to reach scale.
Guarantees and de-risking mechanisms for both market actors in the value chain.	☐	☑	☐	☐	☐	Financial service providers need innovative and affordable financial products tailored to SHFs and DRE service providers.
Training and capacity building to support design and delivery of DRE programmes across government, commercial banks and developers.	☐	☑	☐	☑	☑	It is paramount that high-level managerial representatives be enabled to design market-based programmes, with credit lines at scale to reach commercial SHFs first, then subsistence SHFs.
Training and capacity building to strengthen the institutional capacity to plan and implement DRE programmes and electrification interventions.	☐	☐	☐	☑	☑	Involving the ministries of energy and agriculture.
Establishment of a DRE multi-stakeholder platform, co-hosted by the government.	☑	☐	☐	☑	☐	This should be able to engage private sector voices, improve knowledge of DRE products and appliances and increase co-ordination/co-operation between development partners, companies and other stakeholders.

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