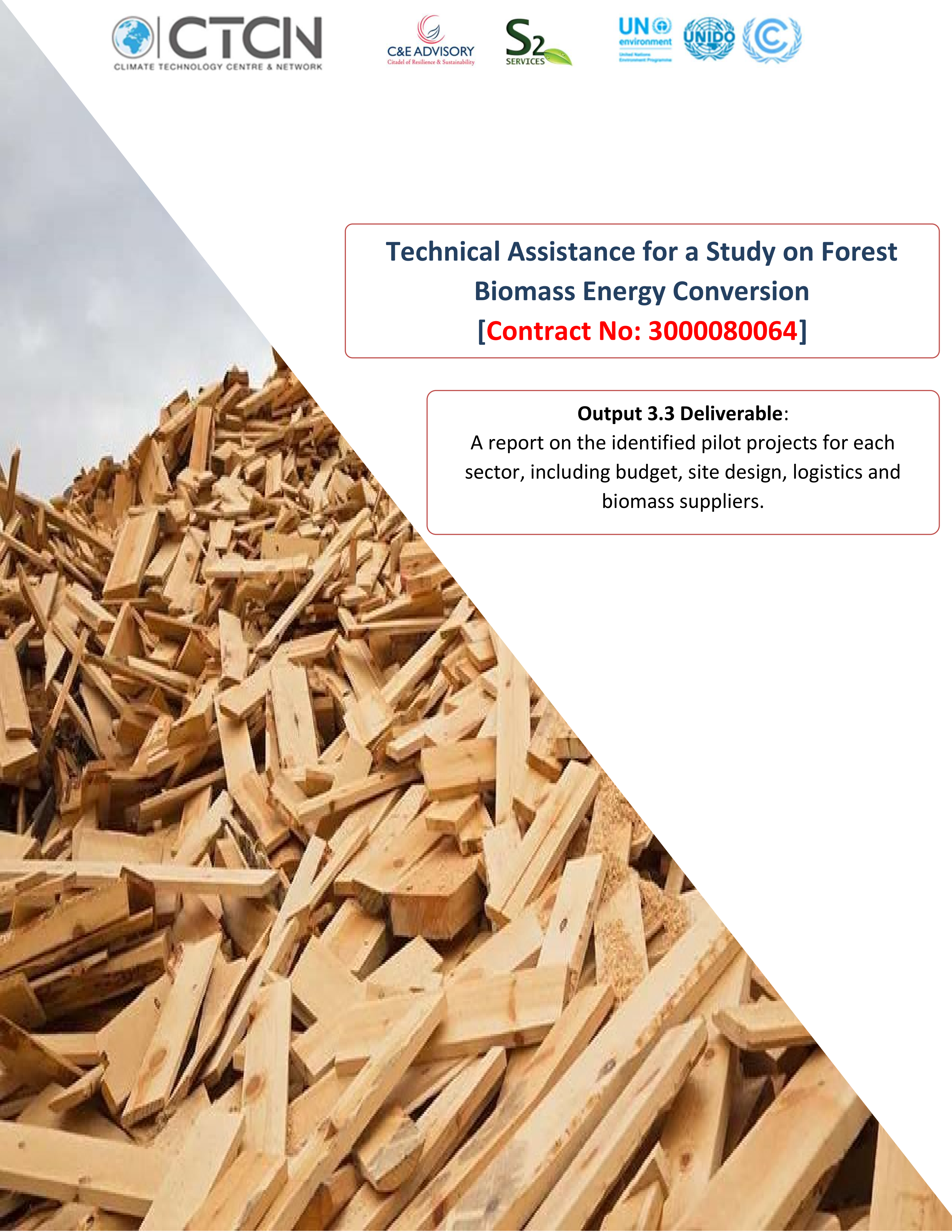
Technical Assistance for a Study on Forest Biomass Energy Conversion
[Contract No: 3000080064]

Output 3.3 Deliverable:
A report on the identified pilot projects for each sector, including budget, site design, logistics and biomass suppliers.



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List of Abbreviations/Acronyms

Abbreviation	Name
ACP	Association of Charcoal Producers
AfDB	African Development Bank
ALUCAM	Aluminium of Cameroon
APFNP	Association of Natural Forest Owners and Plantations Affery
BAU	Business As Usual
CCI	Congo Carbo Industry
CF	Congolese Franc
CH4	Methane
CME	Charcoal Makers Enterprises
CNSL	Cashew NutShell Liquid
CO2	Carbon (IV) oxide
CRD	Capital Return Period
DRC	Democratic Republic of Congo
FAO	Food and Agriculture Organization
FCFA	Central African CFA Franc
GDP	Gross Domestic Product
GHG	Green House Gases
GMDR	Green Mad Retort Kiln
GNI	Gross National Income
ICRAF	International Centre for Research in Agroforestry
IMF	International Monetary Fund
IRR	International Rate of Return
MINEF	Ministry of Water and Forestry

MJ	Megajoules
MW	Megawatt
NPV	Net Present Value
PEF	Forest Operation Perimeter Concessionaire
PPP	Public Private Partnership
PSD	Public Supported Distribution
PSI	Public Subsidy on Investment
RIS	*Réseau Interconnecté Sud*
SDG	Sustainable Development Goals
SIFD	Simulation economique et financiere en fonction des schemas de financement
SME	Small and Medium Enterprises
UNIDO	United Nations Industrial Developmet Organization
UNIFEM	United Nations Development Fund for Women
USD	United States Dollar
WAEMU	West African Economic and Monetary Union
XFA	Central African CFA Franc

1. Introduction

This output 3.3 is the last of the three deliverables under output 3. The report should be read together with output 3.1 and 3.2. The aim of this deliverable is to identify pilot projects focusing on the use of forest and agricultural biomass for energy production in Africa that can create jobs, but also reduce both pollution and dependence on fossil fuels. Increasing the use of biomass is one of the main objectives of energy policy at both national and regional level in various African countries.

The main focus of the projects is on sustainable sources of biomass, such as wood waste from logging operations and industry with various means of conversion. This contribution will focus on the two pathways that currently have the most important applications at the African level: direct combustion and conversion into biogas. In this deliverable, seven different countries broadly represent the situation at the African level (see Appendix xy). The table below presents the main forest biomass and the main country conversion processes.

Table 1: Key forest biomass and key conversion processes in participating countries

Country	Major forest waste / agroforestry biomass waste of interest	Main conversion process
Cameroon	Wood residue	Direct Combustion
Congo	Wood residue	Direct Combustion
Democratic Republic of Congo	Wood residue	Direct Combustion
Burundi	Wood residue	Direct Combustion
Ivory Coast	Cocoa pods	Production de biogas
Burkina Faso	Cashew shells/Shea butter husks	Direct Combustion
Mali	Shea butter	Production du biogas

The original significance of this approach is to identify projects under development that positively influence regional and economic development. This will enable comparison of different success stories in order to assess important key criteria regarding bioenergy success that will bring positive effects for the different regions. The work plan for each of these projects will be developed in deliverable 4 for which field data collection will be carried out.

2. Pilot projects

2.1 CAMEROON -Electricity production from wood waste in Djoum, southern Region of Cameroon

2.1.1 Description of the pilot project and location

Cameroon's 22 million hectares (ha) of tropical forests are a vital part of the forest ecosystem of the Congo Basin. These forests provide an important source of income, employment, livelihoods, ecosystem services and habitat for more than 9,000 plant species, 910 species of birds and 320 species of mammals. According to ICRAF, the sector still has great potential to transform the lives of millions of forest-dependent communities and other neighbours. However, limited access to funding has affected the sector, particularly community forests.

Figure 1: Map of Africa with Cameroon at the inset
Source: (IMF, 2018)

Table 2: Selection of macroeconomic and social indicators 2

Population	**23.4 million (50.05% male/49.95% female)**
Urban Population	55% of the total
PIB	$32.2 billion
GDP growth rate	3.4% (2017)
GNI per capita	1400 USD
Unemployment rate	4.25% (2017)
Poverty rate	37.5% (2014)
Urban	9%
Rural	57%
Currency	Cfa Franc of Central Africa (XAF)
Official language	French, English

Natural Resources	Hydrocarbons (crude oil and petroleum products); agricultural products (cacao, coffee, cotton); ores (aluminium)

Source: (World Bank, 2020)

The Southern Region offers an ideal location for the construction of a cogeneration unit. It is one of ten regions of Cameroon that stretches over the southern and northern part of the country, the lies in front of three Central African countries: Equatorial Guinea, Gabon and the Republic of Congo. It is bordered to the Nord-Westby the Coastal Region, Nord by the Central Region and the East by the Eastern Region. It has a waterfront on the Gulf of Guinéa, which occupies its entire western flank.

The Southern region has 749,552 inhabitants over an area of 47,191 km² and therefore 22 inhabitants per km². It is composed of several ethnic groups: Boulou, Bassa, Bané, Ntoumou, Ewondo, Batanga, Fang, Mabéa, Yassa, Mvaé, Ngoumba and Pygmies. Hunting and agriculture are their main activities. The southern region has a wooded area of about 12,502,150 ha. Its wealth of forest resources attracts many investors. It is one of the regions where forestry activities are more concentrated here. There are about 39 wood processing units. The wood transformation process in this town generates different types of waste. These include sawdust, bark, pits, / peeling kernels, slabs, shavings, heart defects, and many others. Cassava, taro, edible rhizomes (macabo, taro, etc.), coffee, palm oil, plantain are the main agricultural products of the southern region. Several wastes come from their harvest. All these wastes constitute a potential for biomass energy. Therefore the exploitation will allow the population of the South to extract wood resources for other purposes beyond domestic needs.

In Cameroon, there are a number of laws governing the forest sector. These are Law No. 94/01 of 20 January 1994 on the regime of wildlife and fisheries forests and Law No. 96/12 of 5 August 1996 on the framework law on environmental management. The forestry sector in Cameroon consistently represented 6% of Cameroon's GDP between 2016 and 2017.

Between 1990 and 2010, the deforestation rate was around 0.6%. After the afforestation and reforestation projects and the strengthening of the fight against unauthorized logging, the reforestation rate fell to 0.14%. The population of Cameroon and that of the South is growing steadily with an increase of 2.6% each year. The increase in population leads to an increase in households and SMEs, and consequently an increase in energy demand. Thus, for economic reasons, people resort to wood and charcoal for basic energy needs.
The implementation of a cogeneration unit in the region would increase access to energy and reduce pressure on natural resources.

2.1.2 Justification of the broader values that pilot projects should provide.

Despite the South Interconnected Network (RIS), which supplies the Central, Southern, Coastal, Southwest, Northwest and Western regions, the rate of access to electricity is still low in the Southern region. One reason may be the presence of the energy-intensive mining industry ALUCAM, located in the coastal region and connected to the RIS. It would be important to find an alternative to increase access to energy in rural areas of the South. Decentralized energy production is the priority and advantaged option to be implemented to increase access to energy in off-grid areas. Thus, the sustainable and ecological exploitation of the wood rebus potential of this region is an alternative to decentralized electricity generation.

2.1.3 Brief description of the location of the project and benefits to community

Figure 2: Location of Djoum

Djoum is a city located in the southern part of Cameroon. Administratively, the municipality forms a district belonging to the department of Dja-et-Lobo. The town of Djoum is located on the N9 national road 108 km east of the capital Sangmélima. The municipality is located in the tropical forest ecoregion of the Western Congo Basin. The city of Djoum is a forestry centre, which explains the presence of several forestry companies tens of kilometres from the city centre. Exotic species such as Sipo, Sapelli, Okan, Frake, Dibetou and Iroko are the most exploited.

As mentioned in the decentralised electricity generation report, 25 biomass electricity generation sites have been identified in the southern region.

Among these sites, the locality of Djoum has been selected. It is in this context that the forestry operator Rougier, which has been operating in the town for several years, has launched a project to produce electricity using wood waste from its wood industry.

In cogeneration units, electricity and heat are produced by a process of burning organic matter. Combustion takes place in the boiler, which gives off heat to turn the turbines, which in turn produce electricity. This Rougier project was to have a capacity of 2 MW of electricity and 4,227 MWth of heat. The energy requirements of the sawmill were estimated at 1 MW of electricity and 1.5 MWth of heat. The wood scrap potential required to produce this electricity and heat was estimated at 27,577 tonnes. The excess electricity and heat was to be used to supply households and SMEs in the city. This technical assistance study will have to review this project while highlighting the difficulties and limitations in the technical, socio-cultural, financial and political aspects that prevented the Rougier promoter from pursuing and finalising its initiative.

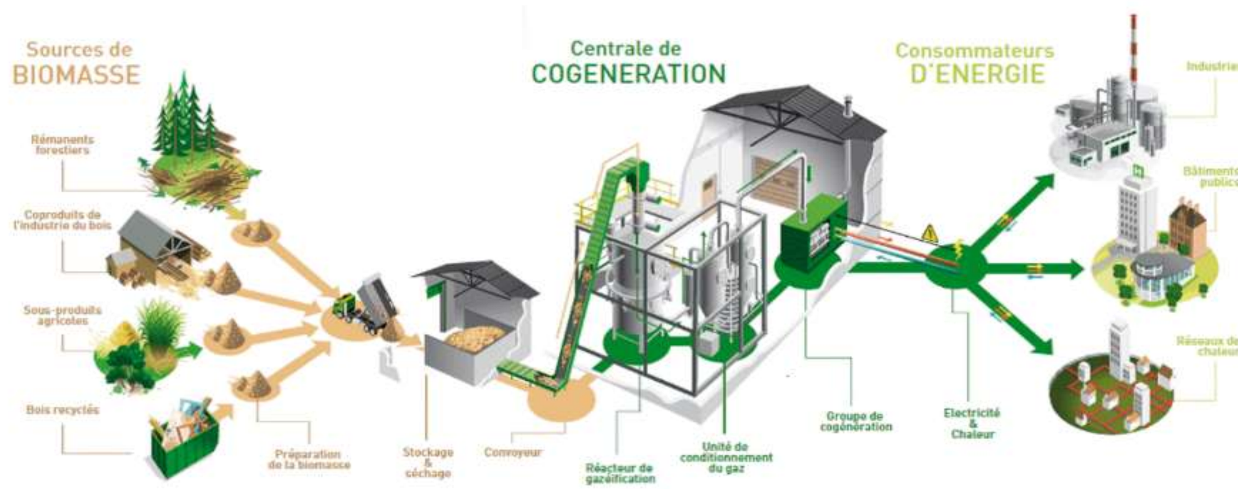

Figure 3: Biomass energy recovery technology

2.1.4 Gender, environment and other factors

Gender. Gender is very complex in Cameroon varying by region, ethnic group or religion. However, there is a persistent value of the gender division of labour in which men assume productive and public roles and women assume reproductive and domestic roles. The majority of the inhabitants of the forest area of Cameroon depend directly or indirectly on the forest for their livelihoods, as well as on medicinal plants and common forest resources to meet basic needs. However, there are gender differences in the way men and women relate to forests and forest resources. Women have very few rights to trees, although they are the main users of tree products. This is mainly due to existing gender relations. Men have power over tree access rights and make all decisions regarding tree management in parks and savannahs. The gender division of labour is such that women do not participate in tree management.

Environment. Cameroon is Africa in miniature when it comes to biodiversity and has for many years provided varieties of products useful to local populations. These uses range from food, medicine, shelter, cultural activities to economic activities. All classes of plant and animal species fall within the range of choice of the various user groups. For example, most people living in forest communities depend heavily on wild plant and animal species for their livelihoods. The tropical forests of Cameroon cover about 46% of the national territory and account for 11% of the forest area of the Congo Basin. Cameroon is grappling with the adverse effects of climate change and increasing pressure on forests. Direct drivers of deforestation in Cameroon include slash-and-burn agriculture, bush fires, infrastructure development, mining and illegal logging. Deforestation is beginning to have a significant environmental impact in some parts of the country. In the north, deforestation has been blamed for increasing soil erosion, desertification and reduced pasture quality.

2.1.5 Economic and financial analysis

The three main indicators to assess the final profitability of a project are:

1. The Net Present Value (NPV) or discounted cash flow represents the additional enrichment of an investment compared to the minimum required by the capital contributors, of which a positive value reflects the profitability of the project;
2. The Internal Rate of Return (IRR), or discount rate for which the NPV is zero, indicates that the project is profitable if the calculated rate is higher than the discount rate required by the investor;
3. The return on investment time (capital recovery period - CRD), which defines the period of time after which the investor recovers the total amount of equity invested.

Table 3: Economic and Financial Simulation based on SIFD/DJOUM Biomass Project Funding Schemes

Simulation économique et financière en fonction des schémas de financement				
Taux d'actualisation : 10%	Taux d'inflation : 3%	Impôt sur les sociétés : 38,5%		
SCENARIOS	**1 - Business as usual (BAU)**	**2 - Subvention publique et prêts concessionnels (SPI)**	**3 - Prise en charge publique de la distribution et prêts concessionnels sur la production (PPD)**	**4 - Scénario 3 + prise de participation publique dans la production (PPP)**
	SBV: 0% FP: 30% EDT: 70% Taux de l'emprunt : 11%	SBV: 70% FP: 10% EDT: 20% Taux de l'emprunt : 6%	SBV : 100%Distribution Production : 100% secteur privé dont : • FP : 30% • EDT : 70% Taux de l'emprunt : 6%	SBV : 100% Distribution Production : 67% secteur privé dont : • FP : 30% • EDT : 70% 33% secteur public dont : • SBV : 70% • EDT : 30% Taux des emprunts : 6%
Simulation Economique et Financière du projet Tarif de rachat du KWh (BAU) constant				
Investissement initial	4,87 milliards	4,87 milliards	4,87 milliards	4,87 milliards
Fonds propres (FCFA)	1,5 milliards	0,5 milliard	0,81 milliard	0,54 milliard
Tarif de rachat du KWh (90%)	**50 FCFA**	**50 FCFA**	**50 FCFA**	**50 FCFA**
Temps de retour sur FP	**15 ans**	**1 an**	**<3 ans**	**<2 ans**
Taux de rentabilité interne sur FP	**4,56%**	**74,78%**	**30,79%**	**56,4%**
Simulation Economique et Financière du projet Temps de retour sur FP (BAU) constant				
Tarif de rachat du KWh (90%)	**50 FCFA**	**18 FCFA**	**28 FCFA**	**23 FCFA**
Temps de retour sur FP	**15 ans**	**15 ans**	**15 ans**	**15 ans**
Taux de rentabilité interne sur FP	**4,56 %**	**4,67 %**	**4,54 %**	**4,79 %**

SBV: FP Grant: EDT Own Fund: Debt

For this analysis four scenarios are considered:

- Scenario 1: Business as Usual (BAU): Borrowing at 70% of the investment cost from a commercial bank at 11% p.a.; equity of 30%.
- Scenario 2: Public Subsidy on Investment (PSI): 70% subsidy, 20% loan at 6% p.a. and 10% equity.
- Scenario 3: Publicly Supported Distribution (PSD): 100% subsidy on distribution; 70% loan on production at 6% per year; 30% equity on production.

- Scenario 4: Public Private Partnership (PPP) - Mixed economy - Distribution: 100% subsidy; - Production: - 67% private sector (70% subsidy and 30% equity) - 33% public sector (70% subsidy and 30% debt) - Public and private loans at 6% per year.

In the next Outputs 4 and 5, detailed budget information shall be availed after field discussion with potential investors, community and relevant local government officials

2.2 CONGO - Congo Carbo Industry (CCI) project based on investments in industrial charcoal production in the Republic of Congo

2.2.1 Description of the pilot project and location

Congo offers the ideal location for such a project as it is at the forefront of regional trends. It has the highest rate of urbanization (65.7%) in sub-Saharan Africa (World Bank 2018) and about 85% of the Congolese population burns wood or charcoal to meet basic energy needs, with demand for charcoal particularly high in cities. Out of a total population of 5.13 million in Congo, about 3.4 million people live in urban centres, the vast majority of whom live in only four cities: Pointe-Noire, Brazzaville, Dolisie and Nkayi.

There are several laws relating to wood energy in the Congo. These include laws on environmental protection (No. 003/91, 23 April 1991); forest management and ecological, social and economic sustainability (No. 16/2000, 20 November 2000); on land tenure (No. 17/2000, 31 December 2000); on the extent of the public domain (No. 10/2004, 24 March 2004); on indigenous peoples and recognition of tenure and rights (No. 5/2011, 25 February 2011).

The urban population continues to grow, increasing by 3.2% in 2016. The demand for charcoal is currently about 150,000 tonnes per year, sold between 160 and 250 CFFs (approximately $0.29-0.45) per kg depending on the location. Given that Congo has a large forest cover (Figure 4) and a relatively small population relative to its land mass, an industrial sector of charcoal could help Congo (and other countries) achieve the Sustainable Development Goals (SDGs) on economic opportunities for rural households, access to sustainable energy, natural resource management and the fight against climate change.

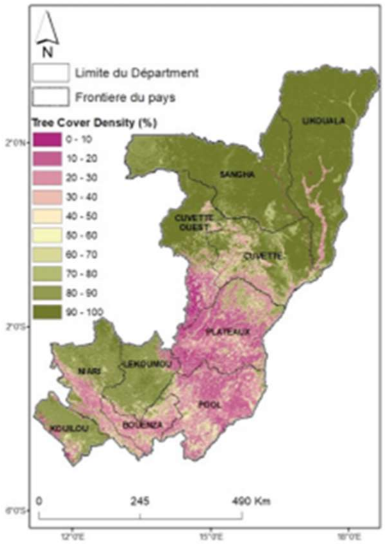

Figure 4: Forest cover of the Republic of Congo

The forestry sector accounts for about 5% of the country's GDP and export earnings (Moses, 2014). Most of the earnings are from timber extraction. In 2017, forests covered about 223,300 sq km (65%) country's area (Figure 4). Forest area has declined at a relatively slow rate in Congo compared to other tropical countries, about 0.1% per year since 1990, when the country had 227,300 km^2 of forests. Data on the extent of forest degradation, a common problem with firewood extraction, is not available.

2.2.2 Brief description of the location of the project and beneficiaries

The Congo Carbo Industry (CCI) project would be the first industrial-scale supply chain for charcoal and related products. It aims to increase the efficiency of charcoal production and stabilize supply by adopting improved production technologies (furnaces), developing a plantation to supply wood and formalizing parts of the supply chain.

The CCI project plans to develop an industrial-scale charcoal production and distribution operation. The project would source wood from existing and newly planted eucalyptus plantations and other fast-growing species. Improved production technologies will include brick kilns, a carbonization plant and the development of charcoal bricking capacity**,** which will improve carbonization efficiency and production scale.

The ICC will produce charcoal on a large scale and with industrial processes. It will use new carbonization technologies to improve quality and increase the amount of charcoal. Advanced furnaces will increase the efficiency of carbonization, doubling it compared to traditional mound furnaces and unimproved ovens commonly used in Congo today. The three technologies that CCI will use, none of which are currently used in Congo, are industrial retort furnaces using the CML process, GMDR and coal briquettes.

Figure 5: Location of the municipality of Kouilou

- **The Green Mad Retort Kiln** (GMDR)*four à cornue Green Mad* is a semi-industrial brick retort furnace. It was originally developed in Madagascar to produce charcoal from eucalyptus wood harvested from local plantations - the same use proposed by the CCI project.
- **CML process with Industrial Retort** Kiln. Industrial production facilities using the CML process consist of a standardized unit comprising 4 or 12 cylindrical retort furnaces, all of which are connected to a post-combustion furnace before the chimney. It uses heat generated by the combustion of pyrolysis gases for drying purposes (for example, firewood) or to generate electricity. The CML unit allows the carbonization of all types of wood, including hardwoods and softwoods, offering significant flexibility in wood. Carbonization efficiency (efficiency and productivity) is directly related to the quality and characteristics of the raw material used (granulometry, humidity, cleanliness, etc.). Charcoal is produced in cylindrical retorts with a top lid and a discharge hatch in the base.
- **Charcoal briquettes (charbrittes**). Most factories in the world produce charbrittes by compacting charred materials. This approach is suitable for developing countries because investment costs are relatively low and briquettes can be made from recycled materials, often wasted. The main challenge with charcoal briquettes is to keep costs as low as possible, as in the market they compete with cheap charcoal. Few successful companies producing renewable charcoal have emerged.

The project is designed to combine a centralised carbonisation plant (CML) and decentralised stoves (GMDR) in order to use the two tools in a complementary way to maximise production.

2.2.3 Gender, environment and other factors

Gender: Women are generally marginal players in the Congolese charcoal supply chain, according to key informants interviewed. Traditionally, women are mainly involved in the charcoal trade. A scenario in which ICC creates employment opportunities for rural women through more formal means, perhaps in the context of charcoal briquettes operations, is possible. Particular attention will be needed to create a space for women's employment if CCI and its investors see it as an important result of creation.
In addition, the availability of charcoal in Congo can also have a positive impact on women's workload. Although no data are available for the country, the women's workload related to firewood and cooking in Congo would be similar to that of other African countries. Women spend disproportionate time on firewood-related tasks. For example, Guinean women spend nearly seven times as much time as men collecting firewood and 33 times more time cooking; in Tanzania, the figures are 2 and 9 times respectively**.** The increased availability of charcoal can reduce the time spent on these tasks and allow for a redistribution of time to other requests.

The land tenure regime. The land leased to CCI is already under government security. The development of industrial plantations of more than 30,000 hectares can have a significant impact on the local population. It is not known how many people live in or around the eventual concession. Impacts may include restricted access to land used for grazing, hunting, search for food, etc. The availability of water resources is also unknown in the region and conflicts over water resources may arise. At this time, it is not known what Congolese law allows. Once granted, it is not known what transactions will be allowed within the boundaries of the concession. In an extreme case, the establishment of the concession can lead to land conflicts and the displacement of villages.

Environment. The land grant has not yet been demarcated. Without clear demarcation, it is not possible to estimate the future impact on water and soil resources. Large-scale eucalyptus plantations are known to generate significant environmental impacts. Concerns include soil health, water quantity and quality, biodiversity and other effects. The final size of the plantation and the conditions of use will ultimately determine the magnitude of the impact.
The GMDR furnace allows the combustion of carbon dioxide, and field tests in Madagascar and Namibia indicate that only 0.2% of the carbon emitted is methane (CH4). In this case, the use of a GMDR saves 1.75 tonnes of CO_2 equivalent per tonne of charcoal produced. CML technology emits virtually no Greenhouse Gas (GHG). Thus, the conversion to advanced furnaces has the potential to avoid a significant number of GHGs.

2.2.4 Economic and financial analysis

The economic and financial analysis follows best practices for assessing feasibility and reflects evidence of similar assessments on the subject in the Republic of Congo, Central Africa and other parts of the world.

The economic analysis assesses the benefits and costs of the project over an eight-year period. Asset costs are depreciated at variable rates (for example, between 5% for buildings and 33% for trucks). Economic projections aggregate the net benefits of the application of the three technologies and the production of charcoal and carts throughout production, as detailed in the table above. The economic analysis does not attempt to include the monetary benefits of avoided carbon dioxide emissions from commitment to carbon markets, although this is an active area of interest. Income tax was included at 30%. It is important to note that while the financial results presented here include amortization of assets, they do not include any annual interest for banks or financial partners. These costs could not be included because the source of project funding was not established. Therefore, the estimates presented here can be considered an upper limit of potential benefits and will need to be reduced accordingly as planning progresses. The following table provides quantitative indicators for assessing economic feasibility.

Table 4: Quantitative indicators for CCI over an eight-year period

Industrial enterprise	Unite	Value
Production		
Charcoal	Tonnes	51,110
Wooden briquettes (Charbriquettes)	Tonnes	4,214
Initial investment		
Fours CML	USD	3,041,844
GMDR and Charbriquettes ovens	USD	2,461,867
Operation		
Fixed costs	USD	4,843,784
Couts variables	USD	16,734,806
Revenue	USD	30,017,968
Period to profitability	Years	4
Return on investment	%	12.2%
Ratio cout-benefice		
Complementary benefits		
Preserved drills	Has	Non-quantified
Emissions of Greenhouse Gas Avoids	tCO_2-eq	72,000
Job creation	People	700

A summary of the economic analysis can be found in the table above. The analysis estimates an investment cost of approximately $5.4 million and operating costs of $0.5 million to $3.9 million per year, depending on the business. The resulting $27.7 million return on investment is approximately $3.4 million, or 12.2%. Economic analysis suggests that the company could make a profit after the fourth year, assuming a selling price of charcoal at 300 CFA francs per kg of charcoal and a purchase price of $47 (26,500 CFA francs) per tonne.

There are clear opportunities to improve the company's financial performance, based simply on the costs of other operations and on the judgment of experts. For starters, plantation management and rehabilitation are estimated at US$5900 per ha, almost double similar estimates in other parts of the world. In total, reforestation costs account for about 25% of annual operating costs. If these operations can be carried out through a group of NGOs, the community or other more cost-effective mechanism needs to be studied.

In addition, the CML and GMDR processes produce high-quality charcoal, assuming that the moisture in the wood and the size of the particles are appropriate. High-quality "green" charcoal offers an opportunity to target a different market segment, perhaps global, that is willing to pay a premium for sustainable Congolese charcoal. Moreover, although cart production accounts for only 10% of sales of charcoal with nominal capacity, it accounts for almost 50% of profits over eight years. This is due to the fact that the investment costs are relatively low while the market price is similar to that of charcoal.

Charcoal dust, the main raw material for the production of briquettes, costs very little because it is a waste of charcoal production. CCI may consider starting to produce carts as soon as sufficient raw materials are available.

Finally, CCI may consider the use of agro-forestry practices (integration of trees with crops and livestock) to diversify and increase the productivity of the land concession. This could help offset some of the significant upfront costs and reduce the initial payback period. In addition, multi-purpose plantations, which incorporate other undersized species, could serve local communities. Successful models of agro-forest systems designed to produce firewood have been in use for many years in the neighbouring Democratic Republic of Congo. None of these options have yet been incorporated into the financial models presented here.

2.3 CONGO DEMOCRATIC REPUBLIC (DRC) - Sustainable cooking solutions for firewood and micro-gasification for rural and urban households

2.3.1 Description of the pilot project and location

With an area equivalent to that of Western Europe, the Democratic Republic of Congo (DRC) is the largest country in sub-Saharan Africa. While its poverty rate has declined slightly over the last two decades, particularly in rural areas, the DRC remains one of the poorest countries in the world. In 2018, 72% of the population, particularly in the North-West and Kasai regions, lived in extreme poverty on less than $1.90 a day. After reaching 5.8% in 2018, economic growth slowed to 4.4% in 2019, due to the fall in the prices of raw materials, particularly cobalt and copper, which account for more than 80% of the country's exports. Ever-increasing activity in the mining sector, the source of most export revenues, has boosted tax revenues and the growth of the DRC's gross domestic product (GDP). The Democratic Republic of Congo (DRC) has the second largest strip of tropical forest in the world - 152 million hectares, representing most of the remaining tropical forest in the Congo Basin. Kinshasa is the capital of the Democratic Republic of Congo. It is located in the west of the country, on the southern bank of the Congo River, at the western coastal exit of Malebo. It is a city, but has the administrative status of a province. The city of Kinshasa developed between the Gombe promontory, closing off the Malebo coast, and also sheltering the bay of Ngaliema before the Livingstone Falls, and the hills to the south sometimes located near the river (Mount Ngaliema in the west), and up to fifteen kilometres south of the Malebo coast (Mount Mangengenge in the east). To the south of the Malebo coast, a large area of marshland reduces the habitable area of the municipalities of Limete and Masina. The province of Kinshasa, has an area of 9,965 km2.

Figure 6: The Democratic Republic of Congo

Kinshasa's population is estimated at 14.3 million in 2020, its urban area is the third most populated in Africa after Cairo and Lagos. As the city limits are very large, more than 90 per cent of its area is rural or forested (particularly in the municipality of Maluku, which alone occupies 79 per cent of the province's territory); the urbanized parts are in the west of the province. Kinshasa has the administrative status of a city and is one of the country's 26 provinces.

The main law relating to the DRC's forest sector is Law N° 011/2002 of 29 August 2002, the Forestry Code. The value added of the forestry sector has consistently represented 2.7% of the overall value added (GDP) between 2008 and 2010. The DRC thus has the lowest rate of participation of the forestry sector in the national budget compared to the countries of the Congo Basin.

Due to the large area of forest that occupies the southern part of Kinshasa, there are several forestry companies established in the city. According to the FAO in 2017 the DRC's net deforestation rate is estimated at 0.2%. This deforestation is caused by the process of exploitation of forest resources and the extraction of wood by households for basic energy needs. These different wood extraction and transformation processes release large quantities of forest waste. This waste, which is largely represented by wood waste, is poorly exploited and yet represents a potential for renewable biomass resources.

2.3.2 Justification of the broader values that pilot projects should provide.

The pilot project aims to produce locally-made pellets and use them in household gasification cookers. Households in the city of Kinshasa and its surroundings mainly use woody forest products (firewood and charcoal) as a source of energy for basic energy needs. Excessive wood energy consumption is due to the use of three-stone hearths which are very inefficient (around 15%) and the production of charcoal by artisanal methods. However, waste products from forest product exploitation processes are a potential source of green charcoal. The combination of green charcoal and the replacement of three-stone stoves with more efficient improved stoves should limit the pressure on Kinshasa's forests. According to data obtained in the literature, the simultaneous production and distribution of improved stoves and pellets implemented in Rwanda can easily be replicated in the DRC.

2.3.3 Brief description of the location of the project, and beneficiaries

The type of improved fireplace distributed under the Program of Activities (PoA) to Rwanda will be the micro-gasifier of wood pellets made from biomass residues. These improved fireplaces burn the wood very efficiently and cleanly. Micro-gasification cooking furnaces produce their own gas from solid biomass in a controlled manner. Gas production occurs separately from the combustion of gas. All improved fireplaces have a thermal efficiency above 20%. Improved fireplaces will be distributed to rural and urban households where they will be used for daily cooking as a replacement for traditional wood and charcoal fireplaces. Households can receive more than one, depending on their size and cooking habits. The wood pellets will be sold to them regularly by the CME. Users will sign user contracts with a unique customer identification number.

Figure 7: Location of Kinshasha in DRC

Monitoring is the measurement of the weight of pellets purchased by customers. By replacing traditional fireplaces, the ACP will replace non-renewable biomass that is either directly used for cooking (basic scenario I) or converted to charcoal before being used for cooking (reference scenario II).

In the case of the project, a smaller amount of biomass residue will be converted to pellets. During the conversion process, some of the biomass is used to dry the rest of the biomass and electrical energy is used for the pellets. Basic facilities to be replaced include traditional wood fireplaces with a thermal efficiency of 10% (basic scenario I) or traditional charcoal fireplaces with a thermal efficiency of 20% (reference scenario II). Biomass residues from different sources can be included. The targeted users are those who use wood biomass or charcoal to cook. They will subscribe to the project that will guarantee them access to micro-gasification cooking solutions.

As far as the details of the plant are concerned, a pellet mill with a capacity of 5 tonnes per hour is chosen and can be integrated in a relatively compact location. Dry storage for sawdust, wood chips, and any other biomass to be used would require a building of approximately 80 feet by 100 feet. A small office space of approximately 10 feet x 24 feet would also be required. Approximately ten acres of land would be large enough to meet production needs. Since mill waste would likely be the most ideal feedstock for pelletizing, a location close to a wood products operation would be preferable as it would reduce transportation costs. Raw material storage will take up the most space. If sawdust from local sawmills is used as the main or only source of raw material, a silo can be used, requiring less floor space. One to two acres of industrial land should be sufficient for this size of operation. We believe that there are several good potential sites in Burundi. Pellet storage will be necessary during the hot months, as the highest production occurs during these months. The storage area required will depend mainly on the relative volumes of bagged pellets compared to bulk pellets produced.

2.3.4 Gender, environment and other factors

Gender. Congolese women face many forms of discrimination on a daily basis, and the current legal and institutional framework is not adequate to improve their situation. Persistent violations of women's rights are encouraged by the existence of discriminatory legislation. There is a lack of recognition on the role of women in the management of forest resources. In the DRC, women play a predominant role in agriculture as producers of food for their families, and their involvement in production activities is almost equal to that of men. However, this does not translate into effective involvement in decision-making within the household.

In this deeply unequal context, women's very limited land rights are a crucial issue for the implementation of community forestry. Differences between men and women in knowledge, access and use of forests have long existed. This gender disparity is due to unequal power relations between men and women. Given these differences in the gender role in forest use and management, research on gender in forest governance has mainly focused on the inclusion of women in decision-making committees and organizations.

Environment. Although deforestation rates in the DRC are low compared to the tropical forests of the Amazon and Southeast Asia, nearly half a million hectares are lost each year. The direct drivers of deforestation in DRC are slash-and-burn agriculture, fuelwood production, bush fires and small-scale, and industrial logging. There is also a plethora of poaching that threatens wildlife populations in the DRC. The second largest tropical rainforest ecosystem on the planet, just behind the Amazon, it also plays an important role in slowing global climate change because the forest absorbs greenhouse gases, preventing them from being released into the atmosphere.

The main environmental problems in DRC include: land degradation, deforestation, loss of biodiversity, water pollution and air pollution in Kinshasa. Conflict is itself a source of environmental degradation. A major post-conflict environmental assessment of the DRC by the United Nations Environment Programme

(UNEP) highlights the global importance and extraordinary potential of the country's natural and mineral resources. However, the study warns of alarming trends, including increasing deforestation, species depletion, heavy metal pollution and soil degradation due to mining, and an acute drinking water crisis that has left an estimated 51 million Congolese without access to safe drinking water.

2.3.5 Economic and financial analysis of the pilot project

The actual production costs of the cooking stoves mentioned above and the machinery to produce wood pellets will be established in the next phase of the study, which will be mostly field work, as this information was not available as during this phase. However, the cost and benefits are estimated below based on the literature review.

Equipment options: Complete pellet systems are readily available, new or used. Anyone can do a quick survey on the Internet and find complete equipment packages starting at United States Dollars one hundred and fifty thousand (US$150,000.00)

Operating costs: There are many studies detailing the operating costs of new pellets and plants. The tables below present a simple analysis that can be a starting point for study. According to this study, a pellet operation can be profitable based on an economic analysis.

Table 5: Cost/benefit analysis at 480 tonnes per month of pellet production

Source	***Costs per month***
Building / real estate lease / loan	5000 $
Workforce management	21,000 $
Enegia	6,500 $
Payment of equipment loan	10,500$
Overhead	6,000 $
Purchasing raw materials	27,840 $
Various	2,000 $
Total expenses	**78, 840.00 $**
Source	Income per month
Sale of pellets in bags and in bulk	110,400 $
Delivery costs	Included in the price
Total income	110,400 $
Net earnings per month	**31,560.00 $**

2.4 BURUNDI - Sustainable bioenergy cooking solutions for rural and urban households in Bujumbura province through the production and distribution of semi-carbonated pellet stoves and wood pellets.

2.4.1 Description of the pilot project and location

A landlocked country in East Africa, Burundi is a low-income economy where 80% of the population is employed in the agricultural sector. It is a country in the Great Lakes region, bordered by Rwanda to the north, Tanzania to the east, the Democratic Republic of Congo to the west and Lake Tanganyika to the southwest. With a population of 11.6 million people, 50.7% (2018) of whom are women, it is one of the most densely populated countries. Burundi is a resource-poor country with an underdeveloped manufacturing sector. Agriculture accounts for more than 40% of GDP and employs more than 80% of the population. Burundi's main exports are coffee and tea, which account for 90% of foreign exchange earnings.

Burundi has 172,000 hectares of forests. This represents 67% of its territory. Approximately 40,000 hectares, or 43%, are classified as primary forest. Planted forests occupy 60,000 hectares. Burundi consumes about 180,000 hectares of wood per year, which exceeds the permanent supply of 172,000 hectares. State-owned plantations cover areas of up to 10 hectares with Eucalyptus sp., Tropical Pines, Callitris calcarata and Grevillea robusta as the most common species. Most of the forest plantations are located on the outskirts of Bujumbura but were neglected during the political crisis that began in the 1990s. In addition, these plantations face poor management, with some of them being converted into agricultural or settlement areas.

2.4.2 Brief description of project location and beneficiaries

Located in the rural province of Bujumbura, Bujumbura is the commercial capital of the Republic of Burundi. The boundaries of the city of Bujumbura contain an area of 49 square miles (127 square kilometers), which was home to an estimated population of one million as of September 6, 2020. Population density is more concentrated in Bujumbura, with an average of 20,673 inhabitants per square mile (7976 per square kilometre). By reducing Burundi's national borders, the population density drops to 1,199 Burundians per square mile (463 per square kilometre). The high population density in the city of Bujumbura combined with inefficient use of biomass makes firewood increasingly scarce and justifies the need to have a bioenergy project close to the city as in Gakara Gahuni which is about 20 km from the city.

Figure: Location of the Garaka community Garaka in Burundi

The proposed project is built on the success of Inyenyeri, a social enterprise currently active in Rwanda (Inyenyeri, 2020). Based in Gisenyi, Rwanda, the social organization currently distributes the Mimi Moto forced-draft, pellet-fed semigasifier cookstove through a business model that claims to emphasize customer service and affordability. The Mimi Moto is currently the best-performing wood fuel cookstove according to lab-based measurements (Clean Cooking Catalog, 2020). Therefore, it offers the potential to drastically reduce indoor emissions (and exposure) compared to traditional solid fuel stoves. There is no similar initiative existing in Burundi but there is potential to try a similar technology with a few modifications based on the needs of the customer.

Wood pellets will be produced from the by-products of wood processing industries (sawdust or wood shavings) or from forest residue collected from Gakara-Gahuni Forest in Bujumbura Province. Because of an additional drying process, biomass pellets made from the wood feedstock offer up to 3100kCal/kg energy content as compared to raw wood which offers much less. This makes the pellet a viable substitute to charcoal. In the pelleting process, forest biomass residue mostly from fallen branches, uprooted trees, sawdust, pole production waste, girdles and slashed napier grass is shredded and then compressed using a specialized pelleting machine; this process is energy intensive and therefore electricity is used to power the entire production process.

Cooks similar to Mimi Moto will be provided to customers, The manner of supplying cookstoves will heavily rely on the lessons learnt in Rwanda which has experience on a similar project. The use of pellet-based gasifier stoves provides a viable step in household transitions toward cleaner energy and in general, reduce the amount of greenhouse gases emitted from traditional fuels.

In Rwanda, customers in Inyenyeri sign a monthly contract to purchase pellets. The prices of pellets are competitive to the market rates of charcoal. Apart from the stove, customers are entitled to regular training, fuel delivery and free repairs.

Adequacy of biomass options for pellet production - The wood pellet process involves drying, grinding, packaging, granulating or extrusion, cooling and sifting wood fibre to produce pellets. Wood fibre is granulated to increase its apparent density, improve handling characteristics and give biomass a regular structure conducive to the automatic feeding systems of burners.

As far as the details of the plant are concerned, a pellet mill with a capacity of 5 tonnes per hour which can be established in a relatively compact location is recommended. Dry storage for sawdust, wood chips, and any other biomass to be used would require a building of approximately 80 feet by 100 feet. A small office space of approximately 10 feet x 24 feet would also be required. Approximately ten acres of land would be large enough to meet production needs. Since mill waste would likely be the most ideal feedstock for pelletizing, a location close to a wood products operation would be preferable as it would reduce transportation costs. Raw material storage will take up the most space. If sawdust from local sawmills is used as the main or only source of raw material, a silo can be used, requiring less floor space. One to two acres of industrial land should be sufficient for this size of operation. We believe that there are several good potential sites in Burundi. Pellet storage will be necessary during the hot months, as the highest production occurs during these months. The storage area required will depend mainly on the relative volumes of bagged pellets compared to bulk pellets produced.

2.4.3 Gender, environment and other factors

Gender. Burundi's still has discriminatory legislation, which encourage violations of women's human rights. Burundi's patriarchal customs and patrilineal inheritance system prevent women from owning and inheriting land. Women must rely on relationships with their male parents to gain access to land.

Environment. Burundi has largely hilly and mountainous terrain, with the wooded mountains of Mitumba to the west giving way to a plateau to the east. Deforestation remains a major environmental problem in Burundi today. The Republic of Burundi has lost almost all of its forest land due to overcrowding and rampant deforestation. This has serious consequences for the wildlife population. Uncontrolled cutting of trees for firewood, combined with agricultural clearing and grazing, has led to almost total deforestation of the country. A massive ethnic civil war and the subsequent collapse of government conservation efforts have further reduced forest areas and led to an increase in wildlife poaching. Soil degradation, deforestation and sanitation problems are Burundi's three main environmental challenges. Already, deforestation and soil erosion, heavy rains have caused flooding and destruction of the country's infrastructure, making it more vulnerable to the effects of climate change.

Working with environmental regulations would be a frequent occurrence for the pellet plant operator, from regulations on logging in the fibre supply to emission regulations controlling particle release during combustion. In particular, air quality regulations for the combustion of solid fuels will present the most difficult barriers to the expansion of pellet heating systems into a broader customer base in the residential, commercial, and public building sectors. Existing air quality regulations cover large power generators and small residential stoves, but there are currently no regulations in place to certify mid-size furnaces suitable for large residential and commercial heating systems. This leaves most potential commercial heating systems without a cost-effective solution for using wood pellets as heating fuel.

2.4.4 Economic and financial analysis of the pilot project

We will have to establish the production costs of the above-mentioned cooking stoves and machines to produce wood pellets - this information is not currently available in Burundi according to the contact person's response and is also not on the Rwanda project website. The estimates of costs and benefits below are based on the literature review

Equipment options: Complete pellet systems are readily available, new or used. Complete equipment packs starting at $150,000.00 can be found online.

Operating costs: There are many studies detailing the operating costs of new plant pellets. The tables below present a simple analysis that can be a starting point for study. According to this study, a pellet operation can be profitable based on an economic analysis.

Table 6: Cost/benefit analysis at 240 tonnes per month of pellet production

Source	**Costs per month**
Building / real estate lease / loan	5000 $
Workforce management	17,000 $
Enegia	2000 $
Payment of equipment loan	5,500$
Overhead	2,000 $
Purchasing raw materials	13,920 $
Various	1,000 $
Total expenses	**46, 420.00 $**
Source	Income per month
Sale of pellets in bags and in bulk	55200,00 $
	Included in the price
Delivery costs	Included in the price
Total income	55200,00 $
Net earnings per month	**8780,00 $**

2.5 BURKINA FASO - Conversion of cashew shells to electrical energy in Bobo-Dioulasso

2.5.1 A. Description of the pilot project and location

Burkina Faso is a landlocked country in West Africa with a young and rapidly growing population heavily dependent on subsistence agriculture. Real GDP growth was 6.7% in 2017 and was supported by increased public investment and higher prices of gold and cotton, the country's two main exports. The country's macroeconomic gains have not translated into improvements for most of the population, and poverty and unemployment rates are very high, especially in rural areas where a large majority of the population lives.

Vitellaria paradoxa (the shea tree) is extremely important in Burkina Faso. Called "women's gold" by Burkinabé villagers, the nuts of the shea tree can be collected and processed by grinding and milling to make shea butter, which is widely used in soap and cosmetics as a moisturizer, ointment or lotion. Shea butter is also edible and can be used in food preparation; it is sometimes used in the manufacture of chocolate. The bark of the tree is also used as an ingredient in traditional medicines and the nut shell is believed to be able to repel mosquitoes and protect existing trees. Shea nuts are important in the economy of Burkina Faso. It is the country's third largest export, after cotton and livestock.

Table 7: Map of Africa showing Burkina Faso

Source: (World Bank, 2020)

Table 8: Macroeconomic and Social Indicators

Population	**18.9 million (50.3% female/49.7% male)**
Urban Population	30.69% of the total
PIB	$11.7 billion (2017)
GDP growth rate	6.7% (2017)
GNI per capita	610 USD
Unemployment rate	6.3%
Poverty rate	40% (2014)
Urban	13%
Rural	47.5%
Currency	West African CFA Franc (CFA/XOF)
Official language	French
Natural Resources	Agriculture (cotton); minerals (gold, zinc, copper, manganese, phosphate and limestone)

Source: (IMF, 2017)

2.5.2 Brief description of project location and beneficiaries

In Burkina Faso, the pilot project will consist of collecting cashew shells and converting them into electrical energy (about 1MW). The electricity will power the cashew factory that produces the shells, and the surplus will be sold to a neighbouring factory. This model is replicable in Burkina because several factories are located in industrial centres. The factory is located in Bobo-Dioulasso. Not using energy to power the factories would mean that the shells are bought and converted in a separate site, so the project is not profitable. Bobo-Dioulasso is a city in Burkina Faso with about 537,728 inhabitants; it is the second largest city in the country after Ouagadougou, the capital of Burkina Faso.

Figure 8: Location of the Bobo-Dioulasso community

The conversion of the meal by cogeneration produces recoverable energy in the form of electricity and heat. First, the hull must be cleared of the oil contained. This liquid, known as Cashew Nut Shell Liquid (CNSL), is contained in the hull to the tune of 20 to 25%. It is a liquid, although commonly called oil, which is not edible. It is also produces smoke during combustion, and the liquid that remains on the shells is an irritant. It is nevertheless a valuable substance, because from the CNSL it is possible to manufacture various products such as paints and polymers, pesticides, and finally as liquid fuel, because of its similarity to heavy fuel oil. The extraction of the CNSL is carried out by extrusion of the hulls in a screw press. The CNSL must be decanted and refined to become a marketable product. The residues that result from these treatment processes can be energy-efficient, starting with the solid residue after the extrusion of the hulls, called cake.

The target consumers are the industries in the area. These could be food processors of oilseeds, fruits, flours or other manufacturing industries such as cement, metallurgy, polymers etc.

2.5.3 Gender, environment and other factors

Gender. In Burkina Faso, women have traditionally played a central role in the extraction of shea butter, from the stage of shea nut collection to its final transformation into shea butter. However, the improvement in the economic conditions of the shea trade did not benefit the women and, as a result, their participation remained limited to their local market, while men obtained the large export market to Europe for the cosmetics industry. Export revenues have been increased through the use of shea butter in cosmetics (for lotions, creams, soaps and other products) by well-known companies such as L'Oréal, The Body Shop and L'Occitane in Provence. These exports are controlled by UNIFEM to ensure that the profits directly benefit local women involved in the industry.

Environment. The main environmental problems facing Burkina Faso are the recurrent droughts and the advance of the northern desert into the savannah. This trend towards desertification has been exacerbated by overgrazing pastures, slash-and-burn agriculture, and over-exploitation of firewood. The Burkinabe government estimates that the country loses just under 110,000 hectares of forest cover each year. Factors of deforestation and forest degradation in Burkina Faso include agricultural expansion, overgrazing of livestock, bushfires and demand for firewood and charcoal.

Shea processing is an important industry in Burkina Faso, but it faces endemic problems such as: impoverishment of forest populations, the emission of large amounts of carbon, health and hygienic risks, and the lack of efforts to improve the socio-economic situation of the country, which remains one of the poorest in Africa.

2.5.4 Economic and financial analysis

The economic analysis for the pilot project will be complete following a field information collection in deliverable 4.

2.6 COTE D'IVOIRE- Conversion of cocoa pods waste into biofuel

2.6.1 Description of the pilot project and location

Côte d'Ivoire is the largest economy in the West African Economic and Monetary Union (WAEMU) and continues to experience high rates of economic growth after emerging from more than a decade of civil conflict and political instability. The country's GDP grew by 7% in 2017, thanks to structural public investment and a strong service sector. More than half of the country's young and fast-growing population lives in urban areas - the economic capital Abidjan is home to 20% of the population, 80% of formal employment and 90% of businesses. In recent years, Côte d'Ivoire's service sector has been an important driver of economic growth; in 2017, the service sector (energy, communications, transport, financial services and trade) contributed half of GDP, with industry accounting for around 30% of GDP and agriculture making up the balance. However, this dynamic is not reflected in the country's employment structure, as two-thirds of the labour force remains in agriculture. Côte d'Ivoire is the world's largest producer and exporter of cocoa beans. Agricultural processing of cocoa, coffee and palm oil contributes significantly to export earnings, while the cocoa sector alone accounts for 10% of GDP and one-third of the country's exports. In 2017, Côte d'Ivoire was the second fastest growing country in sub-Saharan Africa, largely as a result of favourable agricultural conditions and improved terms of trade.

Figure 9: Map of Africa showing Côte d'Ivoire

Table 9: Macroeconomic and social indicators

Population	**23.7 million (50.9% male/49.1% female)**
Urban Population	55% of the total
PIB	$34.4 billion (2017)
GDP growth rate	7.6% (2017)
GNI per capita	1 520 USD
Unemployment rate	9.4% (2013 east.)
Poverty rate	46.3% (2015)
Urban	35.9%
Rural	56.8%
Currency	West African CFA Franc (CFA/XOF)
Official language	French
Natural Resources	Agriculture (cacao, coffee, sugar, palm oil, cashews); minerals (gold, copper, manganese, bauxite)

Source: (World Bank, 2020)

Côte d'Ivoire is the world's largest producer and exporter of cocoa beans used in chocolate production. Although Côte d'Ivoire produced 2.1 million tonnes of cocoa in 2017 (44% of world production), it brought in only $3.3 billion (2.9 billion euros) of this trade, compared with $22 billion in revenue for major U.S. chocolate makers, according to figures from the International Cocoa Organization (ICCO-2020). On the social front, 600,000 farmers work to help about 6 million people living on cocoa income.

The regulation and control of the wood-energy sector is done through documents produced by the Ministry of Water and Forestry(MINEF), namely: For example, to be part of the production chain, an operating permit is required after meeting the following conditions: (i) the payment of a 200,000 CFA bond to the Water and Forest Advances and Revenues Board for certification as a coal and firewood operator under Decree No. 83-455 of May 27, 1983, (ii) the receipt of payment of the annual fee of 50,000 CFA francs for individuals and 100,000 FCFA for legal entities and (iii) the presentation of a contract between the Forest Operations Perimeter Concessionaire (PEF) or the processing plant manager and the secondary products operator.

2.6.2 Brief description of project location and beneficiaries

In Côte d'Ivoire, the pilot project will convert the waste from cocoa pods into biofuel. The project will probably be located around the Gagnoa or San-Pédro regions (southwest of Côte d'Ivoire). The objective is to decide whether fresh biofuel (compacted dry pods) or biochar (carbonated matter) should be selected as products. The choice will depend on the potential market value (Information is collected on the price of fuel around these two cities) and the estimated operating costs for each option. There are massive amounts of cocoa pod waste around the designated areas (3 tons/ha), so tonnage is not really a problem, but logistics are, because the waste is dispersed and the cocoa fields are mostly small. It is therefore important to choose an area where raw materials and products can circulate easily. This will have a big influence on the cost of supplies.

The cortexes are collected in cocoa plantations with the consent of the owners with the help of bags, and then sent to the production site by the scooter. Once the cortexes are on site, they are spread out on the ground to dry them for 7 days before they are stored in the pyrolysis reactor.

Figure 10: Location of the community of Adzope in Ivory Coast

The production of briquettes requires cassava flour (starch) diluted in cold water (volume of 1 to 1.5 liters) and then heated for 10 to 15 minutes, stirring with a handle to obtain a gelatinous paste. This resulting paste is used as a binder. The biochar obtained from pyrolysis, once cooled is introduced into the motorized blender in order to crush it so as to reduce the size of this material. Then, a quantity of the prepared binder is added to this fine charcoal powder and the two materials are mixed in the blender to obtain a homogeneous mixture. The mixing time is 4 minutes for 30 kg of biochar and 7 litres of starch porridge.

For a better agglomeration of briquettes, the project will opt for the motorized press developed by APFNP. This press is equipped with a 4-horsepower reel. For its mode of operation, it is connected to the 380v power grid. The table below shows the characteristics of this technology.

Table 10: Motorized Press test

Technology	Agglomeration	Observations
Press used	APFNP-designed motorized press	Domestic current used from 380V on engine power of 4 Horses.
Need for charred	30 kg	
Type of binder and quantity	0.5 kg of starch or 1.3% of the dry weight of the biocoal	Starch: drying - sifting - dilution and heating
Need for water	7 litres	On all starch water, a volume equivalent to 19% of the mixture
Hourly productivity (kg dry/hour/machine)	36.5 kg	The presses in this category have a daily production capacity of 219 kg for 6 hours of work, operate at medium pressure and are less expensive to buy and maintain. The resulting briquettes come in the form of bars, which are easy to use, transport and marketable. NB: 4 people should be assigned to this task.

The target consumers are the **average households in the surrounding urban areas. The product will be available in as many charcoal selling outlets as possible, so as not to give any image of the product's exclusivity. On the contrary, the strategy seeks to ensure that the product is known to the entire population and thus become a real alternative in the supply of current biofuels.**

2.6.3 Gender, environment and other factors

Gender: A predominant problem in the country is gender inequality. The overall level of schooling in Côte d'Ivoire is very low, especially for girls. The shortfall of a typical household of cocoa farmers in Côte d'Ivoire is about two-thirds of the net income required for a decent standard of living.

Ethical aspects. On the ethical side, and in particular on social responsibility in cocoa production, Côte d'Ivoire must declare or demonstrate that cocoa production complies with the standards mentioned. Specifically, we must indicate that this threat is an appropriate response to the problem of child labour on cocoa plantations.

Environment. Côte d'Ivoire has lost more than 80% of its natural forests in the last 50 years. This significant loss of forests has led to a drastic reduction in related ecosystem services, including the loss of livelihoods from forest resources and reduced climate resilience, which has had a direct impact on the agricultural sector. The loss of forests in Côte d'Ivoire is mainly due to slash-and-burn practices, unsustainable timber and energy wood development, and lack of development, planning and management of forest areas.

2.6.4 Economic and financial analysis

The economic analysis conducted below assesses the benefits and costs of the project over a one-year period. The costs of the assets are depreciated at a rate of 10%. The table below represents the investments needed for a theoretical maximum production of 7.5 tonnes.

Table 11: Investments

discount rate	10%			
Designations	**Amount**	**Unit**	**Unit price**	**Total**
	Operating equipment			
Mixer	1	Room	571 000	571 000
Press	1	Room	850 500	850 500
Pyroliseur	1	Room	883 725	883 725
Biomass dryer	1	Room	371 500	371 500
Dryer	1	Room	165 000	165 000
Tricycle Vehicle	1	Room	1 200 000	1 200 000
Well	1	Room	200 000	200 000
Barrels	7	Room	15 000	105 000
Construction of the production site	1	Room	915 000	915 000
	Financial assets			
Subscription Ivorian Electricity Company	1		1 000 000	1 000 000
TOTAL				**6 156 725**

The table below shows operating costs for a maximum production of 7.5 t per month.

Table 12: Maximum Theoretical Production (7.5 t per month) sold in full

Rubriques	Mois 1	Mois 2	Mois 3	Mois 4	Mois 5	Mois 6	Mois 7	Mois 8	Mois 9	Mois 10	Mois 11	Mois 12	Total
Frais généraux													
Amidon (en FCFA)	187 500	187 500	187 500	187 500	187 500	187 500	187 500	187 500	187 500	187 500	187 500	187 500	2 250 000
Electricité (en FCFA)	35 500	35 500	35 500	35 500	35 500	35 500	35 500	35 500	35 500	35 500	35 500	35 500	426 000
Bache noire (en FCFA)	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	30 000
Transport (en FCFA)	24 400	24 400	24 400	24 400	24 400	24 400	24 400	24 400	24 400	24 400	24 400	24 400	292 800
Emballage (en FCFA)	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	240 000
Charge du Personnel													
Journaliers (en FCFA)- 4 personnes	144 000	144 000	144 000	144 000	144 000	144 000	144 000	144 000	144 000	144 000	144 000	144 000	1 728 000
Rémunération opérareur (en FCFA)	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	1 800 000
TOTAL (en FCFA)	563 900	563 900	563 900	563 900	563 900	563 900	563 900	563 900	563 900	563 900	563 900	563 900	6 766 800

The benefits of bio-coal for a maximum production of 7.5 t per month are present below.

Table 13: Biocoal sales and profits

Rubriques	Mois 1	Mois 2	Mois 3	Mois 4	Mois 5	Mois 6	Mois 7	Mois 8	Mois 9	Mois 10	Mois 11	Mois 12	TOTAL
Production de biocharbon (en Kg)	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	90 000
vente à Affery et alentour (en FCFA)	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	1 125 000	13 500 000
Bénéfice (en FCFA)	561 100	561 100	561 100	561 100	561 100	561 100	561 100	561 100	561 100	561 100	561 100	561 100	6 733 200
Vente vers la capitale (en FCFA)	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	2 250 000	27 000 000
Coûts de transport	713 900	713 900	713 900	713 900	713 900	713 900	713 900	713 900	713 900	713 900	713 900	713 900	8 566 800
Bénéfice (en FCFA)	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	1 536 100	18 433 200

Table 14: Economic analysis of theoretical maximum production (7.5t per month) sold in full

Biocharbon (Vente sur place)	Année 1	Année 2	Année 3	Année 4	Année 5	Année 6	Année 7	Année 8	Année 9	Année 10
Chiffre d'affaires (en FCFA)	13 500 000	13 500 000	13 500 000	13 500 000	13 500 000	13 500 000	13 500 000	13 500 000	13 500 000	13 500 000
Charges prévisionnelles (en FCFA)	6 766 800	6 766 800	6 766 800	6 766 800	6 766 800	6 766 800	6 766 800	6 766 800	6 766 800	6 766 800
Dotation aux amortissements (en FCFA)	615 673	615 673	615 673	615 673	615 673	615 673	615 673	615 673	615 673	615 673
Résultat net avant impôt (en FCFA)	6 117 528	6 117 528	6 117 528	6 117 528	6 117 528	6 117 528	6 117 528	6 117 528	6 117 528	6 117 528
Impôt ou taxes (en FCFA)	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000
Résultat net après impôt (en FCFA)	6 102 528	6 102 528	6 102 528	6 102 528	6 102 528	6 102 528	6 102 528	6 102 528	6 102 528	6 102 528
Dotation aux amortissement (en FCFA)	615 673	615 673	615 673	615 673	615 673	615 673	615 673	615 673	615 673	615 673
Flux nets de tresorerie avec rémunération de l'opérateur (en FCFA)	6 718 200	6 718 200	6 718 200	6 718 200	6 718 200	6 718 200	6 718 200	6 718 200	6 718 200	6 718 200
Flux nets de tresorerie cumulés avec rémunération de l'opérateur (en FCFA)	6 718 200	13 436 400	20 154 600	26 872 800	33 591 000	40 309 200	47 027 400	53 745 600	60 463 800	67 182 000
Flux de trésorerie sans rémunération de l'opérateur (en FCFA)	8 518 200	8 518 200	8 518 200	8 518 200	8 518 200	8 518 200	8 518 200	8 518 200	8 518 200	8 518 200
Flux de trésorerie cumulé sans rémunération de l'opérateur(en FCFA)	8 518 200	17 036 400	25 554 600	34 072 800	42 591 000	51 109 200	59 627 400	68 145 600	76 663 800	85 182 000
Flux nets de trésorerie actualisés (en FCFA)	6 107 455	5 552 231	5 047 483	4 588 621	4 171 474	3 792 249	3 447 499	3 134 090	2 849 173	2 590 157
Flux nets de trésorerie actualisés sans rémunération de l'opérateur en FCF	7 743 818	7 039 835	6 399 850	5 818 045	5 289 132	4 808 302	4 371 183	3 973 803	3 612 548	3 284 135
Délai de récupération du capital investi		365	jours			Valeur Actuelle Nette			35 123 706	
0 ans 11 mois 4 jours	0,92	334,50	jours			Indice de profitabilité			6,70	
0 ans 8 mois 24 jours	0,72	263,81	jours			Valeur Actuelle Nette			46183927	
						Indice de profitabilité			8,50	

A summary of the economic analysis can be found in the table above. The analysis estimates an investment cost of approximately 6,156,725 CFA francs or $11,227 per year for a production option of 90 tonnes per year. Economic analysis suggests that the company could make profits in the first month. There are clear opportunities to improve the company's financial performance, based simply on the costs of other operations.

2.7 Mali - Conversion of shea butter into fuel in Bamako

2.7.1 Description of the pilot project and location

Mali is a landlocked country in the Sahel sub-region of West Africa, with abundant natural resources and vast territory. The economy is heavily dependent on the agricultural sector, which contributes almost half of GDP and employs about 80% of the population. As a result, the country is vulnerable to adverse weather conditions and fluctuations in commodity prices. Economic growth has declined slightly in recent years, estimated at 5.5% in 2017 and expected to reach 5% in 2018 and 4.9% in 2019, partly due to the fragile political situation in the country. High rates of population growth, drought and civil conflict have fuelled poverty, which remains widespread, especially in rural areas (AfDB, 2020; World Bank, 2020).

Figure 11: Map of West Africa with Mali at the inset

Table 15: Macro-economic and social indicators

Population	**18 million (50.1% male/49.9% female)**
Urban Population	41% of the total
PIB	$15.3 billion (2017)
GDP growth rate	5.3% (2017)
GNI per capita	780 USD
Unemployment rate	7.9 % (2017)
National poverty rate	43.6% (2009)
Urban	18.9%
Rural	50.6%
Currency	West African CFA Franc (CFA/XOF)
Official language	French
Natural Resources	Agriculture (cotton); minerals (gold, bauxite, uranium)

Source: (World Bank, 2020)

For centuries, shea and butter produced from its fruit have been at the heart of life in rural communities, mainly women, in Mali and other West African countries. Mali has one of the largest tree areas in the so-called shea belt, but rudimentary production processes mean that production is around 80,000 tonnes/year compared to an estimated potential of 250,000 tonnes per year. At the same time, the country has tended to export nuts or raw shea butter to markets in Burkina Faso or Ghana rather than capitalizing on added value for its own producers.

The country has a huge deficit in the supply of wood-energy to the users. Most of the trees have come out of undeveloped forests and therefore there are no forest laws adhered during logging. This means that tree covered fields can be entirely cleared. There is a rural market scheme that had been implemented to create logistics platforms for the purchase and sale of wood-energy and to structure the sector; but unfortunately, this is no longer being observed. The consumption patterns of people in rural and urban areas are very different: people in rural areas consume increasing amounts of wood, which they collect at no-costs most households. While in the city, the amount of wood consumed decreases proportionally to an increase charcoal consumption. Prices in the city are unsurprisingly higher than in other places. Cost of wood remains relatively cheap in Bamako despite retailers sourcing it from distances up to 150km from the city and experiencing periodic supply shortfalls.

2.7.2 Justification of the pilot projects

For rural communities, which are outside the formal economy, shea butter is an increasingly important but still underdeveloped product. Women continue to hand-pick the fruits of the wild trees that grow in abundance on Mali's red soil. The nuts are extracted, boiled, dried and shelled by groups of women and girls working together. They are then crushed, roasted and ground into a paste to make butter. This physically demanding process has changed little since the late 18th century, when the Scottish explorer Mungo Park first introduced Europe to shea butter and its properties, describing it better than any cow's milk butter.

For the past ten years, UNIDO has been supporting the Government of Mali in its efforts to help rural communities better exploit the value-added potential of shea and improve the livelihoods of women who depend on this value chain for about 80 percent of their income. Shea butter is traditionally used for cooking and as a cosmetic product, particularly in skin creams and soaps. With the growing popularity of natural cosmetics in the West, the demand for shea butter as a raw material in the cosmetics industry has increased. However, women's incomes will only increase sustainably if shea butter producers are able to increase the added value and improve the quality of the products and if they can access international markets.

2.7.3 Brief description of project location and beneficiaries

In Mali, shea butter meal will be turned into fresh fuel. The largest producer of the cake aims to do this on its own, which means that there is a viable site already - the MaliShi plant, a few km south of Bamako. Fuel prices around Bamako are high, therefore this will be a better alternative to electricity. Shea butter bricking is simple and the product must be clean enough to be safely burned in household homes or for productive uses (bakeries, industry, collective cooking). Bamako is located on the floodplain of the Niger River, hampering development along the shore and tributaries of Niger. Bamako is relatively flat, except in the immediate north where there is an escarpment, which is what remains of an extinct volcano. Bamako is a bustling city with a large market, botanical and zoological gardens, an active community of artisans and several research institutes.

Figure 12: Location of the Banankoro community

It supports four colleges and is home to the majority of Mali's industrial enterprises. The national capital, Bamako, is located on the Niger River and is a booming city due to increased immigration from disadvantaged rural areas.

In this context, MaliShi's plant, in Banankoro southeast of Bamako, has a surplus of biomass that it seeks to develop. To produce shea butter, the plant processes 16,000 tonnes of shea almonds this year. About 8000 tonnes of this input is extruded as shea meal waste which is consumed by boilers as fuel. The production of charcoal briquettes of dust and shea cake is done in a press. The raw materials in this site for the production of briquettes is shea meal from the factory, but a a binder has to be added to guarantee the integrity of the briquette. Before making briquettes, a mixture of raw material and binder should be made and moistened a little. The yield will be 100% of the shea cake. The MaliShi plant prefers to house the briquettes manufacturing unit, which facilitates logistics for the supply of raw materials.

Shea meal briquettes are good, non-carbonated fuels (18-20 MJ/kg PCI). These briquettes are produced in cylindrical form with the possibility of adapting diameters to consumer requirements. For example, larger diameter logs can be manufactured for bakeries and other large-scale economic activities.

The briquettes are intended for households and income-generating activities such as bakery and dyeing in the capital. However, the households can access the product through the outlets if they wish. Outside the city, most of the briquettes will simply be distributed to shea nut collectors. The sale of wood to other economic players, such as bakeries in rural areas and small towns, is also possible. In rural areas, 5% of households buy wood while 98% buy it by collection. The resource is therefore mostly free in the latter case. In urban areas in Bamako but also in the surrounding small towns, wood for households and economic use must first be purchased.

2.7.4 Gender, environment, and other factors

Gender. In Mali, ethnicity and religion are social factors that govern gender relations and shape the status of women. These factors are considered social values and underlie household management, which serves as the basis for gender relations. The resulting customary practices build and maintain inequalities and disparities and, to some extent, reinforce the dominance of men in families. Despite the progress made, there are still gender inequalities in the overall situation of the Malian education system.

Sheanut producers are women who collect and process nuts to extract almonds. This processing process (scalding nuts) requires fuel. As previously said women in rural areas go looking for wood near forests. But it has an environmental cost because it is a source of deforestation, and the industrialist would like to mitigate it.

Environment. The major environmental problem in Mali is the growing desertification of the country. Soil erosion, deforestation and loss of pasture pose additional environmental problems. Mali also has an inadequate water supply: only 74% of urban dwellers and 61% of people living in rural areas have access to clean water.

Rampant deforestation, inadequate drinking water supplies, soil erosion, desertification, poaching, land and water pollution (mainly caused by poor sanitary conditions, inadequate disposal of agricultural and industrial waste), etc. are some of the environmental problems facing Mali today.

The numbers tell the story. In 1990, Mali's forests stretched over 14 million hectares. But in 2000, they covered 13,117,643 hectares, according to a 2005 national state of the environment report. This marks a reduction of about seven per cent of the West African country's forests in just one decade.

2.8 Economic and financial analysis

Eventually, the plant will process 30,000 tons of almonds, generating 14,000 to 15,000 tons of meal. They plan to consume a maximum of 6,000tones of meal in-house, i.e. 8,000 to 9,000 tonnes of meal can be potentially converted for bioenergy. The factory is interested in making briquettes with this surplus, and distributing them to their shea almond suppliers.

The economic analysis for the pilot project will be completed following a field information collection in deliverable 4.

2.9 Conclusion and Recommendations

This evaluation suggests that, despite the challenges, there is an opportunity to mechanize bioenergy production in countries such as Cameroon, Congo, DRC, Burundi, Burkina Faso, Ivory Coast and Mali, and generate economic and environmental benefits.

The forecasts of revenue generated and return on investment are encouraging. However, more details are needed. Specifically, there is a need to (1) develop a comprehensive assessment of the risks associated with social and environmental concerns once the location of the concession and plant are delineated and management plans have been developed and, furthermore, (2) the economic model must include debt servicing, which can only be determined when financing instruments (e.g., grants, loans, etc.) are known. Because of these unknowns, this evaluation can be considered an important step towards evaluating revised pilot plans. These projects present ambitious plans to modernize bioenergy production in Africa. If successful, projects will have impacts that can extend far beyond communities. However, technical challenges and economic risks should not be underestimated.

Appendix I

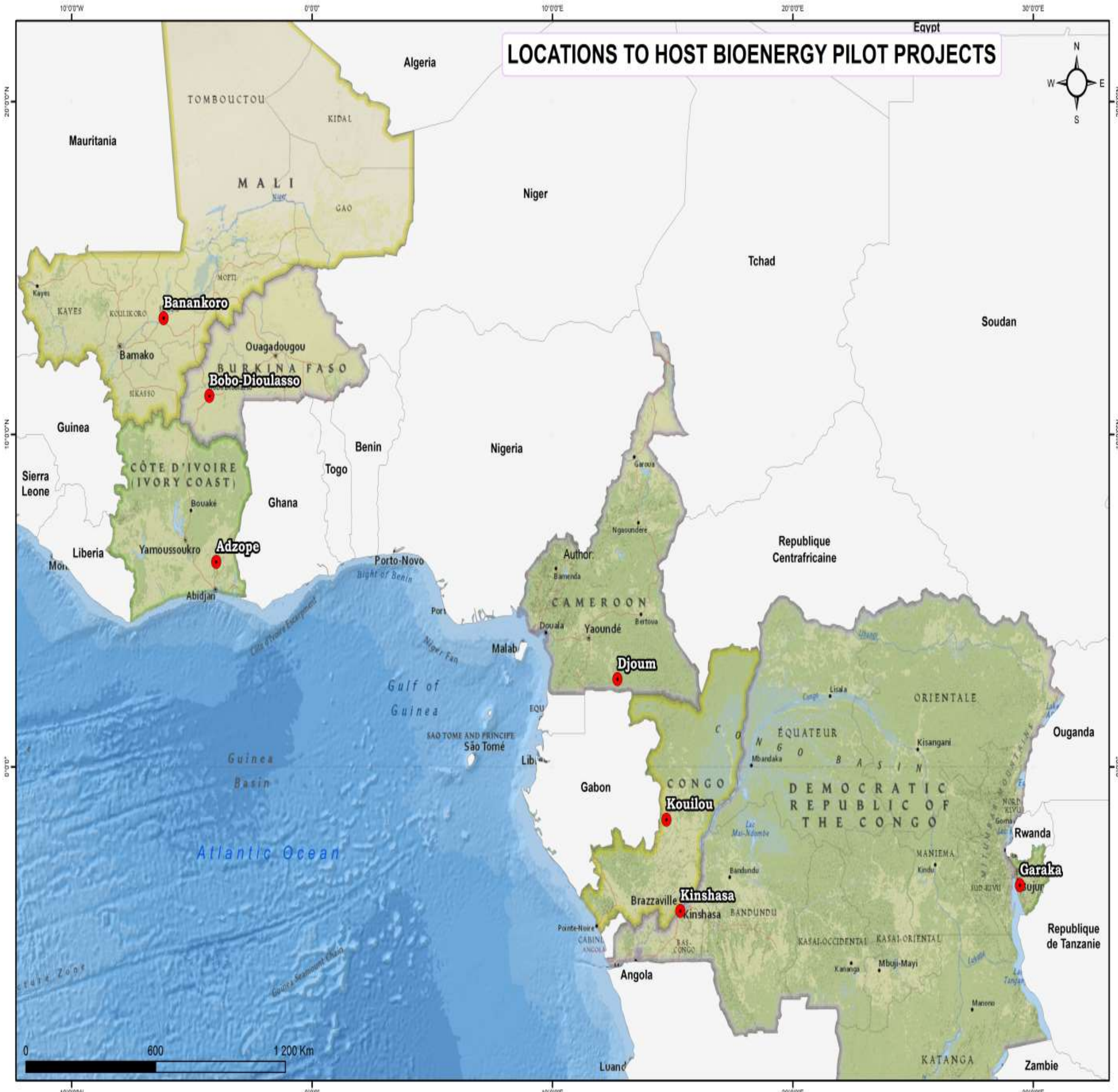

Figure 13: Location of Bioenergy pilot projects in Africa

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