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Technical Paper

Guidelines on Sustainable Bamboo Energy Production and Investment

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About the International Bamboo and Rattan Organisation

The International Bamboo and Rattan Organisation, INBAR, is an intergovernmental organisation dedicated to the promotion of bamboo and rattan for sustainable development. For more information, please visit www.inbar.int.

About this Working Paper

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List of Abbreviations

APBRDA	Arunachal Pradesh Bamboo Resources Development Agency
CCEA	Cabinet Committee on Economic Affairs
CDM	The clean development mechanism
CER	Certified emission reductions
CHP	Combined Heat and Power
CPA	Certified Public Accountant
EEFRI	Ethiopian Environment and Forest research institute
EU	European Union
EUEI PDF	European Union Energy Initiative Partnership Dialogue Facility
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GGGI	The Global Green Growth Institute
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GrEEn	Green Employment and Enterprise
IEA	The International Energy Agency
IFAD	The International Fund for Agricultural Development
IFC	The International Finance Corporation
INBAR	The International Bamboo and Rattan Organisation
IRENA	The International Renewable Energy Agency
MOU	Memorandum of Understanding
MSME	Micro, Small, and Medium Enterprises
NBDA	Nagaland Bamboo Development Agency
NBM	National Bamboo Mission
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organization
NRL	Numaligarh Refinery Limited
PPP	Public-Private Partnership

REDD+	Reduce emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks
SC	The Steering Committee
UNFCCC	The United Nations Framework Convention on Climate Change
UNIDO	The United Nations Industrial Development Organization
VCR	The Verified Carbon Standard

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Executive summary

Bamboo compared to other plants has many advantages such as fast growth, high yield, annual harvesting, adaptation to various soil types, high carbon sequestration potential, in addition to its use in huge number of applications. Besides all of these advantages, from the energy perspective, bamboo has a relatively high calorific value of 19.8 MJ/kg. Hence, it can be utilised to generate heat and electricity (i.e., about 0.83 kWh electricity/kg of bamboo through gasification technology). The charcoal generated from bamboo has high calorific value ranging between 26 and 29 MJ/kg. From the environmental prospective, it has lower smoke emissions (because of its low ash and alkali content) compared to charcoal produced from trees (e.g. Acacia).

Consequently, there are several successful businesses globally that use bamboo in bioenergy generation. This includes electricity generation projects in off-grid areas like the 700 kW project in Indonesia, bio-ethanol projects like the 49,000-ton ethanol/year project in India, in addition to several successful charcoal projects in Africa and Asia. However, the utilization of bamboo as bioenergy source in Africa is still underutilised despite covering 7.2 million hectares of land. Therefore, the aim of this working paper is to provide guidelines for private investors on how to effectively plan a bamboo bioenergy project in Africa. The second main objective is to explain to African policymakers why they should consider bamboo bioenergy as an important sustainable development topic and to provide them with guidelines on starting an effective bamboo bioenergy sector governance.

Methodology

Understanding the baseline situation of using bamboo as a bioenergy fuel or as a raw material for other products is crucial to achieve the abovementioned objectives. To guarantee the quality of the baseline assessment, the baseline data collection was based on diversifying the data sources to cover the perspectives of several countries and several categories of stakeholders. Hence, a mixed approach combining the following sources was followed:

- A virtual focus group meeting gathering various stakeholders from different countries
- Online one-to-one meetings with specialised experts
- Two field missions to Ethiopia and Ghana

- Literature review of previously conducted studies on bamboo generally, specifically bamboo bioenergy

Part 1: Guidelines for private investors on how to effectively plan a bamboo bioenergy project in Africa

Based on the baseline assessment findings and the analysis of the consulting team to the African market, the consulting team developed guidelines are for the local or international private investors who are interested in developing a bamboo bioenergy project in Africa. This was developed in the form of a step-by-step guidance to help the potential investors take the right decisions in the different project development stages. The proposed steps by any potential investor are identifying the type of bamboo bioenergy project, identifying the feedstock availability and reliability, identifying the relevant regulations, selecting the optimum production technology, assessing the project feasibility and identifying the financing options, and finally selecting the optimum business model for product sales according to the type of the bioenergy project.

The first step is to define the type of bamboo bioenergy project according to the analysis of the energy market needs in INBAR member states. Investors should study the market demand of the targeted country. For instance, if a country consumes large amounts of charcoal, charcoal projects will have great potential in that country. The electricity access rate is also important to define whether the country requires off-grid electrification projects. Furthermore, if the country has bio-ethanol commitments, then bio-ethanol production from bamboo can be promising. Section 3.1.3 in the document provides such analysis and accordingly define the recommended bamboo bio-energy project type in each African INBAR Member State.

After identifying the bamboo bioenergy project type, the project developer should identify the required daily/weekly/yearly amount of bamboo. At the beginning of the project, it is especially recommended to consider multiple types of biomass fuel resources (besides bamboo) to secure continuous supply and, accordingly, ensure the project's reliability. Securing a long-term quality, a sufficient quantity and a good price biomass resource are important assets before making the decision to invest in such bioenergy project. For small-scale bioenergy projects, the investor needs to coordinate with the farmers regarding the bamboo supply. While for large-scale projects, a feedstock supply agreement needs to be signed between the bamboo suppliers and project owner in order to secure the raw material supply. Generally, farmers are interested in

plants as long as there is a guaranteed market for them. This fact has been proven from many success stories worldwide, as well as the findings of the field missions.

To mainstream the presence of biomass projects in general and bamboo-based projects in specific, many regulations and policies exist in different countries. Some of such regulations and policies are reformation of fossil fuel subsidies, renewable energy targets, renewable/sustainable energy mandates/obligations, integrating bioenergy projects into the national agricultural and rural development strategies, decreased deforestation targets, availability of clean cooking action plans, in addition to tax incentives (e.g. duty-free access to Europe, and zero duties for bamboo equipment as applied in Ethiopia). Building on the above, it is highly recommended for any investor/project developer to identify such information from the countries' NDCs (publicly available on the United Nations Framework Convention on Climate Change (UNFCCC) website). This will guide the investor/developer towards the most suitable countries for bamboo-based bioenergy projects and the recommended technology/scale type for such countries. Section 3.3.1 in the document provides more analysis in addition to a list of African INBAR Member States and their current status in terms of deforestation targets, clean cooking promotion and alternative fuels.

Once the above steps are completed, the investor should have a clear idea about the project type that he/she will develop. Hence, the next important step is to identify and select the corresponding technology. For electricity generation for example, combustion and gasification technologies can be used. For large-scale centralised electricity generation projects, both technologies can be applied. On the other hand, small-scale gasifiers are used in decentralised off-grid facilities for rural areas (which is mostly the case in Africa). Section 3.4 in the document provides more details about the different technologies for production of bamboo charcoal, pellets, briquettes in addition to bio-ethanol and electricity.

Following that, the investor needs to assess the bioenergy project viability before making the decision to implement the project. This assessment includes technological, organisational, environmental, economic and financial aspects. Several factors should be considered including current costs of energy in the country, stability of the current energy supply, and the current costs relevant to bamboo resource storage and disposal. Carbon markets provide an additional source of revenue for sustainable energy projects by creating commercial value to reduce GHG emissions. This can increase the commercial viability of bamboo bioenergy projects and thus play an important role in the sustainability and development of such projects. Carbon finance is

active in Africa. Section 3.5.2 in the document presents the number of bioenergy programmes in each African INBAR Member State which have received carbon finance including the UNFCCC clean development mechanism (CDM), and voluntary carbon markets. The number of registered programmes per country should also give the investor an idea about the activity level of the country in the bioenergy field. A lot of such registered programmes are for cooking stoves; hence, supplying such programmes with bamboo charcoal is a market opportunity that needs to be studied by investors.

If the investor cannot secure the required project investment as 100% equity, it will be necessary to select the financing institution with the most preferable conditions. For small entrepreneurs in Africa, commercial banks usually lend at a high interest rate, which is not feasible. One of the most successful experiences in Ghana that was able to unlock such a challenge is the 'Orange Corners Innovation Fund' under the 'Fidelity Bank Young Entrepreneurs' Initiative'. It is a revolving fund which can have up to 50,000 euros as a loan, including a 30% grant with a 5% interest rate. Away from the Orange Corners Fund, the Fidelity Bank has its own fund structure, which focuses on supporting young entrepreneurs providing a 10% interest rate per annum for MSMEs. Through discussions with the fund management entity, it is clear that the Fidelity Bank is willing to issue new phases of this programme. In addition, the Dutch government is willing to replicate this in several other African countries. Hence, small-scale bamboo bioenergy investors are recommended to look for similar funding programmes.

The final step in the guidance for the investors is selecting the optimum business model for product sales. For off-grid electrification projects for example there are 3 models; Market-based business models (fee-for-service model, dealer model, lease model), Government-induced community-based business model and Public–private partnership (PPP) model. As for the bamboo charcoal and charcoal briquettes, there are several models including direct sales, third-party private dealers-distributors and retailers, social sector partners, and institutional bulk sales. Section 3.6 presents mode details about each model. Each of these models have specific characteristics; hence, the investor neds to select the appropriate model on case by case basis.

Part 2: Guidelines for African policymakers

The second part of this document present guidelines for policymakers. In this part, the consulting team aims to deliver to African policymakers why they should consider bamboo

bioenergy as an important sustainable development topic, and to provide guidelines for African policymakers on starting an effective bamboo bioenergy sector governance.

Why African policymakers why they should consider bamboo bioenergy as an important sustainable development topic?

African policymakers need to consider bamboo bioenergy as an important development topic because of two key aspects; the first one is related to global market development and the second one is related to meeting the relevant national targets in African countries.

Global Market Development

As for the global market development, the world is quickly changing these days, and the keyword for that is climate change. Most of the countries worldwide (especially the developed countries) are shifting their economies to the sustainable and low-carbon pathway. One relevant global attraction of bamboo is its high carbon sequestration potential, which can be seen as a game changer. According to Paris Agreement (adopted by 196 countries), developing countries will implement ambitious mitigation actions with enhanced support from developed countries. In the last few months, and during the preparations of UNFCCC COP 26 in Glasgow, there has been global pressure to reach net-zero emissions by 2050. Some countries have already committed to it in law, some others have committed in an official policy document, and some others have reported a pledge. To achieve net-zero emissions, big emitters (e.g. USA and EU) need to conduct radical reductions in their emissions and offset their remaining emissions through financing green projects in other countries. Given the high climate change mitigation potential of bamboo, African countries can support the world in achieving its net-zero target by hosting bamboo plantations in the areas devoted to land restoration and reforestation. Moreover, and given the large areas of bamboo that can be planted, African countries can host international investors willing to develop large-scale bamboo-to-ethanol plants (such as the one in India, which will start production soon). The produced ethanol can then be exported to countries with bio-ethanol blending commitments. In addition, the large areas of bamboo can also facilitate the construction of bamboo-based decentralised power plants in African rural areas lacking electricity access. Such local projects will have further GHG emission reduction impacts through the displacement of fossil fuels. Moreover, the large areas of bamboo will facilitate improved and large-scale bamboo processing industry in Africa. This will result in

further replacement for timber-based products and, hence, less deforestation and further reduced GHG emissions. From the policymakers' perspective, this is a perfect example of sustainable development.

Another sign of global market development is that bamboo products have been proving themselves on the market for many years. The global exports of bamboo products amount to more than USD 1.7 billion annually, and the annual market size is approximately USD 53 billion. The EU, for example, has bamboo products' imports valued at more than 500 million dollars annually. Even African countries import bamboo products. Some African governments get surprised when they know that the furniture they are sitting on or the toothpicks they are using are actually manufactured from bamboo and imported. In addition, some bamboo products are already manufactured in African factories and workshops and are welcomed by African citizens, such as toothpicks, furniture, incense sticks and charcoal. Some of the big companies worldwide like IKEA and Procter & Gamble started to publicly announce the use of bamboo in their products due to the several sustainable benefits of bamboo, and to help ensure their products are carbon-neutral. It is important for African policymakers to know such market updates and develop policies that support cooperation with such big brands worldwide by providing them with bamboo raw materials and products. Currently, China has a lion share of global bamboo exports of more than 70%. By comparing the bamboo land area in China to that in Africa, they are nearly the same. Hence, considering the above, this indicates that bamboo is largely underutilised in Africa, and that there is a huge potential for the African countries to have a solid bamboo industry and have considerable share in global bamboo exports.

Meeting the relevant national targets in African countries

The second aspect that makes the bamboo bioenergy an important sustainable development topic to be considered by the African policymakers is its potential to support the achievement of some of the national targets. Nearly all African INBAR Member States listed in their NDCs that they have commitments towards decreasing deforestation. Moreover, all African countries have pledged some targets for forest and landscape restoration under the Bonn Challenge. Planting bamboo results in decreasing deforestation rates, since it regrows quickly and matures faster than most types of trees. In addition, bamboo can be grown in poor soils and restored to be suitable for growing agricultural crops. Hence, policymakers should seriously consider bamboo

plantations as it can help achieve the NDC deforestation targets in addition to the Bonn Challenge pledges.

Nearly half of African INBAR Member States have included the promotion of improved cookstoves as one of their NDC mitigation actions. In addition, nearly all African INBAR Member States have included alternative fuel promotion among their NDC mitigation actions. Deforestation, improved cookstoves and alternative fuels are all highly interconnected. Due to the increased rates of deforestation and the increased population, the switch to alternative fuels needs to be performed at a quicker pace. One of the facts that has been affirmed by various stakeholders met during this report preparation is that there is no 'one size fits all' solution for the improved cookstoves programme. Each area in each country requires an optimised solution for the type of improved cookstove to be used and, more importantly, the type of fuel it can use. For the areas with high access to bamboo forests, for example, cookstoves should be designed accordingly, and the residents should be trained on their use. Some African countries have also pledged in their NDCs to use alternative fuels in non-residential uses (e.g. industry). Most African INBAR Member States have cement plants that consume huge amounts of fossil fuels. In several African countries (e.g. Ethiopia, Kenya…), there are positive experiences from using alternative fuels like agricultural residues as partial fuel substitution in the cement industry. Bamboo has an even higher calorific value than agricultural residues; thus, it can be used as a fuel for cement plants. One of the biggest cement plants in India has recently announced that it will use bamboo as a main fuel. Hence, bamboo can definitely support African countries in achieving their alternative fuels targets.

Guidelines for African policymakers on starting an effective bamboo bioenergy sector governance

Due to the importance of bamboo bioenergy as a sustainable national development topic in African INBAR Member States as discussed above, African policymakers need to have effective sector governance to ensure achieving the aforementioned benefits. In general, governing the bamboo bioenergy sector should be preceded by governing the bamboo sector itself. China and India have significantly important relevant experiences that African policymakers can benefit from. Section 4.2 in the document provides some relevant details.

Some African countries in cooperation with INBAR have started focusing on the bamboo sector. This has resulted in the development of several guiding documents: 'bamboo policies integration analysis,' 'bamboo strategies and action plans' and 'bamboo value chain analysis'. Hence, governments of these countries have already taken a step forward to develop bamboo sector governance, which is considered a good starting point. For any country that needs to work on the bamboo sector governance pathway, seven steps are recommended as follows: identifying the relevant stakeholders, development of the governing coordination structure, deep analysis of the baseline situation, identification of the value chain bottlenecks, integration with relevant initiatives, developing an action plan, and finally adoption and implementation.

The stakeholders in such a sector often include the government, the private sector, civil society and the international community. A coordination structure for the bamboo sector should be established as the first big institutional step; this structure is usually named the 'Council'. A clear and mutually agreed coordinating structure for such a Council is essential for the success of the sector's governance. Usually, this structure comprises a lead institution, steering committee, technical support committee and supporting stakeholders. Section 4.3.2 in the document presents more details about the role of each. Of course, the Council's formation will differ from country to country, based on the national circumstances and the government's structure. One of the very important points that need to be set from the beginning is the financing source for the 'Council' activities.

The first real step after the Council's formation is to conduct a deep analysis of the national bamboo and bamboo bioenergy baseline situation. In this analysis, the bamboo and bioenergy value chains should be well-studied including both the supply and demand sides. The supply side includes all steps of bamboo plantation, growing, harvesting and transportation. The supply side also covers all stages before the energy product reaches the end-users. This includes energy conversion equipment (e.g. charcoal furnaces, briquetting machines and decentralised electricity generation equipment), in addition to production, marketing and sales of fuels and appliances, such as improved cookstoves. The demand side covers bamboo handicrafts, industrial factories and energy users, including households, institutions, commercial enterprises and agro-processing. Section 4.3.3 in the document provides more details about the exact points that need to be covered in such value chain analysis. It is recommended that the results of the baseline analysis be documented in a report and made publicly accessible. Having a validation stakeholder consultation with a wider range of stakeholders afterwards will be

beneficial to confirm/modify some of the study's outcomes. After conducting an in-depth analysis of the baseline situation, a deeper analysis is usually required to identify the different value chain bottlenecks. This is important to recognise the roles of the main market actors and stakeholders, diagnose the market channels for strength, weakness, opportunities and threats analysis and build vision and action plans.

After identifying the weakness points in the previous step, the 'Council' should maximise the integration and mainstreaming of bamboo and bamboo bioenergy into the most relevant ongoing and successful initiatives. This is usually a successful strategy to overcome the inherent weaknesses of bamboo due to weak sector governance at such an early stage. As mentioned above, bamboo can support the achievement of some of the national targets related to deforestation, land restoration, improved cookstoves and alternative fuel maximisation. It can also help the country achieve its rural electrification targets and bio-ethanol commitments (if any). Hence, the 'Council' should identify the role of each SC member in mainstreaming bamboo in the most relevant ongoing initiative and discuss any possible changes in SC meetings. Following that, it is important to develop a well-defined action plan for the bamboo and bamboo bioenergy sector. The action plan should also include other items that are bamboo-specific and might not fit under any relevant initiatives. This action plan should describe the expected short-term actions (5 years) in detail and the medium-to long-term actions to be included more broadly. The action plan needs to be updated regularly (e.g. every two years). The recommended interventions in the bamboo and bamboo bioenergy sector should be a mix of regulatory actions in the form of decrees or laws (e.g. improved regulations for land tenure, tax incentives), institutional actions (e.g. developing master plans for supply centre), coordination actions (e.g. coordinating with donors and banks for developing financing schemes suitable for bamboo entrepreneurs), technical actions (e.g. measures to increase productivity of bamboo forests), and awareness actions (e.g. increase the awareness of the citizens about bamboo products). The developed action plan should then be adopted by the 'Council'. The 'Council' should closely monitor the implementation of the action plan items, and a mechanism for progress reporting should be agreed upon and implemented.

1. Introduction

Bamboo is a perennial plant that has been receiving increased attention recently due to its numerous sustainable features. According to the Global Forest Resource Assessment 2020, bamboo covers about 35 million hectares of land worldwide, with 7.2 million hectares in Africa alone (FAO, 2020). There are approximately 1642 different bamboo species, of which 115 are distributed across 48 countries in the African region, within approximately 50°N–47°S (Bahru & Ding, 2021; Vorontsova, Clark, Dransfield, Govaerts, & Baker, 2016; INBAR, 2015). Bamboo is considered one of the fastest growing plants on the planet, as it records growth rates of more than one meter per day for some species and reaches its full height in one growing season. Furthermore, bamboo can grow in poor soils with little or no input. Bamboo can be harvested after 3–5 years after initial planting and can then be harvested annually without any negative effects on forestation or resource losses. This is because bamboo rhizomes remain rooted in the soil and keep producing new shoots every year, which accordingly helps secure the soil.

1.1 Key advantages of bamboo

Bamboo is known as a plant with thousand advantages (Xu et al., 2020), which make it suitable for use in several applications, such as flooring, furniture, food, packaging, charcoal, basketwork, mats and construction material. Bamboo can also be used in the pulp and paper industry, which has already been implemented in Ethiopia, for example. Furthermore, bamboo has a high yield compared to other plants, with values ranging between 5 and 47 metric tons per hectare according to the management practices followed. Global exports of bamboo products amount to more than USD 1.7 billion annually (INBAR, 2019), and the annual market size is approximately USD 53 billion (Brachytherapy, 2021).

From the energy perspective, bamboo has a high calorific value of approximately 19.8 MJ/kg, which is higher than those of other plants such as eucalyptus, hybrid popular and willow (INBAR, 2015, 2018). Bamboo can be used in electricity generation plants, where approximately 1.2 kg of bamboo can be used to generate 1 kWh of electricity through gasification technology. The latter has been successfully applied in various locations, including Madagascar and Indonesia. According to the research conducted by INBAR, charcoal developed from bamboo has a high calorific value ranging between 26 and 29 MJ/kg. Additionally, bamboo has lower smoke

emissions (i.e. low ash and alkali content) compared to similar amounts of charcoal produced from trees (e.g. Acacia).

One major advantage of bamboo, which is facilitates its high global demand, is its efficiency in carbon sequestration. This is based on the fact that bamboo has a high growth rate compared to other plants. In addition, during harvesting, the plant is only trimmed and not cut from the roots. Hence, bamboo can sequester up to four times carbon dioxide compared to other hardwood species (INBAR, 2015, 2018).

1.2 Bamboo bioenergy success stories

The use of bamboo as an energy source has increased in the last decade, with many successful cases globally. Some of these success stories are presented in this section.

In Indonesia, tropical bamboo can be found in many areas, and it can be easily grown in different soil types, including degraded lands on which there is no conflict with food production. Approximately 40% of the country's population lacks access to reliable electricity, a situation which is similar to that observed in several African countries. Building on this fact, many bamboo biomass projects have been undertaken, with one of the most famous ones being a community-based electricity generation plant set up for three remote villages in Mentawai Islands (Figure 1). The power plant has an aggregate capacity of 700 kW and provides power to more than 1300 households.

Figure 1. Aerial view of one of the power plants in Mentawai Islands (Clean Power Indonesia, 2021)

India is another country with many successful business cases in which bamboo has been used as a bioenergy resource. Soon, the government of India will announce the commercial production of their first large-scale plant for bio-ethanol generation from bamboo in Numaligarh Refinery Limited (NRL). This project relies on a processing technology developed and tested by the Finnish company Chempolis Oy. This plant will have the capacity to process 300,000 metric tons of bamboo (bone dry) to produce 49,000 metric tons of ethanol. One main advantage of this project is that it can accept bamboo material in any form, though the bamboo will be pre-processed into strips to facilitate the transportation process. Another key takeaway from this project is that NRL has signed the Memorandum of Understanding (MOU) with Nagaland Bamboo Development Agency (NBDA) and Arunachal Pradesh Bamboo Resources Development Agency (APBRDA) for securing the required quantities of bamboo resources (UNIDO, 2018).

There are several other success stories in Africa, especially for bamboo charcoal, which will be discussed throughout the next sections.

1.3 Objectives and contents of this report

This report has been developed based on the key findings achieved from meeting African and Asian stakeholders, conducting two missions in Ghana and Ethiopia and a literature review. The first main objective of this report is to provide guidelines for private investors on how to effectively plan a bamboo bioenergy project in Africa. The second main objective is to explain to African policymakers why they should consider bamboo bioenergy as an important sustainable development topic and to provide them with guidelines on starting an effective bamboo bioenergy sector governance.

2. Baseline assessment methodology

To achieve the afore-mentioned objectives, it is critical to have a good understanding of the baseline situation of using bamboo as a bioenergy fuel or as a raw material for other products. This section will briefly present the methodology, followed by the interviewed stakeholders during the baseline assessment. The main findings of the baseline assessment will be provided throughout the report, starting from the next section.

2.1 Methodology

The methodology followed for the baseline data collection was based on diversifying the data sources to cover the perspectives of several countries and several categories of stakeholders. A mixed approach combining the following sources was followed:

- A virtual focus group meeting gathering various stakeholders from different countries
- Online one-to-one meetings with specialised experts
- Two field missions to Ethiopia and Ghana
- Literature review of previously conducted studies on bamboo generally, specifically bamboo bioenergy

The following section shows the interviewed entities throughout this study so that the reader can have a closer idea of the main sources of information used.

2.2 Interviewed entities throughout the study

2.2.1 *Focus-group meeting*

Entity	Category	Country
Stockholm Environment Institute	Non-governmental organization (NGO) in sustainable development and environmental issues	Kenya
LiPRO Energy GmbH & Co. KG	Combined Heat and Power (CHP) plants private business company	Germany
University of Ibadan	Educational entity, University	Nigeria
PROSPERER	IFAD program	Madagascar
Global Bamboo Products Ltd	Social enterprise in the development of bamboo and other non-timer forest products	Ghana
Women In Action Against Poverty	NGO in the field of poverty fight	Ghana
Clean Power Indonesia	Biomass private business company	Indonesia

PT Bambu Nusa Verde	Bamboo private business company	Indonesia
GGGI	Treaty-based international, inter-governmental organisation	Indonesia
INBAR East Africa Office	Intergovernmental development organisation	Ethiopia
INBAR West Africa Office	Intergovernmental development organisation	Uganda
CIFOR	NGO in the field of tropical forests	Indonesia
Ethiopian Rural Energy Development and Promotion Center	Governmental entity, Energy Studies	Ethiopia
Bidipa company Ltd	Charcoal private business company	Ghana
GoodFire Ltd	Clean cooking private business company	Uganda
Vision Nature Africa Green	Clean cooking private business company	Uganda
Josa Green Technologies Ltd	Clean cooking private business company	Uganda
BammGo	Bamboo private business company	Ethiopia
Green Pot Enterprises	Bamboo private business company	Kenya
Ethiopian Environment and Forest research institute (EEFRI)	Governmental entity, Forestry Commission	Ethiopia
Kontiki Bamboo Works Ltd	Bamboo private business company	Uganda
GREEN LENS	NGO in the field of cookstoves	Uganda
National Forestry Authority	Governmental entity, Forestry Commission	Uganda
National Forestry Resources Research Institute	Governmental entity, Forestry Commission	Uganda
Friends of Bamboo Consults Limited	Bamboo plantation and consulting	Uganda
Food and Agriculture Organization of the United Nations- FAO	Specialised agency of the United Nations	Uganda
The Ghana Alliance for Cookstoves and Fuels	Cookstoves private business company	Ghana
Wealth from waste	Biomass private business company	India
INBAR HQ	Intergovernmental development organisation	China

2.2.2 *Online one-to-one meetings*

Entity	**Category**	**Country**
GROWMORE BIOTECH LTD.	Bamboo plantation and consulting	India
Aprovecho Cookstoves Research Center	R&D for cookstoves manufacture	USA
EEFRI	R&D for bamboo bioenergy	Ethiopia
EcoSecurities	Carbon markets	Switzerland

2.2.3 *Ghana field mission*

Entity	**Category**

Energy Commission	Governmental entity, Ministry of Energy
Sustainable Energy and Environmental Solutions	R&D for bamboo plantation and bioenergy
Ghana Alliance for Clean Cookstoves and Fuels	NGO in the field of cookstoves
KWAMOKA bamboo processing Limited	Bamboo private business company
Orange Corners Innovation Fund/Fidelity Bank	Financing entity
Boosting Green Employment and Enterprise Opportunities in Ghana (GrEEn)	Relevant donor project
GAMMA Energy	Bamboo private business company
Global Bamboo Company Limited	Bamboo private business company
Bamboo and Rattan Unit affiliated to the Forestry Commission	Governmental entity, Forestry Commission
Random bamboo transporters	Bamboo value chain
Random bamboo distributors	Bamboo value chain

2.2.4 *Ethiopia field mission*

Entity	**Category**
Adal Industrial PLC	Bamboo private business company
Alternative Fuels Department, Ministry of Water and Energy	Governmental entity, Ministry of Energy
Ethiopian Clean Cooking Alliance Association	NGO in the field of cookstoves
Chalachew & Teamer Briquette Charcoal Enterprise	Bamboo private business company
Dutch-Sino East Africa Bamboo Development Programme	Relevant donor project
Pro Star Bamboo	Bamboo private business company
Ethiopian Environment, Forest and Climate Change Commission	Governmental entity, Ministry of Environment and Forests
Gogle Energy Saving Stoves and Engineering PLC	Cookstoves manufacturer & Bamboo private business company
INBAR-Inter-Africa project	Relevant donor project
The Nature and Biodiversity Conservation Union	Relevant donor project
Random bamboo handicrafts manufacturers	Bamboo private business micro, small, and medium enterprises (MSME) companies

3. Guidelines for private investors in bamboo bioenergy project development

Based on the baseline assessment findings and the analysis of the consulting team to the African market, this section provides guidelines for the local or international private investors who are interested in developing a bamboo bioenergy project in Africa. This section provides step-by-step guidance to the potential investors and guides them on how to make the right decisions in the different project development stages.

3.1 Defining the bamboo bioenergy project type

As previously mentioned, bamboo has many advantageous fuel characteristics compared to its peers. In addition, the African region has more than 7 million hectares of bamboo resources, which can be used on the continent through various bioenergy projects. Such projects can be classified into two main types of energy use.

3.1.1 *Heat generation*

3.1.1.1 Bamboo charcoal and charcoal briquettes

In terms of using bamboo to produce charcoal, multiple potential markets are available in the African region. It can be mainly used as fuel in cookstoves for both residential and commercial purposes (e.g. hotels and restaurants). Many people in the urban areas of Africa have already started using bamboo charcoal and charcoal briquettes. One driver for this is being marketed as smokeless charcoal, which is the preferred choice of the users. Such smokeless behaviour is mainly exhibited by briquettes due to their lower heating rate because of their intensified form, as shown in Figure 2. Another driver for this is its sustainability compared to wood charcoal, which makes it the preferred choice of large hypermarkets to acquire and sell to consumers. The uptake of smokeless charcoal is expected to increase with time as a result of increasing awareness of the negative environmental and health effects of conventional fuel, even in rural areas.

Figure 2. Bamboo normal charcoal and bamboo charcoal briquettes

Raw harvested poles can be directly used as bamboo for charcoal making; however, it is better to use the bamboo wastes generated from bamboo mechanised industries (such as those currently available in Ethiopia) or even the wastes generated from handicraft industries.

3.1.1.2 Pelletised bamboo as fuel for industries

Another thermal use of bamboo is in the form of fuel for industrial plants. Industries generally prefer to have bamboo in the form of pellets for better efficiency and transportation economics. Hence, the business project for the investor in this case will be a pelletising plant. The project scale can vary between medium and large, according to the industry to be served. Serving cement plants, for example, is a huge project that will necessitate a stable supply of bamboo raw materials. One of the cement plants in India will soon start employing bamboo as a main fuel in its kilns (Ramesh, 2021). Biomass palletisation technology is already available in Africa. Ghana has a similar project conducted by Abellon Clean Energy Ghana Ltd—where a pellet production mill has been developed with a production capacity of 150 tons of pellets per day using sawdust, aiming to export to Europe, India and China. Such a project can be replicated using bamboo as a source for producing pellets (INBAR, 2020).

3.1.1.3 Bio-ethanol

Another option is using bamboo to produce bio-ethanol in a bio-refinery. As mentioned in section 1.2, India will soon start the commercial production of bio-ethanol from bamboo. This is typically a large-scale project, which can be a good investment opportunity for foreign investors who can either sell ethanol locally in the African country (can be used as an alternative fuel in cookstoves) or export it to neighbouring countries with commitments towards bio-ethanol targets.

3.1.2 *Electricity generation*

Sub-Saharan Africa is considered the most electricity-poor region in the world, with more than 600 million people not having access to electricity and more millions being connected to unreliable grids that do not meet their energy demands (IEA, 2019). Furthermore, most countries in this region have electricity access rates ranging between 25% and 50%, with approximately 10 countries having less than 25% electricity access rate. Accordingly, there is an opportunity to use bamboo as a bioenergy resource for off-grid electricity generation. Such projects can be of medium decentralised scale or of higher scale. A similar direction to the one taken by Indonesia in utilising bamboo in electricity generation for remote and rural areas (section 1.2) can be followed in the African region.

3.1.3 *Analysis of the African bioenergy market*

Investors should study the market demand of the targeted country. For instance, if a country consumes large amounts of charcoal, charcoal projects will have great potential in that country. Furthermore, the electricity access rate will play an important role in selecting suitable technology for electricity generation.

Table 1 lists the International Bamboo and Rattan Organisation (INBAR) Member States and the status of their charcoal production and consumption, electricity access rates and the existence of bio-ethanol targets. The last column ticks the bamboo bioenergy project type(s) recommended for each country.

Table 1. List of INBAR Member States and the recommended Bamboo bioenergy project type(s)

Country	Electricity access rate*	Charcoal and fuel wood production and consumption**	Countries with bio-ethanol commitments	Recommended bamboo bioenergy project type(s)		
				Bamboo charcoal production projects	Decentralised Electricity	Bio-ethanol generation ***
Benin	✗	✓	✗	✓	✓	
Burundi	✗	✓	✗	✓	✓	
Cameroon	✗	✓	✗	✓	✓	
Central Republic Africa*	✓	✓	✗	✓		
Congo	✓	✓	✗	✓		
Eritrea	✗	✓	✗	✓	✓	
Ethiopia	✗	✓✓	✓	✓✓	✓	✓
Ghana	✓	✓✓	✓	✓✓		✓
Kenya	✓	✓✓	✓	✓✓		✓
Madagascar	✗	✓✓	✗	✓✓	✓	
Malawi	✗	✓	✓	✓	✓	✓
Mozambique	✗	✓✓	✓	✓✓	✓	✓
Nigeria	✓	✓✓	✓	✓✓		✓
Rwanda	✗	✓	✗	✓	✓	
Senegal	✓	✓	✗	✓		
Sierra Leone	✗	✓	✗	✓	✓	
Tanzania	✗	✓✓	✗	✓✓	✓	
Togo	✗	✓	✗	✓	✓	
Uganda	✗	✓✓	✗	✓✓	✓	

* Electricity access rates of 60% and higher are represented by tick mark ✓

** Countries with high charcoal and fuel wood production and consumption are represented with a double tick mark ✓✓, while those with normal production are represented with one tick mark ✓

*** As mentioned above, even if a country does not have bio-ethanol targets, it can still host a bamboo to bio-ethanol project and sell it to neighbouring countries with bio-ethanol commitments

3.2 Identifying feedstock availability and reliability

3.2.1 *Identifying potential bamboo resources*

To establish a successful bamboo bioenergy project, the project developer should identify the required daily/weekly/yearly amount of bamboo. This depends on a number of factors, as follows:

- Size of the project (large-, medium-, small-scale)
- Project type (charcoal, ethanol, pellets, electricity)
- Technology used

At the beginning of the project, it is especially recommended to consider multiple types of biomass fuel resources (besides bamboo) to secure continuous supply and, accordingly, ensure the project's reliability. In one interesting success story in Ghana, the investor knew by experience the advantages of each charcoal type (according to the starting raw material); accordingly, he developed combinations of raw materials (bamboo, coconut and wood) that could achieve the consumer's preference in terms of the ash content, heating rate and price.

In the case of biomass-based power plants, securing a long-term quality, a sufficient quantity and a good price biomass resource are important assets before making the decision to invest in these plants. The project owner should confirm the availability of a sufficient quantity of biomass resources to keep the plant running and ensure a financially viable project in the long term. Table 2 shows the minimum amount of biomass necessary for the project to be technically viable according to the plant size.

Table 2. Biomass amount and electricity production plant sizes (IFC, 2017)

1-5 MWe	**5-10 MWe**	**10-40 MWe**
Minimum input (GJ/day)*		
20 -200 tons/day	100 -500 tons/day	200-900 tons/day

* Biomass tonnages (wet basis) at an average caloric value of 10 MJ/kg, assuming 100% load.

3.2.2 *Assessing the feedstock supply reliability*

As previously mentioned, in Africa alone, there is 7.2 million hectares of available bamboo resources. Table 3 presents the currently planted areas in some of the African countries. The investor willing to develop large-scale projects (e.g. ethanol) should consider such values while making the decision regarding which country should the project be developed in. These values show the huge potential for establishing multiple bamboo-based bioenergy projects in the region. In addition, there is room for growing well-managed bamboo resources to be able to secure potential projects.

However, farmers are interested in plants as long as there is a guaranteed market for them. This fact has been proven from many success stories worldwide, as well as the findings of the field missions. Hence, for small-scale bioenergy projects, the investor needs to coordinate with the farmers regarding the bamboo supply.

Table 3. Available bamboo resources in Africa (INBAR)

Country	Bamboo resources in 1000 ha
Cameroon	1,215
Ethiopia	1,474
Ghana	300
Kenya	133
Madagascar	1,123
Mozambique	500
Nigeria	1,590
Senegal	661
Sudan	31
Uganda	55
United Republic of Tanzania	128

Practically, for large-scale projects, a feedstock supply agreement needs to be signed between the bamboo suppliers and project owner in order to secure the raw material supply. This agreement is usually signed during the planning stage, and it is preferred to be signed as a long-term supply contract to secure the required quantities of feedstock. The contract covers points such as fuel quantity, fuel quality (required specifications), fuel pricing and fuel delivery. In addition, the contract should also include payment conditions and guarantees. It is always recommended to have multiple supplier contracts to avoid temporary shutdowns if the biomass supply is interrupted (World Bank, 2010).

Another scope that went beyond the conventional supply agreement was conducted in India's bio-ethanol project referred to above. In this project, an MOU was signed with NBDA and APBRDA for securing the required quantities of bamboo resources. In this MOU, the required quantities, pricing and other relevant conditions were identified (UNIDO, 2018).

In the case of privately owned projects in which there is no cooperation between different organisations, such as the previous example, the investor should be keen on appointing technical specialists for the supply chain to ensure procuring mature bamboo poles (based on the project's requirements) and guarantee high-quality products. Immature bamboo poles have been proven to result in low-quality products.

The effect of bamboo species on the quality of bioenergy products has been investigated by some researchers. One of such studies focused on bamboo briquettes where it was concluded that the four studied bamboo species can be used for briquetting with without clear impact on product quality (Brand, Junior, Nones, & Gaa, Potential of bamboo species for the production of briquettes, 2019). Some of these studied species in that study such as P. edulis and B. vulgaris are already planted in Africa (Bahru & Ding, 2021). Another study investigated the effect of another four different bamboo species on the generated charcoal yield and characteristics. It was concluded that, at any carbonization temperature, the yield and fuel properties of the charcoal vary within just 10% (Kumar & Chandrashekar, 2014). For manufacturing the bamboo industrial products, and based on the experiences of the farmers in Ethiopia, the bamboo species characterised with hollow culms such as "*Yushania alphina*" are more favored than the species characterised with solid or semi-solid culms such as "*Oxytenanthera abyssinica*". Hence, the species characterised with solid or semi-solid culms can be directly used for charcoal

production (Durai, et al., 2018). However, in both categories of bamboo species, the waste generated from bamboo manufacturing can be also utilised to produce bamboo charcoal.

3.3 Identifying the relevant regulations

To mainstream the presence of biomass projects in general and bamboo-based projects in specific, many regulations and policies exist in different countries. This section highlights the available relevant regulations and policies and how they can positively affect an investor's potential bamboo bioenergy project. This section also presents the possible regulation risks for the investor and the corresponding mitigation actions (IFC, 2017).

3.3.1 *Regulations related to promotion of renewable and sustainable energy*

3.3.1.1 Reformation of fossil fuel subsidies

In the last decade, many countries (e.g. Ghana) have stated to abolish or reduce fossil fuel subsidies, as the presence of such subsidies negatively affects energy use behaviour and encourages the wasteful use of energy. This abolition of fossil fuel subsidies will positively affect the viability of biomass projects and encourage people to use cleaner fuels and other renewable alternatives.

3.3.1.2 Renewable energy targets

Many countries have successfully established official documentation showing their commitment to contributing towards renewable energy development in the future. These targets usually include the exact expected share of renewable energy for a certain year. This weighs in favour of mainstreaming biomass energy projects in the presence of available resources (e.g. bamboo).

3.3.1.3 Renewable/Sustainable energy mandates/obligations

As a sign of some countries' commitments for their renewable energy goals, such countries also include the specific requirements for meeting such goals. For instance, mandates require installation of a certain renewable energy production capacity and blending the targeted shares of certain technologies in the energy mix (e.g. biofuel). Another example is mandating the use of mechanised kilns for charcoal making, as was done in Egypt, for example.

3.3.1.4 Support for biomass supply chain development (bamboo in particular)

Addressing the generation part of the supply chain is not the only approach of the regulations that should be followed. Accordingly, some countries have started promoting investments in feedstock cultivation and biomass refining by integrating bioenergy projects into their agricultural and rural development strategies. From the investors' perspective, countries with such regulations should be preferential for hosting bamboo bioenergy projects.

3.3.1.5 Decreased deforestation targets

In the African region, there has been a high rate of deforestation in the last decade (FAO, 2020); accordingly, many countries have been trying to impose regulations regarding this matter and to clearly instate the country deforestation targets in their Nationally Determined Contributions (NDCs). This will positively affect bamboo plantation rates, as it will actively contribute to decreasing deforestation rates while being an incentive to sustainable charcoal production and improved cookstove programmes.

3.3.1.6 Availability of clean cooking action plans

Similar to decreased deforestation targets, having a clear action plan for promoting clean cooking programmes is also an incentive for using alternative fuels, such as bamboo charcoal, for improved cooking stoves. Rwanda, for example, has set a target of 100% for improved cookstove country penetration by 2030 (UNFCCC, 2015), while other countries, such as Uganda and Ghana, have actively supported the promotion of improved cookstoves in their NDCs.

3.3.1.7 Tax incentives

Tax incentives can be a driver for increasing the uptake of bamboo-based projects in the African region. Such incentives include duty-free access to Europe, tax exemption for the operating companies in the bamboo value chain and zero duties for bamboo equipment. Ethiopia, for example, has such an incentive; moreover, according to the Ethiopian Bamboo Development Strategy and Action Plan (2019–2030), the country has plans to review the current levies, taxes and royalties related to bamboo transport for MSMEs and industry sector (The Enviornment, Forest and Climate Change Commision of Ethiopia, INBAR, 2019).

Building on the above, it is highly recommended for any investor/project developer to identify such information from the countries' NDCs (publicly available on the United Nations Framework Convention on Climate Change (UNFCCC) website). Such a step will guide the investor/developer towards the most suitable countries for bamboo-based bioenergy projects and the recommended technology/scale type for such countries. A list of INBAR Member States and their current status in terms of deforestation targets, clean cooking promotion and alternative fuels is presented in Table 4.

Table 4. List of INBAR Member States and their current status in terms of deforestation and renewable energy targets

List of INBAR Member States	Deforestation Targets	Cook stove Promotions	Alternative fuels promotions
Benin	✓	✓	✓
Burundi	✓	✓	✗
Cameroon	✓	✗	✗
Central African Republic	✗	✓	✓
Congo	✓	✗	✗
Eritrea	✓	✗	✓
Ethiopia	✓	✓	✓
Ghana	✓	✓	✗
Liberia	✓	✓	✓
Kenya	✓	✗	✓
Malawi	✓	✓	✓
Madagascar	✓	✗	✓
Mozambique	✗	✗	✓
Nigeria	✓	✓	✓
Rwanda	✓	✓	✓
Senegal	✓	✗	✓
Sierra Leone	✓	✗	✓
Tanzania	✓	✗	✓
Togo	✓	✗	✓
Uganda	✓	✓	✓

3.3.2 *Regulatory risks and their mitigation action*

For the project developer/investor, it is essential to include a mitigation strategy in the planning stage that can provide solutions to the potential regulatory challenges that they might be faced during the project's lifetime.

Table 5 shows some examples of the potential regulatory risks and the recommended mitigation action in such a case.

Table 5. Potential regulatory risks and corresponding mitigation action (IFC, 2017)

Regulatory Risk	**Strategy for Mitigation**
Implementation of the policy support measures for project viability	The project developer shall seek early engagement with relevant authorities in relevance to eligibility, process and existing policy support measures. The main points to consider are as follows: • Are the support mechanisms in place (e.g. feed in tariffs, energy mandates/obligations, and tax incentives)? • Are there some policies limited in time?
Changes in political authorities that may reduce attractiveness of regulatory regime	To guarantee the project viability, seeking contractual security on regulatory regime is essential in relevance to the time of the investment decision.
Planning permits are not obtained in a timely, transparent manner	• Seeking early engagement with relevant authorities on processes and required documentation is essential. • Dealing with national consultants experienced with the permitting process.
Unclear environmental impact assessment process	Seeking early engagement with relevant authorities and key stakeholders (e.g. NGOs, local communities and financing entities) on the project's environmental and social aspects and the mitigation actions (if needed).

3.4 Selecting the optimum production technology

Once the above steps are completed, the investor should have a clear idea about the project type that they will develop. Hence, the next important step is to identify and select the corresponding technology. This section will present an overview of the several technologies that can be utilised in bamboo-based biomass projects in the African region. These technologies will be classified based on the final energy product.

3.4.1 *Bamboo charcoal production*

Slow pyrolysis is the technology used to produce charcoal. In this process, the organic matter is heated to a high temperature (i.e. above at least 180 °C) in the absence of oxygen. Feedstock sizes vary from wood chips with 25 mm of diameter to logs of up to 250 mm diameter and up to 2400 mm length, with a process taking as minimum as several hours (continuous retort processes) and up to seven days (kiln processes) (Honsbein, 2016). Conventionally, this technology takes place in open piles, a process which results in considerable air pollution, high cycle time and low conversion rate (i.e. the production of one ton of charcoal requires between seven and eleven tons of wood, depending on the moisture content of the wood (Honsbein, 2016).

Slow pyrolysis retorts or converters are capable of recovering and refining charcoal and its by-products in commercial grades and quantities. The products obtained from such a system are approximately 35% charcoal, 35% condensed liquid and 30% non-condensable gases. Carbonisation in a retort allows for integrated utilisation of the energy held in the raw materials at an optimum level, and this occurs through recycling the non-condensable gases to be used as an energy source to sustain the carbonisation process.

3.4.2 *Bamboo pellet production*

Two typical methods are used for densifying woody biomass feedstock to produce refined fuels that align with the properties of conventional fossil fuels: palletisation and briquetting (IRENA, 2019).

Pellets are small (68 mm diameter, 612 mm length) cylindrical pieces of compressed biomass particles, which are agglomerated. The production process of biomass pellets starts with

acquiring a feedstock such as sawdust, after which it is dried, then screened to remove any unwanted material. After that, it is ground using a hammer mill and pressed at a temperature above 100 °C, followed by cooling and packaging (IRENA, 2019). Similar to other biomass pallet production processes, bamboo pellets follow the same process. What distinguishes bamboo from other energy crops is that the entire bamboo plant, including its stem, branch and rhizome, can be used in the palletisation process, which makes it significantly resource-efficient with limited wastage (INBAR, 2020). Figure 3 shows the stages of the bamboo palletisation process.

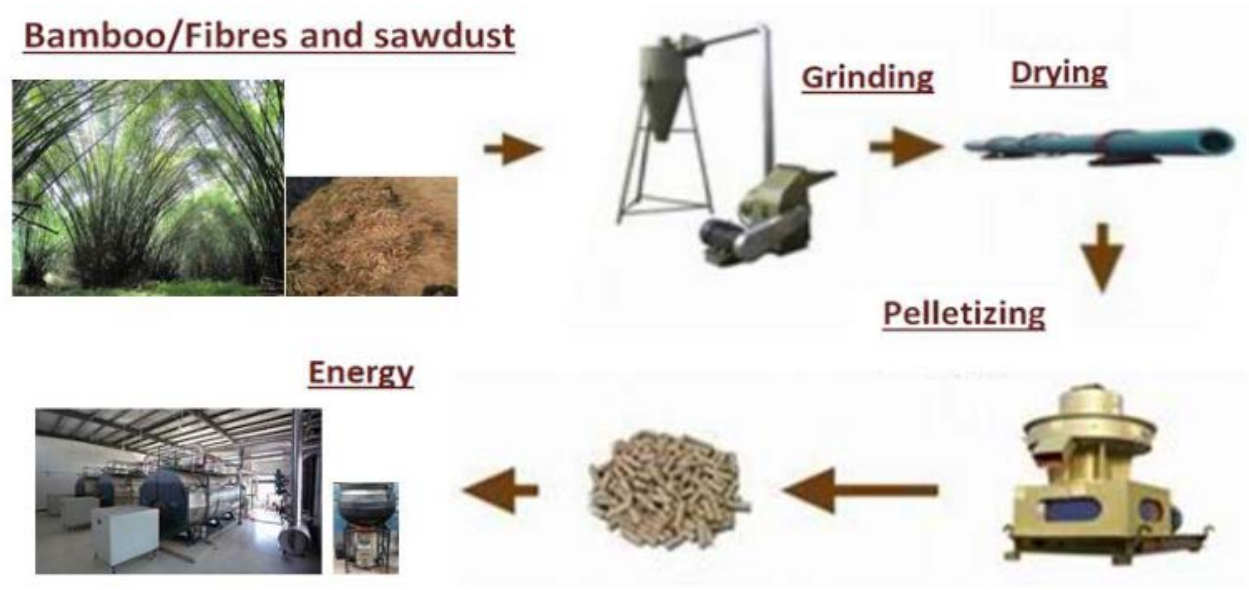

Figure 3. Bamboo palletisation process (INBAR, 2020)

3.4.3 *Bamboo charcoal briquette production*

Charcoal briquettes were invented to shape the charcoal into a more intensified form, which yields higher energy density and lower heating rate. They can be developed from leftover residues of charcoal at the lump charcoal production sites. Charcoal briquettes can also be developed from the charcoal prepared from biomass that could not be manufactured as lump charcoal, such as agricultural residues (e.g. coffee husks, cotton stalks and chat stem) (Seboka, 2008)**.**

Through the briquetting process, which is shown in Figure 4, a binder (e.g. starch) is mixed with the charcoal fines, and then the mixture is formed into a briquette through a press. To achieve a

successful formation process, a sticking or agglomerating material is required. The strength of the press must be sufficient to agglomerate the mixture of charcoal fines and binders. Consequently, the formed briquette can be handled through a drying oven (i.e., 80 ℃) to eliminate most of the water content (Njenga, 2014).

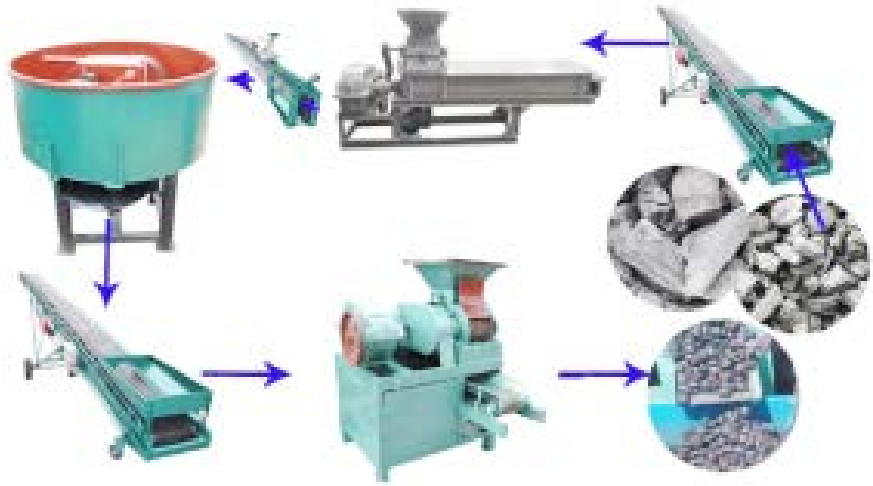

Figure 4. Bamboo charcoal briquette machine

Briquettes of bamboo charcoal can be found in many Asian and African countries, which are primarily used for heating and cooking purposes. Bamboo briquettes exhibit satisfactory physical and energetic properties, with bulk density ranging between 1100 and 1200 kg/m^3 and energy density ranging between 1.2 and 1.4 GJ/m^3 (Brand et al, 2019).

3.4.4 *Electricity generation*

The two main technologies used for electricity generation from biomass fuels are combustion and gasification. These technologies are used in centralised electricity generation projects, while small-scale gasifiers are used in decentralised electricity solutions for rural areas. As most bamboo-driven electricity projects target the local bamboo forests in rural areas, potential investors are mainly interested in decentralised small-scale gasifiers.

Gasification is the production of a gaseous fuel from a solid fuel, such as wood, bamboo and agricultural residues. It is a complex thermal and chemical conversion process of organic materials. The process occurs at high temperatures under limited air supply, and the resulting

gaseous product enters an electric generator to produce electricity. This thermochemical conversion is characterised by faster conversion rates and higher temperatures compared to microbial conversion (e.g. biogas). The products of the gasification process are solid ashes; partially oxidised products, such as soot, which must be removed periodically from the gasifier and the generator gas. The main flammable components of the resulting generator gas are carbon monoxide (CO), hydrogen (H_2) and methane (CH_4). However, the produced gas has a low calorific value compared to other fuels due to its high nitrogen content (more than 50%) and other incombustible components. The calorific value of the generator gas is only approximately 5–6 MJ/kg as compared to the value of 35–50 MJ/kg for natural gas (Dimpl, 2011). A simplified diagram of bamboo biomass gasification is shown in Figure 5.

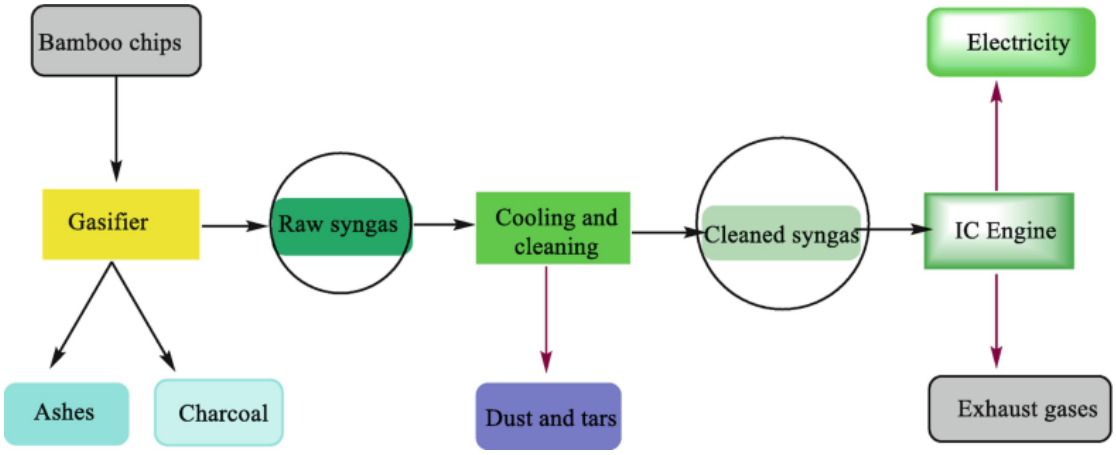

Figure 5. General process of bamboo gasification (Kerlero de Rosbo G & De Bussy J, 2012)

Small-scale power gasifiers use almost exclusively the downdraft fixed-bed technology, as shown in Figure 6. The air/gas stream moves downwards through a fixed bed of biomass chips. Such technology is suitable from below 10 kW to 250 kW, which can provide sufficient energy for household lighting, televisions, refrigerators as well as for operating small machinery. In addition, the provision of biomass resources (e.g. bamboo and agricultural wastes) to the investor can be a source of income for small farmers and an incentive for reforestation.

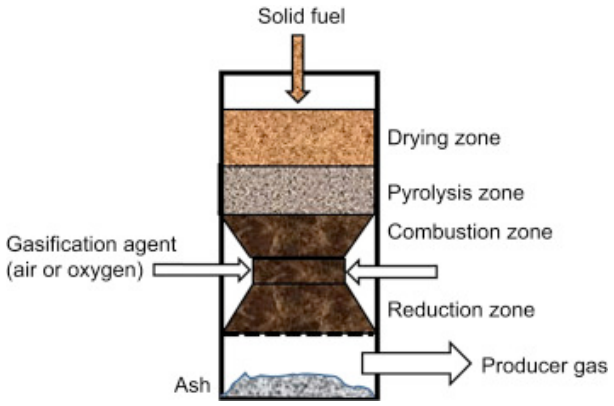

Figure 6. Schematic of the downdraft fixed-bed gasifier (Pang, 2016).

3.4.5 *Bio-ethanol generation*

Hydrolysis and fermentation technologies are used for liquid fuel production (e.g. bio-ethanol) from lingo cellulosic feed stocks. During the process, the feedstock size is reduced, then pre-treated, followed by chemical or enzymatic hydrolysis for fermentation of sugar (saccharification). Finally, the fermentation process takes place and produces the liquid fuel.

Multiple pre-treatment conditions for hydrolysis and fermentation of bamboo have been examined; the results have indicated that the treated bamboo has similar digestibility to that of other lignocellulosic materials (He et al, 2014; Yuan et al, 2017; Sathitsuksanoh et al, 2012).

Chempolis Limited, a Finland-based bio-refining technologies company, is the licensor of the bio-ethanol project from bamboo in India, which was mentioned hereinbefore in section **Error! Reference source not found.**1.2. As shown in Figure 7, this technology is not just for the production of bio-fuel (e.g. bio-ethanol) but also for the co-products of sugar and lignin, such as furfural and acetic acid (INBAR, 2021; Chempolis, 2020).

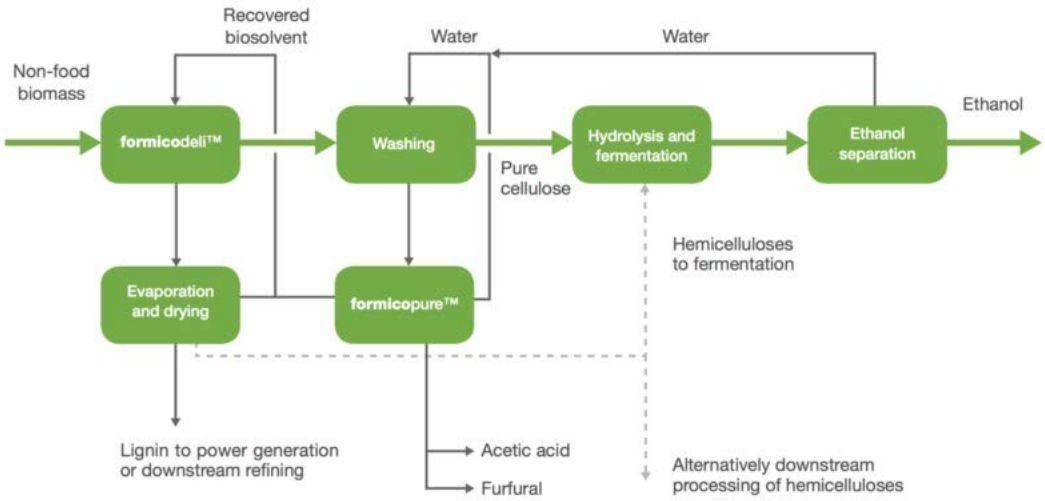

Figure 7. Formicobio bio-ethanol technology by Chempolis (Green Car Congress, 2015)

3.5 Feasibility assessment calculations

3.5.1 *Financial analysis*

The assessment of a biomass project's viability is a crucial step that should be conducted before making the decision to implement the project. This assessment includes technological, organisational, environmental, economic and financial aspects. The following factors should be considered in this assessment (IFC, 2017):

- Current costs of energy: market price of electricity and heat or cost of own-production based on coal, oil or gas.
- Stability of the current energy supply
- Current costs relevant to biomass resource storage and disposal
- Planned reinvestment costs in an existing plant

The financial analysis will assess the viability of the project by evaluating its benefits from an investor's perspective. One of the essential indicators for a financially viable investment is the return on investment, which must be higher than the investor's weighted average cost of capital. There are other financial indicators that are also essential, such as the net present value,

internal rate of return, economic levelised cost of electricity, debt service coverage ratio and payback period.

A sensitivity analysis should also be conducted to assess the impacts of risks by changing each risk parameter while maintaining the other variables constant. The typical parameters that should be exposed to the sensitivity analysis include investment costs, energy prices and biomass supply prices (IFC, 2017).

3.5.2 *Potential for carbon finance as an additional source of revenue*

3.5.2.1 What is carbon finance?

Carbon finance is a general term applied to resources provided to projects that generate or are expected to generate reductions in greenhouse gas (GHG) emissions. Carbon finance is expressed in the form of purchase of such emission reductions that can be traded in the carbon market. Carbon markets provide an additional source of revenue for sustainable energy projects by creating commercial value to reduce GHG emissions. This can increase the commercial viability of renewable energy and low-carbon projects and, thus, play an important role in the sustainability and development of such projects (Disch, Rai, & Maheshwari, 2010).

3.5.2.2 Already registered projects/programmes under the clean development mechanism

The clean development mechanism (CDM) of UNFCCC is one of the most famous examples of carbon finance. It allows developed countries to use certified emission reductions (CERs) from sustainable development projects in developing countries to achieve some of the emission reduction targets under the Kyoto Protocol. Developing countries, in turn, receive carbon funds when they prove the occurrence of emission reductions. One CER is equivalent to one ton of carbon dioxide equivalent (Boukerche et al, 2013). Table 6 lists the African countries and the number of biomass projects or programmes registered under CDM. A programme refers to a bundle of small-scale projects, and this is the most common means of accessing carbon finance for such projects. As shown, approximately 85% of INBAR African countries have already accessed carbon finance through CDM for bioenergy projects. In fact, most of these registered programmes are for cooking stoves. Hence, supplying such programmes with bamboo charcoal is a market opportunity that needs to be studied by investors. The number of registered programmes per country should also give the investor an idea about the activity level of the country in the bioenergy field.

Table 6. Number of registered bioenergy projects under CDM

Country	No. of registered bioenergy projects/programmes under CDM	Project or Programme
Senegal	4	1 Project 3 Programmes
Mozambique	6	Programme
Kenya	11	Programme
Uganda	10	Programme
Cameroon	2	Programme
Ethiopia	8	Programme
Malawi	6	Programme
Rwanda	9	Programme
Ghana	6	Programme
Madagascar	5	Programme
Congo	2	Programme
Nigeria	7	Programme
Togo	1	Programme
Mali	1	Programme
Benin	1	Programme
Burundi	2	Programme
Liberia	3	Programme
Sierra Leone	1	Programme

3.5.2.3 Already registered projects/programmes under the voluntary carbon markets

Reduced GHG emissions can also be converted into carbon credits under voluntary carbon markets, the most famous of which are the Gold Standard, American Carbon Registry and Verified Carbon Standard (VCR) by Verra Organization. In the African region, there are nine energy demand projects registered under Verra credit registration, all of which are clean cooking projects (Table 7). As for the projects registered under Gold Standard, there are 856 projects in the African continent, including 713 projects located in INBAR Member States (Table 8). These registered projects include multiple technologies: clean cooking, biogas heat and electricity and biomass electricity projects. Again, the investor needs to check such programmes and see whether they can supply the improved cookstoves with bamboo charcoal.

Table 7. VCR relevant registered projects

Country	VCR Registered Projects

South Africa	Recipe for Change Grouped Project
Madagascar	Madagascar Improved Cook stove Project By Kcm-Wood#CPA-W-001
Zambia	Fuel Efficient Stoves in Zambia CPA 3
	Fuel Efficient Stoves in Zambia CPA 2
	Fuel Efficient Stoves in Zambia CPA 1
Kenya	Paradigm Kenya Clean Cook stoves Project
Mozambique	Improved Cook stoves Project For Malawi And Cross-Border Regions Of Mozambique CPA MAL 005
Ghana	African Improved Cooking Stoves Grouped Project
Kenya	Efficient Cook Stove Programme: Kenya CPA NO. 2 Mathira East District Co2balance UK LTD

Table 8. Number of relevant registered projects under "Gold Standard" for each INBAR Member State

Country	Total gold standard registered projects
Benin	5
Burundi	7
Cameroon	5
Congo	5
Eritrea	44
Ethiopia	46
Ghana	8
Kenya	116
Malawi	58
Madagascar	16
Mozambique	45
Nigeria	12
Rwanda	164
Tanzania	10
Togo	21
Uganda	151

3.5.2.4 Carbon finance opportunities for new projects

As shown above, carbon finance is active in Africa. However, the investor should note that registering projects/programmes is a lengthy and complicated process. Hence, the project investor cannot assess the finance for their project unless the project is of a large scale. In the case of small-scale projects, the investor can usually access carbon finance when bundled together with similar projects. The project proponent, which is usually an NGO or a carbon project developer, is the one who contacts the relevant small-scale market players to develop the financing project document.

3.5.3 *Applying for financing entities*

If the investor cannot secure the required project investment as 100% equity, it will be necessary to select the financing institution with the most preferable conditions. For small entrepreneurs in Africa, commercial banks usually lend at a high interest rate, which is not feasible.

One of the most successful experiences in Ghana that was able to unlock such a challenge is the 'Orange Corners Innovation Fund' under the 'Fidelity Bank Young Entrepreneurs' Initiative'. It is a revolving fund of 500,000 euros issued by the Dutch Fund. Each beneficiary can have up to 50,000 euros as a loan, including a 30% grant with a 5% interest rate. During the current cycle, the applications are filtered such that 15–16 companies are selected to take a 6-month course on various topics, such as compliance, financial literacy and financial investment readiness. At the end of such training, each business owner develops a presentation showing their business plan to the Fidelity Bank. Upon being accepted, the money is not given to the beneficiary at once, but rather on 2–3 tranches. Note that away from the Orange Corners Fund, the Fidelity Bank has its own fund structure, which focuses on supporting young entrepreneurs providing a 10% interest rate per annum for MSMEs. Through discussions with the fund management entity, it is clear that the Fidelity Bank is willing to issue new phases of this programme. In addition, the Dutch government is willing to replicate this in several other African countries. Hence, small-scale bamboo bioenergy investors are recommended to look for similar funding programmes.

3.6 Selecting the optimum business model for product sales

3.6.1 *Off-gird electrification projects*

There are three main categories of business models for off-gird electrification projects (Cameron, et al., 2014; ASEAN-RESP, 2013)

I. Market-based business models (fee-for-service model, dealer model, lease model)

II. Government-induced community-based business model

III. Public-private partnership (PPP) model

In reality, the hybrid forms of these models are applied, combining the advantages of different approaches. Table 9 shows the key features of each model.

Table 9. Project types and business models for off-grid electrification (Cameron, et al., 2014; ASEAN-RESP, 2013)

Business model	Key features
	Market-based models
Fee-for-service model	• A project investor/developer invests and owns the project • The system supplies electricity to rural customers. • The investor/developer ensures operation, maintenance and replacement of the power system. • Customers pay for the electricity used based on metering (kWh) or a fixed (monthly) charge. • Electricity tariffs are usually set at a financially viable level (cost covering) and are significantly higher than those of other models.
Dealer model	• Customers/end-users purchase the power system either with their own cash or loans (e.g. microfinance institutions and dealer credits). • The customers normally are a household or facility owner (e.g. rice miller). • The consumer has full responsibility for operational and replacement costs (aside from warranty service). • There is no payment for consumed electricity.
Lease Model	• Ownership of the power system: ESCO/ lessor during the leasing period and customer/end-user (after leasing period), the customer pays a rental fee (monthly) during the leasing period • This model is generally applicable for small-scale standalone projects • Tariff system: Market-based rental fee • Operation and maintenance : Lessor (during the leasing period) and customer(after the leasing period has expired)
Example of market-	Energy Corporation in Canada has signed a 15 year lease agreement with

based model	BioSource Power Ltd. (Candian Biomass, 2011)
Government-induced community-based business models	
Fully and partially grant-based models	• In case of partially granted financed models, the project is financed by a mix of grant and long-term soft loans and/or local contribution (e.g. government or community budget) • Ownership of the power system: community-based entities • Tariff system: strongly subsidised (low tariffs) • Operation and maintenance: local community
Community-Based Models	Similar to the previous model except for tariff systems: • Tariff system: Break even tariffs with financial incentives
Example	A community-based electricity generation plant for three remote villages in Mentawai Islands, where the power plant aggregate capacity is 700 kW, which provides power to more than 1300 households (Clean Power Indonesia, 2021).
PPP Models	
Operation-Maintenance PPP Model	There are public and private partners in this model. The public partner invests in an off-grid power system while the private partner will be contracted to operate and maintain the system. The public partner shall maintain ownership and overall management of the system.
Operation-Maintenance-Management PPP Model	Under this model, the public partner should contract a private partner to operate, maintain and manage the off-grid system. The public partner shall be the owner of the system, though the private partner might invest in their own capital in the system.
Example of PPPs	A 500 kW gasifier project in Gosaba island in West Bengal was established to supply electricity to remote villages in Gosaba. The project is 100% funded by the government of India and the state Government of West Bengal, but owned and operated by Gosaba Rural Energy Cooperative as it is a pilot project (ENVIS Resource Partner on Renewable Energy and Climate Change, 2015).

3.6.2 *Bamboo charcoal and charcoal briquettes*

Having a proper marketing strategy for bamboo charcoal is essential so that the project can achieve the targeted benefits. Clean cooking companies have been using various distribution models over the past decade (World Bank Group, 2014). It is recommended here that bamboo charcoal project developers/investors benefit from clean cooking experiences in distributing their products. Another key takeaway is the importance of depending on multiple distribution channels for marketing the green charcoal, as the project targets cannot be met by relying on a single model. Table 10 shows the difference between each model.

Table 10. Potential distribution channels for bamboo charcoal inspired from the clean cooking models (World Bank Group, 2014)

Item	**Direct sales**	**Third-party private dealers-distributors and retailers**	**Social sector partners**	**Institutional bulk sales**
Description	Sell directly to customers via sales staff, branded commission-based agents or store network	Sell to third-party distributor networks or direct dealers and retailers (large or small)	Sales rely on microfinance institutions /NGO forces /government agents	Bulk purchases and redistribution by institutional clients, such as relief agencies, schools and government programmes
Pros	Better control from the producer side	Utilise existing warehousing and sales forces of a well-established partner and represents a convenient, low-cost option	Utilise the ground networks of organisations that are already familiar with local market and existing customer base	Large quantities of product sales
Cons	More costly and difficult to achieve in large rural areas	Producers have less control over their products and limited by partners' reach, which might not include remote or rural areas	Producers loose part of their control and NGOs sometimes do not plan for scale and sustainability once the programme ends	Producers have less control over their products

4. Guidelines for policymakers

Based on the baseline assessment findings and the analysis of the consulting team to the African market, this section presents two key outcomes. The first one is to deliver to African policymakers why they should consider bamboo bioenergy as an important sustainable development topic. The second key outcome is to provide guidelines for African policymakers on starting an effective bamboo bioenergy sector governance.

4.1 Why African policymakers should consider bamboo generally and bamboo bioenergy specifically as an important development topic?

As mentioned in section 1, bamboo has several advantages that make it a very attractive raw material for agroindustry. However, this section will discuss in detail why bamboo deserves to be considered by African policymakers as an important development topic. This will be discussed from two key aspects: the first one is related to global market development and the second one is related to the relevant national targets in African countries.

4.1.1 *Global bamboo attractions*

The world is quickly changing these days, and the keyword for that is climate change. Most of the countries worldwide (especially the developed countries) are shifting their economies to the sustainable and low-carbon pathway. Over time, this has even been transferred to normal citizens, where a significant fraction of these citizens are environmentally conscious and only buy low-carbon commodities. As mentioned in section 1, one global attraction of bamboo is its high carbon sequestration potential, which can be seen as a game changer. Figure 8 categorises the global bamboo attractions into three main items, which will be discussed in the following sub-sections.

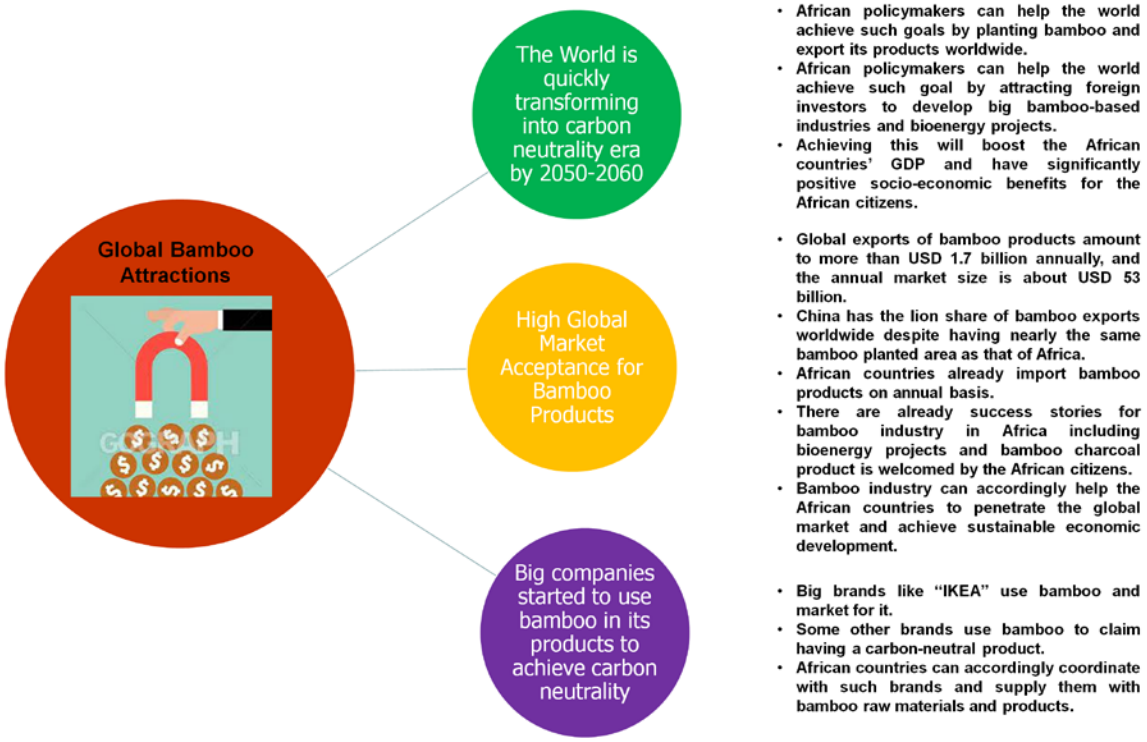

Figure 8. Global bamboo attractions and their potential positive impact on African countries

4.1.1.1 Global Carbon Neutrality Goal 2050-2060

The world has witnessed a political change in the fight against global warming in 2015 after the Paris Agreement. This historic agreement has been adopted by 196 countries, which mentions that developing countries will implement ambitious mitigation actions with enhanced support from developed countries. In the last few months, and during the preparations of UNFCCC COP 26 in Glasgow, there has been global pressure to reach net-zero emissions by 2050. As shown in Figure 9, some countries have committed to it in law, some others have committed in an official policy document, some others have reported a pledge, while many developing countries have not yet provided any commitment as the topic is still under study.

To achieve net-zero emissions, big emitters (e.g. USA and EU) need to conduct radical reductions in their emissions and offset their remaining emissions through financing green projects in other countries (Nature, 2021). Given the high climate change mitigation potential of bamboo, African countries can support the world in achieving its net-zero target by hosting bamboo plantations in the areas devoted to land restoration and reforestation (Table 11).

Moreover, and given the large areas of bamboo that can be planted, African countries can host international investors willing to develop large-scale bamboo-to-ethanol plants (such as the one in India, which will start production soon). The produced ethanol can then be exported to countries with bio-ethanol blending commitments (Table 12) and, hence, further support the world in reducing GHG emissions by displacing petroleum gasoline. The large areas of bamboo can also facilitate the construction of bamboo-based decentralised power plants in African rural areas lacking electricity access. Such local projects will have further GHG emission reduction impacts through the displacement of fossil fuels. Moreover, the large areas of bamboo will facilitate improved and large-scale bamboo processing industry in Africa. This will result in further replacement for timber-based products and, hence, less deforestation and further reduced GHG emissions.

From the policymakers' perspective, this is a perfect example of sustainable development in which foreign investments will be attracted, large amounts of jobs will be created, technology will be transferred, the country's GDP will be boosted, forests will be preserved, and significantly positive socio-economic benefits will be yielded for African citizens.

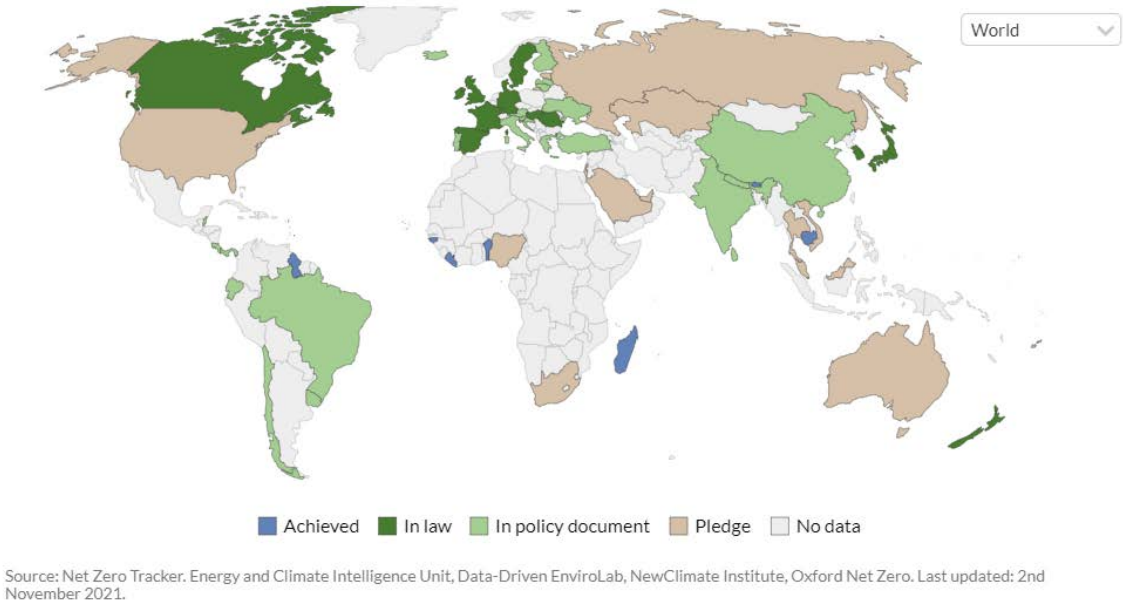

Figure 9. Status of net-zero carbon emission targets worldwide

Table 11. Committed land areas to be restored/reforested in African INBAR countries (afr100; INFOFLR)

Country	Committed Area (Million Hectares)
Benin	0.5
Burundi	2
Cameroon	12
Central Republic Africa	3.5
Congo	8
Ethiopia	15
Ghana	2
Kenya	5.1
Liberia	1
Madagascar	4
Malawi	4.5
Mozambique	1
Nigeria	4
Rwanda	2
Senegal	2
Sierra Leone	0.7
Tanzania	5.2
Togo	1.4
Uganda	2.5

Table 12. List of countries with bio-ethanol blending targets (Saravanan, Pugazhendhi, & Mathimani, 2020)

Country/Region
India
Indonesia
China
Thailand
Russia
Brazil
United States
Europe Union
Gulf Countries/ UAE

4.1.1.2 High global market acceptance for bamboo products

Bamboo products have been proving themselves on the global market for many years. As mentioned in section 1, the global exports of bamboo products amount to more than USD 1.7 billion annually, and the annual market size is approximately USD 53 billion. Such market size is expected to grow by 5.7% annually due to the increased global demand on bamboo products (GVR, 2021). The EU, for example, has bamboo products' imports valued at more than 500 million dollars annually.

According to the global trade statistics, even African countries import bamboo products. Some African governments officially get surprised when they know that the furniture they are sitting on or the toothpicks they are using are actually manufactured from bamboo and imported. In addition, some bamboo products are already manufactured in African factories and workshops and are welcomed by African citizens, such as toothpicks, furniture, incense sticks and charcoal. Hence, bamboo is not just globally accepted; it is also locally accepted in African countries.

Currently, China has a lion share of global bamboo exports of more than 70%. By comparing the bamboo land area in China to that in Africa, they are nearly the same. Hence, considering the above, this indicates that bamboo is largely underutilised in Africa, and that there is a huge potential for the African countries to have a solid bamboo industry and have considerable share in global bamboo exports. This will definitely have positive impacts on sustainable development in African countries.

4.1.1.3 Big companies have started using bamboo in their products to achieve carbon neutrality

In reflection of the above, some of the big companies worldwide have started to publicly announce the use of bamboo in their products. A highly reputable entity 'IKEA', for example, announces on its website that many of its products are manufactured from bamboo, which is driven by the several sustainable benefits of bamboo (IKEA). In addition, some other brands have announced using bamboo as part of their products to ensure they are carbon-neutral. An example of this is the 'Bic' company, which recently announced the release of its first carbon-neutral Bamboo Razor in Sweden (Ho, 2021). In addition, Procter & Gamble has announced using bamboo as one of its sustainable packaging materials in some of its products (P&G). It is important for African policymakers to know such market updates and develop policies that

support cooperation with such big brands worldwide by providing them with bamboo raw materials and products.

From the success stories all over the world (including Africa), creating the demand for bamboo products is the key step which will automatically incentivise the farmers to plant bamboo. When farmers grow bamboo, they will automatically use it as fuelwood for their residential applications and, accordingly, reduce deforestation.

4.1.2 *Bamboo supporting the achievement of various national targets*

In addition to the global attractions of bamboo, its potential to support the achievement of some of the national targets should make African policymakers consider bamboo generally and bamboo bioenergy specifically as an important development topic. Figure 10 categorises the national targets that bamboo can support into two main items, which will be discussed in the following sub-sections.

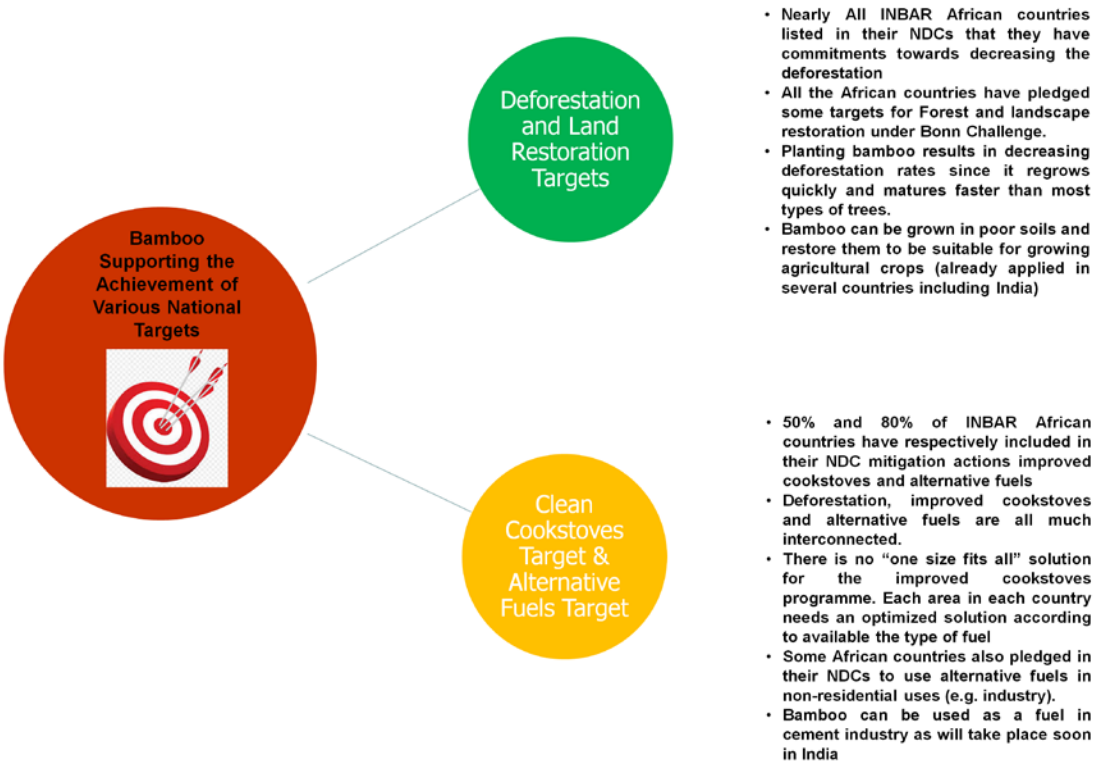

Figure 10. National targets that can be achieved using bamboo

4.1.2.1 Targets for reducing deforestation and land restoration

As shown in Table 4, nearly all INBAR African countries listed in their NDCs that they have commitments towards decreasing deforestation. Moreover, all African countries have pledged some targets for forest and landscape restoration under the Bonn Challenge. Planting bamboo results in decreasing deforestation rates, since it regrows quickly and matures faster than most types of trees. Hence, using it as a source of fuelwood instead of trees guarantees a reliable fuel supply, with much reduced pressure on forests. In addition, bamboo can be grown in poor soils and restored to be suitable for growing agricultural crops. In Allahabad, India, bamboo has successfully restored 85,000 ha of infertile land, where it has raised the water table by over 15 m (United Nations Office for South-South Cooperation, INBAR, 2017).

Hence, policymakers should seriously consider bamboo plantations as it can help achieve the NDC deforestation targets in addition to the Bonn Challenge pledges.

4.1.2.2 Targets for improved cookstoves and alternative fuel promotion

Table 4 shows that half of INBAR African countries have included the promotion of improved cookstoves as one of their NDC mitigation actions. The same table also shows that nearly all INBAR African countries have included alternative fuel promotion among their NDC mitigation actions. Deforestation, improved cookstoves and alternative fuels are all highly interconnected. Considering that the countries have increased limitations over deforestation, promoting improved cookstoves is important for fuelwood conservation. However, due to the increased rates of deforestation and the increased population, the switch to alternative fuels needs to be performed at a quicker pace. One of the facts that has been affirmed by various stakeholders met during this report preparation is that there is no ‘one size fits all’ solution for the improved cookstoves programme. Each area in each country requires an optimised solution for the type of improved cookstove to be used and, more importantly, the type of fuel it can use. Some areas may have a high supply of coconut, some may have a high supply of agricultural residues and some may be closer to bamboo forests (USAID & Winrock International, 2017). For the areas with high access to bamboo forests, for example, cookstoves should be designed accordingly, and the residents should be trained on their use.

Some African countries have also pledged in their NDCs to use alternative fuels in non-residential uses (e.g. industry). Most African INBAR countries have cement plants that consume

huge amounts of fossil fuels. In several African countries like Egypt, Ethiopia, Kenya and Senegal, there are positive experiences from using alternative fuels as partial fuel substitution in the cement industry. Agricultural residues are one of the most successful alternative fuels used, where they are mainly pelletised before being supplied to the cement kiln (IFC, 2017). Bamboo has an even higher calorific value than agricultural residues; thus, it can be definitely used as a fuel for cement plants. Even in Africa, one of the bamboo processing plants uses bamboo as a fuel for steam boilers. One of the biggest cement plants in India has recently announced that bamboo will be used as a main fuel in its cement kilns, and it has accordingly requested the government to plant a bamboo wasteland to maintain a continuous supply to their plant (Ramesh, 2021). These case studies indicate that bamboo can definitely support African countries in achieving their alternative fuels targets.

4.2 Bamboo sector governance: lessons learned from China and India

Section 4 showed the importance of bamboo bioenergy as a sustainable national development topic in INBAR African countries. Having believed in that, African policymakers need to have effective sector governance to ensure achieving the benefits referred to in Section 4. In general, governing the bamboo bioenergy sector should be preceded by governing the bamboo sector itself. The next subsections provide some of the key lessons learned from China and India in achieving such governance.

4.2.1 *India*

India started to effectively manage bamboo in 2006, with the first bamboo mission launched between 2006 and 2014, which at that time focused on bamboo plantations in forest and non-forest areas. Then, in 2018, the National Bamboo Mission (NBM) was restructured and re-launched by providing funds of approximately 17 million USD for two years. The NBM lies under the mission for sustainable agriculture to address the complete value chain and development of the bamboo sector and to form a link between farmers and the industry (Raje, 2018). The Cabinet Committee on Economic Affairs (CCEA), chaired by the prime minister, has approved this mission. In addition, the CCEA has been granted approval regarding the empowerment of the Executive Committee to formulate the NBM guidelines, which includes cost estimation for the required interventions from time to time. Some of the restructured NBM goals include promoting product development at different business scales (i.e. micro, small and medium),

renovating the underdeveloped bamboo industry and promoting skill development and capacity building for developing the bamboo sector (Business-Standard, 2018). The NBM has also focused on the 'integration' between different ministries/departments/agencies, with are assigned specific implementation responsibilities based on their mandate.

4.2.2 *China*

China is considered one of the very first countries to focus on bamboo sector development. One success story of many others is in Anji County, which is a small one with a population of 443,880, 87% of which are living in rural areas. Here, an important reform took place in the early 1980s, where the collective system of bamboo management was replaced by the approach of household responsibility. This reform enabled farmers to lease collectively owned bamboo forests under contracts. Through these contracts, farmers were given 15-year user rights to bamboo forests (later changed to 30 years) and were allowed to either keep or sell the bamboo products after paying 5%–10% of the lease fee. By 1994, 91% of the bamboo forests were distributed to farmer households based on the family size. The families received technical assistance from local government and were introduced to an extensive bamboo management technology to improve the productivity of bamboo production (Wang, 2006).

In addition to tenure reform, market reform was also implemented in the bamboo marketing system. This free market generated multiple trading units, including enterprises and trade companies, and later unlocked a larger domestic and international market. This resulted in huge market growth and numerous jobs. Another positive impact of land ownership reforms is the increase in rural income, which has significantly increased, reaching an average rural per capita net income of 2,896 Yuan, which was higher than the states' average of 1,221 Yuan in 1994. This was clearly seen through the changes in rural homes and the increased living space per person (Wang, 2006).

4.3 How to achieve bamboo bioenergy sector governance?

Recently, some African countries in cooperation with INBAR have started focusing on the bamboo sector. This has resulted in the development of several guiding documents: 'bamboo policies integration analysis,' 'bamboo strategies and action plans' and 'bamboo value chain analysis', as shown in Table 13. Governments of these countries have already taken a step forward to develop bamboo sector governance, which is considered a good starting point.

Similarly, other African countries can coordinate with INBAR to start developing an efficient bamboo economy and bioenergy governance.

Table 13. List of the countries that have cooperated with INBAR in developing bamboo sector guidance documents

Country	Developed Documents		
	Bamboo Policies Integration Analysis	Bamboo Strategies and Action Plans	Bamboo Value Chain Analysis
Ghana	✓	✓	✓
Kenya			✓
Uganda		✓	✓
Ethiopia	✓	✓	✓
Cameroon	✓		✓

Figure 11 presents the key steps that need to be followed to be on the right path of bamboo sector governance. The following sections will lay down bamboo bioenergy as a component of a bigger bamboo picture.

Figure 11. Key steps required to establish efficient bamboo sector governance

4.3.1 *Identifying the relevant stakeholders*

A stakeholder in the bamboo and its bioenergy sector can be identified as a person, a group or even an organisation (public or private) that has an admissible interest in the production, processing, consumption or regulations processes in a relevant project. The stakeholders in such a sector often include the government, the private sector, civil society and the international community, as shown in Table 14. For each stakeholder, the following characteristics that should be considered (GIZ, EUEI PDF, 2014):

- The potential mandates, roles, activities and interests for the stakeholder in relevance to bamboo and bamboo bioenergy
- Availability of resources, expertise and capacity to conduct the potential roles

Table 14. Overview of relevant stakeholders of bamboo sector

Governmental Entities	Private Sector	Civil Society and International Community
• Ministries/Agencies of: o Energy o Forestry o Agriculture o Lands o Environment o Health o Education o Rural development o SME, trade and industry o Women's Affairs/Gender o Finance/Planning	4.3.2 *Forestry companies and private concessionaires* • Representatives of bamboo businesses • Stove producers • Financial institutions, • Farmers	• International and local NGOs working on energy access, rural development, environment, forestry and gender • Donor agencies • Universities and research institutions (which may be government) • Consumers (households, industries and institutions)

4.3.2 *Development of the governing coordination structure*

A coordination structure for the bamboo sector should be established as the first big institutional step; this structure is usually named the 'Council'. A clear and mutually agreed coordinating structure for such a Council is essential for the success of the sector's governance. Usually, this structure comprises a lead institution, steering committee, technical support committee and supporting stakeholders. Figure 12 shows the cooperation structure through different institutions. Of course, the Council's formation will differ from country to country, based on the national circumstances and the government's structure. One of the very important points that need to be set from the beginning is the financing source for the 'Council' activities (GIZ, EUEI PDF, 2014).

4.3.2.1 Lead institution

The responsibilities of the lead institution include the following (GIZ, EUEI PDF, 2014):

- Chairing the Steering Committee (SC)
- Overall management responsibility and implementation of SC decisions
- Coordinating SC members' meetings
- Contributing to SC discussions
- Cooperating with consultants and donors
- Responsible for coordinating the development of strategic developments.

4.3.2.2 SC

The role of SC in the Council is to guide the process and make relevant decisions based on the scope of the sector governance. The SC is chaired by the lead institution and comprises multiple key decision makers from different ministries that are responsible for energy, forestry, lands, environment, gender and SME or trade and industry. SC members should have decision-making power and a high level of hierarchy to be able to make efficient decisions. SC's responsibilities include the following (GIZ, EUEI PDF, 2014):

- Making executive decisions
- Setting targets and monitoring progress
- Providing strategic input

4.3.2.3 Technical support committee

To ensure a well-established governance of bamboo and bamboo bioenergy sector, technical inputs, feedback on market structures, law and technologies are required. This is achieved by having technical staff from the relevant ministries and private consultants.

a) Technical staff

Each SC member organisation should appoint technical staff that will act like the technical secretariat of the Council, each in their specialisation. The technical staff will be assigned the following responsibilities:

- Providing technical support to SC by identifying the key points to be discussed
- Providing technical knowledge and statistics to any 'consultant' involved in the process
- Providing feedback on developed draft documents

b) Private Consultants

A database of private consultants in the various sectors of bamboo and bioenergy fields needs to be developed by the lead institution. Consultants are hired whenever there are technical issues that need detailed study. These consultants should possess the relevant technical knowledge (e.g. in energy, forestry and policy development) and in-depth knowledge of the country and its governing structures.

4.3.2.4 Additional stakeholders

Additional stakeholders should include the private sector, civil society, donor representatives and regional and district representatives. They are assigned the following responsibilities (GIZ, EUEI PDF, 2014):

- Providing feedback on findings, analysis and proposal
- Sharing experiences and knowledge
- Supporting the implementation of the action plans

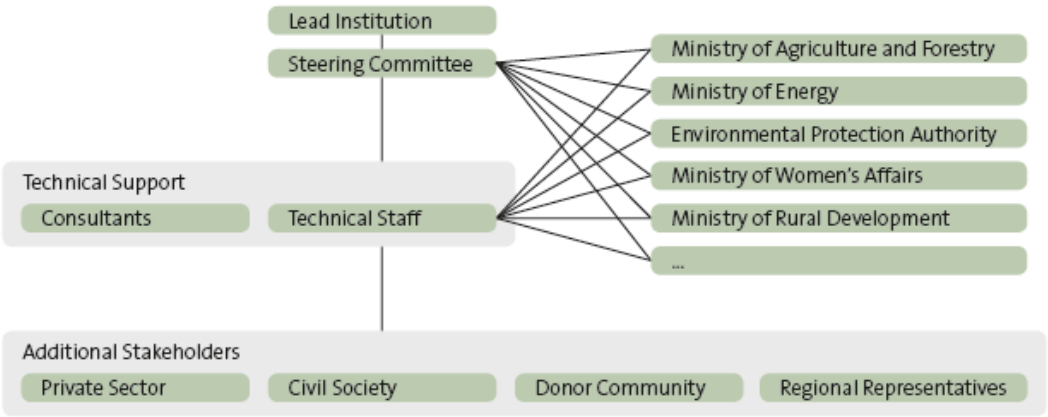

Figure 12. Cooperation structure among the different institutions (GIZ, EUEI PDF, 2014)**.**

4.3.3 *Deep analysis of the baseline situation*

The first real step after the Council's formation is to conduct a deep analysis of the national bamboo and bamboo bioenergy baseline situation. As a starting point for such analysis, certain national and local statistics should be available, such as population sizes and distribution, projected growth rate by region, urbanisation rates and economic data (e.g. household income and expenditures and income growth for both rural and urban populations). Another analysis that needs to be conducted as part of the baseline assessment is the bamboo and bioenergy value chains. This should include an analysis of both the supply and demand sides. The supply side includes all steps of bamboo plantation, growing, harvesting and transportation. The supply side also covers all stages before the energy product reaches the end-users. This includes energy conversion equipment (e.g. charcoal furnaces, briquetting machines and decentralised electricity generation equipment), in addition to production, marketing and sales of fuels and appliances, such as improved cookstoves. The demand side covers bamboo handicrafts, industrial factories and energy users, including households, institutions, commercial enterprises and agro-processing.

For the supply side, the following details need to be carefully studied:

- Forestry: land cover by category, mean annual bamboo production for each type of land cover, availability of bamboo resources, and ownership and user rights
- Other biomass resources: availability of non-forest biomass resources

- Technology use for plantation and harvesting: type of technologies applied in the supply chain and their efficiency
- Bioenergy local technology: type of technologies applied in the supply chain and their efficiency
- Supply of cooking equipment: production, sales, availability, efficiency and quality of the improved cook stoves and affordability
- Geography: transportation routes, production centres, distribution centres, and retail

For the demand side, the following details need to be carefully studied:

- User categories: all types of users, including handicrafts, bamboo processing factories, households, institutional and commercial users of bioenergy and informal sector
- Consumption purposes: domestic demands for institutions and commercial cooking, heating, industrial use, and electricity production
- Large consumption centres: usually urban areas and industrial complexes
- Fuel types: different fuels used for cooking and heating
- Fuel costs: prices that are usually paid by households and industries

Based on the previous findings, the baseline analysis conducted should answer the following questions:

- What are the main challenges/problems that hinder the growth of bamboo and bamboo bioenergy energy sectors?
- Who are the most affected stakeholders?
- What are the most affected regions/areas?
- What are the main barriers to sustainable bamboo and bamboo bioenergy sectors?

The results of the conducted analysis will be verified by the SC, technical staff, and stakeholders. It is recommended that the results of the baseline analysis be documented in a report and made publicly accessible. Having a validation stakeholder consultation with a wider range of stakeholders afterwards will be beneficial to confirm/modify some of the study's outcomes (GIZ, EUEI PDF, 2014).

4.3.4 *Identification of the value chain bottlenecks*

After conducting an in-depth analysis of the baseline situation, a deeper analysis is usually required to identify the different value chain bottlenecks. This is important to recognise the roles of the main market actors and stakeholders, diagnose the market channels for strength, weakness, opportunities and threats analysis and build vision and action plans. The main actors in the bamboo value chain and their functions are presented in Table 15:

Table 15. Main actors in the bamboo value chain

Actors	Functions
Resource production players	Entrepreneurs producing the seedlings and the farmers cultivating bamboo
Collectors/harvesters	Community members harvesting bamboo from forest for sustainable use, handicraft production and sale.
Handicraft manufacturers	Community members and farmers involved in the production of simple bamboo handicrafts and furniture products
Industrial processing business owners	Private sector bamboo processing industries
Bamboo poles traders	Citizens responsible for trading of bamboo poles and products
Charcoal producers	The charcoal producers even from wood, not necessarily bamboo
Bamboo bioenergy investors	The small-scale and big-scale investors of the different bamboo bioenergy products
Cookstove producers	The different companies working on the manufacture of improved cookstoves
Bioenergy consumers	Final Market for bamboo bioenergy products covering the different sectors
Retailers	Big supermarkets and medium-scale markets selling charcoal

Based on interviewing representatives from each of these actors, the study should identify the key bottleneck. The following points should be studied and highlighted (GIZ, EUEI PDF, 2014):

- The governing policy or enabling frameworks for the bamboo sector
- Linkages and coordination among institutions, governmental organisations and NGOs

- Awareness of bamboo propagation techniques
- Awareness of sustainable plantation and land management techniques
- Making charcoal traders and charcoal consumers aware about bamboo charcoal
- Lack of dedicated technical support and manpower and insufficient budget

4.3.5 *Integration with related initiatives*

After identifying the weakness points in the previous step, the 'Council' should maximise the integration and mainstreaming of bamboo and bamboo bioenergy into the most relevant ongoing and successful initiatives. This is usually a successful strategy to overcome the inherent weaknesses of bamboo due to weak sector governance at such an early stage. As mentioned above in section 4, bamboo can support the achievement of some of the national targets related to deforestation, land restoration, improved cookstoves and alternative fuel maximisation. It can also help the country achieve its rural electrification targets and bio-ethanol commitments (if any). Hence, the 'Council' should identify the role of each SC member in mainstreaming bamboo in the most relevant ongoing initiative and discuss any possible changes in SC meetings.

At this stage, it is also important that the 'Council' harmonically coordinates with the donors to investigate their activities and see how bamboo and bamboo bioenergy can fit into the ongoing and recently upcoming projects (GIZ, EUEI PDF, 2014).

4.3.6 *Developing an action plan*

Based on the discussions conducted in the Council about the role of each SC member and donor in mainstreaming bamboo and bamboo bioenergy into the ongoing and upcoming initiatives, it is important at that stage to develop a well-defined action plan for the bamboo and bamboo bioenergy sector. The action plan should also include other items that are bamboo-specific and might not fit under any relevant initiatives.

This action plan should describe the expected short-term actions (5 years) in detail and the medium-to long-term actions to be included more broadly. The action plan needs to be updated regularly (e.g. every two years). For each action plan item, the following information should be defined:

- Intervention: The exact required actions
- Specific objective: How the interventions can achieve the specified objective
- Responsible implementer: Which agency should be held responsible for the implementation process
- Time: The time required to conduct the action and become effective (short, medium and long-term)
- Detailed budget estimation
- Potential funding resources; for example, government budgets, credit mechanisms, donors or the private sector
- Required framework conditions: Assumptions and success requirements
- Interdependencies: As one intervention can rely on or proceed with the other
- Potential externalities: Whether it is positive or negative, this should include the effects on vulnerable groups, such as the poor and women

The recommended interventions in the bamboo and bamboo bioenergy sector should be a mix of the following categories (GIZ, EUEI PDF, 2014):

- Regulatory actions in the form of decrees or laws (e.g. improved regulations for land tenure, tax incentives for imported bioenergy equipment, and tax incentives for bamboo charcoal products)
- Institutional actions (e.g. developing master plans for supply centres, formation of inter-ministerial committees, and coordination mechanisms between entities for data flow)
- Coordination actions (e.g. coordinating with donors and banks for developing financing schemes suitable for bamboo entrepreneurs)
- Technical actions (e.g. measures to increase productivity of bamboo forests, and setting specifications for mechanised bamboo charcoal kilns)
- Awareness actions (e.g. increase the awareness of the citizens about bamboo products)

4.3.7 *Adoption and implementation*

The developed action plan should then be adopted by the ‘Council’. The ‘Council’ should closely monitor the implementation of the action plan items, and a mechanism for progress reporting

should be agreed upon and implemented. The lead institution should call for an urgent SC meeting if there are significant barriers to implementing the action plan according to the time plan. The 'Council' should be flexible in updating the action plans according to the varying circumstances that occur (GIZ, EUEI PDF, 2014).

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