Development and Promotion of Bamboo Housing Technology in East Africa

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ABSTRACT

With an average yearly urbanization rate of 3.5%, slums have become dominant settlement types across Africa. Identifying local, environmentally sustainable and affordable building materials is a priority. Therefore, INBAR implemented "*Development and Promotion of Bamboo Housing Technology in East Africa*", with the goal of assessing bamboo's potential to meet regional housing needs in a low-cost, eco-friendly manner. This project built one conventional and one modern bamboo building in both Kenya and Uganda, trained over 60 people on bamboo cultivation, management and construction, and conducted feasibility, value chain and sustainability studies on Ethiopian bamboo construction. This increased civil society awareness on bamboo's potential as a construction material; two universities adopted bamboo construction in their curriculums. We also found that mid/low-income urban bamboo housing and tourism lodges can be economically viable in Ethiopia. However, barriers still remain to mainstreaming bamboo construction. Therefore, further research is needed to 1) promote government institutional and policy support and integration with the private sector, 2) integrate bamboo with local building materials and promote a broader range of bamboo construction projects, 3) prepare bamboo building codes and construction product standards, and 4) assess resource management and water requirements of supplying bamboo on an industrial scale for construction.

Keywords: bamboo housing, technology transfer, capacity building

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ACKNOWLEDGEMENT OF NO-COST EXTENSION OF THE GRANT

Research activities for this grant were originally planned to finish on the 30th June 2011. However, upon formal request from INBAR, IDRC granted a four-month, no-cost extension until November 1st 2011. IDRC primarily granted this extension to the project to provide INBAR and our partners with the time to produce a peer-reviewed publication based on the project results.

Following this extension, INBAR has now successfully prepared the Final Technical and Financial Grant Reports. A draft a paper entitled "*Bamboo as a building material for meeting East Africa's Housing Needs: a value chain case study from Ethiopia*" has now also being completed, which, after final editing, will be submitted to the peer reviewed *Journal of Bamboo and Rattan* during November 2011. A copy of the final submitted paper will be sent to IDRC separately during November 2011.

1. RESEARCH PROBLEM

With an average urbanization rate of 3.5% per annum[3], slums in Africa are emerging as a dominant and distinct type of settlement in many cities across the continent. This raises severe development challenges, with slum housing often being unsafe, unhygienic, overcrowded, and built to sub-par standards. In Ethiopia, Kenya and Uganda, the project's target countries, urban slum generation is a particularly pressing problem. For example, in Ethiopia, the German Technical Cooperation (GTZ)[4] estimates 75% of the urban population lives in inhuman, unhygienic, and confined spaces, while, in Kenya and Uganda, the current annual housing deficits are 100,000 and 500,000 units respectively[5]. Therefore, there is a vital need to identify and develop alternative, sustainable, safe, and affordable building materials to meet the current housing crisis.

Given this situation, this project aimed to assess the potential of local bamboo resources to provide an alternative, sustainable, safe, and affordable building material in Ethiopia, Kenya and Uganda.

The project team decided to assess bamboo's potential as an alternative material for construction based on several key factors. Firstly, there is already a traditional culture of construction with bamboo in East Africa, particularly in Ethiopia, where it is estimated 4.8 million people live in bamboo homes[6]. However, this construction is largely informal in nature, producing structures of generally poor quality. Therefore, the project aimed to assess how existing value chains could be improved. Secondly, from the results of INBAR and partner organisation research in Asia and Latin America, INBAR has already demonstrated that due to its

[3] http://www.unep.org/dewa/africa/publications/aeo-1/203.htm; accessed Sept. 29th 2011
[4] Low cost housing: Technical Manual II. GTZ low cost housing project, Addis Ababa 2005, available at http://www.gtz.de/en/dokumente/en-low-cost-housing-ethiopia-technical-manual-II.pdf; accessed Sept. 28th 2011
[5] http://www.habitat.org/ ; accessed September 28th 2011
[6] National population and Housing census of Ethiopia 2010

strength, versatility, and earthquake-resistant, fast-growing, and self-regenerating properties, when treated and used properly, bamboo is a highly renewable and generally affordable material that can be used in every component of housing[7]. Based on these experiences, INBAR hypothesised that proven traditional bamboo construction technologies from Asia and Latin America can be adapted in an East African context. Finally, in recent years, INBAR and our partners in China have also demonstrated that laminated bamboo can be used in structural applications, presenting new opportunities to standardise bamboo-based construction and produce modular modern housing designs that are potentially suitable for East African markets. To assess the role modern bamboo homes can play in East Africa, this IDRC grant was, therefore, also linked and co-funded with a Common Fund for Commodities (CFC)-funded project "Development and Commoditization of the Pre-fabricated Modular Bamboo Housing in Asia and Africa". Under the CFC project, bamboo lamination technology is being transferred from China to Ethiopia.

Based on the above rationale, the key research problems investigated in the project were:

1. Rising cost of building materials: A number of East African countries import building materials, making construction expensive and often unaffordable for many local people. Alternatively, local bamboo resources have been relatively ignored as a sustainable building material. Due to high costs, the gap between demand and supply of housing has been rising in the region.
2. Lack of awareness on using bamboo as a building material: One of the major problems in promoting bamboo as a building material is lack of awareness among government, researchers, builders and local communities.
3. Lack of technical knowhow and skilled human resources: The other major problem associated with bamboo housing promotion in the region is lack of skilled human resources and technical knowhow. As architectural schools in the universities don't include bamboo in their curriculum, students lack exposure to bamboo as a building material.

[7] In 2004, INBAR and our partners' work on bamboo construction was validated by the International Organization for Standardisation (ISO), which issued international standards *ISO/DIS 22156 – bamboo: structural design* and *ISO/DIS22157 - Determination of physical and mechanical properties of bamboo*

4. Lack of supportive bamboo housing policies: No African country has policies on using bamboo as a building material, with no approved codes for bamboo building across the continent.

Research Problem Evolution based on Implementation

While the majority of research problems identified before commencement of the project have proven accurate, INBAR understanding of the problem of local awareness for bamboo construction (see research problem 2) has become more nuanced during implementation, with an increasing realisation that apart from lack of awareness, there are often additional acceptance issues with bamboo. These acceptance issues need to be overcome to foster uptake of bamboo housing. For example, in both Kenya and Uganda, although no surveys were undertaken, from local stakeholder interaction during implementation, INBAR found that people were hesitant to accept bamboo as a building material for permanent and modern housing, as they considered it only appropriate for building temporary shelters. In addition, in Ethiopia, the project value chain and feasibility study also showed that despite bamboo being a widely used traditional building material, the majority of bamboo dwelling communities are now tending to opt for concrete-based housing systems when they can afford them.

In retrospect, to address this acceptance issue, the project would have benefitted from placing stronger emphasis on dissemination objectives from the start of the project to spread project results to a larger group of stakeholders. The final framing of project objectives adopted by the project team and IDRC meant that academics, students and building professionals were mainly targeted through the project, while the objectives provided limited scope for reaching the private sector and government; important potential end-users of the project results.

Although INBAR could have placed a stronger emphasis on dissemination in the project objectives (see next section), the project did enhance knowledge and awareness on using engineered bamboo for modern building, which, as this report will show, has started to alter local attitudes. Furthermore, in recognition of acceptance barriers, in Ethiopia, INBAR has also

increased engagement with government agencies and concerned stakeholders to mainstream bamboo construction into public housing development schemes. This is evidenced by our work with the Addis Ababa Housing Authority (see Project Outcomes Section). This represents an entry point that has considerable potential for increasing acceptance of bamboo construction, and, could be replicated across the region (see Overall Assessment and Recommendations Section).

2. OBJECTIVES

The research's overall goal was to test and assess bamboo, as an eco-friendly, low-cost building material to promote bamboo as a sustainable building material in Africa.

The specific objectives of the research were:

I. To incorporate local tradition and design into bamboo housing systems.
II. To test conventional bamboo building systems in Uganda and Kenya and assess their implementation through action research sites, training and demonstration buildings.
III. To transfer modern pre-fabricated bamboo housing technologies from China to Ethiopia and to demonstrate these technologies in Uganda and Kenya.
IV. To improve sustainable production and marketing of modern bamboo housing through value chain analysis and technology research.
V. To build local capacities to sustainably produce and supply bamboo materials by training local communities to cultivate, manage and pre-process bamboo resources for the housing industry.

Objective Evolution

Given the accuracy of the project team's original research problem identification, the above overall objectives remained unchanged during implementation. However, objective III was amended, with engineered bamboo being supplied from China, instead of Ethiopia, to Kenya and Uganda. This was due to a delay in the co-funding CFC project, which will now only establish a processing centre for bamboo plywood and laminated lumber in Ethiopia by 2012; a year later

than originally planned[8]. Importantly, given that modern bamboo housing demonstrations were still successfully completed in Uganda and Kenya, the origin of the houses' production had minimal influence on the subsequent impact of the project in these countries (see Outcome Section).

Objective Achievement

Objective I and II were both successfully accomplished with bamboo construction technology from Asia and Latin America successfully incorporated into local design through the projects two demonstration structures. In addition to this pilot level achievement of the two objectives, bamboo's inclusion an amended architecture curriculum at Makerere University and through an new faculty on non-conventional building materials at Maseno University is now providing increased scope for bamboo to be applied in local design applications and projects (See Outcomes Section).

Due to the unforeseen delay in release of project funds from the co-financing UN CFC-funded project, objective III has yet to be achieved. It is now expected that processing equipment will be transported and installed in Ethiopia by early 2012, with construction of engineered bamboo plywood and laminated lumber commencing around March to April 2012. Despite this delay, it is expected that there will be no significant influence on the long-term impact of the project.

For objective IV, INBAR expects that sustainable production and marketing of bamboo housing will be established in Ethiopia through analyzing the current value chain system of bamboo in the country. An INBAR consultant, Prof. Jacob K. Kibwage, who was also the Project Coordinator for Kenya, has completed a value chain study and made recommendations for improvements. These recommendations will feed into the ongoing CFC-funded project with the aim of supporting realisation of objective V. However, at present, due to CFC project delays, we are unable to assess the efficacy of these recommendations.

[8] The CFC project has experienced an unforeseen one-year delay, due to the request of the CFC to add a feasibility study activity into the project

3. METHODOLOGY

Project Management Structure

The project was developed and coordinated by INBAR in close collaboration with partners in Kenya, Uganda, Ethiopia, and China. The key project partner organisations were: Makerere University, Uganda, Maseno University, Kenya, the Federal Small and Micro Enterprise Agency (FeMSEDA), Ethiopia, Advanced Bamboo and Timber Technology (ABTT), Ltd. Changsha, Hunan Province, China, and the International Centre for Bamboo and Rattan (ICBR), China. The project management structure is depicted in figure 1.

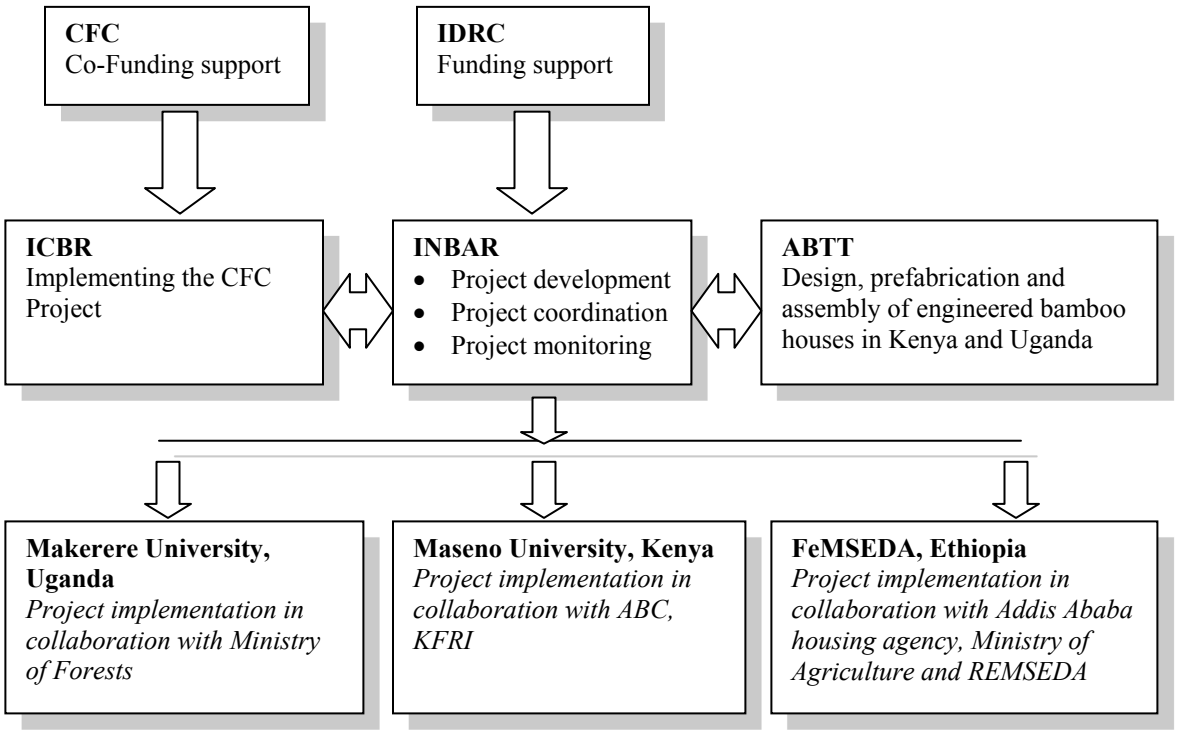

Figure 1: Project structure and responsibilities

Data collection and analysis

On-site action research, where lessons are learnt through hands-on doing and observations from community participation, was the primary method used in this project for training, construction demonstration, and architecture design. In addition to action research, a suite of methods, such as literature review, questionnaires and semi-structured interviews were also used during the commissioned project studies. Finally, material science methods were also employed to test the structural properties of laminated East African bamboos. In total, there were five research components to the project focusing on design, training, bamboo material properties assessment, bamboo value chain assessment, and bamboo housing feasibility assessments. The methods applied for each component are summarized below along with problems encountered and lessons learned (for more detail on implementation of the methods please see the Activities Section).

I. Design methods

Traditional bamboo houses were designed using a free design competition method, where competition participants were provided with a set of design criteria, such as the need to include protection of bamboo in the design, incorporating traditional culture and values, and complementing bamboo with other locally used building materials. In general, INBAR found that this was an excellent means of stimulating local architect students, thereby helping to achieve the first objective of the project – *incorporating local tradition and design into bamboo housing systems*. However, this action research method could have been further refined, by increasing the lead-in time given to students before INBAR sent resource persons to the project sites. In the project, the local coordinators only informed the students about the competition after INBAR architects from Asia and Latin America had arrived, thereby limiting the amount of feedback and interaction that was possible.

II. Training methods

Hands-on training methods were applied in all 5 of the project's training events, covering construction, bamboo processing and semi-processing, and bamboo resource management.

Using this method, local trainees were expected to participate in practical, real-life situations, where they needed to apply the skills they were taught to an actual ground–based project, such as on a building site or in a community forest management system. This was done to help trainees gain experiences faster, as well as to provide feedback to the project researchers on potential barriers that might exist to local adoption of introduced technology and practices.

Through the project, this method worked well in disseminating new technologies and skills to trainees. However, the technology and practices introduced by the project have yet to be widely accepted and up-taken, beyond the trainee groups. This suggests that action research methods need to be undertaken in collaboration with further policy and institutional-based research (see Overall Assessment and Recommendations Section)

III. Bamboo material property testing methods

As part of the co-funding CFC project, bamboo plywood and laminated lumber products made from two Ethiopian bamboo species, namely *Yushania alpina* (highland bamboo) and *Oxytenanthera abyssinica* (lowland bamboo), were tested in China to assess the quality of the products.

The bamboo species were converted into bamboo plywood and curtain laminated lumber.

Based on the standards listed below, bamboo curtain laminated lumber, which is used in load bearing structural components, such as trusses, pillars and beams, was tested for moisture content, density, boiling water soak de-lamination ratio, horizontal shear strength, compressive strength parallel to grain, bending strength, and modulus of elasticity:

- JAS MAFF Notification No.989, July 2000, *Structural laminated veneer lumber.*
- GB/T 17657-1999 Test methods of evaluating the properties of wood-based panels and surface decorated wood-based panels
- ISO 3787-1976 Wood- Test methods- Determination of ultimate stress in compression parallel to grain

Similarly, bamboo plywood, which is mainly used for flooring, walling, and roofing panel applications, was also tested for moisture content, density, swelling rate of water absorption,

bending strength, modulus of elasticity, and internal bond strength of boiling of the material using the following standards:

- EN300-2006 Testing method of the oriented strand board
- GB/T 17657-1999 Test methods of evaluating the properties of wood-based panels and surface decorated wood-based panels

IV. Feasibility study on bamboo housing in Ethiopia

The feasibility study started with a literature review of the Ethiopia's housing situation to gather a general idea and concept of building systems based on traditional architecture and local climate. Due to the relatively limited amount of research in this area, the majority of literature was taken from grey sources, such as Government and international donor and technical agency reports. Based on the review, a set of questionnaires were developed to understand the local needs, affordability and acceptability of bamboo housing. Semi-structured Interviews were also conducted with professionals working in the housing-related agencies, such as the Addis Ababa City Government, and the Addis Ababa housing agency officers. This was done to gain policy and cultural insights into the feasibility of mainstreaming bamboo housing and to collect economic data[9]. FeMSEDA, the project partner in Ethiopia, provided a list of stakeholders for the questionnaires and interviews based on their 30 years of experience working in the national bamboo sector; no specific sampling method was applied due to the relatively limited number of stakeholders and the informal nature of most of the sector.

While the methods used were appropriate for the task, due to the limited time constraints and scope of the project, it was not possible to collect detailed economic data on comparative housing systems, which would have added strength to the final analysis. Given greater budgetary and time resources, an LCA analysis would have also added considerable strength to the study by giving a stronger environmental weighting to the sustainability assessment[10].

V. Value chain and sustainability research:

[9] All Questionnaires used in the study are included in the annex to this report and a copy of the report has been provided to IDRC as a separate document

[10] A copy of this report has been provided to IDRC with this final report

Prof. Jacob Kibwage[11] from Kenya conducted a bamboo value chain and bamboo housing sustainability study in Ethiopia. The study was completed using a participatory social survey method. Questionnaires and checklists were prepared to collect necessary primary data and information from the related informants. Secondary information related to the bamboo value chain and housing situation in the country were collected and verified from primary and secondary sources. FeMSEDA and the INBAR regional office for East Africa in Addis Ababa provided the list of key informants to be interviewed for the study. This included officials from the government housing agency, private housing industries and representatives from the Ministry of Agriculture, which is responsible for bamboo forest management in the country. Discussions were also held with the private sector, bamboo industries, and bamboo-related project stakeholders. The study comprehensively synthesized and analyzed the existing information to provide a basic foundation to carry out the actual field study. Formal interview, focus discussion group and informal discussion methods were also used to collect data from bamboo farmers, buyers, suppliers, producers, processors, traders, architects, civil and structural engineers, building experts, and government and non–governmental agencies with bamboo housing and, or, construction-related activities in the southern and western parts of the country. Formal and informal discussions were also held with local farmers and bamboo-based enterprises in major Ethiopian locations for bamboo trade and industry, such as Addis Ababa, Hawasah, and Assosa.

Descriptive statistics and charts have been used to analyse and present the data. The findings were triangulated and validated by sharing these with key stakeholders, with stakeholder feedback incorporated into the final report. Finally, a Net Profit Value (NPV) and Internal Rate of Return (IRR) analysis was also conducted to assess the economic sustainability of four different bamboo housing systems; very low income urban housing, low income urban housing, mid/low-income condominium urban housing, and tourism lodges.

The major challenge of this study was to cover the large scope (from bamboo value chain to bamboo housing sustainability) in Ethiopia, which is a big country with diverse socio-economic conditions. Another challenge was to choose a conventional house to compare with bamboo

11 Prof. Jacob Kibwage was initially involved in the project as a coordinator at Maseno University in Kenya. He left the university during the project. In the later stages of the project, he applied as an independent consultant to provide consultancy service on value chain analysis in Ethiopia, and was duly selected from a list of six applicants.

housing systems, as there are a wide variety of existing designs and systems of traditional building in the country. However, the consultant decided to compare concrete buildings, which are commonly used in urban areas and supported by Government housing schemes.

4. PROJECT ACTIVITIES

The major activities carried out to achieve the outputs and objectives of the project are explained in this section. In table below, a timeline for completion of IDRC-funded activities is provided. The summary of project objectives, activities and outputs is shown in Annex 1 of the report.

SN	Activities/Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	Project inception																																
1.1	Site visits and partner discussions																																
2	Objective 1: Design																																
2.1	design studio establishment																																
2.2	Students and faculties study local architecture																																
2.3	Finalization of concept designs																																
2.4	Structural designs of the buildings																																
3	Obj 2: Model house construction																																
3.1	construction prepartion in Uganda																																
3.2	Construction in Uganda																																
3.3	Construction preparation in Kenya																																
3.4	Construction in Keyna																																
4	Obj 3: Modern house demonstration																																
4.1	processing center set up in Ethiopia																																
4.2	pre-fabrication																																
4.3	transport and assembly in Uganda																																
4.4	transport and assembly in Kenya																																
4.5	Demonstration in ethiopia																																
5	Obj 4: Study and research																																
5.1	Ethiopian value chain & sustainability study																																
6	Obj 5: Capacity building																																
6.1	conventional bamboo building in Uganda																																
6.2	conventional building in Kenya																																
6.3	management & pre-processing in Ethiopia																																
6.4	bamboo construction in India																																
6.5	processing technology in China																																
7	Final reporting																																
7.1	draft project completion report prepared																																
7.2	final report preparation																																
7.3	Preparation of journal paper																																

4.1 Setting up of design studios in Kenya and Uganda

As a part of the project, design studios have been set up in Uganda and Kenya. The studios are currently located at engineered bamboo buildings built by the project in the universities.

4.2 Training of trainers on bamboo construction in India

Two trainees, one each from Uganda and Kenya, participated in an international training course on modern bamboo structures. The international course was organized by INBAR from 5th to 14th Oct, 2009 in Dehradun, India. The course provided hands-on training in construction of pre-fabricated bamboo houses. During the training, participants learned how to design and construct bamboo houses using small-scale models from bamboo slivers. Participants also learned to make composite structures using bamboo and other building materials. Instruction on bamboo joints and bamboo preservation was also provided. Jeffree Trudeau, President of Bamboo Technologies, Hawaii, USA, was the key resource person for the training.

Picture 1: Bamboo housing training in India

4.3 Designing bamboo houses

Bamboo specialist architects worked with local architects and architecture students from Makerere University, Uganda and Maseno University, Kenya to come up with final designs for two conventional bamboo buildings. The participants were graduate students from the Universities' Architectural Departments, who were interested in the project's design competition. The participants were provided with criteria for designing a bamboo structure, as discussed in the Methodology Section of this report. A design competition was held in

Makerere University, Uganda to select the best design for the construction of the model house. The designs were based on local knowledge, experience and the future use of the demonstration buildings. In both universities, students came up with a set of designs that are based on local knowledge and culture.

One lesson learned from this design competition process was on partner coordination and project management structure. As this was the first time INBAR had been involved in demonstration house building in Uganda and Kenya, it was found that the cost of building in Uganda was actually higher than our previous experiences in Ethiopia. Due to the higher than expected cost of construction in Uganda, the design for the final demonstration building built in Kenya had to be revised. Although INBAR originally tried to work with our project coordinator, we received minimal support during this period. Therefore, the final design had to be revised with support from the African Bamboo Centre, a local NGO established with the support of the IDRC-funded project entitled "Bamboo as Alternative Crop and Livelihood to Smallholder Tobacco Farming Research Project". This lesson highlights how the project, which relied on a partner network model for implementation, would have benefitted from a stronger regional presence of INBAR staff.

4.4 Training on construction in Uganda and Kenya

Two intensive hands-on training courses on *"Bamboos as Modern Construction Materials"* were held at Makerere University Kampala, Uganda from (February 1st to 7th) and in Kisumu, Kenya (Feb 8th to Feb 20th). The intensive training included theoretical, practical and design sessions and involved local architecture students, practicing architects, engineers, carpenters, builders and bamboo enthusiasts. Participants were encouraged to design their own structures, solve technical issues, and build sample connection joints based on the bamboo construction work that was on-going at the adjacent construction site. The trainees were also exposed to designs from different parts of the world.

In Makerere University, the 14 trainees came from academic backgrounds and their interest focused on theoretical and design aspects of bamboo. Interactive design sessions were held with them and they built bamboo connection joints based on their own designs. Participants built a model bamboo bridge in which all the bamboo connections were designed by the participants

themselves. One technical session was purely dedicated to different housing problems in Uganda and on how bamboo could mitigate them, and also included discussion of different social, economic and cultural aspects related to bamboo.

At Maseno University, there were 11 trainees, who mostly came from a carpentry background. In accordance with the participants' background, the emphasis of the training workshop in Kenya was on hands-on construction. The participants built a whole roof within the 12-day workshop, and were taught about different connection joints, wall types, treatment methods and bamboo constructions techniques from around the world.

Picture 2: Architects Juan Carlos and Nripal Adhikary teaching trainees about bamboo joints

4.5 Feasibility study in Ethiopia

A feasibility study on the bamboo housing sector in Ethiopia was carried out by an independent consultant. Besides Ethiopia, the study also includes Nepal and China as required by the project's co-funding donor, the United Nation's Common Fund for Commodities (CFC). The study included

assessment of the housing situation in each country, existing building materials, potential sustainable alternatives and financial aspects of developing the bamboo housing sector.

The study acknowledged that the housing situation in Ethiopia is very poor, with low average incomes prohibiting the majority of people from purchasing a house. The study also noted that government policy on housing currently has two main directions; supporting community development; and building affordable apartments. Therefore, the study recommended adopting a "Nature Box" solution to the housing problem in Ethiopia.

The concept of the "Nature BOX" house is based on using natural and green materials, which are prefabricated. The study proposes that individuals can rent a site from the government, where they are able to develop their own homes. In general, concrete and concrete blocks are the most basic building materials in the country. However, with concrete prices increasing rapidly, the "Nature Box" approach offers a more economically and environmentally sustainable alternative in the long-term. Furthermore, the study noted that Government concrete apartments (condominiums) that are being built for low-income households require large amounts of material for interiors. This provides a large potential market opportunity for locally made ply-bamboo sandwich panels, which can be used as a replacement for concrete blocks in interior walls[12].

As there is a need for very low cost housing ranging from US$2,000 - 3,000, the study found that low cost bamboo panel "nature box" houses can meet this demand. The study recommended establishing a product line, which should develop a wider range of bamboo panel housing products with basic components that are flexible in combinations with different materials and can meet different households' needs. Finally, the study also recommended following an existing wood frame technology for bamboo construction. The "Canadian Wood-frame House Construction" (supported and published by CMHC Canada) technology was selected very for this purpose[13].

[12] INBAR has followed the studies advice and now successfully established a link up with the Addis Ababa Housing Authority to use bamboo plywood panels as wall partitions in the Capital's Government urban condominium developments (see Outcomes Section for more details)

[13] INBAR's partner ABTT adopted this technology in the projects two modern demonstration houses based on this recommendation

4.6. Testing of Ethiopian Bamboo Species

On behalf of the co-funding CFC project, the Institute of Wood Industry, Chinese Academy of Forestry conducted physical property tests on Bamboo plywood and curtain laminated lumber made from two Ethiopian bamboo species[14]. The two species tested, *Yushania alpina* (highland bamboo) and *Oxytenanthera abyssinica* (lowland bamboo) grow widely across East Africa.

The manufacturing process flow used for production of test specimens of bamboo curtain laminated lumber and bamboo plywood was as follows:

Bamboo selection → cross cutting → splitting → conversion to strips→ removal of outer & inner nodes → splitting strips into slivers (20mm in width, 1-1.8mm in thickness)→ curtain weaving → drying (MC 6-10%) → PF adhesive dipping → air drying (MC 5-12%) → assembling (glued curtains along grain direction for bamboo curtain laminated lumber and adjacent layers oriented perpendicular to one another for bamboo plywood) → hot-pressing → trimming

For curtain laminated lumber, the targeted density was 1.0g/cm^3. A thickness gauge was used in the hot press to control thickness, with the following pressing conditions applied; temperature 140 ~ 150 ℃; pressing time 1.5 ~ 2min/mm; and pressure of 5 ~ 8 MPa.

For plywood, as, after long-distance transportation, the bamboo culms received from Ethiopia were not fresh enough for making mats; the plywood prepared for the testing was made without bamboo mat facings, which are usually used to enhance smoothness. A thickness gauge was used in the hot press to control the thickness, with the following pressing conditions applied; temperature 140 ~ 150 ℃; pressing time 1~1.5 min/mm; and pressure 2 ~ 3 MPa.

It was found that lowland bamboos are not applicable for processing bamboo panels. However, highland bamboos can be used to produce laminated lumber and plywood with properties that are better than *Moso* bamboo, the most commonly used species for making bamboo plywood and curtain laminated lumber products in China. The main test results for highland bamboos, along with comparative results for Moso bamboo, are depicted in tables 1 and 2 below.

[14] A copy of the testing report has been submitted to IDRC with this report

Properties	Unit	Bamboo curtain laminated lumber			JAS No.237
		Yushania alpina		Moso	
Thickness	Mm	16	25	25	
Moisture content	%	7.5	6.3	7.1	
Density	g/cm^3	1.061	0.982	1.024	
Boiling water soak delamination ratio	%	6	8	10	<10
Modulus of elasticity (MOE)	GPa	22.35	14.25	12.20	120E(12.0)
Bending strength (MOR)	MPa	182.74	126.23	160.9	180E(67.5)
Compressive strength parallel to grain	MPa	100.25	93.31	85.47	
Shear strength (horizontal/vertical)	MPa	17.81/13.83	13.49/9.00	22.7	65V-5.5H (6.5-5.5)

Table 1: Properties of the bamboo curtain laminated lumber made with *Yushania alpina* (highland bamboo)

Properties	Unit	*Yushania alpina*				Moso bamboo	OSB/4 in EN300
Thickness	mm	9		12		12	10~18
Density	g/cm^3	0.986	0.827	0.908	0.781	0.832	
Moisture content	%	6.6	6.7	6.4	7.0	6.4	
Modulus of elasticity (vertical/horizontal)	GPa	14.54/ 7.97	12.41/ 7.09	13.07/ 8.69	10.58/ 5.04	9.87	4.8/1.9
Bending strength (vertical/horizontal)	MPa	158.90/ 83.59	114.24/ 80.80	127.84/ 92.28	105.33/ 51.32	109.4	28/15
24h Swelling in thickness	%	15.06	17.40	18.25	14.44	14.15	12
2h Internal bond after boil test	MPa	0.86	0.41	0.57	1.04	0.21	0.15

Table 2: Properties of the bamboo plywood made with *Yushania alpina* (highland bamboo)

The results of the tests, which show that East African bamboo species have excellent mechanical and structural properties as plywood and laminated lumber, are being used as a basis for product standards under the co-funded CFC project in Ethiopia. In the future, these standards could potentially be adapted for other countries in the region.

4.7 Construction of conventional bamboo buildings in Uganda and Kenya

As part of capacity building and awareness raising among the stakeholders in Kenya and Uganda, the project built demonstration bamboo buildings in Kenya and Uganda. The designs of the buildings were based on inputs from local architects and were adjusted to fit with bamboo architecture. Through the construction process, INBAR's specialist architects provided local participants to gain hands on experience in bamboo construction. In Uganda, the building has an outside framework of bamboo with bamboo roof trusses and clay roof tiles, and walls of brick. In November 2010, the University Vice-President inaugurated this building. The building in Kenya is now been used as a University canteen, while the building in Uganda is being used as a conference hall (from more information on the buildings please see the Outputs Section).

4.8 Capacity building on bamboo processing and pre-processing

Six people (1 from Kenya, 1 from Uganda and 4 from Ethiopia) participated in a bamboo processing and pre-processing training event from October 26th to 31th, 2010 in Yong An, Fujian Province, China. China has state-of-the-art examples on well-established, community-based bamboo pre-processing and processing value chain systems, where local farmers maximize their financial benefits by linking their small-scale or home-based enterprises to large industries. It was a great opportunity for the participants to see how bamboo can help to boost local farmers' livelihoods, as well as the economy at large. The participants learned the various steps of bamboo pre-processing and processing techniques, as well as how to operate pre-processing and processing tools and machinery. They also visited a few bamboo processing and pre-processing sites and learned about practical supply chain issues, such as how to select bamboo culms, grade culms based on shape and size, treat bamboo, season bamboo, cross-cut bamboo into different lengths, split bamboo, weave bamboo into mats, and transport semi-processed products to processing centres for final processing.

4.9 Capacity building bamboo cultivation and management

A training event on bamboo cultivation and management was held from Feb 14thto 18th, 2011 in Kisumu, Kenya. A total of 26 participants, including 4 from Uganda, attended the event, which provided background information on the need for improved management of bamboo. The training facilitators, Dr. Fu Jinhe, from INBAR, and Prof. Jacob Kibwage, Kenyan Project Coordinator, provided participants with training on detailed procedures for bamboo propagation, field planting, tending, maintenance of plantations, and harvesting and treatment. In order to diversify bamboo utilization, some current and potential uses of bamboo, such as housing, scaffolding, furniture, and mat making, were also discussed during the training. The training included both classroom lectures and practical field work in Kakamega forest.

Picture 3: bamboo cultivation and management training

4.10 Value chain and sustainability study

INBAR contracted Prof. Jacob Kibwage, the Project Coordinator for Kenya, as a consultant to carry out bamboo housing based value chain and sustainability studies in Ethiopia. Originally, this work was supposed to be prepared as two separate studies. However, the consultant has integrated the two studies into one report. The study has been completed and a report has been submitted to INBAR. A separate copy of the report has been provided to IDRC with this Final Technical Grant Report.

INBAR found that this activity provided a good framework for understanding the barriers and challenges to sector development in Ethiopia. The study also complements many of the findings of the CFC co-funded feasibility study (see activity 4.5). However, this activity could have been more beneficial had it been conducted earlier in the project cycle, where it could have complimented the findings from the feasibility study at the inception of the CFC co-funding project. Furthermore, while INBAR had already conducted Production to Consumption Studies (PCS) for Kenya and Uganda in 2000[15], which outlined the key actors, bamboo growing regions and sectors in Uganda and Kenya, a sustainability and value chain analysis with an emphasis on the housing sector would have helped INBAR to engage the wider range of institutional/public sector stakeholders necessary to mobilize support for bamboo-based construction in larger

[15] Rattan and Bamboo in Uganda: A Study of the Production to Consumption Systems; Available at: http://www.inbar.int/publication/pubdetail.asp?publicid=75&catecode=
Production-to-Consumption Systems: A Case Study of the Bamboo Sector in Kenya ; Available at: http://www.inbar.int/publication/pubdetail.asp?publicid=74&catecode=

Government construction and business support/development programmes. A brief summary of the main findings from the study in Ethiopia are given below.

The study showed that besides having vast natural stands of highland bamboo, highland bamboo can also be found in many private farms, mostly in the south-western part of the country. However, despite the availability of ample bamboo resources, utilization was found to be of sub-optimal standard. This was due to diminishing supplies in the quality and quantity of raw bamboo, as well as a lack of modern processing facilities and designs, which restrict access of bamboo products to the local market only. Despite these facts, bamboo furniture and handcrafts sectors are growing in Addis Ababa, the capital of Ethiopia. The study found that the following key barriers constrained bamboo sector development in Ethiopia:

1. A lack of working capital;
2. High transportation costs of raw material;
3. Low quality products;
4. Poor networking among bamboo value chain actors;
5. Lack of skills and tools for processing bamboo;
6. Lack of a clear bamboo conservation and utilization policy - the Forest Development, Conservation and Utilization Proclamation No. 542/2007 of Ethiopia, does not even have explicit statements on bamboo.
7. Insecurity of land tenure right, and;
8. Lack of economic incentives to promote rural communities to value bamboo as a useful commodity.

The study also found that bamboo is a popular construction material among rural communities in the country, especially in regions where it grows naturally. The country is rich in traditional bamboo housing designs, practices and skill. However, the sustainability of the traditional and modern architectures used by the poor communities in Ethiopia is under threat due to decreasing resource availability, increasing rural populations, and a lack of modern processing technologies.

Financial and economic analysis undertaking during the study also found that, by using bamboo for tourist lodges or low cost housing in urban areas, property development investors could potentially receive a return on their investment within 2 to 4 years. The government is also willing to develop bamboo as an alternative construction material using laminated bamboo and is planning to establish a manufacturing industry in Addis Ababa. This will provide a possible avenue for incorporating bamboo into the formal housing industry.

4.11 Pre-fabrication and assembly of engineered bamboo houses in Kenya and Uganda

The project pre-fabricated two engineered bamboo houses in Hunan Province, China, in collaboration with Advanced Bamboo and Timber Technology (ABTT). The designs of the buildings were made by ABTT in close consultation with local partners from Kenya and Uganda. The buildings were transported and assembled in the premises' of Maseno University and Makerere University. Two Chinese experts visited the countries to assemble the pre-fabricated structures. Students and local labourers were invited to work together with Chinese experts to assemble the structures.

4.12 Bamboo processing and pre-processing centres in Ethiopia

Due to previously mentioned delays in the co-financing CFC project, which is financing this component of the project, bamboo processing and pre-processing centres in Ethiopia are still in the process of establishment. The International Centre for Bamboo and Rattan, China (ICBR), the implementation agency for the CFC project, has already finalized the list of equipment for the centres. It is expected that all machines and tools will be delivered from China to Ethiopia by early 2012. Therefore, Ethiopia will only begin trial production in 2012. FeMSEDA has selected three pre-processing centres that will be located in Agarsalam, Tikuinchini and Assosa areas. The local communities will manage the pre-processing centres, with FeMSEDA providing technical assistance.

4.13 National building codes for Kenya, Uganda and Ethiopia

Due to delays in the co-funding CFC project, which was financing this component of the project, the final building code activity has experienced some changes from the original plan presented in the project proposal. Within the CFC project, the building code activity was meant to be primarily focused on Ethiopia, where a pre-fabricated modern housing industry is being

established. The codes were meant to be based on the houses that will be produced by the processing centre being established in Ethiopia. However, due to the unforeseen project delay, the processing factory has not been set up yet, and will only come online in March-April 2012. Therefore, at the last CFC project meeting on November 19th - 20th 2010, in Yong Yan, Fujian Province, China, the International Centre for Bamboo and Rattan (ICBR), China, the implementing agency for the CFC project, in consultation with the project partners, decided that development of building codes needed to be delayed. Instead, the CFC project has now drafted product standards for structural grade bamboo mat-curtain plywood and structural grade bamboo curtain laminated lumber. These standards are applicable for other African countries, including Uganda and Kenya, which have common bamboo species. Due to the time constraints of the project and the need to focus on providing standard frameworks for the bamboo laminated products that will be produced in Ethiopia, conventional bamboo building codes have also been dropped from the CFC project.

Although the project partners have dropped work on modern building codes from the CFC project, after internal discussions, it has now also been decided that ICBR, the project implementing agency for the UN CFC project, will adopt provincial building codes on modern bamboo housing that are being prepared for Sichuan Province in China, as part of INBAR's ongoing EC-funded Switch Asia project on post-earthquake recovery. The provincial building code for China will be directly applicable to Ethiopia, which will be using the same Chinese technology, transferred through the CFC grant. The codes will also be made available to partners in Uganda and Kenya. A first draft of these building codes will be prepared by April of next year and then translated into an English language version for dissemination. Therefore, a building code output will still finally be achieved, but at a later date due to internal changes in the CFC funded project that was originally intended to co-finance this activity.

5. PROJECT OUTPUTS

The major outputs of the project are:

I. *Trained human resources:* The project has trained 60 people from Kenya, Uganda and Ethiopia in the aspects of bamboo cultivation, management, processing and construction.

- Two participants each from Kenya and Uganda were trained as a trainer on bamboo housing in Dehradun India
- A total of 26 people from Uganda and Kenya have been trained on construction of bamboo building (annex 2)
- A total of 26 people have been trained in Uganda and Kenya on bamboo cultivation and management (annex 3)
- Six people from Ethiopia, Kenya and Uganda have been trained in bamboo processing and pre-processing in China (annex 4)

II. *Design studios in Kenya and Uganda:* The project has established design studios in Uganda and Kenya.

III. *Demonstration of conventional bamboo buildings in Kenya and Ethiopia:* The project constructed a 220m² conference centre at Makerere University, Kampala, Uganda. The building is being used as conference hall by the University Guest House Management Committee. Similarly, the project team constructed a 60 m² bamboo canteen in Maseno University, which is servicing students and university staff, as well as external visitors.

Picture 4: Finished bamboo structures in Uganda (top row and bottom left) and Kenya (bottom right)

IV. *Engineered bamboo buildings in Kenya and Uganda:* the Project assembled two engineered bamboo houses; one in Kenya and one in Uganda. The sizes of the buildings in Kenya and Uganda are 56m² and 60m² respectively. A full report on the engineered bamboo buildings will be provided separately to IDRC. In Kenya, the structure will be used for a newly established University Department of Architecture and Urban Planning. In Uganda, it will be used as faculty research laboratory

Picture 5: Engineered bamboo house in Kenya (left) and Uganda (right)

V. *Bamboo housing feasibility study report:* A final report on bamboo housing feasibility has been prepared. The report consists of housing feasibility in terms of needs, resources availability, local capacity, costs and acceptability in the country and aims to explore the opportunities for Pre-Fabricated Modular Bamboo. The study recommended establishing a product line for making low-cost bamboo panel houses and to adopt "Canadian Wood-frame House Construction" (supported and published by CMHC Canada) using engineered bamboo lumber and plywood.

VI. *Value chain and sustainability study report:* The report highlights that despite the vast bamboo resources in Ethiopia, utilization is limited to rudimentary processing for local markets. The study also found that bamboo is a popular construction material among rural communities. However, most rural communities are shifting from traditional bamboo housing to conventional materials as their income improves, indicating people's preference for concrete buildings if they can afford them. This preference is been driven in part by the limitations of traditional bamboo housing designs, which often require regular maintenance and provide limited security. Furthermore, bamboo materials are becoming scarcer. The report recommends that to overcome these issues traditional designs need to be updated and improved, while clear bamboo conservation and utilization policies need to be adopted to secure the bamboo resource base.

VII. *Bamboo processing and pre-processing centres in Ethiopia with funding support from CFC:* One processing centre is going to be established in Addis Ababa to produce laminated curtain lumber and bamboo plywood, and three pre-processing will be located in the countryside. The pre-processing centres will be managed by local farmers under the supervision FeMSEDA.

VIII. *Journal paper:* Based on outputs from the value chain and sustainability study, a journal paper entitled "Bamboo as a building material for meeting East Africa's Housing Needs: a value chain case study from Ethiopia" is being prepared, with Prof. Jacob K. Kibwage, Project Coordinator for Kenya and study consultant, acting as the lead author. A draft of the paper has now been completed, with a final draft to be submitted to the *Journal of Bamboo and Rattan* during November 2011.

6. PROJECT OUTCOMES

As the project focuses on promoting an alternative building material, with limited tradition of local utilization and social acceptance in permanent construction, assessing the full nature of project outcomes would require a longer timeframe than the current project cycle. However, we have already found several important outcomes in the target project countries.

I. Formal agreement for bamboo plywood panels to enter government housing markets in Ethiopia: In Ethiopia, after the processing centre becomes operational in 2012, the Addis Ababa Housing Authority has already agreed to use bamboo plywood panels as wall partitions for Government urban condominium developments that target low-income households. This means there is a direct link to the market and the panels can enter the formal housing sector. According to experiences from bamboo factories in China, a factory, with a capacity of 2000m³ bamboo panels per year, can directly employ more than 100 people and provide indirect employment to at least 500 families by involving them in the production chain. The centre in Ethiopia will have a maximum annual capacity of 2970m³.

II. Increased awareness and interest in bamboo-based construction among the media and general public: The project has already generated considerable interest from the public on the potential uses of bamboo for construction, both in its traditional and engineered form. This heightened interest is demonstrated by several newspaper reports and articles that have been written about the demonstration houses in Kenya and Uganda. The link for these publications are as follows:

- http://www.monitor.co.ug/Magazines/HomesandProperty/-/689858/1187432/-/11e55o0z/-/index.html
- http://www.irinnews.org/report.aspx?reportid=89283
- http://www.unhabitat.org/list.asp?typeid=54&catid=640&start=11&page=2
- http://www.michellemalancaconsulting.com/images/proceedings.pdf
- http://davisgardenshow.com/bamboo/ABS/BambooAug2011/PaudelarticleAugust2011.pdf

Similarly, according to the Africa Bamboo Centre, Kisumu, Kenya[16], since the project activities were completed, they have received at least two enquiries per day from both urban and rural people about the bamboo houses constructed during the project.

According to Prof. Barnabas, Project Coordinator for Uganda, Makerere University is now also getting regular enquiries on bamboo building. Additionally, there are regular enquiries about bamboo farming in both countries as a result of the media reports about the bamboo projects at Makerere University

III. Increased incidence of bamboo resource development in Kenya: Five youths from the Africa Bamboo Centre, trained by the project, are now employed in the bamboo sector. Following the training, the Africa Bamboo Centre is now expanding its nursery and consultancy services to the community on bamboo nursery, cultivation and management. They are also offering services to the participants to establish their own bamboo nursery for income generation. The Bamboo Centre reported that the number of demands for bamboo seedlings from their nursery in Kisumu has also doubled in the last year compared to the previous one. The centre was initially established with the support of the IDRC-funded project entitled "Bamboo as Alternative Crop and Livelihood to Smallholder Tobacco Farming Research Project" to help the project carry out its activities. This outcome demonstrates that there has been a clear complementary link between these two IDRC-funded projects

IV. Two bamboo processing centres being established in Kenya: Following the increased demand for bamboo resource development in Kenya based on the two IDRC-funded projects, the Kenya Forestry Research Institute (KEFRI) is now establishing two bamboo processing sites at its KEFRI-Karura Research Centre in Nairobi and KEFRI-Londian Research Centre, which is located roughly 200 kilometres away from Nairobi. The processing centres will provide an avenue for the increasing numbers of farmers who are now growing bamboo under the IDRC-funded bamboo tobacco substitution project to process their harvested culms. Furthermore, after completion of IDRC-funded

[16] An organisation involved in the implementation of another IDRC-funded project that is promoting bamboo as a substitute for tobacco.

bamboo housing activities at Maseno University, there is now considerable interest in construction, with the to-be-established processing centres including construction in their operation plans. The centres are expected to begin production in January 2012.

V. Bamboo construction integrated into two University Curricula: The project has led to Makerere University, Uganda's leading university, incorporating bamboo as an important part of its building materials syllabus. INBAR has provided a copy of the July 2010 updated BSc Curriculum for Architecture to IDRC as a separate document. Since the syllabus change, at least 5 out of 20 final year students have already incorporated bamboo into their design projects on topics, such as low-cost housing, a tourist lodge for a national park, interior design of a restaurant, and a multi-purpose community hall in a bamboo region of South-Western Uganda. It is hoped that curriculum development will facilitate the development of a generation of trained architects who can drive demand for bamboo-based architecture and construction projects.

The project has also motivated Maseno University to set up a new Department to study and research in building material. The new Department, which is named the "School of Planning and Architecture", is located in the project-built engineered bamboo house.

7. Overall Assessment and Recommendations

In general, with the exception of some delayed co-funded CFC activities, the project has been highly successful in delivering planned activities and accomplishing stated objectives. For example, INBAR and our partners have trained 60 people on bamboo processing, cultivation and management, completed the construction of 4 demonstration buildings in Kenya and Uganda, which are being actively used by local universities, raised awareness among African society on the use of bamboo as a modern building material, and built local capacity on bamboo management and utilization for modern bamboo structures.

The project has also directly benefitted from Canadian building technology as per the recommendation of the project's bamboo housing feasibility study. Laminated bamboo was used to build bamboo-framed modern houses in Kenya and Uganda in accordance with the Canadian wood framing system. Although the project originally did not plan to follow the Canadian wood framing system, our partner, Advanced Bamboo and Timber Technology (ABTT), decided to use the system based on the recommendations of the CFC co-funded feasibility study (see project activities section).

Therefore, the project has provided an excellent foundation for the development of national bamboo construction sectors that can build on local tradition, culture and skills, while also incorporating the latest technological developments on bamboo lamination and best-practices from Canadian wood-framed houses. For example, in both Kenya and Uganda, the project partners have adopted introduced construction technologies and initiated teaching and research in their respective universities. Maseno University in Kenya, which previously had no curriculum for building and architecture, has now set up the School of Planning and Architecture, a major outcome for the project. In Ethiopia, the soon to be established processing centre will also provide a basis for expanded bamboo construction activities.

However, during implementation, INBAR and our partners have also identified several additional barriers that need to be taken into account if the bamboo construction sector is to become mainstreamed in the project target countries and the region as whole. In this section, INBAR

analyses these outstanding issues and then provides recommendations for future bamboo construction sector actions, as well as recommendations for the project management structure.

Firstly, while the project has been successful in disseminating new technologies and practices to the target countries, the major goal of the project to promote bamboo as a sustainable building material in the project countries has yet to be realized. In the cases of Kenya and Uganda, this is because there are still a lack of support mechanisms for replication and upscaling of bamboo-based construction. Therefore, although the project has successfully introduced technology for conventional bamboo building systems in both countries, this has not been significantly adopted due to a lack of government and private sector organisations that are responsible for, and, or, have the capacity to construct bamboo houses.

In Ethiopia, there are much more promising signs that laminated bamboo plywood will start to enter the formal housing sector, initially in the capital, Addis Ababa, where an agreement now exists with the Housing Authority to use bamboo plywood panels from the soon-to-be-established processing centre as wall partitions in low-income urban condominium housing. The lessons from the value chain and feasibility study for Ethiopia, which highlighted Ethiopia's strong institutional support for the bamboo sector, headed at the enterprise development-end by the Federal Government's Federal Small and Micro Enterprise Agency (FeMSEDA), could provide useful insights for both Kenya and Uganda.

As previously mentioned in this report, in Kenya and Uganda, where the role of institutional/public sector stakeholders remained particularly limited during implementation, the project could have benefited from stronger dissemination objectives and activities. Therefore, as sector development moves forward in the region, it remains critical that a greater range of stakeholders are engaged to enable adoption of the project results, as well as up-scaling of bamboo-based construction. In Uganda, the project partners have now begun to strengthen stakeholder engagement further by establishing a bamboo club, based at Makerere University, and a bamboo research group, including researchers from Makerere University and other research institutions. The club is now conducting sensitisation seminars for members of the public. Under the Innovation Systems and Clusters Programme based at Makerere, a bamboo cluster has now also been launched in western Uganda, which brings together bamboo

farmers and artisans using bamboo for various art crafts. Meanwhile in Kenya, NGO groups, such as the African Bamboo Centre, remain active in reaching out at the community level. However, while these actions are positive, INBAR acknowledges that an outstanding challenge from the project is to engage institutional/public sector stakeholders, who can drive sector development. If institutional support is provided to the sector, there are significant opportunities for promoting bamboo-based construction in all three project countries, which can build on the project training and capacity building already conducted with local partners during this project.

In addition to the need for further institutional and policy research to promote mainstreaming of bamboo construction, this project also highlighted that additional practical research and demonstration is also required to increase acceptance levels for bamboo-based construction. Throughout the project, it became increasingly apparent that acceptance issues are a major barrier to promoting bamboo's use in the housing sector. This realisation also informed the project's decision to build public space buildings, rather than homes, for the demonstration construction activities. Similarly, in Ethiopia, where bamboo plywood will formally enter housing markets, this has been achieved through focusing on a specific function; wall partitioning. Significantly, in wall partitioning, bamboo plywood can be concealed from the outside, thus overcoming potential acceptance barriers from occupants. These examples, illustrate that promoting bamboo for construction may also benefit from a broader approach, which is not narrowly focused on housing units, but also incorporates specific construction products (e.g. bamboo plywood) that can be used in tandem with existing, accepted building materials, as well as other construction functions for public spaces and buildings.

Finally, through the project, INBAR found that serious resource management questions, especially on the reliability of raw material supply and bamboo's suitability as a local replacement for timber plantations, still need to be answered before bamboo can be mainstreamed as a construction material in East Africa. For example, the value chain and feasibility study for Ethiopia suggest that bamboo resources are already being depleted through predominantly informal value chains. This is evidenced by community informants' interviews, which suggest distances for collecting bamboo are growing longer and that the price of raw materials is increasing. In Kenya, bamboo management has also been a longstanding issue, with a 1982-Government harvesting ban on bamboo seriously disrupting growth of the sector. In Uganda, where bamboo resources also tend to be found mainly in natural forests, scarcity of

supply of high-grade construction bamboo material is a major potential impediment to growth of a national bamboo construction sector. Therefore, in order to develop sustainable bamboo construction sectors, it is likely that considerable work still needs to be done on developing bamboo resources for industrial purposes, including the development of plantations, in all three target countries. In line with the recommendations of the sustainability and bamboo value chain assessment study for Ethiopia, this will also entail developing clear policy and plans for bamboo conservation and utilizations.

Many countries in the East African region now realise the potential attractiveness of bamboo as a fast-growing, self-replenishing source of timber. As a result, bamboo is already being planted by Governments, such as Rwanda, who aim to use bamboo for riverbed stabilisation and as a replacement for eucalyptus plantations. Similarly, in Kenya, The Interim Coordination Secretariat, Mau Forest Complex (ICS), directly under the Office of the Prime Minister, is now also preparing to promote bamboo to the National Economic Council as a potential driver in economic development, as well as a tool for environmental conservation. In Ethiopia, the Ethiopian Government has also established a Bamboo Development Unit under the Ministry of Agriculture. The Bamboo Development Unit is responsible for aligning all bamboo projects in Ethiopia with other development programmes, such as education, housing, and industry and trade, through a Bamboo Sector Strategy Framework (BASS).

These trends suggest that there is already a growing policy shift in the region towards industrial bamboo development, which would entail an increase in bamboo plantations. Given that bamboo is often heralded as a better alternative to eucalyptus, another fast growing source of timber that, however, is also contested to consume high levels of water and drain rivers and groundwater, more research is now urgently required to compare native bamboo species' own water consumption, especially when used in plantations. This is especially relevant to East Africa, where many countries suffer from water stress and droughts.

Recommendations

Based on the overall project assessment, INBAR has the following recommendations:

I. *Follow up research on Government institutions and policies role in promoting the bamboo construction sector and stimulating private sector involvement:* This project has demonstrated that when government and public institutions start using bamboo technology, this can help to raise awareness and begin to alter attitudes to bamboo-based construction. In Ethiopia, government support through FeMSEDA and the Addis Ababa Housing Authority are also showing that Governments and their agencies can be real drivers for mainstreaming of bamboo-based construction in formal housing sectors. In order to engage institutional/public sector stakeholders in Kenya and Uganda more effectively in the future, the sustainability and value bamboo chain assessments from the project should be extended to these two countries to provide a stronger policy basis for future interventions. Furthermore, given that many East Africa countries are now forming industrial development and economic policies for bamboo, a future follow up to this project should be to encourage and work with responsible government agencies and the public sector on further institutionalising bamboo use in public works, such as Government buildings, housing, hospital and school programmes. Similarly, future projects should research how Government sectors can effectively create links to the private sector between builders and contractors.

II. *Continue to integrate bamboo with local building materials and explore a wider range of construction-based applications:* The positive reviews for the traditional bamboo demonstration house built by the project in Uganda, where bricks and a clay roof were incorporated into the design, indicate that complimenting bamboo with other accepted building materials is a good entry point for broader acceptance of bamboo. This approach is also likely to increase acceptance among builders and contractors, who can then incorporate bamboo more easily into their existing construction practices. INBAR has now proposed a new project to IDRC, which builds on this concept, and aims to demonstrate and trail bamboo's use as reinforcement for ferrocement rainwater

harvesting tanks. By increasing the range of bamboo construction applications, INBAR believes this can raise community acceptance levels and promote wider use.

III. *Prepare building codes and product standards for bamboo housing and construction products:* The project has successfully tested bamboo plywood and laminated lumber specimens made from indigenous East African bamboo species. These results, coupled with INBAR and our partners existing body of research on the structural properties of both natural and laminated bamboo show that local bamboo species are a structurally adequate and sound building material for East Africa. The development of building codes and product standards for bamboo would help to formalise bamboo status in the target countries and commercialise the sector.

IV. *To conduct research and obtain data on the influence of bamboo plantations on water resource conservation and water quality, especially in relation to eucalyptus plantations:* As mentioned in the overall assessment, bamboo plantations are likely to grow in number in East Africa, with several countries aiming to industrialise their bamboo sectors and use them as a driver for green growth. In addition to developing clear conservation and utilisation plans for bamboo in the region, more scientific data still needs to also be collected on bamboo's water consumption rates as opposed to eucalyptus, the current major source of plantation timber in many East African countries. As part of INBAR's new project proposal to IDRC that builds on the work of this current grant, INBAR hopes to begin this important process of providing Governments with the needed scientific data upon which they can make informed forestry management decisions.

Strengthen regional coordination in future projects: During implementation, the project experienced some coordination difficulties, especially in Kenya, where the departure of the Project Coordinator, Prof. Jacob K. Kibwage, from Maseno University, the project partner created several challenges. In Uganda, INBAR was also fully dependent upon the partners to coordinate and implement the project. However, as the lead implementing organisation, INBAR did not always receive expected coordination and cooperation support from local partners in project countries. A good example of this was the delay in receiving custom clearance in Uganda and Kenya for the project's engineered bamboo

houses, which were pre-fabricated in China. INBAR acknowledges that, in part, these problems were the result of trying to manage the project from a distance, which was a weakness of the original proposal design. Therefore, for future projects INBAR will ensure that it has a local stronger presence in the management of its field projects. For example, In East Africa, INBAR will strengthen the project management role of its East Africa Regional Office based in Addis Ababa, so as to provide stronger oversight support for both administrative and technical matters.

ANNEX 1: ACTIVITIES, OUTPUTS, AND OUTCOMES OF THE PROJECT

SN	Proposed activities	Status at the end of the project	Outputs achieved	Outcomes achieved or expected
1	**Objective 1: Design**		Design studios established in Kenya and Uganda	Will promote long-term capacity building on bamboo building in Kenya and Uganda
1.1	Setting up design studios in project countries	Completed		
1.1	Study of local architecture by students and faculties	Completed		
1.3	Finalization of concept designs	Completed		
1.4	Structural designs of the buildings	Completed		
2	**Objective 2: Construction of model houses**		Two bamboo buildings demonstrated each in Kenya and Uganda and are currently being used for bamboo architecture research in University	Curriculum on bamboo construction at Makerere University in Uganda and new faculty on planning and architecture at Maseno University in Kenya
2.1	construction preparation in Uganda	Completed		
2.2	Construction in Uganda	Completed		
2.3	Construction preparation in Kenya	Completed		
2.4	Construction in Kenya	Completed		
3	**Objective 3: Demonstration of modern houses**		(i) Three pre-processing centres in Ethiopia; (ii) one processing centre in Ethiopia and (iii) two engineered bamboo buildings demonstrated in Kenya and Uganda	Bamboo laminated products to be used for urban construction in the near future in Ethiopia. Bamboo as a building material promoted in other African countries expected.
3.1	Setting up of processing centre in Ethiopia	In process. Expected to be installed by early 2012		
3.2	pre-fabrication	Completed. It was done in PR China		
3.3	transportation and assembly in Uganda	Completed		
3.4	transportation and assembly in Kenya	Completed		
3.5	Demonstration in Ethiopia	Completed		
4	**Objective 4: Study and research**		Value chain and sustainability	Improved bamboo value

4.1	value chain study in Ethiopia	Value chain and sustainability research was combined to make one study. The study has been completed	research report.	chain expected in Ethiopia
4.2	Technology sustainability research in Ethiopia			
5	**Objective 5: Capacity building**		60 trained people from Kenya, Uganda and Ethiopia in bamboo cultivation, management, pre-processing, processing and construction	It is expected that more people will be involved in bamboo business, income generation and construction in the future. Bamboo is expected to be one of major income generating sources in the rural areas
5.1	Capacity building on conventional bamboo building in Uganda	Completed		
5.2	capacity building on conventional building in Kenya	Completed		
5.2	capacity building on bamboo management and pre-processing in Ethiopia	Completed. It was done in Kenya due to availability of logistics		
5.3	capacity building on processing technology in China	Completed		

ANNEX 2: NAME LIST OF PARTICIPANTS OF TRADITIONAL BAMBOO HOUSING TRAINING

S.NO	NAMES	PROFESSION	INSTITUTION/ COMPANY
Uganda			
1	Samuel Kapasa	Civil engineer	Makerere University
2	Grace Nakimuli	CIVIL Engineer (f)	Makerere University
3	Glorious Katushabe	Technician (f)	Makerere University
4	Richard Semujju	Technician	Makerere University
5	George Gasana	In charge of Bamboo	National Forestry Authority
6	Were Charles	Mason	Construction
7	Sulava Piya	Social Worker	Free Lance
8	Vicent Tumusiime	Student	UTC Bushenyi
9	Aisha Nalubega	Student (f)	UTC Bushenyi
10	John Bosco Mulwana	Student	Makerere University
11	James Byansi	Student	Makerere University
12	Bukenya Peter	Student	UTC Bushenyi
13	Zizanga Fluke	Builder	Free Lance
14	William Pullin	Industrial Designer	Free Lance
15	Mugabe Susan	Civil engineer	Technology Consults Ltd.
Kenya			
16	Collins Mulavi Asuza	Carpenter	African Bamboo Centre
17	Job Odhiambo Migwa	Carpenter	African Bamboo Centre
18	Silas Omondi Ondiwa	Carpenter	African Bamboo Centre
19	Lamek Ngetu	Carpenter	African Bamboo Centre
20	Davis Oriento were	Carpenter	African Bamboo Centre
21	Austine Otieno	Carpenter	African Bamboo Centre
22	Erik Otieno Omolu	Carpenter	African Bamboo Centre
23	Nyasio	Carpenter	African Bamboo Centre
24	Sulava Piya	Social Worker (f)	Freelance
25	Anthony Morombe	Mason	African Bamboo Centre
26	Sylvia Morombe	Industrial Designer (f)	Maseno University

ANNEX 3: LIST OF PARTICIPANTS IN BAMBOO CULTIVATION AND MANAGEMENT TRAINING

NO	NAME	ID NUMBER	COUNTRY	CONTACTS
1	Masabe E. Ogongo	22991870	Kenya	nipponsukidesu@gmail.com
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7	Godfrey Netondo	28950079	Kenya	+254 722538934
8	Glorious Katushabe	35419	Uganda	gloriouskatushabe@gmail.com
9	Samuel Kapasa	09044	Uganda	+256 774985876
10	John M. Seganne	E0019	Uganda	designerspace@alive.com
11	Geofrey Were	Iscd-4/002	Uganda	-
12	Henry Tegere	2833066	Kenya	+254 710724339
13	Ezekiel Nyandonge	1518675	Kenya	+254 710 522295
14	John Okeyo	2582963	Kenya	+254 718344787
15	Ezekiel Oloo	10597614	Kenya	+254726465953
16	Naftal Muhiri	2832084	Kenya	+254 737296201
17	Tobias O. Obongo	1514439	Kenya	+254 716009826
18	Cosmas O. Odngo	4418054	Kenya	+254 729 367232
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24	Dories Auma	1516234	Kenya	+254 726 554321
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ANNEX 4: NAME LIST OF PARTICIPANTS FOR BAMBOO PROCESSING AND PRE-PROCESSING IN CHINA

SN	Name	Contact details	Institution
1	Samuel Kapasa	+256 774985876	Makerere University
2	Masabe E. Ogongo	nipponsukidesu@gmail.com	Africa Bamboo Centre
3	Seyoum Teshome Mengistu	seyoum.teshome20@yahoo.com	Housing Agency
4	Damtew Zenebework Belaynh		FEMSEDA
5	Shitaye Molla Alemu (F)		FEMSEDA
6	Fiseha Gebrehiwot Fekadu		FEMSEDA
7	Yared Terefe HAILESELLASSIE	yar221007@yahoo.com	Housing Agency
8	Atakilt Teka Alemayehu		FEMSEDA

ANNEX 5: QUESTIONNAIRES/CHECKLISTS USED FOR VALUE CHAIN AND SUSTAINABILITY STUDY

Questionnaire 1 for Slums

Location:

1) What is your
    a. Name(optional)
    b. Age
    c. Gender
    d. Marital status
    e. Level of Education
2) What is your occupation?
3) What is your monthly income?
4) How much of your monthly income do you spend on:
    a. Rent
    b. Water
    c. Garbage collection and or disposal
    d. Electricity
    e. Fuel
5) How big is your household?
6) How big is your house?
7) In your view, what is the condition of your house?
8) What materials have been used in the construction?
9) What is your estimation of cost of construction for the house in which you live?
10) Who built the house?
11) Do you own this house?
12) If no above
    a. Who is your landlord?
    b. What is the mode of payment of rent?
    c. For how long can you stay in a house without paying rent?
    d. What happens if you don't pay rent?
    e. How easy is it to get a new house? (provide scale)
13) How often do you get water supplied to your house/ estate?
14) Who supplies the water?
15) Is the water supplied to your house directly?
16) If no, how far is the nearest water point from where you stay?
17) From where is the water sourced?
18) How do you dispose your
    a. Black water?
    b. Grey water?
    c. Kitchen waste?
    d. Other household waste?

19) What form of energy do you use for:
    a. Cooking
    b. Lighting
    c. others
20) Do you own any land
21) If yes:
    a. Where?
    b. How big is it?
    c. What is it used for currently?
22) Have you ever seen a bamboo house?
23) Where did you see it?
24) What was it used for?
25) What is your view of a bamboo house?
26) Would you build one for yourself?
27) Would you rent a bamboo house?
28) Have you ever lived in a bamboo house?
29) If yes, how does it compare to your current house?
30) If you would want anything to change in your current house, what would it be?
31) What is your definition/understanding of a good house?
32) Describe your ideal house.

Questionnaire 2 for rural dwellers

Location:

1) What is your
    f. Name(optional)
    g. Age
    h. Gender
    i. Marital status
    j. Level of Education
2) What is your occupation?
3) What is your monthly income?
4) How big is your household?
5) How big is your house?
6) In your view, what is the condition of your house?
7) What materials have been used in the construction?
8) What is your estimation of cost of construction for the house in which you live?
9) Who built the house?
10) Do you own this house?
11) If no above:
    a. Who is your landlord?
    b. What is the mode of payment of rent?

c. For how long can you stay in a house without paying rent?
d. What happens if you don't pay rent?
e. How easy is it to get a new house? (provide scale)

12) How often do you get water supplied to your house/ estate?
13) Who supplies the water?
14) Is the water supplied to your house directly?
15) If no, how far is the nearest water point from where you stay?
16) From where is the water sourced?
17) How do you dispose your
    e. Black water?
    f. Grey water?
    g. Kitchen waste?
    h. Other household waste?
18) What form of energy do you use for:
    d. Cooking
    e. Lighting
    f. others
19) Do you own any land
20) If yes:
    d. Where?
    e. How big is it?
    f. What is it used for currently?
21) Have you ever seen a bamboo house?
22) Where did you see it?
23) What was it used for?
24) What is your view of a bamboo house?
25) Would you build one for yourself?
26) Would you rent a bamboo house?
27) Have you ever lived in a bamboo house?
28) If yes, how does it compare to your current house?
29) If you would want anything to change in your current house, what would it be?
30) What is your definition/understanding of a good house?
31) Describe your ideal house.
32) Are you involved in any way in bamboo farming/harvesting?(tick appropriate)
33) How so?
34) How much are your earnings from bamboo?
35) How do you utilize your bamboo?

Questionnaire 3: for Bamboo harvesters

Location:

1) What is your

k. Name(optional)
l. Age
m. Gender
n. Marital status
o. Level of Education

2) What is your occupation?
3) How big is your household?
4) How is each member involved in bamboo harvesting?

Task>				
Male				
Female				
Children > 10 yrs				
Children < 10 yrs				

5) For how long have you been harvesting bamboo?
6) What is your annual income?
7) What percentage of this comes from bamboo harvesting?
8) What are your other sources of income?
9) How much land in acres do you own?
10) Do you have any bamboo in your farm? [Y] [N]
    a. If yes above, what proportion of your land is covered bay bamboo?
    b. Did you plant the bamboo yourself? [Y] [N]
       If no, who plated it?
    c. What method of propagation do you use?
11) Are you linked to any association or co-operative?
12) Where do you harvest your bamboo from?
13) Do you know for how long people have been harvesting from this area?
14) Who owns the land from where bamboo is harvested? [STATE] [COMMUNITY] [PRIVATE]
15) For how long have you been harvesting bamboo?
16) How much/how often do you harvest per year?
17) Do you pay any royalty, commission or tax on the area harvested?

HARVESTING

18) Number and duration of harvesting trips in a month: .....
19) Mode of transportation: .....
20) Cost and source of finance for wild bamboo harvesting: Cost.....Source.....
21) How far from the point of assembly is the bamboo found?:
    .....km…….
22) Average number of persons in the harvesting
    team:.....
23) How do you determine the maturity of the culms to be harvested?

24) Describe the bamboo harvesting process: .....
……
……
……
……
……

25) What tools and inputs are required for bamboo collection?

Item/Input	QTY	Unit cost	Total amount	Remarks
machete				
Saws				
File (Sharpener)				
Others (specify)				

26) Season/months when bamboo harvesting is carried out: .....
27) Quantity of raw bamboo harvested per trip (No. of culms).....
28) Cost of cutting and de-limbing per culm:.....
29) Cost of transport to the assembly point per culm; Birr.....
30) What are the species/varieties of bamboo harvested?: .....
31) State the average: length [.....].diameter [.....] and wall thickness [....] of bamboo culms collected.
32) How much of the bamboo must be rejected at the point of assembly? (No. of culms):.....
    For what reasons are they rejected? [IMMATURE] [DAMAGED] [SIZE] [OTHER]
33) Is any of the raw bamboo collected used for your household?: [Y] [N]
    How much? (No. of culms):.....
    How is it used?.....
34) What factors affect the volume of bamboo harvested?:.....
    .....
    .....
35) To whom do you primarily sell your bamboo? [LOCAL CONSUMERS] [DISTANT MARKETS][INTERMEDIARIES]
36) For those selling to intermediaries, have you ever considered selling bamboo to other markets directly? [Y] [N]
    Why/why not……..
37) Describe bamboo in your own words……

COSTS/ REVENUES:

38) Distance from site to point of delivery.....km.....m
39) Transportation cost to/from site: To site.....From site.....Total.....
40) Food costs:.....

41) Tools/other inputs: (Table below)

Item/Input	QTY	Unit cost	Total amount	Remarks
machete				
Saws				
File (Sharpener)				
Others (specify)				

42) Payment to hired help/field guides: Birr.....
43) Fees, access taxes, royalties, commissions, etc. per collection trip: Birr.....
44) Miscellaneous expenses Birr.....
45) How much does each raw bamboo culm sell for? Birr.....
    Who are the buyers?.....
    Where do they come from?.....
46) How much income do you make per trip from sales of raw bamboo? Birr.....
47) What is your opinion of the income you realise through bamboo collection?:.....

PROCESSING:

48) Do you carry out any processing activities on the raw bamboo? [Y] [N]
    If yes, specify type and describe process.....
49) What are the inputs and tools required for this processing?.....
50) What are the costs incurred for this processing? (Per culm). Birr.....
51) How much does the processed bamboo sell for? (Per culm) .....
    To whom?.....
    Where do they come from?.....
52) How much income do you make per trip from sales of processed bamboo? Birr.....
53) What are the end products made from the bamboo that you harvest?.....
54) Where are they sold? (Specify all locations, with geographic directions if necessary).....
55) Who are the buyers?:.....

Questionnaire 4 for Bamboo suppliers (intermediaries)

Location:

GENERAL

1) What is your
    p. Name(optional)
    q. Age
    r. Gender
    s. Marital status
    t. Level of Education
    u. Address
    v. Telephone

2) What is your occupation?
3) How big is your household?
4) How is each member involved in bamboo supply?

Task>				
Male				
Female				
Children > 10 yrs				
Children < 10 yrs				

5) How long have you been in this line business?
6) What is your annual income?
7) What percentage of this comes from bamboo?

SOURCING

8) How do you select the culms to buy?
9) Do you specialize in any particular bamboo species?
10) What quantity of culms do you buy annually?
11) What is your profit per culm? Birr
12) Do you have any particular harvesters you buy from regularly?
13) Do you have any other source of bamboo apart from this?
14) How much land in acres do you own?
15) Do you have any bamboo in your farm? [Y] [N]
    d. If yes above, what proportion of your land is covered bay bamboo?
    e. Did you plant the bamboo yourself? [Y] [N]
       If no, who plated it?
    f. What method of propagation do you use?
16) Are you linked to any association or co-operative?
17) Do you pay any royalty, commission or tax on the bamboo bought?
18) What mode of transport do you use to transport the bamboo?
19) What is the cost of transport?
20) Are there any other costs associated with the business?
21) What is the average number of people in your supply team?
22) How many other suppliers do you know?
    i. From this region
    ii. From other regions

SELLING

23) Where do you sell your bamboo?
24) Who are your primary clients?
25) What kind of culms do they demand?
26) How can you describe the market you have now in terms of profitability?
27) How do you get your customers?

28) Do you know what is made from this bamboo?
29) Have you ever received training on bamboo?
30) When?
31) From who?

Questionnaire 5 for Bamboo processors/manufacturers/ workers

Location:

1) What is your
    w. Name
    x. Age
    y. Gender
    z. Marital status
    aa. Level of Education
    bb. Address
    cc. Phone number
2) What is your occupation?
3) Household size:
4) Number and gender of household members involved in bamboo processing

Activity	M	F	Children <10

5) Monthly remuneration:
6) Primary source of income:……Estimated monthly income……
7) What kind of goods does this company produce?
8) Position in the company: [OWNER] [EMPLOYEE]
9) If employed, please answer the following questions:
    i. What is the nature of employment [APPRENTICE] [CONTRACTUAL] [CASUAL] [PERMANENT]
    ii. What are the terms of employment (specify below)

Weeks/month	Nature of contract	No. months	Wage/month
	Full-time		
	Part-time		
	Sub-contract		
	Piece-wise		

    iii. Does your employer provide any other benefits?: [Y] [N]
    If yes, state:

LABOUR INPUT

10) Hours worked per day:
11) Number of days/week that production/manufacturing takes place:
12) When is production/manufacturing at its peak?
    Why?
13) When is production/manufacturing at its lowest point?
    Why?
14) What tools/equipment is used in the production process?

Tool	Purpose(s)

15) Where did you train in the processing techniques?
16) How long does it take to become independently established?
17) Describe the whole process of production and challenges faced
18) List all your products and briefly describe each

Questionnaire 6 for Bamboo product producers

Location:

1) What is your
    a) Name
    b) Age
    c) Gender
    d) Marital status
    e) Level of Education
    f) Address
    g) Phone number
2) What is your occupation?
3) Number and gender of household members involved in bamboo processing

Activity	**M**	**F**	**Children <10**

4) Estimated total annual income (from all sources):
5) Estimated annual income from bamboo processing:
6) Type of product made and volume of production (specify below):

Product	**Low volume**	**Medium**	**High**

7) For how long have you been doing this business?

8) Is the enterprise registered? [Y] [N]
   a. If so, with whom?
9) Who supplies your culms?

Name of supplier	Location of supplier	Volume of purchase	Unit price paid	Method of payment

10) How often do you have them supplied?
11) From which area do the culms come?
12) Labour employed:

	Number of employees	**Wage paid**
Full-time		
Part-time		
Sub-contract		
Piece-wise		

13) Input cost structure (examine income statement of the enterprise if possible)

	Activity:	Activity:	Activity:	Activity:
Raw materials, with unit cost				
Labour cost				
Land/Workshop rent				
Transportation cost				
Equipment, list with unit cost				
Interest on loans				
Taxes, overheads				
Other fees/levies paid				

14) Where do you obtain your capital investments?

Name of source	Location of source	Amount of principal	Interest rate	Repayment period

15) Outputs from processing/manufacturing:

Product	Quantity	Price received	Sold to	Location of buyer

16) Have you encountered problems in processing/manufacture bamboo products?: [Y] [N]
    a) If yes, specify:
17) Has the enterprise ever had a need for technical assistance?: [Y] [N]
    a) If so, where do you go?
    b) How much do you pay?
18) Pricing scheme:
    a) Who sets the price for the finished goods?
    b) What is considered in price setting?
19) Are women involved in the enterprise? [Y] [N].
    a) If so, in what capacity?
    b) How do they perform compared to their male counterparts?
20) Do you involve children? [Y] [N].
    a) If so, in what capacity?
    b) How much do you pay them?
21) Do you encounter any problems in the following activities? PROCUREMENT [Y] [N] PROCESSING [Y] [N] MARKETING [Y] [N]
22) Briefly outline the problems and their possible solutions in the table below.

Activity	**Problem**	**Solution**
procurement		
processing		
marketing		

23) Have you ever had any form of training? [Y] [N]
    a) If yes, state when and where
    b) If not, state the reasons why
24) Have you been changing your products through time? [Y] [N]
    a) If not, state the reasons why?
25) How well do you think your customers like your products?
26) Are there any associations/ cooperatives involved in your kind of business?[Y] [N]
    a) If yes, are you a member of any?[Y] [N]
27) In your opinion, what should be done to improve this industry?

Questionnaire 7 for Bamboo product consumers

Location:

1) What is your
    a) Name
    b) Age
    c) Gender
    d) Marital status
    e) Level of Education
    f) Address
    g) Phone number
2) What is your occupation?
3) What bamboo products have you purchased recently?
4) What bamboo products do you have in your home?
5) What do you use bamboo products for?
6) What is the availability of bamboo products?
7) How do bamboo products compare to similar products not made from bamboo?

item	Material made from	quality	price	Shelf life	Aesthetic value

8) Do you feel that you get good value for the price that you pay for bamboo products?
   [Y] [N]:
   If no, please explain
9) What other products would you like to see made from bamboo?
10) Do you have any comments or recommendations regarding bamboo products?
    If yes, outline them briefly

Questionnaire 8 for Bamboo product Retailers

Location:

1) What is your
    a) Name
    b) Age
    c) Gender
    d) Marital status
    e) Level of Education
    f) Address
    g) Phone number
2) What is your occupation?
3) Annual income from bamboo product sales:
4) Other sources of income (specify)

5) How long have you been selling bamboo products?
6) Which bamboo products do you sell?
7) What other non-bamboo products (used as alternatives) do you sell?
8) Supply/costs of bamboo products:

Product	Quantity purchased	Supplier	Location of supplier	Unit cost of product	Terms of purchase

9) Do you have any special arrangements with the suppliers of your bamboo products?[Y] [N]
10) Sales/revenue of bamboo products:

Product	Quantity sold	Type of buyer (household, business, bulk, tourist)	Sales price of product	Revenue from product	Comment

11) What proportion of your total sales are from bamboo products
12) How do bamboo products compare to other products in profitability?
13) What is the consumer's perception of the quality of bamboo products?
14) What comments do you have on the quality of bamboo products?
15) What trends have you observed in:
    a) Demand for bamboo products:
    b) Cost:
    c) Type of bamboo products being made:
16) What other bamboo products do you think could be produced?
17) What problems are there in selling bamboo products?
18) Are you involved in any other stage in the production/processing/transportation of bamboo products? [Y] [N] if yes, what stage?

Questionnaire 9 for Professional Association of Architects

Location:

1) What is your occupation?
2) Name of professional association
3) For how long have you been working with this association?
4) For how long has the association been in existence?
5) What are your primary goals as an association?
6) What do you think about the housing situation in this country?
7) Have you done anything towards this?
    a) As an individual [Y] [N]
        i. If yes, outline

ii. If not, explain

b) As an association [Y][N]

i. If yes, outline

ii. If not, explain

8) Do you have any members working with bamboo as a building material
9) Have any of your members carried out research on bamboo?
10) What is the general perception of bamboo housing among your members?