Report on Assessment of bamboo bio-energy development in Africa and Latin America" funded by G 77PEREZ-GUERRERO(L-056/2012)

Prof. Ding Xingcui

China National Bamboo Research Center

Tel:+86 571 88869217, Fax:+86 571 88860944

Email:dxc01@hotmail.com

No. 310, Wenyi Rd., Hangzhou, China

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Summerization

Bamboo is widely grown in developing countries of Asia, Africa, Latin America and the Pacific Regions. It has 1250 species, 150 genera, and an area of 23 million ha. Bamboos are recognized to be one of best bio-energy resources: 1. its rapid-growth (mature around 3 years), short-cycle (harvesting around 3 years), big biomass (3 times higher than wood on average),strong regeneration and big carbon sequestration capability (much higher than tree as per year per ha.) ; 2. high combustion value (over 4500), longer burning time, low ash content.

China, known as a "Bamboo Kingdom", has state-of-the-art technology for bamboo resources sustainable management, high-value agro-processing and rich marketing experiences . China's bamboo sector is growing into prosperious industry streamlined from cultivation, integrated processing into export, and becoming a pillar of the agricultural economy. Its total production value in China in 2015 was over US$ 20 billion.

Bamboo resources are extremely rich, but not tapped out in most developing countries. Their social and economic conditions are not good to follow up the China' model, but are excellent for bamboo bio-energy development considering 1. acute shortage of electricity supply: bamboo pellet can supply local power generation and export to international market . 2. By-side product of bamboo bio-energy generation are bi-char which is excellent for soil improvement and vinegar which is bio-growth-promoter and bio-pesticide for crops and fruits, or benefits to development of organic agriculture development. (3) Small investment, easy operation.

Therefore, this project approach is to combine Chinese bamboo technology of bio-energy technology and plantation management with local rich bamboo resources in Africa and Latin America for providing electricity and pellet to local market and export.

In this context, the project, headed by Prof. Ding Xingcui of China National Bamboo Research Center (CBRC) , follow the below approach or methodology:

1.On financial aspect. We integrate all grants offered by Assessment of bamboo bio-energy development in Africa and Latin America" funded by G 77PEREZ-GUERRERO(L-056/2012)with other grants provided by the below Chinese government to conduct technical research, demonstration, and personnel training in China and outside China for maximizing project results and achievements :

(1) Technical R. & D.:

----Rwanda Bamboo Industry Development Aided by Ministry of Commence of China to Rwanda

----Brazil Bamboo Industry Development Aided by Ministry of Science and Technology of China to the Brazil

---Bamboo bio-energy power generation funded by Zhejiang Provincial Govement of China

(2) Personal training

----Human resources training program by Ministry of Commence of China to all developing countries. Since 1993, CBRC has trained over 3,000 people (incl. 20 ministers) from 106 developing countries, and made a close cooperation with 35 countries.

2. On R. & D. Aspects. Considering the supply-chain agro-business charateristics in Africa and Latina America, the project has done in the below 3 lines:

(1)Bamboo bio-mass Cultivation. It has successfully introducted 1000 pieces of bamboo plants of 1 fine bamboo shoot species from China to Rwanda, and explored 2 local fine bamboo species in Rwanda, Uganda, Brazil, set up a central green-house nursrey and 10 demonstration bamboo nurseries with an annual production capacity of 20,000 bamboo plant, established 4 patches of bamboo

bio-energy demonstration plantation with a total area of 250 ha. , trained around 160 persons .

(2).R. & D on bamboo pellet and bio-power generation . It has successfully found out 2 sets of technologies for pellet production and bio-power generation , 3 lines of bamboo pellets made, and electricity generated to the national grid .2 Feasibility study reports worked out on bamboo pellet production plant of an annual production capacity of 50,000 ton in China and Uganda. Around 20 persons trained in China

All the R. & D., Demonstration, and training activities should lay down a very firm foundation for the development of bamboo bio-energy in Africa and Latin America

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1. Bamboo Shoot Cultivation

1.1Description of 1 bamboo biomass-oriented species imported to Rwanda from China

(1)Bambusa textilis. This is a medium-sized sympodial bamboo with culms up to 15 m tall, straight and smooth, diameter 3-5 cm, internode 35-60 cm, leaves lanceolate 9-25 x l-2.5 cm; Little information on flowering and fruiting. Several cultivars and varieties recognized cv.Albostriata, var, glabra, var, gracilis. It is mainly distributed in the southern China, but now successfully introduced to other countries of Aisa, Latin America and Africa. It grows well in rich soils and rainfall

Fig. 1 *Bambusa textilis.*

1.2 2 Local main species of bio-mass production

(1) *Guadua angustifolia*. This is a large spectacular, sympodial bamboo with culms reaching 30 m, dark green colour, white bands at nodes, diameter up to 20 cm; leaves medium size. It is considered outstanding in stature, with superior mechanical properties and durability of culms . It plays an important role in rural economics and house or building construction. Bamboo shoot tastes , but a little bit more bitter They are originally distributed in South America and cultivated in

Central and South America , but Introduced to many other countries. It grows on rich to medium soils, especially along rivers and on hilly ground, tolerates -2°C.

(2) *Bambusa Vugalis.* This is a medium-sized bamboo, not densely tufted with culms 8-20 m tall. Culms with yellow or green stripes, flowering not common. Internodes 25-35 cm long, 5-10 cm diameter and thickness of wall ranges 7-15 mm. Inflorescence panicle, with many spikelets, no seeds. Vegetative propagation methods - culm cuttings, rhizome planting,branch cutting, layering, marcotting. It is naturally distributed poluparly in Asia, Africa, Latin America, also most commonly cultivated everywhere, especially the horticultural varieties with yellow culms (Fig. 8), green culm varieties common in naturalized populations. It grows in a wide range of climates and on a range of soils; from 400 mm anual rainfall up to about 1500 mm, frost hardy up to -3°C; plants with green culms are more common, drought resistant, very vigorous on moist soil.

Fig. 2 *Guadua angustifolia*

Fig.3. *Bambusa vugalis*

1.3. Description of quarantine treatment and packing of *Bambusa textilis* to be imported to Rwanda from China

Fig.6 .Pruning leave , bad branch and root

Fig. 7. Treatment by special pesticide

Fig.4. Temporary planting in soil-free bed .

Fig.5. Temporary planting in quaratine

Fig.6. Growing in quaratine house for shipping

Fig.7. Packaging with plastic clothing

Fig. 8. Padded with moisture-adsorbed material

The above 8 pictures show you how we prepare bamboo plants which will be shipped to Mexico, please be sure all procedures are in accordance with international quarantine practice and standard, incl., bamboo treatment by special pesticide to kill all damaged insect, fungi, no soil in bamboo, planted in quarantine house which is free soil, insect, packaged in export board box padded with moisture-kept material, and closed by plastic clothing, etc.

1.4. Bamboo Propagation in nursery and bamboo biomass orientation plantation establishment

Fig. 9 Bamboo branch cutting

Fig. 10 Nursery shelter

Fig. 11. Bamboo cutting propagation Fig. 12. Bamboo cutting growing

Fig. 13 Bamboo plants of importing from China in nursery

Fig. 14 Bamboo growing in modern green house by water spray

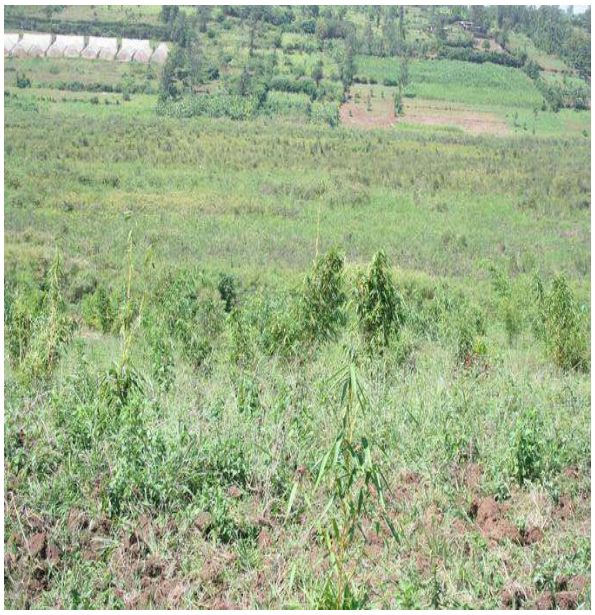

Fig. 15 Bamboo planting along river bank

Fig.16 Bamboo growing in plains

Fig. 17 Prof. Ding Xingcui at Bamboo bio-mass plantation in Rwanda

Fig. 18 Bamboo bio-mass plantation in Uganda

Fig. 19 Bamboo bio-mass plantation in Uganda

Fig. 20 Bamboo bio-mass plantation in Uganda

Fig. 21 Bamboo bio-mass plantation in Brazil

Fig. 22 Bamboo bio-mass plantation in Brazil

Fig. 23 Bamboo bio-mass plantation in Brazil

Fig. 24 Bamboo bio-mass plantation in Brazil

Fig. 25 Bamboo bio-mass plantation in Brazil

1.5. Training results of bamboo cultivation technology in Uganda and Rwanda

(1) Main Training Achievements

Table 1 Main training achievements for bamboo cultivation in Rwanda, Uganda and Brazil

Contents	Achievements
Number of Trainees	100
Bamboo Cultivation Training Technology	1.Nursery management technologies. (1) Land preparation for bamboo cutting propagation; (2)Nursery preparation: measures adopted to prevent from strong sunshine, rains storm and insects; and (3) Watering: spraying and irrigation
	2.Propagation technologies: (1) Mother culms selection for mass propagation; (2)Propagation methods: by branch cutting, node cutting and whole culm, etc; (3) Preparation for propagation materials: cutting methods for branches and nodes, etc. (4) Preparation: preservation, moisture-keeping and hormonal treatment; (5)Nursery preparation: Site preparation, soil sterilization, fertilization, ditch for drainage , simple green-house making by plastic clothing; (6). Burying in soil, incl. burying depth, location, direction, spacing in row and line; (7)Management for newly-shooting seedling , watering, shading and fertilization; and (8)Mature seedling management .
	3.Set-up of new plantation; (1)Site preparation: Land reclaiming, hole making and base fertilizer application, etc. (2) Planting: season selection, planting depth, distance, spacing, irrigation; (3)New plantation management: irrigation, fertilization and seeding; (4) Mature bamboo plantation management: Irrigation, fertilization, harvesting and method of leaving shoot to grow into new culm; (5)Sustainable management for high-yield bamboo shoot plantation: bamboo stand density, structure, culm age for harvesting, pest and disease prevention

(2) Result Comparison before training and after training

Table 2 Result comparison of bamboo cultivation technology before training and after training in Rwanda, Uganda and Brazil

Training contents	Before training		During training		After training	
Bamboo cultivation	Trainees from	Rwanda Bamboo Association, Rwanda Ecology Society and Rwanda Forestry Bureau				
	Propagation Technology	Only by stump	Propagation Technology	By clum and cutting	Propagation Technology	Mastered the major propagation technologies
	Market	Almost no			Market	Farmers can sell bamboo seedlings as government organizes them to plant more bamboo
	Tools	very little, hoe	Tools	Pruning shears, shovel ,hoe	Tools	Pruning shears, shovel ,hoe
					Economic benefits	Bamboo seedling sells in market at price of RWF 1000 for each, around USD1.75

(3) Training on bamboo bio-energy in China

Over 15 persons (inc. 3 ministers) from Uganda, Brazil and Agentina have been trained at CBRC, China on bamboo bio-energy funded by Ministry of Commence Under framework of China Aid Human Resources to Developing Countries,

2. Bamboo Bio-energy Pellet

In the European and American countries, the biomass energy pellet has been widely used in indoor heating and thermal power-generation in the 1980s. Biomass energy pellet is used as fuel, or is co-firing with coal to generate power in some thermal power plant. In recent years, biomass energy pellet is strongly encourage to be used. A lot of government in some European countries provide subsidies to bio-power generation with 50 Euros per ton. Bio-power plants, but their local bio-mass supply companies could not meet the daily-increasing high demands for bio-power generation, therefore they are expecting to produce biomass energy pellet in other developing countries to meet such supply gaps

Now the main raw materials of biomass energy pellet production are the forest resources. Considering the great logging of wood resources leads to the damage to the environment, more and more countries take measures to ban the

wood cutting, therefore wood raw materials to convert pellet for bio-power is decreasing sharply.

Crops straws are rich resources in the world, but they are too soft to produce into pellet production, therefore, they can fit with pellet production of large-scale industrialization, in stead with one of small-scale small-machine , or they can't be become the mainstream of the biomass pellet production raw material.

Bamboo is an ideal material to large-scale production of biomass pellet. Bamboo is widely grown in developing countries of Asia, Africa, Latin America and the Pacific Regions. It has 1250 species, 150 genera, and an area of 17 million ha. In most developing countries, their natural and socio-economic conditions are excellent for bamboo growing and processing industry. Bamboo is silent with a harmonious combination of social, economic and ecological benefits.

High attention is switched to pay bio-energy due to its zero carbon emission considering the factor fossil fuels is reduced in resources, rising in price and emitted seriously in carbon, in which wood pellet is one of best bio-energies to met market demand. In 2010, wood pellet consumption is approx. 13 million ton in Europe with an annual increase rate of 20%, but wood pellet production is at a highly cost of large timber logging, particularly, more and more countries start to ban their forest depletion for ecological consideration

Bamboo pellets is recognized to be one of best alternative pellets forsmall investment, easy operation, quick effect, intensive labor which is very suitable for soci-economic conditions

(1) Its rapid-growth (mature around 3 years), short-cycle (harvesting around 3 years), big biomass (3 times higher than wood on average),strong regeneration and big carbon sequestration capability (much higher than tree as per year per ha.) ;

(2) high combustion value (over 4500), longer burning time, low ash content (see figure

To develop bamboo pellet for local power generation or export to USA, EU by use of favorable natural and social conditions in Africa and Latin America develop bamboo plantation has a huge potential, further bamboo plantation can also produce versatile bamboo products for livelihood and marketing. It will not only meet high market demand, but also help global warming mitigation. Argentina, Uganda and Rwanda all are planning to develop bamboo plantation for bio-energy and other products.

In this case, the experiment has been done on bamboo pellet production by the team headed by Prof. Ding Xingcui of China National Bamboo Research Center under funding of G77 G 77PEREZ-GUERRERO FUND , and co-funded by the Project titled Innovation Project of Bamboo Bio-power Generation of Zhejiang Province, P.R. China

2.1 Experiment designing

It was done in Bamboo Bio-energy Company located in Anji City, Zhejiang Province, P.R. China. The species of bamboo material is Phyllostachys edulis . 100 tons of fresh bamboo was harvested. 20 tons of bamboo pellet was produced. Properties of bamboo pellet were analyzed in the Lab of China National Bamboo Research Center

Fig. 26 Bamboo pellet production workshop

Fig. 27 Different color bamboo pellets productioned under different production temperature

2.2 Experiment Results

2.2.1 The technical difficulties to manufacture bamboo into biomass energy pellet

Bamboo is completely different with wood materials or other crops.Bamboo material is hard, because of a lot of stone cells.The cell walls of stone cell are not easily broken, or not easily plasticized after breaking because bamboo materials itself can be plasticized and bonded together with temperature rising. Bamboo has higher carbohydrate content, the carbohydrate will be hardened with heating resulted by pellet pressing process , will destroy bamboo plasticity ,or adverse to the pellet production .

So far there are not equipment available special for bamboo pellet production in the world, therefore we have to adapt the wood pellet design and equipment

to conduct trial production of bamboo pellet. We found the wood pellet machine and design do not absolutely fit to bamboo pellet production, since machine operates well initially, but big problems are happening after 30 minutes, or a large of bamboo materials are jammed inside machine ,and the machine temperature is rising sharply, and pellet cannot be pushed out , then entire bamboo material is congested inside . As a result, the machine temperature is continued rising, the water and other ingredients of bamboo will be volatilized to produce high pressure gas, the machine could be exploded once the high pressure would reach up to a certain degree. If so, at first , the main shaft of machine could be fractured, and then the bearing be broken. A spindle of machine costs RMB 60,000 Yuan, a set of main shaft bearing costs RMB 200,000 Yuan. And then the circular mould would be broken down, and motor would be burn down due to the huge resistance of bamboo materials and overload. But finally, it is just successful by adjusting the parameters and designing

2.2.2 The biomass energy pellet production

Bio-energy, recognized as 4th kind of energy after coal, petroleum oil, natural gas , is environment-friendly, renewable and clean energy. The combustion of bio-fuel can not emit out air pollutants such as SO2, the CO2 produced from the combustion will not be increased atmospheric CO2 concentration, because CO2 will be absorbed or consumed by the plants.

Bamboo biomass pellet is made from bamboo as the main raw material, its production technology process is chipping, screening, drying, extruded moulding , packaging and so on， the pellet is sized in columnar grains of 6 ~ 9 mm in diameter

Compared with the direct gasification of other biomass fuel, the bamboo biomass pellet fuel is featured with below advantage: good combustion performance , high thermal efficiency, less pollution, etc. But when the bamboo is direct burned, the thermal efficiency is very low, and very uneven. But bamboo pellet combustion efficiency is over 80%, while the common coal combustion

efficiency is only 60%. Bamboo pellets is easy for transportation and storage, and very safe.

2.2.3The characteristics of bamboo bio-energy pellet

(1) Easy to be combusted. Bamboo bio-energy pellet is quiet easy to be ignited , fired and used .

(2)High calorific value . The calorific value of the bamboo bio-energy pellet is ranged around 4500 calories, even up to 4800 calories, and the calorific value is stable, even.

(3)Other features. Bamboo bio-energy pellet can be combusted fully, and will not form into carbon sediment in the combustion chamber.

(4)Wood bio-energy pellet will produce acrid smoke once used , but the bamboo bio-energy pellet could produce fresh scent once used in civil bio-energy boiler Therefore bamboo bio-energy pellet is wonderful for civil boiler use. Bamboo bio-energy pellet can also be used by mixture with coal, and such a mixture can promote coal burning in higher efficient way , reduce emissions an and air pollution.

(5)Bamboo bio-energy pellet could eliminate some awful volatile substances gas once combusted with other material pellet which will produce some awful volatile substances, because, on one hand, bamboo has high calorific value , and fully-combusted which will make other pellet material burned completely , or reduce emission of awful gas produced by other material; On the other hand, the fragrant smell produced by bamboo during its combustion reduce awful smell feeling produced by other material gas.

It can get conclusions by comparative experiments that the bamboo bio-energy pellet is much better than other material bio-energy pellet.

2.2.4 The indicator index of bamboo bio-energy pellet

(1) Calorific value：> 4560kcal/kg

(2) Density：1.1g/cm3

(3) Ash content：<=0.4%

(4) Moisture：<=10%

(5) Combustion ratio：>=95%

(6)Thermal efficiency：>=81%

(7)The degree of smoke blackness（Ge Lin Man degree)：<1

(8) Discharged dust consistence：<=80mg/m3

(9) Cylindrical pellet：∅6~8mm

2.3 Feasibility report of bamboo bio-energy plant construction with an annual bamboo bio-energy pellet production capacity of 50000 tons --- Case study in Anji City of Zhejiang Province, China

2.3.1 The total investment costs

(1)Bamboo material costs

The annual consumed bamboo pole Phyllostachys edulis in Anji City in zhejiang province are 70 million pieces, in which 50 millions pieces are locally harvested, and another 20 million pieces are supplied from other counties nearby, because Anji has a very developed bamboo agro-processing industry . so far there are over 2000 factories to produce over 15 lines of bamboo products from bamboo flooring, bamboo furniture, bamboo curtain, bamboo handicrafts to bamboo shoot as a food, the total annual production value is over RMB 40 billion Yuan (1 USD Dollar is exchanged to 6.6 RMB Yuan). There are a huge of waste bamboo material from bamboo production industry. Therefore we take use of such waste material to convert bamboo bio-energy pellet. But in other developing countries, there are a

huge bamboo resources which have not been used, and are very low price, so we can use the bamboo pole directly convert to bamboo bio-energy pellet.

Taking 1 piece of bamboo pole as 20 kg on average , therefore a total annual consumption of 70 million pieces of pole is 1.4 million tons of raw bamboo. Taking bamboo pole use rate as 50% , therefore the total waste material is weighted as 0.7 million tons . It is a wonderful way to convert such a low-valued waster material into high-valued bamboo bio-energy pellet

Based on our experiment, 2 tons of bamboo residue can produce 1 ton of bamboo bio-energy pellet. The total annual capacity of bamboo pellet in Anji is 0.35 million tons. The present average price of bamboo waster material is RMB 195.5 Yuan per ton (ex. Factory). The total costs for purchase waster bamboo material is RMB 19.55 million Yuan (100,000 million tons X RMB195.5 /ton), and the bamboo raw material costs is

(2) Factory building land costs

A land of 25 mu (1ha=15 mu) needed for annual bamboo pellet production capacity of 50,000 tons, the land price of local industrial zone of Anji Zhejiang is RMB 200,000 Yuan / mu. The total land purchase costs 5 million yuan.

(3) Costs for special equipment and other equipment

Main sets of equipment for bamboo pellet production are purchased in China except for some components imported from the United States , total purchase costs RMB 12 million Yuan.

The finished pellet storage will use the world advanced three-dimensional storage tank, so it not only can save land, but also improve the efficiency of storage, loading and unloading. It needs 2 storage tanks, tank price is RMB 1 million Yuan, or 2 tanks costs RMB 2 million Yuan.

The costs of other equipment and devices like forklift, load meter, boiler, and power supply equipment, etc is RMB 1 million Yuan.

The total investment is RMB 15 million Yuan.

(4)Electricity costs

2 shifts per day and night, the average electricity price is RMB 1 / w. A total electricity consumption for annual output of 50000 tons of bamboo pellet plant is 4 million w, or the total electricity costs RMB 4 million Yuan.

(5) Worker and management costs

50 workers , 2 shits , 10 management staff, each person average salary welfare for staff and worker is RMB 35000 Yuan/person, a total annual salary is RMB 2.1 million Yuan.

(6) Factory building costs

10000 square meters for main factory building, 2000 square meters for auxiliary buildings (office etc.)

Building cost is RMB 1200 Yuan/square meters. Total costs are RMB 15 million Yuan.

(7) Working capital

RMB 5 million Yuan.

In short, the total investment is RMB 65.65 million Yuan.

2.3.2 Annual production output value and profit of 50000 tons of bamboo pellet

(1) Productions costs

Table 3. Bamboo pellet production cost break-down in China

No.	Category	Costs
1	Bamboo material	RMB 19.55 million Yuan(195.5 /ton * 100,000 ton)
2	Electricity Power	RMB 4 million Yuan

3	Consumable material (Incl.depreciation）	RMB 2.75 million Yuan
4	Tax	RMB 2.5 million Yuan
5	Sale cost	RMB 500,000 Yuan
6	Salary	RMB 2.1 million Yuan（RMB 35000 Yuan/ person * 60person）
	Total	RMB 31.4 million Yuan

(2) Production value and profit

Table 4. Bamboo pellet production value and profit break-down in China

No	Category	Production value
1	Sale price of pellet	RMB 850Yuan/ ton
2	Annual sales output value	RMB 42.5 million Yuan(RMB 850 Yuan /ton * 50000 ton)
3	Profit	RMB 11.1 million Yuan (RMB 42.5 million Yuan - RMB31.4 million Yuan)
4	Profit margin	26.11%

(3) Factory establishment time

The total duration of 6 months are spent on land requisition, examination, approval, equipment purchase, factory building, workers training, etc.

2.4 Analysis for bamboo bio-energy plant with an annual production capacity of 5000 ton—Case study in Uganda

2.4.1The total investment

(1)Bamboo material costs

It is mainly to use bamboo pole in mountain areas, bamboo pole price is cheaper, but high costs for harvesting and shipping. Therefore bamboo pole costs

could be nearly same as China' bamboo waster material. So the total costs are RMB 19.55 million Yuan

(2) Factory building land costs

A land of 25 mu (1ha=15 mu) needed for annual bamboo pellet production capacity of 50,000 tons, the land price in general conditions in Uganda is RMB 1,000 Yuan / mu. The total land purchase costs RMB 0.25 million yuan.

(3) Costs for special equipment and other equipment

The equipment purchase costs in China are as same as in China, or RMB 12 million Yuan. The 2 finished pellet storage tanks cost RMB 2 million Yuan . The costs of other equipment and devices costs RMB 1 million Yuan. But extra shipping costs to Uganda is RMB 1 million Yuan. The sub-total investment is RMB 16 million Yuan.

(4)Electricity costs

It costs are same as China, or RMB 4 million Yuan.

(5) Worker and management costs

50 workers , 2 shits , 10 management staff, each person average salary welfare for staff and worker is RMB 17500 Yuan/person, a total annual salary is RMB 1.05 million Yuan.

(6) Factory building costs

10000 square meters for main factory building and auxiliary buildings (office etc.)

Building costs are RMB 1000 Yuan/square meters. Total costs are RMB 10 million Yuan.

(7) Working capital

RMB 1 million Yuan.

In short, the total investment is RMB 51.85 million Yuan

2.4.2 Productions costs

Table 5. Bamboo pellet production cost break-down in Uganda

No.	Category	Costs
1	Bamboo material	RMB 19.55 million Yuan(RMB195.5 Yuan /ton * 100,000 ton) .Same as China for bamboo pole, high costs for shipping
2	Electricity Power	RMB 4 million Yuan (Same as China)
3	Consumable material (Incl.depreciation）	RMB 1.38 million Yuan (same as China) (50% of China)
4	Tax	RMB 1.25 million Yuan (50 % of China)
5	Sale cost	RMB 250,000 Yuan (50 % of China)
6	Salary	RMB 1.05 million Yuan（RMB 35000 Yuan/ person * 60person）(50 % of China)
	Total	RMB 27.48 million Yuan

2.4.3Production value and profit

Table 6. Bamboo pellet production value and profit break-down in Uganda

No	Category	Production value
1	Sale price of pellet	RMB 750Yuan/ ton
2	Annual sales output value	RMB 37.5 million Yuan(RMB 750 Yuan /ton * 50000 ton)
3	Profit	RMB 10.02 million Yuan (RMB 37.5 million Yuan – RMB27.48 million Yuan)
4	Profit margin	26.72%

3. Bamboo Bio-power Generation by Gasification Poly-generation

Clean and renewable energy utilization has gained increasing attention due to severe shortage of energy supply in the world and depletion of fossil energy resources. Nowadays, biomass resource is considered as the best alternative to fossil resource. Biomass resource is comprised of various tree branches, fruit shells and all processing residues in agriculture and forestry (crop straw, rice husk, etc.) Due to its abundance, large variety and wide application, biomass resource has been extensively utilized in China.

In recent years, multiple ways of utilizing agro-forest biomass have been developed in China . Biomass Gasification Poly-generation Technology (BGPT) refers to a pyrolysis process of biomass at high temperature and under oxygen-free or oxygen-deficient condition, which efficiently utilizes biomass resource. It produces gas with high calorific value, which can be used for power generation. Bio-char can be intensively processed into activated carbon and widely applied in civil use, food, medicine, chemical engineering, environmental protection and military. The liquid product can be processed into biomass extract, which is ideal sterilizing agent and liquid fertilizer for organic plants. Therefore, BGPT not only addresses the pollution and waste issues caused by agro-forest residues, but also generates remarkable economic and environmental benefits.

China boasts the most abundant bamboo resource in the world. Recognized as the “bamboo kingdom”, China is top-ranked globally in bamboo species, plantation area, stock volume, production and export value of bamboo products. Bamboo features perennial utilization once planted, fast growth, short rotation and high productivity. China produces 1.539 billion bamboo culms every year, which is equivalent to 23 million m3 of wood timber. Today, bamboo is mainly used to produce bamboo weaving plywood, bamboo chip plywood, bamboo sheet/curtain plywood, bamboo cargo board, bamboo concrete board, bamboo strip laminated board, bamboo floor, bamboo wood composite, sliced bamboo veneer, reconstituted bamboo lumber, bamboo wind-turbine blade,

unfurled bamboo board, bamboo intertwined composite pressure tube, etc. However, as a clean and renewable biomass resource, bamboo is endowed with huge utilization potential as energy source. This project adopts biomass gasification poly-generation technology and relies on 500 kW gasification power generation system in Muke Eco-agriculture Development Co. Ltd. in Jiande City, Zhejiang Province, China to conduct a large-scale bamboo gasification poly-generation experiment. This study intends to obtain data in electricity generated by bamboo of unit weight, yield of bamboo bio-char by gasification process, etc. so that it can provide fundamental experimental data for bamboo gasification power generation and realize the high-value added bamboo utilization as an energy source.

3.1 Experiment Designing

3.1.1 Designing based on Theory and process flow of Biomass Gasification Poly-generation Technology (BGPT)

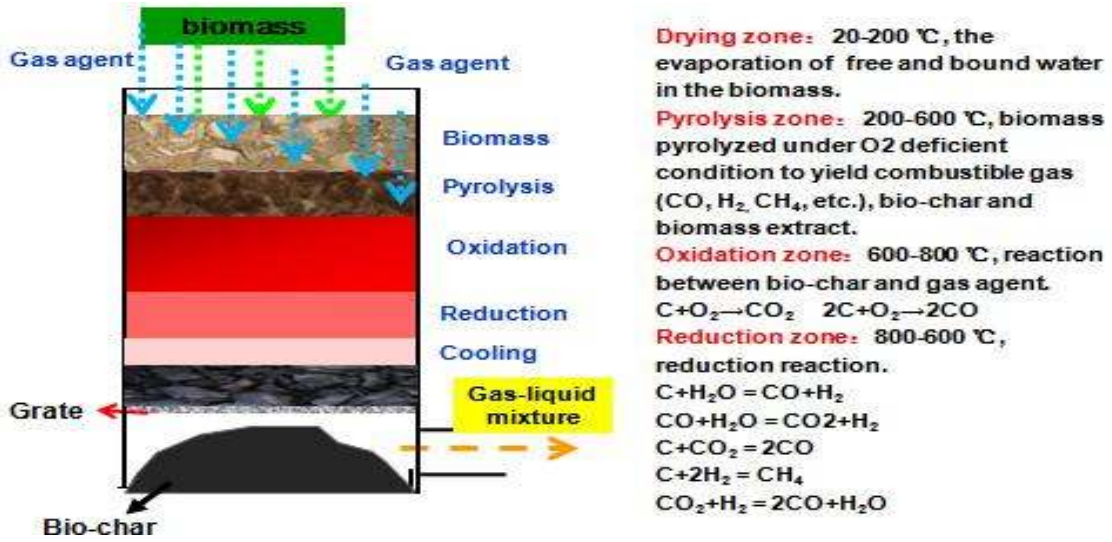

Fig.28 Theory of BGPT

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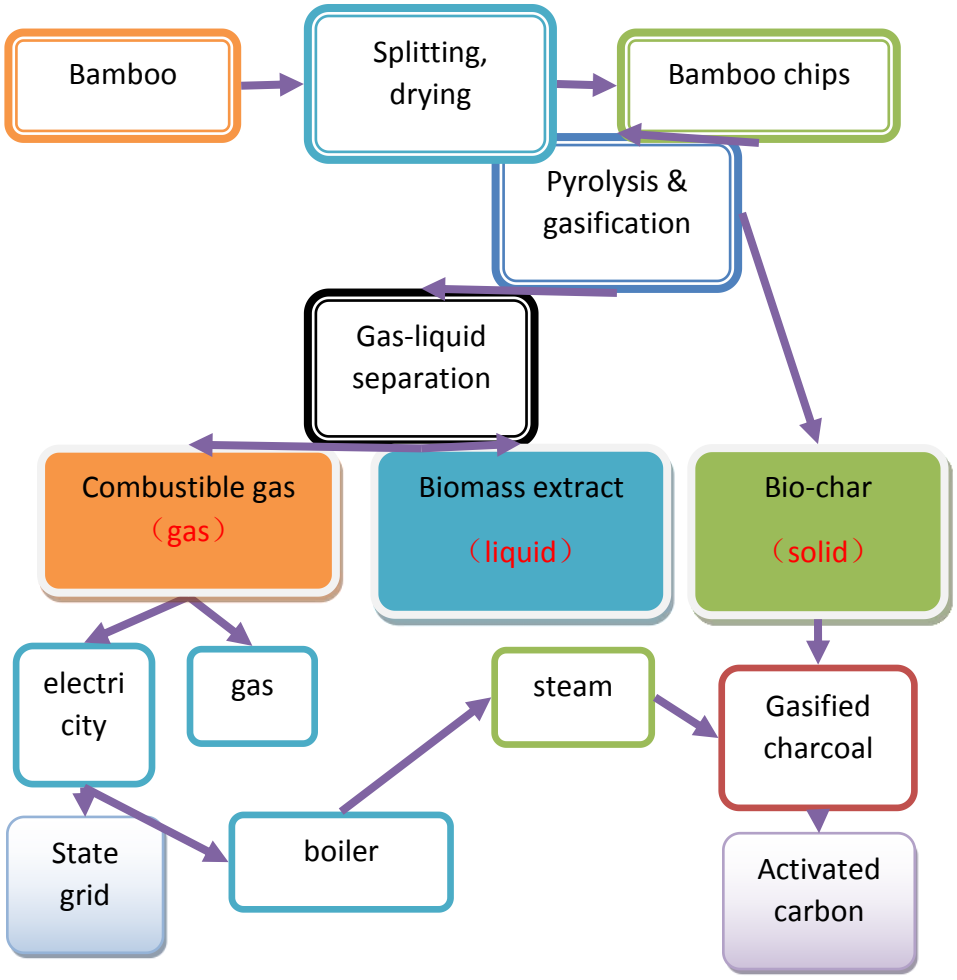

Fig. 29 Process flow of BGPT and its application

3.1.2 Moso bamboo as raw material

Raw material is shown in Fig 30. The moisture content of the whole bamboo culm was 40~50 wt.%. After splitting, the length and width of bamboo chips were roughly 30-40 mm. They were then exposed to sunshine for 2 days until the moisture content decreased to 20~25 wt.%. After pre-treatments such like cutting and drying, bamboo chips (Fig. 31) were ready for gasification experiment. Around 80 tons of bamboo in total were procured.

Fig.30 Bamboo raw material

Fig.31 Bamboo chips after splitting

3.1.3 Gasification equipment and techniques

This bamboo gasification power generation experiment adopted 500 kW updrafting fixed-bed gasification system produced by Debo Co in Hefei, China which included gasifier, purification system (cyclone, spray tower, condenser, dry coke cutting machine and surge drum), internal combustion engine, PLC control system and grid-connected power generation system, as shown in Fig.32

Fig.32 Bamboo gasification power generation system

The process flow is shown in Fig.33

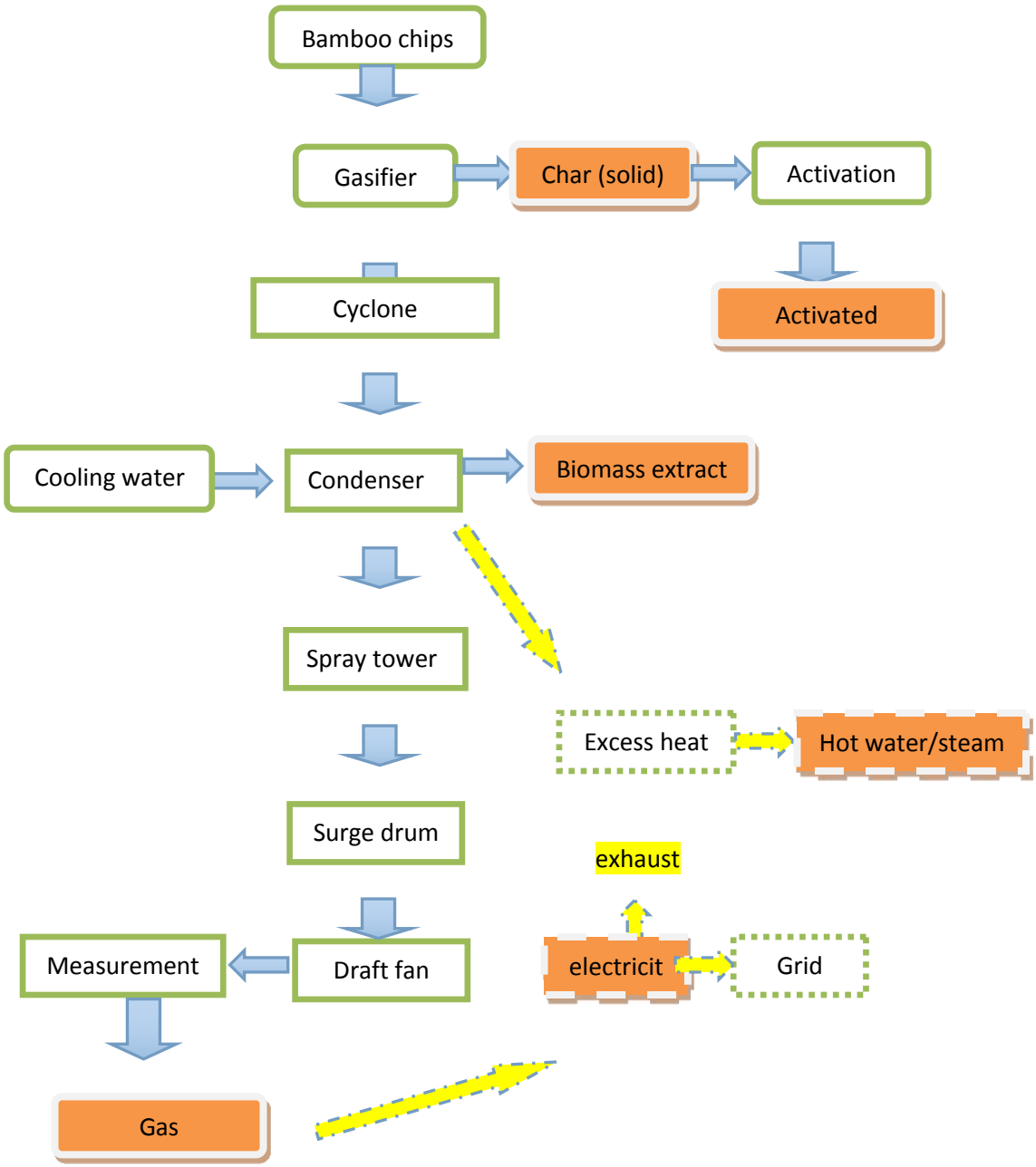

Fig.33 Process flow of bamboo gasification poly-generation experiment

As shown in figure 33, after bamboo chips entered gasifier, they were firstly dried. As the feedstock descended and the temperature increased, it was

pyrolyzed at high temperature and the volatiles were emitted. After pyrolysis, gas and bio-char underwent oxidation reaction with gas media (air, oxygen, steam, etc.) in oxidation zone, which generated heat to maintain the drying, pyrolysis and reduction reactions. The combustible gas from gasification could be used to generate electricity. Meanwhile, the exhausted gas from power generation and the hot water from condensation and purification equipment could be re-used for boiler to supply heat. The process yielded bamboo bio-char, which could be further processed into activated carbon with high added-value. In addition, together with bio-char, biomass extract, as a by-product, could be produced into char-based compound fertilizer. Through biomass gasification poly-generation technology, bamboo willow, as biomass, could be converted into multiple products including bio-char, electricity, heat and fertilizer, hence the green and sustainable utilization.

3.1.4 Analytic instruments and method

Real-time gas analyzer (Fig. 34) determines the composition and calorific value of the gas.

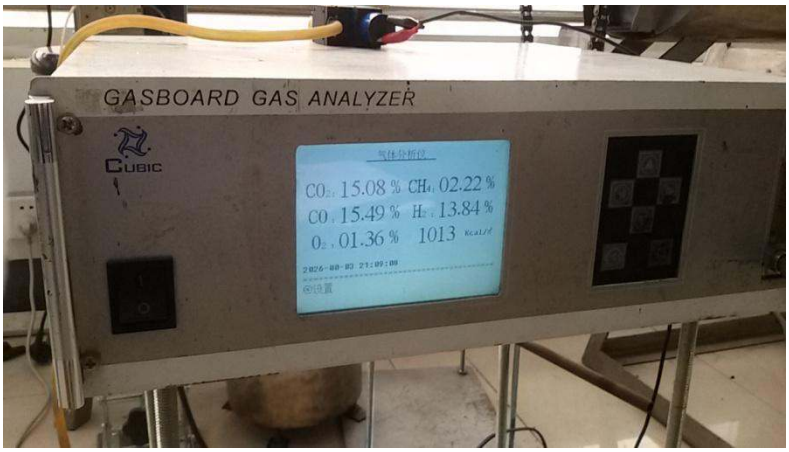

Fig.34 Real-time gas analyzer

Industrial analysis and element analysis on bamboo timber and bamboo bio-char were performed by muffle furnace, element analyzer and calorimeter, as shown in figure 2.6. The industrial analysis of bamboo timber referred to “GB/T 28731-2012 National Standard of Industrial Analysis Method for Solid Biomass Fuel”. The industrial analysis of bamboo bio-char referred to “GB/T17664-1999 National Standard of Experimental Method for Wood Charcoal”.

Fig.35 Muffle furnace, element analyzer and calorimeter

3.1.5 Experiment flow

（1） Raw material pre-treatment: Moso bamboo was procured by Muke Eco-agriculture Co. Ltd. in Jiande, Zhejiang Province, China . Total weight was 80 tons (moisture content 4-~50wt.%). After pre-treatment such like splitting and drying, the moisture content was determined and the industrial analysis was performed.

（2） Gasification process: Firstly, the stability of the gasification equipment, i.e., its ability to operate continuously, was tested. Secondly, electricity generated by

bamboo chips of unit weight and the yield of bamboo bio-char/extract were determined.

（3） Collecting and analysis of the products: At the end of the experiment, solid bio-char, combustible gas and biomass extract were collected. The properties of bio-char were analyzed (industrial analysis, element analysis, calorific value).

3.2 Experimental results

3.2.1 Stability analysis of gasification equipment

The gasification power generation system operated for consecutive 15 days. Backfire did occur in the cylinder of internal combustion engine because of the aged parts of the valve in generator. After replacing the parts of the valve, no equipment failures ever occurred again. The gasifier was absolutely suitable for bamboo chips. The dump grate could continuously and steadily discharge bamboo bio-char. The temperature inside gasifier remained stable during gasification. The gas production and the electricity generation were generally steady.

3.2.2 Gasification data analysis

This experiment totally consumed 36.44 tons bamboo chips, generated 18,492 kWh electricity and produced 4.14 tons bio-char. On average, 0.7 tons raw material was consumed to generate 340 kW electricity per hour. Calculation indicates that every kilogram bamboo chips can generate 0.507 kWh electricity and the yield of bio-char is 11.36%.

3.2.3 Gasification product testing and analysis

Industrial analysis and element analysis of bamboo chips and bamboo bio-char were performed by instruments. The results are shown in Table 7 and 8.

Table 7 Eelement analysis of bamboo timber and bamboo bio-char

Sample	C (wt.%)	H(wt.%)	N(wt.%)	O[a](wt.%)
Bamboo timber	47.66	6.18	0.15	46.01
Bamboo bio-char	88.15	1.77	0.44	9.64

Table 8 industrial analysis and calorific values of bamboo timber and bamboo bio-char

Sample	Volatiles(wt.%)	Fixed char(wt.%)	Ash(wt.%)	Higher calorific value (MJ/Kg)
Bamboo timber	84.26	14.14	1.60	19.29
Bamboo bio-char	6.36	89.08	4.56	31.57

Bamboo bio-char can be processed into bamboo activated carbon with much high-value addtion as shown in Fig.36.

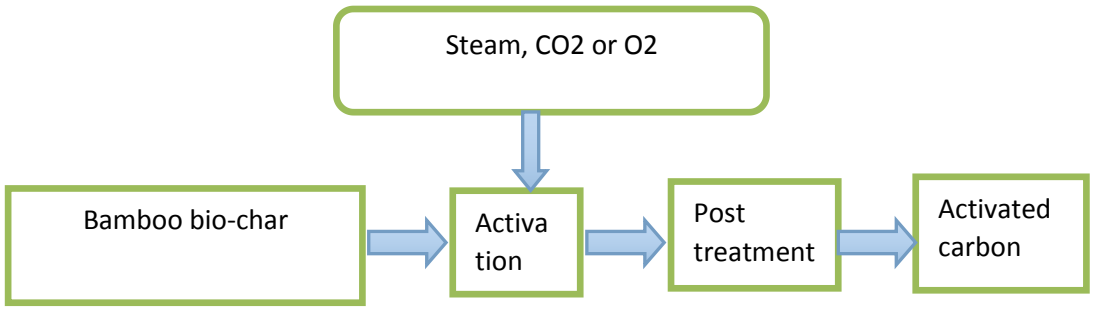

Fig.36 Process flow of physical activation technique to produce activated carbon

In conclusion, bio-char is a pollution-free product that benefits both human and environment.

(1) It helps increase porosity of the soil, reduce bulk density of the soil, improve air and water permeability, enhance maximum water capacity and mitigate soil hardening.

(2) It can supplement the field with essential major elements such like N, P, K, etc. In addition, it adds trace elements such as Si, Ca, Mg, Na, Cu, Fe, Zn, Mn, Mo, etc. so as to improve the production and quality of the crops.

(3) It can restrain phosphorus adsorption to the soil, which helps the release of phosphorus and enhances phosphorus absorption by plants.

(4) It helps rehabilitate the soil contaminated by heavy metals. It boasts strong ability to absorb Cd in the soil.

(5) It maintains sustained-release of fertilizer and pesticide in the soil.

(6) It elevates the water retention capability of the soil.

(7) It helps to stabilize pH value of the soil.

(8) It improves the microbial environment. Bio-char serves as a nice vehicle for micro-bacteria in water treatment and catalytic industry.

(9) It increases soil temperature by 1-3℃, which is beneficial to plant growth. The growth and maturity of the crops can be accelerated (typically 5 days earlier).

(10) Bio-char (with 50%-90% carbon content) can sequester CO2. Every ton of bio-char can sequester more than 2 tons of CO2.

A bio-char experiment in rice shows (1) the rice production was increased by 13%; (2) rice crops were resistant to lodging; (3) the content of heavy metals in rice was reduced by over 50%.

In conclusions, using Moso bamboo as raw material, 500 kW bamboo gasification poly-generation experiment was conducted. The result shows:

(1) Dump-grate updrafting fixed-bed gasifier is suitable for bamboo chips. After replacing parts of the generator, the whole gasification system can operate automatically, continuously and steadily. The solid and liquid products can be easily collected, which achieves the purpose of gasification poly-generation.

(2) Each ton of bamboo chips with moisture content of 20~25% can generate 507 kWh electricity and 113.6 kg bamboo bio-char, whose calorific value is 31.57 MJ/kg.

4.Financial Settlement Sheet as per format of Perez-Guerrero Trust Fund

No.	Description	Expenditure (USD)	
		Perez-Guerrero Fund Input	Chinese in-kind input
1	International Consultant travelling	7000	
2.	Domestic Consultant travelling	3,000	12,000
3.	Subcontract A and B	6,000	43,000
4	Training	2,500	35,000
5	Expendable equipment	1,500	12,000
6	Non-expendable equipment	3,000	6,000
7	Reporting Costs	2,800	
8	Misllaneous Component	3,200	5,000
Sub Total		29,000	113,000
Grand Total		142,000	

Note:

1. The approved grant of Perez-Guerrero Trust Fund is USD 33,000, In-kind support from Chinese side and participating partners is USD 62,000, or the total is USD 99,000.

2. So far, the total expenditure is USD 142,000, in which USD 29,700 from Perez-Guerrero Trust Fund, and USD 113,000 from in-kind support.

3. Remaining USD 4,000 from Perez-Guerrero Trust Fund including unpaid 10 % (or USD 3,300) for report and others.