# Overview of bamboo biomass for energy production

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# OVERVIEW OF BAMBOO BIOMASS FOR ENERGY PRODUCTION

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# SUMMARY OF MAIN FINDINGS


Bamboo biomass energy has great potential to be an alternative for fossil fuel. Bamboo biomass can be processed in various ways (thermal or biochemical conversion) to produce different energy products (charcoal, syngas and biofuels), which can be substitutions for existing fossil fuel products.

Bamboo biomass has both advantages and drawbacks in comparison to other energy sources. It has better fuel characteristics than most biomass feed stocks and suitable for both thermal and biochemical pathways. The drawbacks of bamboo biomass includes establishment, logistic and land occupation. It can also impose negative impacts to environment if not well-managed, therefore, selection of bamboo as an energy dedicated feed stocks need to be evaluate carefully to avoid or minimized any possible risks.

Bamboo biomass alone cannot fulfill all the demand for energy. It needs to combine with other sources to best exploit their potential and provide sustainable energy supply.

Both studies and investment in bamboo plantation for energy purposes are increasing greatly. In Vietnam, energy generation from bamboo is a new concept despite the fact that Vietnam is rank fourth in bamboo production. However, efforts are undergoing to make bamboo biomass energy closer to its potential.



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# INTRODUCTION

Bamboo is a term used to describe a group of large woody grasses (including 1250 species) that normally grow in warm and humid condition. Bamboos are distributed mostly in the tropic, but they can naturally live in subtropical and temperate regions except for Europe.

Bamboo has been planted and used by human for thousands of year for many purposes. Bamboo have strong, light and flexible woody stem which is suitable to use as construction material. Bamboo fibers are used to make paper, textiles and board. In many Asian countries, bamboo shoots of some species as a source of food. In recent years and in the urge of finding alternative energy source to replace fossil fuel, which is running out of stock, a new way of utilizing bamboo has been added to the list. It is the exploitation of bamboo biomass as a source to produce different type of energy, for instance, electricity and biofuels.

This new approach need to be study carefully to utilize bamboo biomass in the most effective way as well as to avoid or minimize any possible risks that can be imposed to the environment and human life. However, the number of studies in bamboo biomass is still limited. In Vietnam, bamboo is very popular for being a source of food and material for housing and furniture therefore, the potential of bamboo mass has not been verified.

Within the scale of this report, bamboo biomass potential will be discuss, particularly in Vietnam context, to provide an overview and to assess the feasibility of planting bamboo for energy production.

# 1. CHARACTERISTICS OF BAMBOO AS A GOOD SOURCE OF BIOMASS

## *1.1. Physiological characteristic*

In taxonomy, bamboo falls to family Poaceae (grass family), subfamily Bambusoideae which contains 1250 species. Despite of being a grass, they still have “woody stem” or culm that can reach 15-20m in height or even 40m with the largest species known (*Dendrocalamus giganteus*). Bamboo is considered to be the fastest growing plant in the planet with the recorded grow speed of 91cm per day (“Fastest growing plant,” n.d.). The harvestable time for bamboo is about 3-5 years in comparison to 10-20 years for most softwood (*Cultivation of Bamboo and its bioenergy production*, n.d.) It also has high biomass productivity, self-regeneration and can tolerate poor soils so that it can grow in degraded land that which makes it one of the best-known biomass resource.

Another physiological feature of bamboo is that most of the species flower very infrequently with intervals as long as 60 to 120 years. Normally, all plants in the population will flower at the same time and after that the plant will die. This phenomenal, called “mass flowering”, has restricted the commercialization of many species. As the consequence of rarely flowering, bamboo plantation are usually established from vegetative material rather than from seedlings.

Bamboo normally grow in warm and humid environment (average annual temperature of 15-20°C and annual precipiation of 1000-1500mm) (Scurlock et al., 2000). Natural and planted bamboo forest can be found in 3 continents including Asia, Africa and South America. Bamboo forest covered more than 36 million hectares worldwide. It is most abundant in the monsoon area of East Asia, especially in India and China with 11.4 million ha and 5.4 million hectares covered, respectively. Over the last 15 years, the bamboo area in Asia has increased by 10 percent, primarily due to large-scale planting of bamboo in China and India (Lobovikov et al., 2007). The inventory of bamboo resource worldwide is illustrated in table 1.

| Continent | Area of bamboo (1000ha) | | | |
|---|---|---|---|---|
| | 1990 | 2000 | 2005 | % of global total (in 2005) |
| **Asia** | 21,230 | 22,499 | 23,620 | 65 |
| **Africa** | 2,758 | 2,758 | 2,758 | 28 |
| **Latin America** | - | 10,399 | 10,399 | 7 |
| **Global total** | 23,988 | 35,656 | 36,777 | |

*Table 1. Area of bamboo forest (Lobovikov et al., 2007, p. 12)*

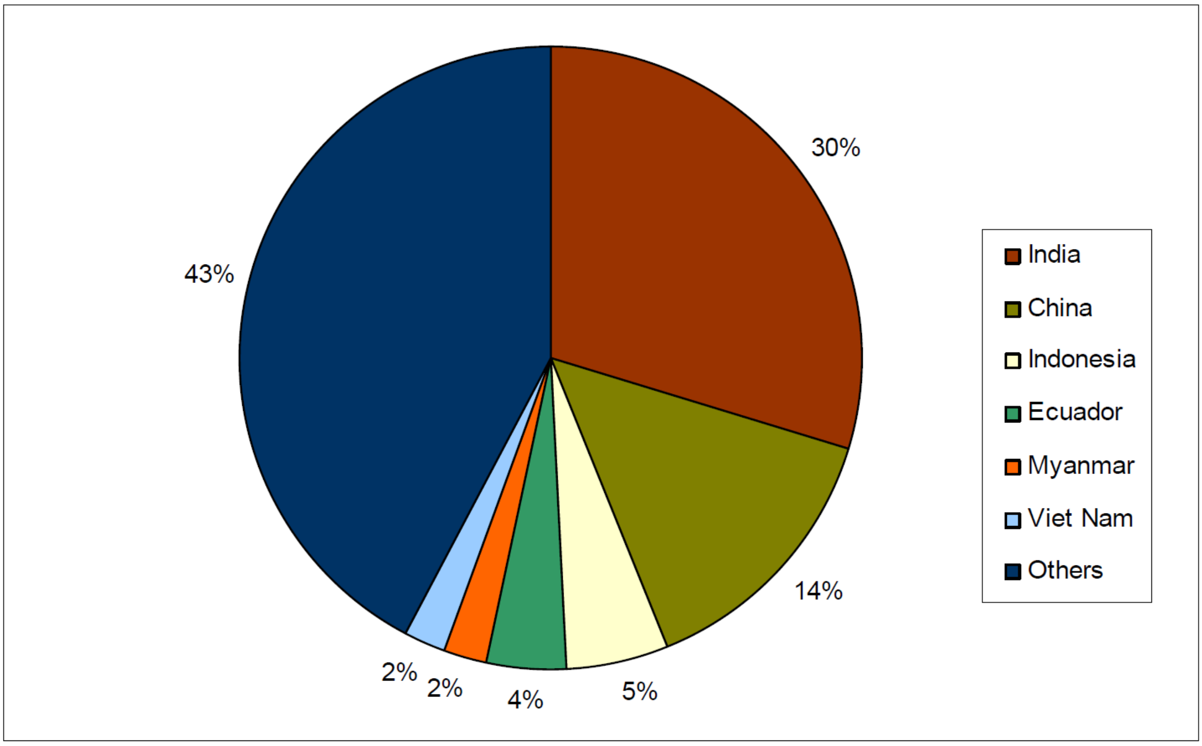


*Figure 1. Countries with the largest bamboo resource (Lobovikov et al., 2007, p. 11)*

### *1.2. Fuel characteristics*

Bamboo has a number of desirable fuel characteristic such as low ash content and alkali index. The high heat value (HHV) of bamboo is higher than most agriculture residue. The moisture content in bamboo is relatively low (8-23%)(Scurlock et al., 2000) in comparison to other type of plant. Comparison of bamboo and other type of biomass will be discussed in section 3.3. Fuel characteristic of some bamboo species are shown in table 2 below.

| Properties |
|---|

| **Bamboo species** | Moisture (%) | Ash (%) | Volatile matter (%) | Fixed carbon (%) | Higher heating value (kJ/kg) |
|---|---|---|---|---|---|
| *Bambusa deecheyama* | 14.30 | 3.70 | 63.10 | 18.90 | 15.700 |
| *Dendrocalamus asper* | 5.80 | 2.70 | 71.70 | 19.80 | 17.585 |
| *Phyllostachys nigra* | 13.62 | 0.41 | 72.27 | 13.7 | 19.27 |
| *Phylotachys bambosoides* | 9.54 | 0.53 | 75.55 | 14.38 | 19.49 |
| *Phyllostachys bissetii* | 21.97 | 0.9 | 64.99 | 12.14 | 19.51 |

*Table 2. Fuel characteristics of some bamboo species(Scurlock et al., 2000; Sritong et al., 2012)*

### *1.3. Productivity*

The productivity of bamboo stands is summarized in the table below. If planted in region with optimal conditions and well-managed, bamboo can reach maximum yeild of nearly 50,000 kg/ha/year.

| **Location (latitude, where available)** | **Mean annual temperature and precipitation** | **Total ANPP (maximum number reported) t ha$^{-1}$ year $^{-1}$** | **Above-ground wood productivity (average reported) t ha$^{-1}$ year$^{-1}$** | **Special stand features (elevation, management) and other remarks** |
|---|---|---|---|---|
| **Southern India (11ºN)** | 31ºC; 600 mm | 47.0 | N/A | Highland (540m) fertilized and irrigated |
| **Central Japan (35º)** | N/A | 24.6 | 15.5 | |
| **Japan** | N/A | 18.1 | N/A | |
| **Georgia, USA (32ºN)** | | N/A | 9.1 | Sustainable yeild |
| **Central Chile (40ºS)** | 4000mm | 10.5 | 6.2 | Mountain (700m) |

| | | | | |
|---|---|---|---|---|
| **Zhejiang, China (30ºN)** | 16ºC; 1800mm | 10.5 | 7.7 | Managed by harvesting |
| **Alabama, USA (32ºN)** | | N/A | 7.4 | Probably fertilized |
| **Thailand (14º)** | 28ºC; 950 mm | 8.1 | N/A | |
| **Northern India (25ºN)** | 26ºC; 830 mm | 7.7 | 2.2 | |
| **Central China (32ºN)** | 1200 mm | 4.5 | 3.1 | Mountain (2750 m) ANPP figure corrected for grazing |

*Table 3. Reported maximum above-ground productivity of bamboo stands(Scurlock et al., 2000) (ANPP= above-ground net primary productivty. All data are reported as overn-dry biomass.*

## 2. METHODS TO PRODUCE ENERGY FROM BAMBOO BIOMASS

There are several ways to recover energy from bamboo biomass, each process results in different products, which can be utilized in many aspects. Energy production from bamboo biomass can be classified into 2 main ways: thermochemical conversion and biochemical conversion. In the former methods, heat is used to transform bio-matters in bamboo biomass (mostly cellulose) into various products. Biochemical conversion involves the action of microorganism to transform biomass to biogas or biofuel. An diagram of bioenergy conversion is provided below.

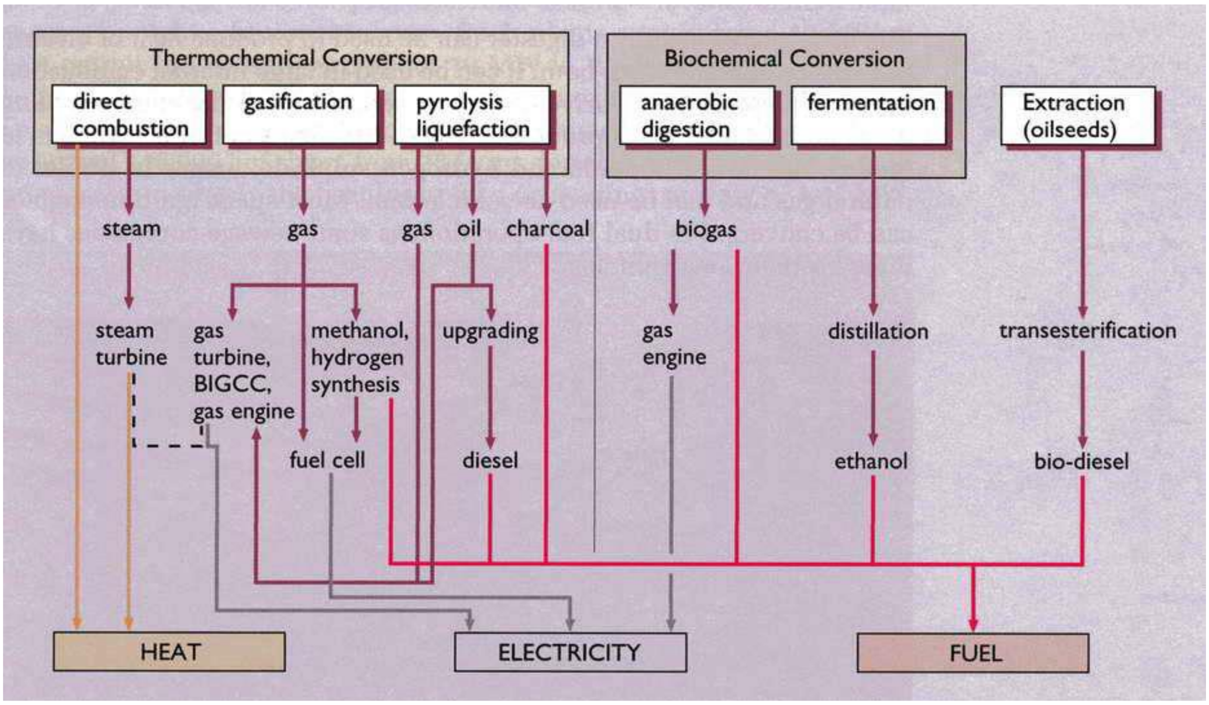


*Figure 2. Main bioenergy conversion routes (Boyle, 2004)*

### *2.1. Direct combustion*

Dry bamboo biomass can be used as firewood to generate heat for cooking, boiling and warming in households. It is a good source of energy for remote area where people cannot access electricity.

Direct combustion of bamboo biomass can also applied in industrial scale, for example, in form of co-generation to produce heat and power in thermal power plant for electricity production or other plants such as cement or steel. The co-generation helps reduce the amount of fossil fuel used in these plants.

The technical principle of combustion is very simple. It consists in burning any fuel composed of carbon and hydrogen atom, under controlled conditions. The product of combustion process is water ($H_2O$) and carbon dioxide ($CO_2$). Combustion usually takes place inside a chamber, followed by a heat exchanger where the hot gas stream transfers its heat to another fluid (water or air). This fluid then can be used for power production through an engine or turbine. When combustion heat water, the heat exchanger is called a boiler. Water boilers are used for large-scale steam generation at medium and high pressure (>20 bar) (Kerlero de Rosbo and de Bussy, 2012).

To achieve good efficiency, combustion control is required to completely burn out of the biomass in order to maximized energy recovered and to avoid  and tars production and emission of non oxidized gases such as carbon monoxide (CO) and volatile organic compounds (VOC) (Kerlero de Rosbo and de Bussy, 2012). Factors that affects biomass combustion process includes air supply, temperature control and biomass quality and distribution.

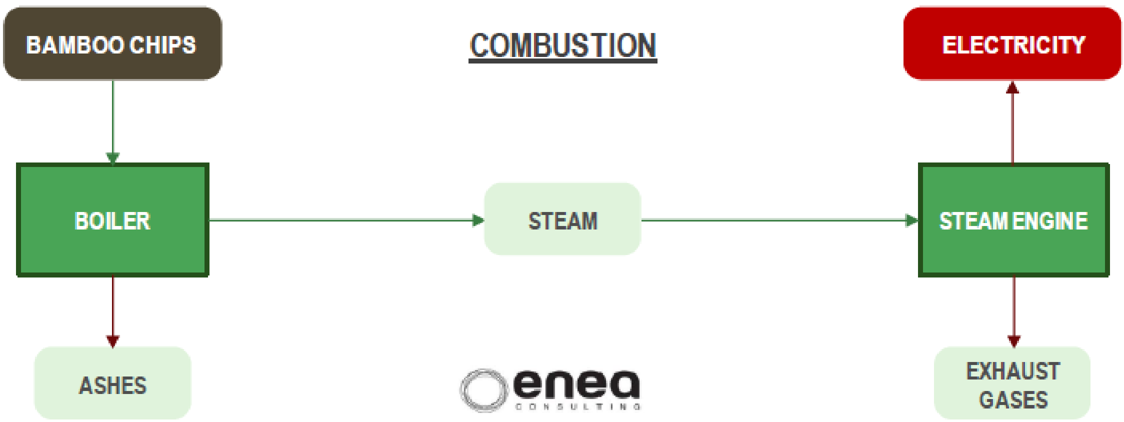


*Figure 3. A diagram of combustion process from bamboo biomass to electricty(Kerlero de Rosbo and de Bussy, 2012)*

### *2.2. Pyrolysis*

Pyrolysis is the thermal ("pyro") degradation ("lysis") of organic materials at a moderate temperature (350 to 600ºC) in the absence of oxygen. The products of pyrolyisis process consist of charcoal (solid phase), condensable pyrolysis oils (heavy aromatic and hydrocarbons) and tars (liquid phase) and con-condensable gases or syngas (gaseous phase). Charcoal can be used as a secondary fuel the same way that coal has been used.

Syngas, consists of carbon monoxide, hydrogen and methane, can be burnt in a boiler for electricity generation or in a gas engine for power production. Pyrolysis oils can be further processed in “bio-refinery”, very similar to the current crude oil refinery process, to produce bio-fuels and other useful chemical products. The principle of pyrolysis is illustrated in Figure.3.

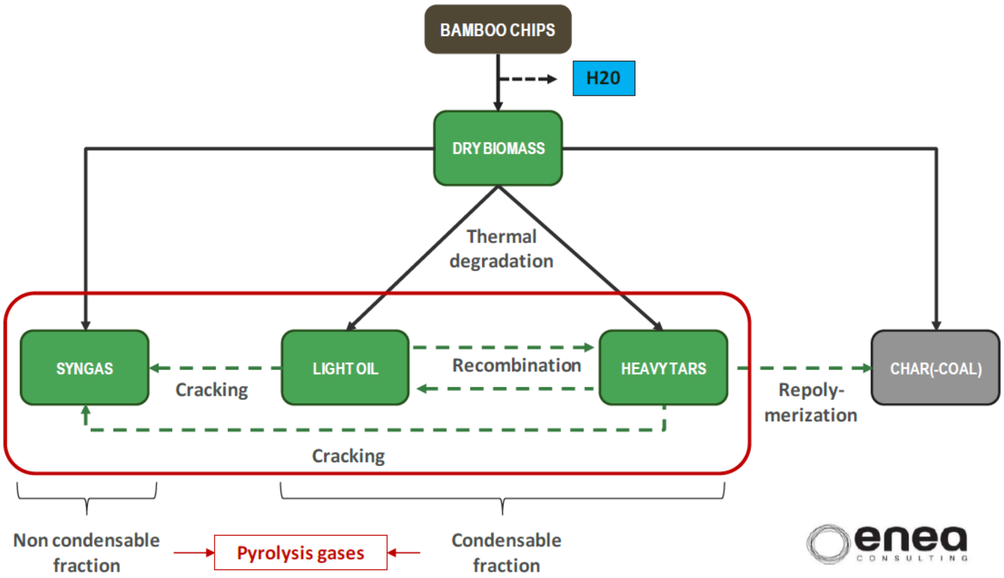


*Figure 4. Pyrolysis reactions and product (Kerlero de Rosbo and de Bussy, 2012)*

The quantities of pyrolysis products are depend on the operating conditions (temperature and residence time). For instance, high temperature (500-600ºC), short residence time, also called flash pyrolysis, will maximized the production of condensable oils. In contrary, low temperature (350-400ºC) and long residence time, called carbonization process, will maximized the production of charcoal and syngas. The typical proportions of product in 2 types of pyrolysis is shown in the table below.

| For ton of dry mater | Flash pyrolysis | Carbonization |
|---|---|---|
| **Gas (kg)** | 110 | 380 |
| **Oil (kg)** | 730 | 190 |
| **Charcoal (kg)** | 160 | 430 |

*Table 4. Pyrolysis types and associated products (Kerlero de Rosbo and de Bussy, 2012)*

### *2.3. Gasification*

Gasification is the production of a gaseous fuel from a solid fuel. It consist a complex thermal and chemical conversion of organic material at high temperature under restricted air supply. Gasification process includes both a pyrolysis step and a partial combustion. It is occur at very high temperature, typically between 750ºC and 1200ºC, with little oxygen.

Products of gasification process include syngas and ash. The syngas is a mixture of combustible gases (carbon monoxide, hydrogen and methane) and incombustible gases (carbon dioxide, nitrogen and other gases). Around 40% of volume of syngas made of combustible gases that can be used for power or heat generation. The heating value of syngas depends on oxygen supply source. If air is used, the produced syngas has a low calorific value (4-7 MJ/m$^3$), however, if oxygen-enriched air is used, the heating value can reach 10-15 MJ/m$^3$. In practice, as the oxygen enrichment process is expensive, air is normally used. (Kerlero de Rosbo and de Bussy, 2012)

| Syngas | CO | $H_2$ | $CH_4$ | $CO_2$ | $N_2$ |
|---|---|---|---|---|---|
| %vol (dry) | 20 | 15-18 | 3 | 10-12 | rest |

*Table 5. Typical composition of syngas (Kerlero de Rosbo and de Bussy, 2012)*

In comparison to combustion, gasification shows lower thermal losses and better energy recovery of the fuel. The theoretical efficiency of fuel conversion by gasification under optimal conditions is 95% mass,dry (Kerlero de Rosbo and de Bussy, 2012). In reality, due -to heat losses and secondary reaction, the efficiency is reduced to 70-80% energy in the biomass recovered in produced gases.

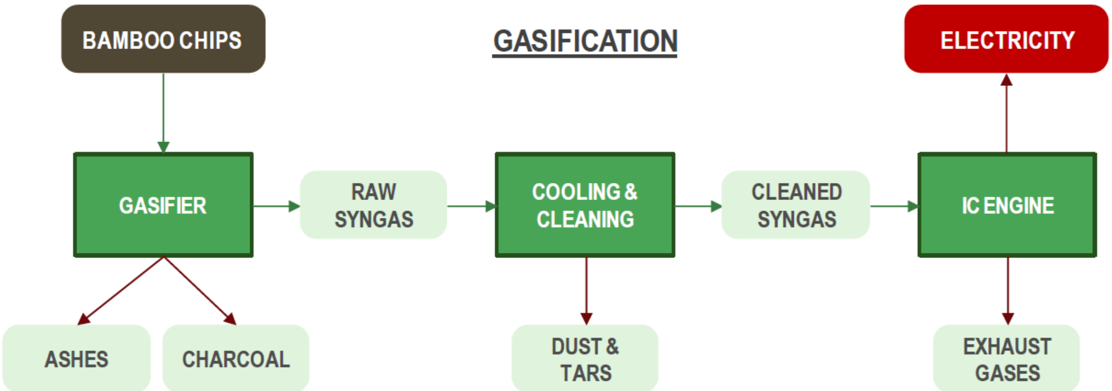


*Figure 5. Gasification general process flow(Kerlero de Rosbo and de Bussy, 2012)*

### *2.4. Biochemical conversion*

In biochemical conversion pathway, different strains of microorganisms are utilized to produce various biofuel products. The basic principle of biochemical conversion is the fermentation of sugar or other substances contained in biomass by microorganism into ethanol, methane and other fuels, chemical and heat. There are two main ways of bioconversion:

- Anaerobic digestion is the biological degradation of organic matters in biomass by microorganisms (anaerobic bacteria) with the absence of oxygen (anaerobic). This process produces biogas (methane) (60%) and $CO_2$ (40%)(Girard, 2013).

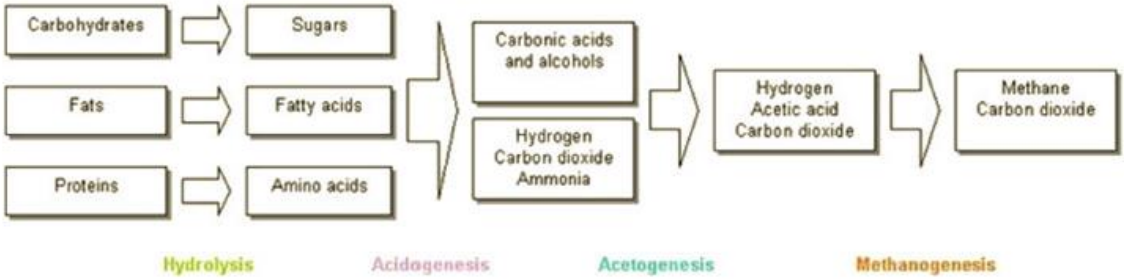


*Figure 6. Anaerobic digestion pathway (Girard, 2013)*

- Fermentation is the decomposition of starch/sugar by microorganisms (yeasts and bacteria) to produce ethanol.

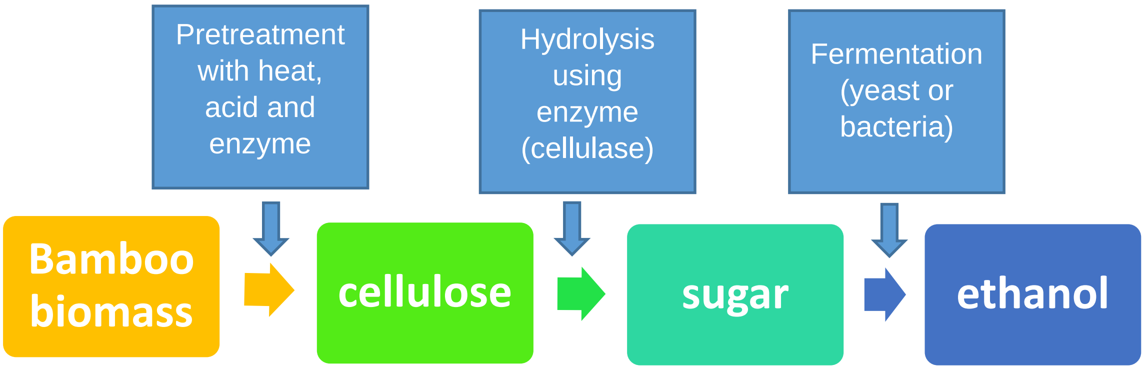


*Figure 7. Simplified process of producing ethanol from bamboo biomass*

## 3. ASSESSMENT OF THE SUITABILITY OF BAMBOO BIOMASS AS A SOURCE OF ENERGY

### *3.1. Compare to traditional fossil fuels*

Traditional fossil fuels, including oil and product from oil refinery, natural gas and coal, are widely used because they have series of characteristic of good fuel such as convinient, producing large amount of energy and very stable. Fossil fuels are considered as a portable form of energy so that they are easy to use, store and transport. They are the concentration form of energy so that they are very combustible and produce a large amount of energy in comparison to other type of fuels such as biofuel or wood fuel. Fossil fuels are the highest producers of calorific value in terms of energy(Kukreja, n.d.).

| Fuel | Lower heating value (MJ/kg) | Higher heating value (MJ/kg) |
|---|---|---|
| **Natural gas** | 47.141 | 52.225 |
| **Gasoline** | 43.448 | 46.536 |

| | | |
|---|---|---|
| **Coal** | 22.732 | 23.968 |
| **Bamboo biomass (*Phyllostachys bissetii)*** | N/A | 19.51 |

*Table 6. Heating value comparison between bamboo biomass and fossil fuel(Boundy et al., 2011; Scurlock et al., 2000)*

Lower heating value and higher water contain means that we need more volume or mass of biomass to produce the same amount of energy. This will also be a constrains in storage and transportation of biomass.

Another point is that the fossil fuel quality extracted from different reserves is quite unified while the biomass and biofuel quality varies substantially. The current engines are designed for fossil fuel consumption only so that the biofuel from biomass does not suitable for these kind of engines. Thus, when we make transition to biofuel, either these engines need to be redesign or biofuel quality need to be improve to meet the standards.

However, there are also a lot of issue regarding to the use of fossil fuel. The two biggest problems associated with producing energy from fossil fuels are resources limitation and pollution. As we all know, fossil fuels are non-renewable sources which means they cannot refill itself and they are running out of stock in an alarming rate. It is estimated that the oil peak (the point when oil production begins to decline) will occur in 40 years, and for coal and natural gas, the estimated peak will be in 220 years and 60 year, respectively (Astier, 2013, p. 10). The shortage of fossil fuels means that their price will rise continuously in the future. The other serious problem is that they release large amount of $CO_2$ – a major greenhouse gas – to the atmosphere, hence, contribute to global warming and climate change. This amount of $CO_2$ has been captured by the ancient plants millions of years ago and now it is added to the atmosphere in a much shorter period. The earth may not be able to respond and to adapt to this huge change promptly so that the environment and all living things, including human, might suffer from it negative consequences.

Because of these issues, people tend to find the alternatives of energy sources to reduce our dependence to fossil fuels and biomass is considered to be a promising replacement. Bamboo biomass (dry form) can combust directly so that it suitable for domestic use such as cooking and warming in remote area and for poor people. It is able to use biomass in co-generation plant to produce electricity. Biomass can go through different processes which produce char (similar to coal), combustible gas and biofuel which has similar characteristics of fossil fuel. In general, biomass is capable of taking over the role of fossil fuel in the future of energy sector.

The two importance advantages of biomass over fossil fuel are sustainability and level of $CO_2$ emission. Bamboo biomass is a renewable source which means it can re-generated in a sustainable rate for extraction. Although the processing of biomass (thermal conversion and biochemical conversion) also release $CO_2$, it does not contribute to the increasing of greenhouse gases concentration in the atmosphere because the $CO_2$ emitted from these process is the very same carbon dioxide in the atmosphere fixed by photosynthesis within the bamboos.

Another aspect need to be discuss is the price. Currently, the electricity price of power plant using fossil fuel is higher than electricity generated from biomass. However, due to fossil fuel shortage, the situation will reverse in the future. When this happen, biomass will be more cost-effective than fossil fuel and the transition will occur naturally.

| **Criteria** | **Fossil fuel** | | **Bamboo biomass** | |
|---|---|---|---|---|
| Availability | + | Extracted directly from existing reserve and use directly after extraction | _ | Have to plant and harvest after a period of 3-4 years |
| Energy produced (per same mass) | + | Much larger | - | Much smaller |
| Logistic (transportation, storage) | + | Easy to transport and store | - | More difficult (need larger space for transportation and storage) |
| Quality | + | Unified | - | Vary |
| Sustainability | - | Non-renewable source | + | Renewable source |
| $CO_2$ emission | - | Increase the concentration of $CO_2$ in the atmosphere | + | Not increase the concentration of $CO_2$ in the atmosphere |

*Table 7. Summarized table of characteristics of fossil fuels and biomass*

### *3.2. Compare to other types of renewable energy*

Beside biomass, other available type of renewable energy sources include hydropower, wind and solar. All of these sources has been recognized by human from the early time to generate power (hydro, wind) and heat (solar and biomass). In current situation of energy demand and usage, the goal of renewable resources development is to replace fossil fuels. Fossil fuels are using to generate heat (in cement or steel plants), power (in combustion engine in industry and vehicles) and electricity. With available technology, hydro, wind and solar can now produce grid connected electricity, however, they cannot compensate for the heat and power provided by fossil fuel. Biomass, on the other hand, can cover all these aspect. It can be use to generate electricity in a thermal power plant and generate heat in related plants or in can be transformed into biofuels to feed combustion engines. The products of biomass conversion process can go through bio-refinery to supply chemicals needed in many other industry that currently provided by oil refinery.

Because of this reason, in this section we only compare biomass with other type of renewable energy on the ability to generate electricity. In the part below, several sustainability criteria will be used to compare different types of renewable energy sources in term of electricity production.

- *Efficiency*

| Technology | Efficiency range |
|---|---|
| ***Photovoltaic*** | *4-22%* |
| ***Wind*** | *23-45%* |
| ***Hydro*** | *>90%* |
| ***Biomass*** | *16-43%* |

*Table 8. Efficiency of different electricity generation technologies(Evans et al., n.d.)*

- *Greenhouse gases emission*

Wind, biomass residue and hydro have very low emissions with average of 25,30 and 41 gCO2e/kWh. Most emissions from wind power are the result of turbine manufacture. Biomass residue emissions are from the collection and transportation of low energy density fuel. For hydro, the dam construction contributes most emissions of greenhouse gases (methane in most cases). Photovoltaics and biomass energy crop (including bamboo biomass) have low to moderate average emission. Similar to wind power, emissions from photovoltaics come from the making of photovoltaic panel. In case of biomass energy crop, emissions are associated with plantation, fertilizers used, collecting and transportation.(Evans et al., n.d.)

- *Water use*

Water use can be divided into 2 types, consumption and withdrawal. Consumption is the water that is evaporated or lost from the system that cannot be return to the source. Withdrawal is the total amount required to operate the technology and includes water available for recycling.

Wind power has negligible water use (1g/kWh) since it does not require water for operation. Photovoltaic also use very little water (10 g/kWh) for cleaning the panel in some cases.

Hydropower has the largest water withdrawal (13,600 kg/kWh) as it needs the water flow to produce electricity. However, this water is then return to the system. The water loss (11kg/kWh) in hydropower is due to evaporation. Biomass residue has large amount of water used (3.2 kg/kWh) but it is still 10 times less than dedicated energy crop (34 kg/kWh) because for crops, they need a lot of water to grow. Therefore, in term of water used, bio-energy crops such as bamboo biomass is the least sustainable.

- *Availability*

Wind and sunlight are available everywhere, however, wind speed and sun radiation is limited by the geological and topological characteristic of a certain site. Therefore, the right amount of wind and sunlight is not available in every places. For example, wind turbines can only operate with the wind speed in the range from 5 m/s to 25m/s.

Hydropower also has limitation as we cannot place as many dam as we want in a river system because this will have great impact to the environment.

Biomass shows the highest availability since we can access biomass sources anywhere in every countries. However, if we look at the particular case of bamboo biomass, it only available in the region that has favorable conditions for the bamboo to grow.

- *Land use*

Land occupation is the area required for a technology to operate. It does not convey the way the land is used and how much damage is done to the site as a consequence of the technology. The land used for different technologies in demonstrated in the table below.

| Technology | Land occupied ($m^2$/kWh) |
|---|---|
| **Photovoltaic** | 0.045 |
| **Wind** | 0.072 |
| **Hydro** | 0.152 |
| **Biomass energy crop** | 0.533 |
| **Biomass residue** | 0.001 |

*Table 9. Land used by different technologies (Evans et al., n.d.)*

According to table 8, biomass residue has negligible land use. Photovoltaic and wind require a significant of land area. However, the use of land for both type is sustainable (does not change the land quality significantly). Moreover, this is the total land use for the whole photovoltaic plant and wind farm. If the photovoltaic panels are mounted in the building and rooftop, this area will be reduced. Same for wind farm, the actual land occupied by wind turbine is only 1-10% of the total area stated in the table. The remaining can be use for grazing, agriculture and recreation. Hydropower land occupation is the second highest due to the reservoir. The land needed for dedicated energy crops is extremely high (4 times of that for hydropower) and the cultivation of these crops also impact the soil quality.

- *Technology limitation*

The intermittent nature of wind and solar radiation is the biggest limitation of these technologies when the electricity generation is injected to the grid.This require storage capability for these system, thus increase the pirce of electricity generated. On the contrary, this is not an issue for hydro and biomass because fuel can be collected and store until there are sufficient amount available to operate without interruption. Therefore, electricity generated from biomass and hydropower plants is much easier to manage and control for grid connected purpose

### *3.3. Compare to other types of other energy crops*

Bamboo biomass has relatively higher heating value than other type of biomass which means it is a good candidate for direct combustion (e.g co-combustion in thermal power plant). The moisture contain of bamboo is similar to rice husk and rice straw but much less than bagasse and corn stalk. The low moisture contain reduce the energy input to dry the biomass, hence, increase the efficiency of utilization. The fuel characteristic of some biomass feedstocks is provided in the table below.

| Type of biomass | Moisture % | Ash % | Volatile matter % | Fixed carbon % | Higher heating value kJ/kg |
|---|---|---|---|---|---|
| **Rice husk** | 12.05 | 12.73 | 56.98 | 18.88 | 14.638 |
| **Rice straw** | 10.12 | 10.42 | 60.87 | 18.80 | 13.275 |
| **Bagasse** | 50.76 | 1.75 | 41.99 | 5.86 | 9.664 |
| **Palm shell** | 12.12 | 3.66 | 68.31 | 16.30 | 18.446 |
| **Corncob** | 40.11 | 0.95 | 45.55 | 13.68 | 11.198 |
| **Corn stalk** | 41.69 | 3.80 | 46.98 | 8.14 | 11.634 |
| **Bamboo (*Bambusa Deecheyama*)** | 14.30 | 3.70 | 63.10 | 18.90 | 15.700 |
| **Bamboo (*Dendrocalamus asper*)** | 5.80 | 2.70 | 71.70 | 19.80 | 17.585 |

*Table 10. Properties of some common biomass feedstocks (Sritong et al., 2012)*

However, using bamboo as a dedicated energy crop for large scale biomass production will have some drawbacks compare to other energy crop (Poppens et al., 2013) such as:

- It is difficult to mechanize harvesting bamboo because only mature shoots should be harvested selectively.
- Non-energy applications in most cases have a more extractive market
- Bamboo has to be established vegetative rather from seeds, making large plantings relatively expensive
- It takes several years before a stand can start producing.
- Quality for thermal conversion is lower than for wood.

*Conclusion*

Bamboo biomass has both advantages and drawback in comparison to other type of energy source. It is hard to evaluate the suitability of bamboo biomass in energy sector in general. Instead, we should put it in context to assess whether to choose bamboo to be planted and use as a sustainable energy source.

### 3.4. Potential risks of using bamboo biomass

#### *3.4.1. Environmental and ecological risks*

Dr Jun Borras, associate professor of rural development studies at the International Institute of Social Studies, the Hague, adds that the large-scale farming of any single crop will necessarily bring negative consequences (Rees, 2011). This is also true for the case of bamboo plantation for biomass. Demand for bamboo biomass may lead to mass conversion of natural forest into bamboo monoculture forest which might lead to biodiversity loss (Poppens et al., 2013). Another concern is that bamboo plantation can compete with food crops for land. Although bamboo can tolerate poor nutrition soil, no guarantee can be given that the blooming of bamboo plantation will not take over the fertilized land used to grow food crops. Further more, if bamboo species is imported for plantation, there will be a risk of invasion of new species (Schill, n.d.).

#### *3.4.2. Economical risk*

There are risks associated with forest investment and the most important risks for bamboo plantation are poor growth, biological, physical and management risks (Ongugo et al., 2012).

Poor climate conditions could affect the bamboo growth and delay harvesting. This could be due to poor fertility and poor establishment methods or poor protection and care. Bamboo plantation also vulnerable from pests and diseases. The physical risks include fire and drought.

The potential risks can affect the productivity of bamboo and thus affect the investment return of a bamboo plantation projects. Also, the bamboo selection together with biomass quality will have impacts to the efficiency of energy conversion from bamboo biomass.

## 4. CURRENT SITUATION OF BAMBOO BIOMASS FOR ENERGY

### 4.1. Bamboo biomass energy in international context

Recently, bamboo has emerged as a new source of biomass for energy production. Many studies and research has been conducted to evaluate the suitability of bamboo as a source of energy. Studies has been carried out in many countries (mostly where bamboo are abundant such as China, India, Indonesia and Thailand). Many studies refered to bamboo as a competent alternative for biomass resource. However, research on bamboo potential at country level is not adequate in some countries which has substantial bamboo resources such as Vietnam and Thailand. However, attention to bamboo is these countries are being raised and more and more studies are being conducted and more project on bamboo will be invested.

Many projects on bamboo energy are operating or implementing all over the world. In Africa, bamboo biomass projects are mostly used to replace firewood or produce charcoal for domestic use. For instance, a four-year project “Bamboo as sustainable biomass energy” is carried out in Ethopia and Ghana to provide bamboo charcoal for local people to fulfill energy demands in sustainable way and generate income as well as to takes pressure off other forest resource.The project is implemented by International Network for Bamboo and Rattan (INBAR) and funded by European Commisison.

India has the largest bamboo forest area, therefore, bamboo biomass projects are developing fast in this country. Here, bamboo is not only used in direct combustion way, instead, the technologies applied to convert bamboo biomass are quite diverse and advanced in comparison to the projects in Africa. Bamboo biomass is used for co-generation to produce electricity or go through gasification and pyrolysis process.

These studies together with implementing projects will provide us a clearer look to the future of bamboo biomass as a sustainable energy source.

### ***4.2. Bamboo biomass energy in Vietnam***

#### *4.2.1. Bamboo biomass potential in Vietnam*

In Vietnam, bamboo has been used mainly for housing materials, handcraft production and food at village level for local market and floor production at an industrial scale for export markets.Bamboo is among the 10 fastest growing sectors for export according to Vietnam Trade Promotion Agency.

The estimated cultivation area of bamboo in Vietnam is 800,000 hectares of plantation with an average annual yield of 10 to 13 ton per hectares and 600,000 hectares of mixed forest, comprised of up to 70% of bamboo.(Heinze and Zwebe, 2012)

In Southern Vietnam, bamboo is concentrated in Lam Dong province which contains 6.2% of bamboo plantations and 16% of mixed bamboo forest. In Northern of Vietnam, bamboo production is concentrated in the four north-eastern provinces of Tuyen Quang, Son La, Bac Kan and Yen Bai. These five provinces contribute 7% of bamboo plantation and 43% of mixed forest. (Heinze and Zwebe, 2012)

#### *4.2.2. Bamboo biomass in national plan and current situation of bamboo biomass in energy production*

The current policies framework of Vietnam not yet include the regulation for bamboo biomass for energy production. However, separated plans for development of biomass energy and bamboo plantations in Vietnam has been issued. Decision no./11/2011/QD-TTg dated 18th February 2011 of the Prime Minister on Incentive policies for development of rattan sector stipulated the investment incentive in taxes, financial support, land lease and so on for entities who invested in rattan plantation and production. In Decision no.177/2007/QD-TTg dated 20/11/2007 of the Prime Minister on Bio-energy development study report for period up to 2015, outlook to 2025 the objectives and target for bio-energy has been established as per following:

- 2010: development of models for experimenting and using of bio-energy, meeting 0.4% gasoline and oil demand of the country
- 2015: production of ethanol and vegetable oil is 250,000 tons, meeting 1% of gasoline and oil demand of the country
- 2025: production of ethanol and vegetable oils is 1.8 million tons, meeting 5% of gasoline and oil demand of the country

Bio-energy from bamboo is a new concept and has not attracted attention from the government as well as from private sector. Currently, biomass for energy production are mostly municipal waste and animal waste biogas, ethanol production from cassava and molasses and co-generation of bagasse.

Vietnam already has 6 bio-ethanol plants run on cassava, however, the operation of these plants is facing with great difficulty in term of financial and cash flow. At the time of investment of these plant, the national policies stated that by June 2012, it is mandatory to use E5 gasoline (gasoline contain 5% of ethanol) for vehicles nationwide. In fact, this regulation has not been implemented yet and there is no timeline for this regulation to take effects in practice. This constrain make it impossible for bio-ethanol from bamboo to be invested in the current context of Vietnam.

Nevertheless, the market is still open for bamboo biomass, for example, using bamboo biomass in co-generation plant to reduce the amount of fossil fuel used and the commercialization of products from bamboo biomass thermal conversion process (charcoal, syngas and oil). These thermal pathway is suitable for biomass that rich in cellulose therefore it less suitable for agricultural residue (such as rice husk or straw) and municipal solid waste. Hard wood is not as efficiency as bamboo because the harvestable time is much longer. Thus, bamboo is the best candidate to produce biomass for gasification and pyrolysis process.

### *4.2.3. Existing projects*

As mentioned in section 6.1, Lam Dong province has the most potential in bamboo biomass. In fact, this province is known as one of the pioneer province who launch "pilot projects of plantation, management and protection of *Thyrsostachys siamensis* bamboo and *Dendrocalamus* bamboo". Therefore, a project called "Bio-energy source from sustainable bamboo" has been proposed to implement in Lam Dong.

The project is hosted by Biocandeo Company (Netherlands), Bamboo Matter Co., Ltd and International University-Vietnam National University (IU-VNU).

After surveying the situation of bamboo resources in the province, the proposed project area in 3 districts of Bam Lam, Di Linh and Dam Rong has about 20,000 hectares of mixed and pure bamboo forest. The aim of the project is to generate bioenergy from sustainable bamboo from these forest area so that it will create the economic value of local bamboo and help protect and improve natural forest area and increase income for poor people living near the forest. The biomass from bamboo will be used to produce sustainable biofuels with the potential to export through the support of the Council Certified Forest Management (FSC). (*Bioenergy source from sustainable bamboo*, n.d.) The project has 5 phases:

- Phase 1: Complete feasibility study on the project
- Phase 2: Training and providing protection system to manage bamboo with at least 5 training field staffs and five demonstration pilot sites. Training at least 500 farmers/workers for the management of projects and harvesting. Establishment of collection system.
- Phase 3: Get forest certification
- Phase 4: Start the production of biomass. The proposed project will produce at least 10,000 tons of bamboo biomass. Biofuels will be produced and marketed internationally.
- Phase 5: preparing for next steps: complete assessment report and publication of the project study for the community, local government agencies as a basis for forest owners to expand the business in the context of regional resources and the relative status of bamboo forest application.

The estimated time to complete the phase of project study is 3 years, 20 years following the period of sustainable development. Currently, the first research of phase 1 “Nutrient partitioning, fuel properties and biomass estimation of Bambusa procera (Lo O) in natural stand” has been completed.

# CONCLUSION

Bamboo has been planted and used by human for very long times. However, utilization of bamboo biomass for energy generation purposes is a relatively new approach. Recently, bamboo receive a lot attention as being a competitive bio-energy crops. Although many people consider bamboo as a “green gold”, concerns have been raised mostly in sustainable and environmental aspects.

In theory, bamboo biomass can replace fossil fuel since it is a renewable resources and can be processed to make different kinds of fuels (solid, liquid and gaseous fuels). Various technologies can be applied to transform bamboo biomass into other form of energy including thermal conversion (direct combustion, gasification and pyrolysis) and biochemical conversion. The products of these processes which can be commercialized are charcoal, syngas, oil and ethanol.

Bamboo biomass has both advantages and disadvantage in comparison to other renewable resources as well as other biomass feed stocks. Compare to new renewable technology such as wind and photovoltaics, its strength point is that beside of electricity generation, bamboo biomass can produce other energy products (bio-fuel). Moreover, electricity generation from bamboo biomass plant is easier to be injected to the grid. The drawbacks of bamboo biomass is land occupation and water use.

Compare to most energy crops, bamboo biomass has better fuel characteristics. It can grow in degraded land so that it require less care and less compete with food crops for land. However, bamboo takes time to mature and is hard to harvest. The plantation of bamboo is also more expensive because it established vegetatively instead of seed.

Just like other energy dedicated crops, plantation of bamboo also projects some environmental risks including biodiversity decrease, species invasion and land competition with food crops.

To obtain sustainability in bamboo plantation for energy purpose, evaluation should be made carefully based on actual situations. It is also a good approach to combine various type of renewable resources to fulfill energy demand rather than depending solely on some certain sources.

In many countries, a number of bamboo biomass energy projects are being implemented, ranging from domestic use to industrial scale. Vietnam has a great potential of bamboo biomass. However, the use of bamboo in term of energy production are still in initial stage. It require more studies to assess the ability and the sustainable way to utilize this potential resource.

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