# The Present State, Potential and Future of Electrical Power Generation from Biomass Residues in Vietnam

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**ABSTRACT**

Process heat and electrical power for the rural area in Vietnam is in the state of serious deficiency. In fact, for Vietnamese rural area, electric energy has not been being well-supplied, but it profits by a high potential of renewable energy from biomass, such as crop, wood, livestock waste, etc. Especially, the source of wasted biomass from the agricultural residues is very abundant. However, at the present, only a low amount of the available biomasses is used for households' cooking, animal feed or manure; while the most biomass are disposed of into lakes, ponds and rivers, leading to environmental pollution and waste of fuel resource. This article describes the present state and potential of biomass residues in Vietnam and introduces the state-of-the-art of combustion technology in the world. It can be shown that Fluidized Bed Combustion (FBC) technique would be mostly favourable to produce the heat/power resource from biomass residues in the future.

**Keywords:** Biomass residues, potential, heat, power, fluidized bed combustion

## 1. INTRODUCTION

Vietnam, one of the developing countries in South East Asia, with the area of 329,247 $km^2$ has approximately 35% the natural forest and 28.5% the cultivation area which mainly locates in the Red River Delta in the North and in the Mekong River Delta in the South (GSO, 2003). Vietnam has a low power consumption level, approximately 210 kg of oil equivalent per capita/year (EVN, 2003; Nguyen and Tran, 2004). In the developing period of 1995 to 2000, power consumption was remarkably boosted with an average of 15% per year (Nguyen and Tran, 2004), and up to 17% per year in the recent years. The increment was, partially, due to developing rate of industrial (19.5%), service (18.5%) zones, and household usage demand of 14.2% per year. As described in Nguyen and Tran (2004) and EVN (2003), large part of energy power consumption is derived from residential population (47%) and both industrial production and construction field (42.3%) (Fig.1). Correspondently, electricity consumption, for an instance of 2002, requires several power plants with about more than 8,860 MWh (Megawatt-hour), in which there were about 51% from hydro-electricity plant, 27% from gas turbines and diesels engines, 17% from steam condensing turbines, and 5% from the other fuel sources. Following it, electrical requirements are predictable to be up to 89-93 TWh (Terawatt-hour) in 2010 and 160-200 TWh in 2020 (Nguyen and Tran, 2004; EVN, 2003; and ReiA, 2005).

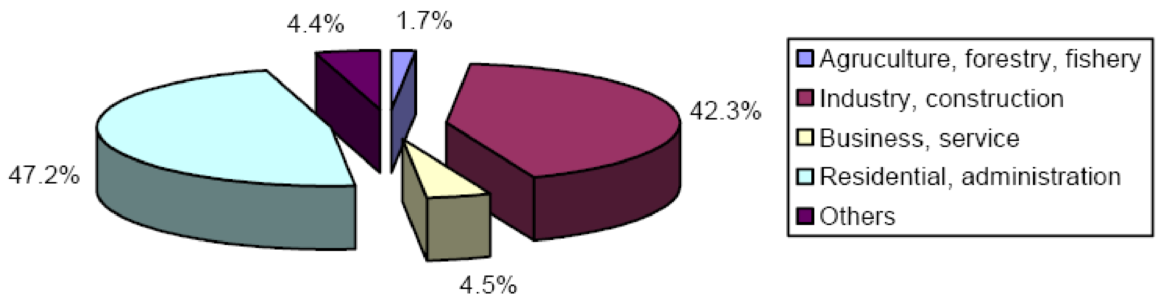


Figure 1. Percent electricity consumption in other fields for Vietnam in 2002 (Nguyen and Tran, 2004)

At present, traditional fuel sources such as coal, petroleum, natural gas, etc. are used for electricity production at most of power plants. This causes environmental pollution, exhaustion of unrenewable fuel sources, and fluctuation of fuel prices. Therefore, it is suggested that power stations using other sustainable fuel sources should be built in the future. In this regard, biomass which can be applied in heat and power production is considered for its cheap, available, controllable and stable material resources.

## 2. POTENTIAL OF BIOMASS FOR ENERGY GENERATION IN VIETNAM

In Vietnam, as in almost all other South East Asia countries, biomass energy plays an important role in its national energy balance (ReiA, 2005). Biomass provides 60-65% of the total primary consumed energy (ReiA, 2005; Nguyen, 2005 and Nguyen and Tran, 2004). The largest part of biomass energy is used for the need of household energy in rural area (75% of Vietnamese population), whereas just only 60% of such population benefits by the power network (Nguyen, 2006; Pham, 2005 and Pham and Thang, 2003). Biomass resources include wood residues, municipal wastages, crop residues, and livestock wastages (Fig. 2) (Nguyen, 2005); most of them are from crop residues (agricultural residues) such as paddy straw, rice husk, maize husk, bagasse, coconuts shells, firewood, etc. (Fig. 3 and Table 1), (Tung, Steinbrecht and Vincent, 2009; ReiA, 2005).

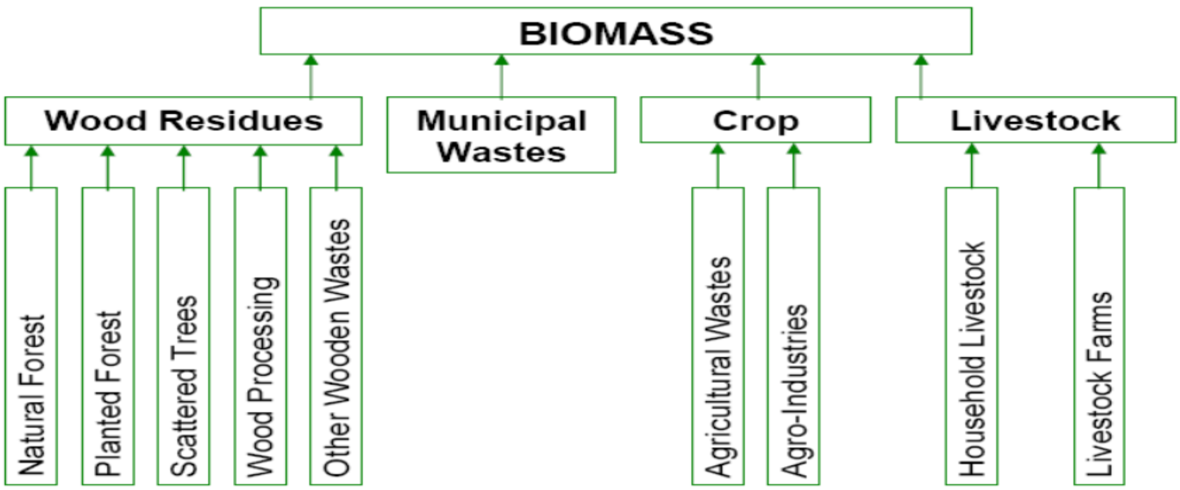


Figure 2. Major Biomass Sources in Vietnam (Nguyen, 2005)

The amounts of biomass sources are summarized in Table 1; and parts of energy in biomass sources are presented in Fig. 3 (Nguyen and Tran, 2004).

Table 1. Availability of major biomass sources in Vietnam (2002) (Nguyen and Tran, 2004)

| No. | Agro-Industries residues | Amount ($10^6$ ton/year) | Primary Energy Content ($10^3$ GJ) |
|---|---|---|---|
| | Wood residues and fire wood | | |
| 1 | Saw dust | 0.3 | 3.1 |
| 2 | Wood chip | 1.3 | 20.0 |
| 3 | Firewood | 12.4 | 186.0 |
| | **sum** | **14** | **209.1** |
| | Crop residues | | |
| 4 | Paddy straw | 64.7 | 905.8 |
| 5 | Rice husk | 6.8 | 77.6 |
| 6 | Maize husk | 5.8 | 72.5 |
| 7 | Bagasse | 5.5 | 39.7 |
| 8 | Coconut shell | 5.0 | 90.0 |
| 9 | Cane trash | 1.7 | 21.0 |
| 10 | Cassava stem | 1.3 | 15.6 |
| 11 | Coffee husk | 0.3 | 4.4 |
| 12 | Peanut shell | 0.1 | 1.5 |
| | **sum** | **91.2** | **1228.1** |

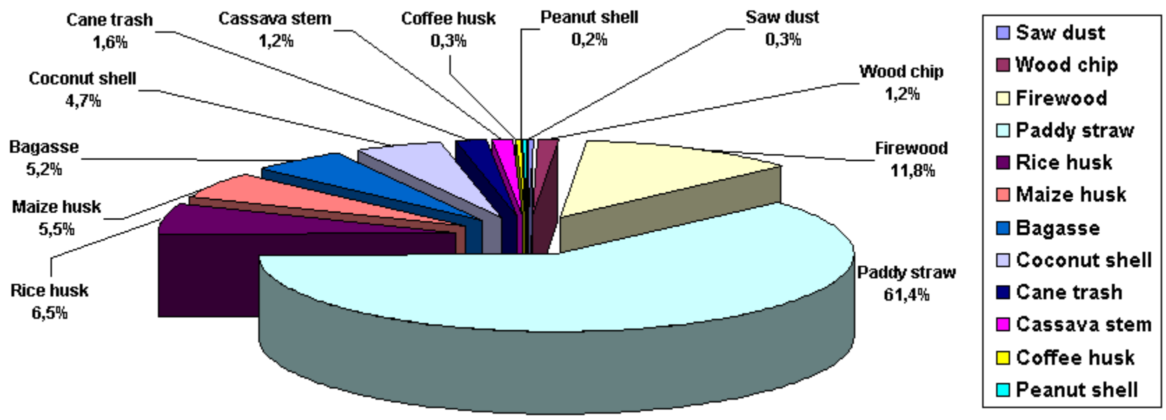


Figure 3. Parts of biomass energy content in main biomass residues in Vietnam (Nguyen and Tran, 2004)

Table 2 summarizes the amount of those biogas sources, which is $1540 \times 10^6$ m³. In Fig. 4, the distribution of energy in biogas sources is demonstrated (Nguyen and Tran, 2004).

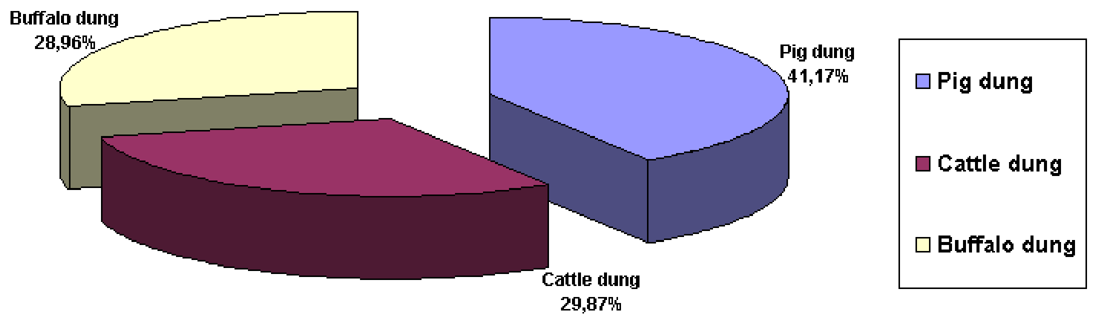


Figure 4. Parts of biogas energy content in main biomass residues in Vietnam

Table 2. Availability of major biogas sources in Vietnam (2002) (Nguyen and Tran, 2004)

| No. | Agro-Residues | Amount ($10^6$ m³) | Primary Energy Content ($10^6$ GJ) |
|---|---|---|---|
| | | Biogas from livestock manure | |
| 1 | Pig dung | 634.0 | 12.7 |
| 2 | Cattle dung | 460.0 | 9.2 |
| 3 | Buffalo dung | 446.0 | 8.9 |
| | **sum** | **1540.0** | **30.8** |

In conclusion, the contribution of biomass and biogas in the entire energy supply in Vietnam does not correspond to its actual potential.

## 3. EQUIPMENTS AND TECHNIQUE FOR ENERGETIC USE OF BIOMASS

Biomass combustion is mainly used for heat production in small and medium scale units such as wood stoves, log wood boilers, pellet burners, and straw fired furnaces. According to (Nussbaumer, 1999 and Nussbaumer, 2003), the heat used in their processing systems is often in the range of 0.1-0.5 $MW_{th}$. The combined heat and power (CHP) production with biomass is applied by steam cycles (i.e. Rankine cycle), or Organic Rankine Cycle (ORC) for the typical power outputs in between 0.5 and 10 $MW_{el}$.

Table 3 gives an overview of the most furnace types used for biomass combustion.

Table 3. Types of biomass furnaces with typical applications and fuels(*) (Nussbaumer, 2003)

| Application | Type | Typical size range ($MW_{th}$) | Fuels | Ash content (%) | Water content (%) |
|---|---|---|---|---|---|
| | Wood stoves | 0.002- 0.01 | Dry wood logs | < 2 | 5 - 20 |
| manual | Log wood boilers | 0.005 - 0.05 | Log wood, sticky wood residues | < 2 | 5 - 30 |
| | Pellet stoves and boilers | 0.002 - 0.025 | Wood pellets | < 2 | 8 - 10 |
| | Understoker furnaces | 0.02 - 2.5 | Wood chips, wood residues | < 2 | 5 - 50 |
| | Moving grate furnaces | 0.15 - 15 | All wood fuels and most biomass | < 50 | 5 - 60 |
| | Pre-oven with grate | 0.02 - 1.5 | Dry wood-residues | < 5 | 5 - 35 |
| | Under-stoker with rotating grate | 2 - 5 | Wood chips, high water content | < 50 | 40 - 65 |
| briquettes | Cigar burner | 3 - 5 | Straw bales, grass | < 5 | 20 |
| automatic | Whole bale furnaces | 3 - 5 | Whole bales | < 5 | 20 |
| | Straw furnaces | 0.1 - 5 | Straw bales with bale cutter | < 5 | 20 |
| | Stationary fluidized bed | 5 - 15 | Various biomass, d < 10mm | < 50 | 5 - 60 |
| | Circulating fluidized bed | 15 - 100 | Various biomass, d < 10mm | < 50 | 5 - 60 |
| | Dust combustor, entrained flow | 5 - 10 | Various biomass, d < 5mm | < 5 | < 20 |
| Co-firing | Stationary fluidized bed | 5 - 50 | Various biomass, d < 10mm | < 50 | 5 - 60 |

| | | | | | |
|---|---|---|---|---|---|
| e.g. with coal | Circulating fluidized bed | 100 - 300 | Various biomass, d < 10mm | < 50 | 5 - 60 |
| | Cigar burner | 5 - 20 | Straw bales | < 5 | 20 |
| | Dust combustor in coal boilers | 100 -1000 | Various biomass, d < 2 - 5mm | < 5 | < 20 |

(*)- Totally from Nussbaumer (2003); d- diameter

To achieve the complete burnout and high efficiencies in small scale combustion, downdraft boilers with inverse flow have been introduced, which applies the two-stage combustion principle described in Fig. 5. An operation of log wood furnaces which takes a very low load is not encouraged since it can lead to a high emission of unburnt pollutants.

According to (Nussbaumer, 1999, and Nussbaumer, 2003), wood boilers are recommended to be used with heat storage tank. Since wood pellets are well suited for automatic heating due to the small heat outputs, it is nowadays necessary to build and extend the pellet furnaces. Furthermore, pellet furnaces can easily achieve high combustion quality for well-defined fuel with low water content. Thus, they can be applied for both stoves and boilers (Nussbaumer, 2003).

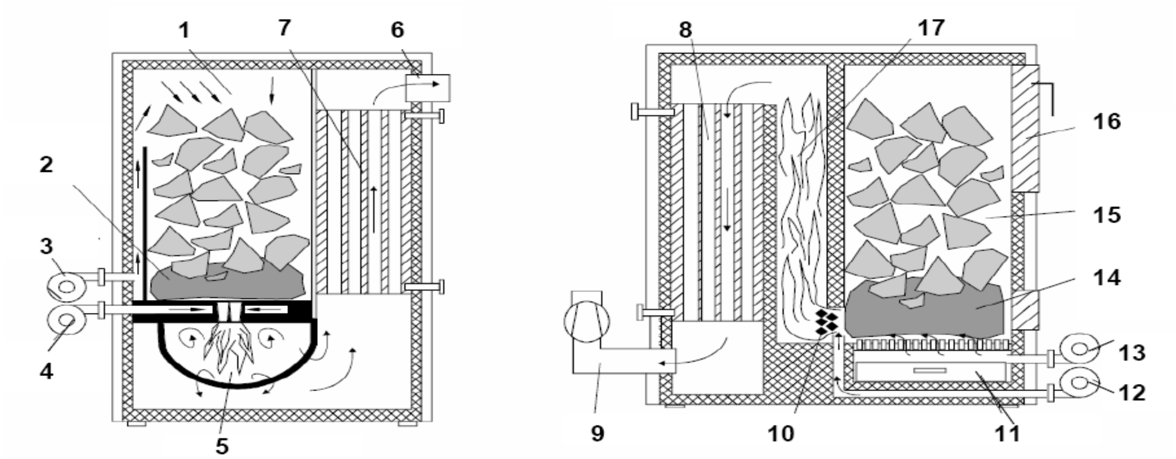


Figure 5. Downdraft boilers with inverse firing of chip wood (left) and side under firing (right), according to Nussbaumer (2003), and Hartmann et al. (2007)
1, 15- hopper; 2, 14- firebed with gasification area; 3, 13- primary air supply; 4, 12- secondary air supply; 5, 17- after-firing chamber; 6- flue outlet; 7, 8- heat exchanger; 9- induced draught fan; 10- turbulent-channel; 11- ash box; 16- filling-door

Special types of furnaces have been developed for the straw storing in bales and having very low density. Besides, conventional grate furnaces operated with whole bales, cigar burners and other specific furnaces are also in operation (Nussbaumer, 2003), and (Scholz et al., 1997) (Fig. 6). **F**luidized **b**ed **c**ombustion (FBC) in its various forms offers a technology that can be designed to burn a variety of fuels efficiently and in an environmentally acceptable manner for a variety of applications. There are two main derivatives of the technology namely **s**tationary **f**luidized **b**ed **c**ombustion (SFBC) or **b**ubbling **f**luidized **b**ed **c**ombustion (BFBC) and **c**irculating **f**luidized **b**ed **c**ombustion (CFBC). Both of them can operate either in atmospheric or in pressurized condition (Minchener, 2003). These are often used for wastage biomass or mixtures of biomass and industrial wastage (Nussbaumer, 2003) e.g., the agricultural wastages after harvesting, agro-industries' residues after processing, and the pulp from paper industry (Fig. 7), (Fig. 8).

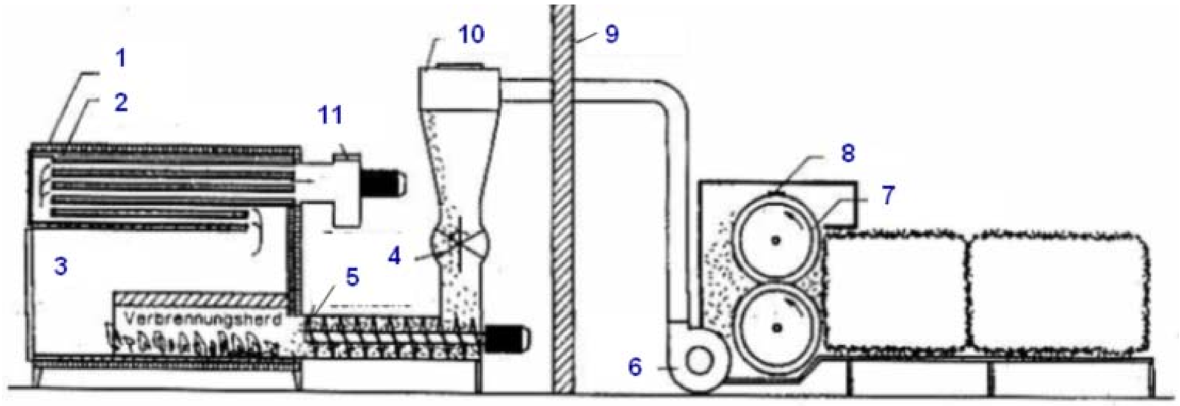


Figure 6. Cigar burner for straw (Scholz et al., 1997)
1- insulation; 2- water; 3- firing chamber; 4- sluice; 5- stoker screw; 6- straw-ventilator; 7- pulper; 8- scraper; 9- fire wall; 10- cyclone; 11- flue gas-ventilator

Fluidized Bed boilers (FBB) are nearly homogeneous in temperature conditions and concentrations, achieve high burnout quality, and diminish the excess air (Nussbaumer, 1999, and Nussbaumer, 2003). The choice of different bed materials in CFB offers additional opportunities of catalytic effects. In addition, heat removal can be chosen following the control of bed material for combustion temperature leading to the operation of the FBB at a low excess air without any ash sintering (Nussbaumer, 2003). Similar to the conditions of nitrogen conversion, those of air and fuel can relatively lead to low $NO_x$ emissions achieved (Nussbaumer, 1999; Nussbaumer, 2003, and Simeon and Anthony, 2004).

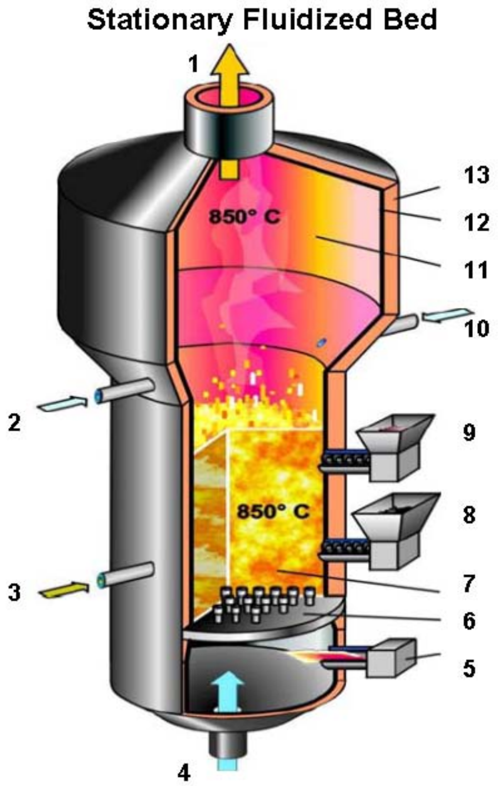


Figure 7. Construction of a Stationary Fluidized Bed Combustor-SFBC (Steinbrecht, 2008)
1- Flue gas; 2, 10- Secondary air; 3- Entry liquid media; 4- Whirl air inflow; 5- Start burner; 6- Nozzle floor; 7- Fluidized bed; 8- Transportation of solid fuels; 9- Dose of additives; 11- Freeboard; 12- Steel-cladding; 13- Insulation

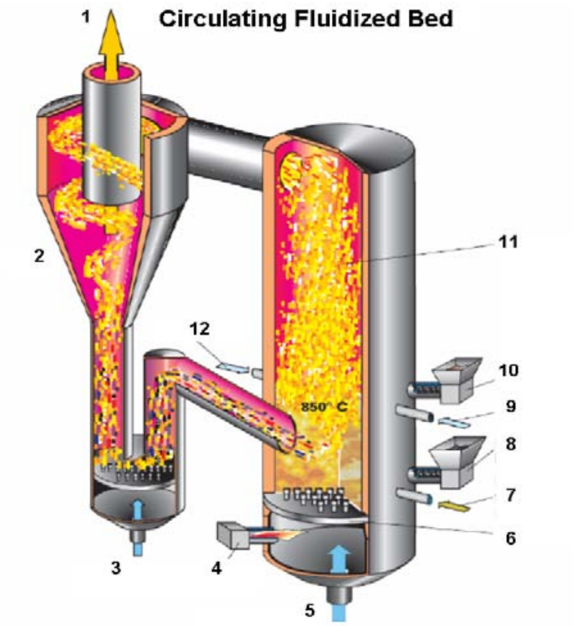


Figure 8. Construction of a Circulating Fluidized Bed Combustor-CFBC (Steinbrecht, 2008)
1- Flue gas; 2- Cyclone; 3, 5- Whirl air inflow; 4-Start burner; 6- Nozzle floor; 7- Entry liquid media; 8- Transportation of solid fuels; 9, 12- Secondary air; 10- Dose of additives; 11- Riser

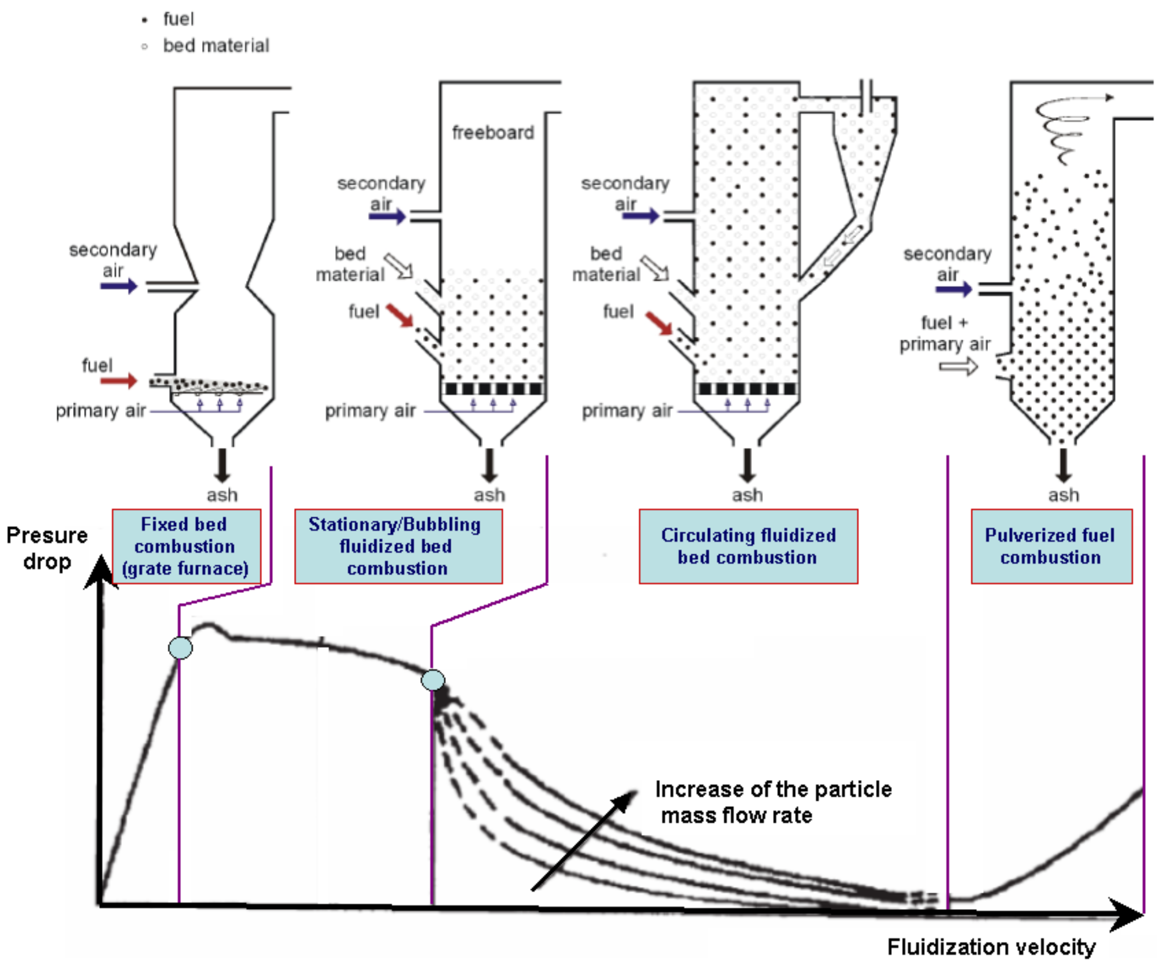


Figure 9. Furnace types and flow conditions: (pressure drop in dependence of fluidization velocity for different fluidization regimes)
(Simeon and Anthony, 2004; Loo and Koppejan, 2007)

Fixed bed combustion, SFBC/BFBC, turbulent-FBC, fast fluidization, and pneumatic transport presented in Fig. 9 shows that the change of pressure drop for the follow states of solid-gas mixtures in the furnace types, especially in the SFBC (Simeon and Anthony, 2004). It also can be seen that different states of solid-gas mixtures are used in conventional and contemporary modes of solid fuel combustion.

As visualized in the diagram showing the relationship between pressure drop and fluidized bed velocity in Fig. 9, SFBC is the best furnace. In addition, SFBC is also advanced than the others, which can be seen in the comparison with the grate firing. As a result, SFBC which can be used for heat and electric energy production is better than fixed firing and grate firing, therefore will be recommended in our future application in Vietnam.

The main criteria for the selection of the apparatus leading the choice of SFBC plant are of the following advantages (Steinbrecht *et al*, 2001):

- Moderate investment costs for plant are greater than 10 $MW_{th}$
- The efficiency of $NO_x$ reduction by ventilation controlled
- High flexibilities concerning grain size, water content and nature of solid fuels
- Increasing the efficiency by reducing the air surplus ratio
- Simple addition of additives
- Efficient incorporation of sulfur in the ash, if enough calcium available.

## 4. TECHNOLOGY OF POWER GENERATION FROM DIRECT-FIRED WASTAGE OF BIOMASS IN SFBC

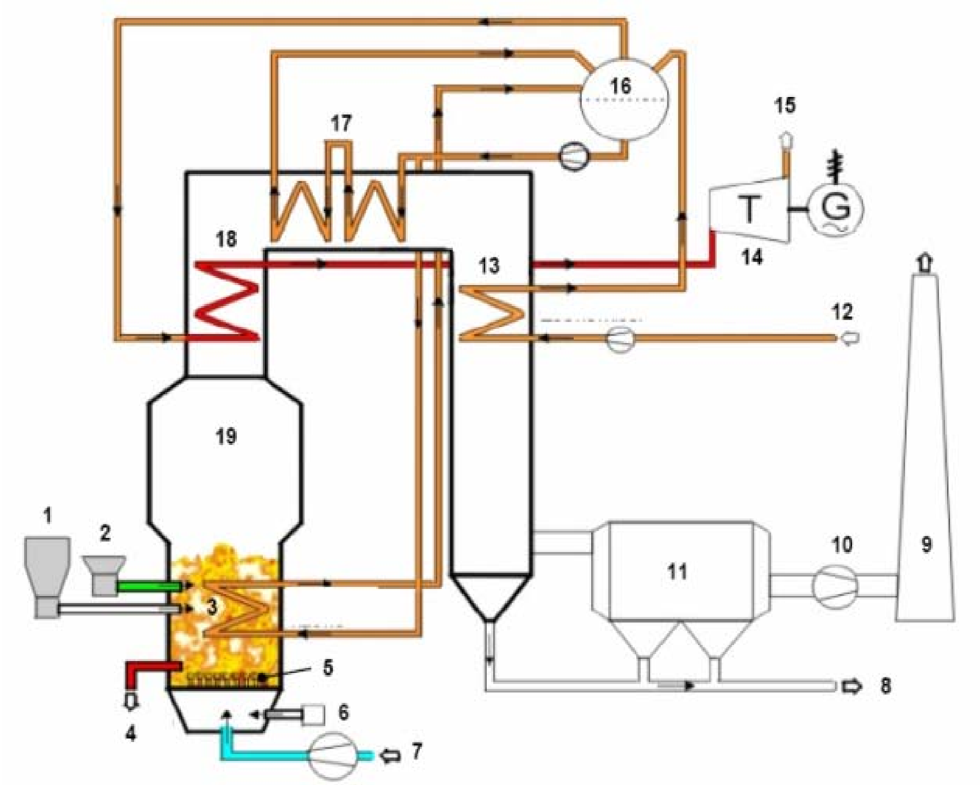


Figure 10. SFBC small capacity in connection a power plant process, with heat extraction from fluidized bed (Steinbrecht, 2008)

1- Fuel; 2- Additive; Combustion bed ash; Bed heating face; 5- Nozzle floor; 6- Start burner; 7- Air; 8- Fly ash; 9- Chimney; 10- Induced draught fan; 11- Electric filter; 12- Feeder water; 13- Economizer; 14- Steam turbine; 15- To the process; 16- Drum; 17- Vaporizer; 18- Superheater; 19- Fluidized bed module

Technology for the conversion energy of biomass for electricity production consists of direct combustion, pyro-lysis, and gasification. Fig. 10 illustrates the direct combustion of biomass technology, in which heat energy of flue gases is used in the heat exchange sections of boilers to produce steam. The steam is used to generate electricity in a Clausius - Rankine cycle. In this regard, according to Steinbrecht (2008), electricity is produced in a condensing steam cycle while electricity and steam are co-generated in an ambitious steam cycle; and the optimum boiler configurations used for steam generation with biomass are SFBC (Fig. 10). Today's biomass combustion furnaces designs include reheat and regenerative steam cycles.

The small scaled SFBC combined with a cogeneration plant is shown in Fig. 10. It would be reminded here that the advantages of SFBC are completely combusted and emission flue gas diminishing. The temperature level of the flue gas after the freeboard is in range of 800-900$^{\circ}$C. Small scaled SFBC plants are economic, simple to build, and usefulness concerning waste heat-steam. The waste heat of the boilers can be used to preheat water (e.g. as in the Economizer), to evaporate, or to superheat the steam. With this plant, the principle design gives the maximum combustion capacity of approximately 10-15 $MW_{th}$. The steam pressure level on boilers is limited to maximum 25 bar (Steinbrecht, 2008; Steinbrecht, Sankol, 1986).

## 5. THE PROMISING TECHNOLOGY OF COMBINED HEAT AND POWER PLANT FROM BIOMASS DIRECT-FIRED RESIDUES WITH FBC FOR THE FUTURE USES IN VIETNAM

The aim of implementing the Combined Heat and Power plant (CHP- plant) in Vietnam is to utilize the energy from agricultural residues (paddy straw, rice husk, maize husk and Bagasse) and to generate power and heat for agricultural processing industry (Fig.11).

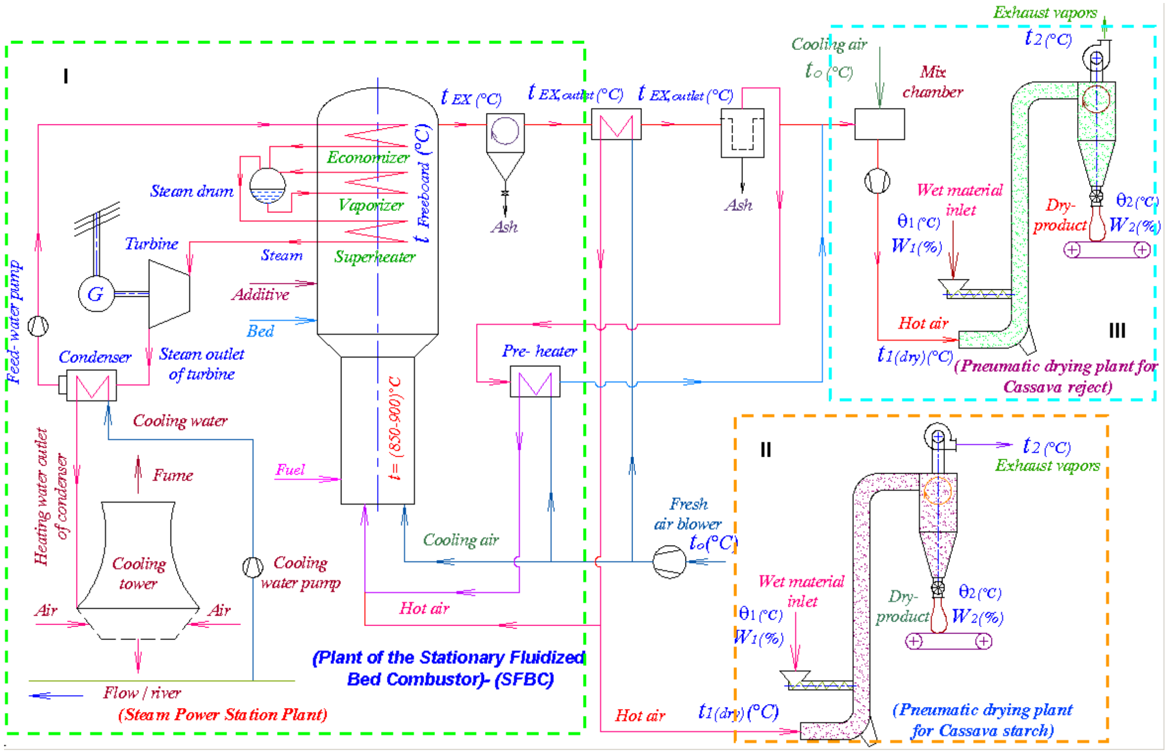


Figure 11. Scheme of the combined heat and power plant with SFBC which have a recirculation exhaust with biomass fuels in Vietnam: (Nguyen and Steinbrecht, 2008)
I- Steam Power Station Plant; II- Indirect Drying Plant; III- Direct Drying Plant

Some modules in this CHP- plant are created such as: SFBC, steam power process, pneumatic drying of cassava starch for exportation, and pneumatic drying of unused cassava for cattle's feed (Nguyen and Steinbrecht, 2008). The plant is economic, strategic, social meaning, and leads to the protection of environment in Vietnam (Nguyen and Steinbrecht, 2008).

The heat of flue gases following the combustion can be used in thermo-technical power as the heat source for steam power process. Besides, waste heat from the steam power process can further be applied for heat consumption facilities as well as for drying facilities.

The overview of systematic combined heat and power plant deriving from Fig. 11 can be simplified as presented in Fig.12.

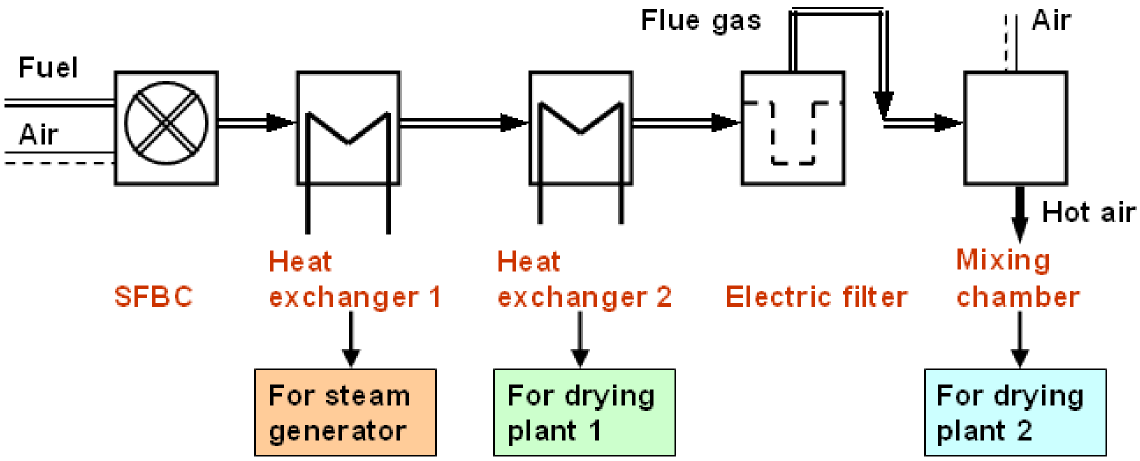


Figure 12. General scheme of the combined heat and power (CHP) using biomass for combustion fuels

## 6. CONCLUSION

As presented, the combustion of biomass contributes to the actual global energy supply. It is promisingly the dominant technology for biomass conversion in the near future in Vietnam. It can be widely applied to agricultural productions drying of few kW to power stations based on steam cycles of several MW. Following the needs of research & development and by practicing, biomass combustion can be seen as an open research topic which requires further investigation for our better economic societies.

Besides, another important topic to be considered is the residues of fuels from biomass. Since they are widely used nowadays, bio residues can significantly contribute to the future of energy supply.

Biomass-combustion cogeneration is not only friendly to environment and energetic production, but also has high energy conversion efficiency.

In conclusion, combined heat and power generation using biomass residue has a many-fold benefit: waste minimization, $CO_2$ reduction potential, reduction of energy-related production cost and additional income from selling the excess electricity to the utility.

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**Nomenclature**

| | |
|---|---|
| BFBC: | **b**ubbling **f**luidized **b**ed **c**ombustion |
| CFBC: | **c**irculating **f**luidized **b**ed **c**ombustion |
| FBC: | **F**luidized **b**ed **c**ombustion |
| $MW_{el}$: | Electrical Megawatt |
| MWh: | Megawatt-hour |
| $MW_{th}$: | Thermal Megawatt |
| SFBC: | **s**tationary **f**luidized **b**ed **c**ombustion |
| TWh: | Terawatt-hour |

**Indices**

| | |
|---|---|
| el: | Electrical |
| th: | Thermal |