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Progress in the technology of energy conversion from woody biomass in Indonesia

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Abstract Sustainable and renewable natural resources as biomass that contains carbon and hydrogen elements can be a potential raw materials for energy conversion. In Indonesia, they comprise variable-sized wood from forests (i.e. natural forests, plantations and community forests that commonly produce small-diameter logs used as firewood by local people), woody residues from logging and wood industries, oil-palm shell waste from crude palm oil factories, coconut shell wastes from coconut plantations, traditional markets as well as skimmed coconut oil and straws from rice cultivation.

Four kinds of energy-conversion technologies have been empirically tested in Indonesia. First, gasification of rubber wood from unproductive rubber trees to generate heat energy for the drying of fermented chocolate seeds. Secondly, energy conversion from organic vegetable waste by implementing thermophylic fermentation methods that produce biogas as a fuel and for generating electricity and also concurrently generate organic by-products called hygen compost. Thirdly, gasification of charcoal and wood sawdust for electricity generation. Finally, environment-friendly energy conversion by carbonizing small-diameter logs, sawdust, wood slabs and coconut shells into charcoal. This yielded charcoal integrated with wood vinegar production through condensation of smoke/vapors emitted during carbonization, thereby mitigating the impact of air pollution.

Among the four experimental technologies that of integrated charcoal and wood vinegar production had been spectacularly developed and favored by rural communities. This technology brought added value to the process and product due to the wood vinegar, useful as bio-pesticide, plant-growth hormone and organic fertilizer. Such integrated and environment-friendly production, therefore, should be sustained, because Indonesia occupies a significant and worldwide position as charcoal-producing and marketing country. The technology of integrated wood vinegar-charcoal production hence deserves its dissemination throughout Indonesia, particularly to the charcoal industry that still produces charcoal without condensing the generated vapor/smoke, hence polluting the air.

Key words energy conversion, biomass, integrated production, charcoal and wood vinegar, friendly environment

1 Introduction

Wood and charcoal belong to an energy convention which can sustain fluctuation in their status as a non-conventional fuel, coupled with their uncertain supply. Customers or users of firewood stem from a former era, which until the present, remain associated with simple communities, while the consumption of fossil fuels indicates an industrial society. Along with the progress in industrial development where markets can provide cheap and easy fuel, inherently simple-community consumption turns as well to such commercial fuels. However, when a crisis in the fossil fuel markets hits worldwide, they (the simple communities) tend to go back to conventional energy sources. The price of fossil fuels is so high, currently reaching USD 70 per barrel, that it has an unfavorable impact on the global economy. Indonesia is no exception. Currently, Indonesia is experiencing an unstable situation in energy uses due to the sharp increase in kerosene fuel price (almost 200%).

Indonesia is endowed with enormous biodiversity as reflected in its tropical climatic condition where photosynthesis in plants during the day can proceed throughout the year. The formation of polymer compounds from C (carbon), H (hydrogen), O (oxygen) and other plant elements produces biodiversity as shown by numerous wood species, agriculture plants, crops estate/plantations and other similar cultures. This biodiversity reveals its potential in that it further can afford its various uses for human lives and is an integral part of their life-support system. One of the supports and as such, urgently needed by humans, is energy.

Energy generated by petroleum/fossil fuel is not inexhaustible and commonly difficult if not impossible to reclaim/renew. The case for firewood is different, since it is biomass, derived from living matters and therefore its renewability or sustainability can be ensured. This terminology implies for firewood that we plant today and it can be harvested later. This does not apply to petroleum/fossil fuel, since its continuous exploration sooner or later will cease owing to exhaustion of the stock.

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An efficient conversion technology of biomass energy from woody materials is needed to overcome or relieve the crisis faced by commercial fuels, the production of which will decline to the point where it is considered uneconomical. This article narrates in brief the progress of energy-conversion technology in Indonesia for its potential as alternative or partial substitute for petroleum/fossil fuels. The narrative deals with information on woody biomass potential, energy-safe kilns, carbonization technology and fermentation.

2 Potential and consumption of woody biomass

Wood as one of hydrocarbon matters contains 50% carbon (C), 6% hydrogen (H) and 4% oxygen (O), largely constituted as cellulose, hemicellulose and lignin polymers. Such polymers can also be encountered in other lingo-cellulose matters, such as bamboo, coconut shells, oil-palm shells, rice husks, rice straw and bagasse (residue of sugarcane processing). The capacity for renewal of lingo-cellulose matters (particularly wood), as described before, differentiates it clearly from petroleum/fossil fuels. Commensurate with the procurement from its sources, the potential woody biomass fuel (firewood) can be categorized as forestry, community plantation and agriculture (Nurhayati et al., 1998). Procurement/supply of firewood from mixed plantations owned by communities occupies the greatest portion (58%), followed in decreasing order by that from forestry (28%), crops estate/plantation (6.1%) and agriculture and other related sources (8%). Sources of firewood from forestry (i.e. forest plantations) are elaborated in Table 1, which in this regard provides particular wood species for energy (firewood) such as lamtoro, mangrove, mangium and calliandra. Meanwhile, other biomass sources for firewood are logging wastes (e.g. stems, branches and stumps) and wastes of commercial wood industries (slabs, sawdust, trimming materials, etc.), as presented in Table 2.

Table 1 Production of wood biomass intended for energy, procured from plantation forests

Wood species	Growth rotation (year)	Growth increment ($m^3 \cdot hm^{-2} \cdot year^{-1}$)	Energy released ($GJ \cdot hm^{-2} \cdot year^{-1}$)
Acacia	4–8	23.3	2,929.125
Sengon	4	36.8	460
Calliandra	4	35	421.75
Rubberwood	20	8–15	100.0–187.5
Mangium	4	29	362.5
Lamtoro	4	30	625

Source: Nurhayati et al. (2002).

Table 2 Potential of woody waste intended for firewood

Kind of woody wastes	Yield (%)
Tree felling/cutting	
Stems of branches	39.8
Branches from bigger branches	27.2
Branches	9.7
Stumps	23.3
Wood sawmills	
Slabs	25.8
Trimming residues	11.7
Sawdust	10.6

Source: Nurhayati (1995).

As well, the potential of woody biomass afforded by crops plantation/estate is comprised of old/unproductive rubber and oil-palm trees when they reach, respectively, the age of 30 and 25 years, of coconut shells (i.e. weighing some 200–250 g per fresh coconut fruit), of oil-palm shells (100 t per month) and of bagasse.

In more detail, the potential of woody biomass from old/unproductive rubber and oil-palm trees following the replacement/replanting with their young corresponding trees are presented in Tables 3 and 4. These elaborations can further illustrate the potential of woody biomass matters, should all or part of it be intended for energy conversion.

About bagasse, it is a residue consisting, among others, of ligno-cellulosic fibrous stuff that remains after the juice is extracted from the sugarcanes in a sugar mill. Bagasse residue occurs in significant amounts in some countries, including Indonesia. It is estimated that each ton of sugar production can create 1.25 t (moisture-free) bagasse (FAO, 1968). Hence, the amount of bagasse residue in Indonesia can be estimated from the figures of Indonesia's sugar production (Table 5) and illustrate its possible biomass potential for energy purposes.

Table 3 Potential of woody biomass wastes from old/unproductive rubber trees and their replacement/replanting activities

No.	Years of replacement/replanting activities [1]	Area of replacement/replanting (hm^2)	Potential of rubber wood from replaced or old/unproductive rubber trees ($m^3 \cdot year^{-1}$)
1	1975/2005	64,783	3,239,150
2	1976/2006	111,316	5,565,800
3	1977/2007	108,801	5,440,050
4	1978/2008	159,078	7,593,900
5	1979/2009	198,218	9,910,700
6	1980/2010	129,046	6,452,300

[1] Under assumption that rubber trees become unproductive when they reach age 30 years.

Source: Balfas (2003).

Table 4 The potential of woody biomass wastes from old/unproductive oil-palm trees and their replacement/replanting activities

No.	Years of replacement/ replanting activities 1)	Area of replacement/ replanting (hm^2)	Potential of oil-palm wood from replaced or old/unproductive oil-palm trees (m^3·year^{-1})
1	1980/2005	24,407	5,369,540
2	1981/2006	40,934	9,005,480
3	1982/2007	75,745	16,663,900
4	1983/2008	106,375	23,402,500
5	1984/2009	85,341	18,775,020
6	1985/2010	90.418	19,891,960

1) Under assumption that oil-palm trees become unproductive when they reach age 25 years.

Source: Balfas (2003).

Table 5 Sugar production in Indonesia and potential of bagasse residue

No.	Years	Sugar production (t) 1)	Potential bagasse residue (moisture-free) (t·year^{-1}) 2)
1	1998	1,928,700	2,410,875
2	1999	1,801,400	2,251,750
3	2000	1,780,100	2,225,125
4	2001	1,836,100	2,295,125
5	2002	1,869,200	2,336,500

1) Source: Anonymous (2003).

2) Under assumption that production of 1 t of sugar creates 1.25 t of bagasse residue (FAO, 1968).

Other biomass sources that also have a significant potential for energy uses in Indonesia are, among others, those from community-controlled forests. Relevant information is presented in Table 6 which lists areas of community forests specified by the administration system, together with its potential wood biomass for energy.

Table 6 Areas of community-administered forest, and the potential of their corresponding wood biomass for energy uses

No.	Types of community forestry according to the administration systems	Area (hm^2)	Approximate potential of wood biomass (m^3) 1)
1	Forest established by community's own efforts	966,723.3	33,650,443.1
2	Forest established under a government subsidy	131,090.5	4,935.417.5
3	Forest established under the mixed government subsidy and community's own efforts	41,785.9	744,129.9
4	Forest established through the assistance of government reforestation plan	18,917.9	86,567.0
5	Forest established through the national activities of and rehabilitation	409,899.0	0
	Total	1,568,415.6	39,416,557.6

1) Under assumption that rotation period is 12 years and then the annual potential of wood biomass = 39,416,557.5/12 = 3,284,125 m^3 per year.

Source: Wardana (2005).

Woody biomass material generated or procured from forestry as well as crops estate/plantation in general are consumed entirely or in part by the related products-processing industries to meet or supplement their energy needs, such as wood wastes from sawmill industries that are further used to dry lumber, bagasse as a fuel to heat the boiler in the sugarcane factory. Oil-palm shells and coconut shells are used either as fuel in the corresponding oil-palm factories and shredded coconut-meat factories or as raw material for charcoal manufacture. The woody biomass from mixed plantations owned by communities is consumed by small restaurants, households and small-scale as well as medium-sized industries in rural areas. Table 7 shows the kinds of waste-generating wood products, waste potential and portion of the waste used for energy. It turns out that this part ranges from about 75%–99% of the overall total available woody wastes. This also suggests that sources of energy from wood are still preferred by rural community (as firewood) for household cooking and small as well as medium-sized industries or used for purposes such as fermenting soy sauce, brown sugar and curing tobacco. In Table 8 are illustrated the consumptions of firewood by households and small to medium-sized industries.

Table 7 Kinds of waste-generating wood products, waste potential and waste portion for energy

No.	Kinds of waste-generating wood products	Potential of woody waste (kg·m^{-3})	Portion for energy uses (%)
1	Plywood, type A	3,850	87.80
2	Plywood, type B	4,038	86.40
3	Plywood, type C	4,250	82.20
4	Laminated wood, type A	7,550	93.23
5	Laminated wood, type B	7,313	88.90
6	Particleboard	3,500	88.30
7	Wood frame for pictures, certificates, art paintings, etc.	3,250	75.30
8	Wood-working stuff	3,750	52.53

Source: Nurhayati et al. (1994).

Table 8 Consumption of firewood by households and small to medium-sized industries in Indonesia

No.	Households (in Java island) and small to medium-sized industries	Consumption of firewood and its derivatives (i.e. charcoal)
1	Households	0.75 m^3 per capita per year
	Small to medium-sized industries:	
2	Soy sauce	0.55 m^3 per 1,000 packets
3	Iron work (ironsmith)	417 kg of charcoal per 1,000 big-blade knives
4	Lime	13.5 $GJ\cdot t^{-1}$
5	Bricks	5.7 GJ per 1,000 pieces
6	Tiles for house roofs	6.6 GJ per 1,000 pieces
7	Fermentation of soybeans	113 GJ per 1,000 packets
8	Drying of chocolate seeds	2.79 $GJ\cdot t^{-1}$
9	Plywood	0.31 m^3 per 1 m^3 firewood
10	Laminated beam	0.60 m^3 per 1 m^3 firewood
11	Particleboard	0.28 m^3 per 1 m^3 firewood
12	Wood frame	0.08 m^3 per 1 m^3 firewood
13	Wood drying	0.30 m^3 per 1 m^3 firewood

Sources: Anonymous (1987) and Nurhayati et al. (1994).

The several advantages obtained from the use of firewood and its derivatives (e.g. charcoal) are: 1) non-commercial energy is renewable and hence effective to cope with global climatic change; 2) it affords high/satisfactory calorific (heating) value (Table 9); 3) the calorific value is species dependent, while production of energy is affected by tree-growth and rotation (Table 1); 4) the supply of firewood can conform to the needs/demands and productive capacity anywhere; 5) the use of firewood is not dangerous/harmful due to no-sulphur content; 6) special storage systems/places are not required and firewood can in practice last long (durable); 7) technology of wood conversion to energy (fuel) is relatively simple and not too complicated; and 8) the price of firewood is relatively cheap in term of Joule unit (price/kJ) compared to that of commercial fuel and moreover consumers/users prefer cheap prices (Table 9).

Table 9 Heating value and price of commercial fuels

No.	Types of commercial fuel	Heating value	Price per unit	Price per kJ
1	Electricity:	3.6 GJ per MWh		
	Block I		Rp. 275 per kWh	0.095,9
	Block II		Rp. 445 per kWh	0.123,0
	Block III		Rp. 495 per kWh	0.137,5
2	Liquefied petroleum gas (LPG)	45.2 $GJ\cdot t^{-1}$	Rp. 52,000 per 12 kg	0.095,9
3	Kerosene	32.7 GJ per 10^3 L	Rp. 1,200 per L	0.036,7
4	Coal	29.3 $GJ\cdot t^{-1}$	Rp. 380,000 per t	0.013,0
5	Non-resinous firewood	19.1 $GJ\cdot t^{-1}$	Rp. 20,000 per 3 m^3	0.066,7
6	Resinous firewood	21.3 $GJ\cdot t^{-1}$	Rp. 20,000 per 3 m^3	0.066,7
7	Firewood	12.5 $GJ\cdot m^{-3}$	Rp. 15,000 per 3 m^3	0.012,0
8	Agriculture wastes	12.0 $GJ\cdot t^{-1}$	–	–
9	Charcoal	28.9 $GJ\cdot t^{-1}$	Rp. 1,500 per kg	0.033,4

Sources: Anonymous (2004).

3 Technology of energy conversion

3.1 Energy-safe firewood and charcoal stoves

Conversion of woody material into heat energy reveals an intrinsically simple technology, which has developed in the community since ancient days. In its perfect burning process, wood can release an amount of heat energy estimated at about 12.5–21.3 $GJ\cdot m^{-3}$. The amount of heat needed for a particular consumptive use, such as cooking, is affected by wood species, moisture content, theoretical/true calorific value and equipment used in the heat/energy conversion or so-called firewood/charcoal stove.

Low efficiency firewood stoves will sustain considerable energy losses compared to high efficiency stoves. Firewood stoves used by households, small restaurants and other micro-scale industries have an energy/heat efficiency that varies from about 1.6%–23.9%. Household stoves which are energy-safe are so-called SAE and capable of achieving 25%–50% efficiency. The SAE stove is made of clay and sand particles, measures 55 cm in length and consists of two fire mouths. Besides, this stove can be made either permanent or portable. The front fire mouth measures 25 cm in diameter and stands 18 cm in height from the stove base, while the back fire mouth has a 20 cm diameter and has a height of 21 cm. The SAE stove is also provided with a burning/flaming mouths measuring 6 cm by 5 cm and with 3 air vents, each with a 2 cm diameter. Cooking with this stove will consume as much as 4,342 g of firewood of lamtoro-gung species at 14.5% moisture content. This wood species has a theoretical calorific value of 4,299 calories per gram and suffices for the cooking of nutritious food with daily human consumption of 2,027 metabolic calories per person. These food calories are adequate to meet the consumption of 5 persons. Cooking with this SAE stove will take 159 min.

In another aspect, the firewood stove used by a micro-scale industry that manufactures brown sugar from coconut reveals variations in its shape and heating efficiency. The stove, which is made of cement and bricks, has low efficiency (15%), while one made of clay and bricks can achieve a somewhat higher efficiency (18.6%). The highest efficiency ever recorded (30.1%) is the stove made almost entirely (100%) of clay. With this efficient kiln, the industry can manufacture as much as 231 t of brown sugar per day, consuming 115.5 t of a particular firewood per year or in term of energy/heat: 19,690 GJ per year. This firewood has 22.7% moisture content with a theoretical calorific value of 4,417 calories per gram. This kiln has undergone modification in its shape and its material contains a mixture of abrading charcoal powder, sand particles and clay (in weight proportions of 1:1:1). This modified kiln can obtains 40.6% heating efficiency, has one fire mouth with a 20 cm diameter, measures 25 cm in height and 40 cm in length and is provided with three small air vents each with a 2 cm diameter on the kiln wall. Given this kiln, the brown-sugar industry can save considerable amounts of firewood estimated to be as much as 10.4%–25.5%.

Besides firewood, charcoal that results from wood carbonization is also consumed by households and small restaurants as a fuel for cooking using what is called a charcoal stove. The material of this stove consists of a mixture of sand particles and bricks. It measures 18 cm in diameter and 25 cm in height and has one fire mouth of 17 cm diameter. This stove is also provided with air vents and an exhaust opening for ash (burning residue), measuring 8 cm by 6 cm. It has a 25% heating efficiency. If using coconut-shell charcoal with 10.3% moisture content, this stove will require 1.4 kg of that charcoal per day per household. The use of coconut shell charcoal, which has a theoretical calorific value of 6,970 calories per gram, in this charcoal stove, will suffice for the cooking of nutritious food that further can generate 1,500 metabolic calories per person, whereby the cooking takes about 148 min. When using wood charcoal, however, this stove, in order to afford the same efficiency as the one using coconut shells (i.e. 25% efficiency), will consume as much as 1.6 kg of charcoal with 9.8% moisture content. The wood charcoal has a theoretical calorific value of 6,730 calories per gram and in this way the cooking takes about 245 min. Those overall figures of using coconut-shell charcoal as well as wood charcoal for cooking in the charcoal stove will be comparable to those with the use of kerosene which uses as much as 2.2 L per day per household in a regular kerosene stove and requires 257 min for cooking.

3.2 Integrated charcoal kiln

There are several kinds of integrated charcoal kilns, which in the design/shape are conformed to be characteristically used for burning ligno-cellulosic raw materials.

3.2.1 Wood/waste wood as raw material

The integrated charcoal kiln for this raw material can develop 40% efficiency, has a dome-shaped structure and is constructed of bricks and clay, and has a 1.3 m^3 input material capacity per batch. This kiln is also equipped with water cooling system to condense the smoke/gas fractions emitted during the carbonization of wood/waste wood, into liquid-phase mass or more popularly so-called “wood vinegar”. In this way, the integrated/concurrent production of charcoal and wood vinegar can be implemented without affecting those two products in term of their production processes as well as their quality. Moreover, it has been discovered that wood vinegar can be effective as organic fertilizer, bio-pesticide and as plant growth hormone. In this way, two beneficial products (i.e. wood vinegar and charcoal) can be produced in one simultaneous operation/process. Therefore, wood vinegar production in this regard reveals part of the charcoal-production process during the carbonization of wood or other ligno-cellulosic stuffs, which terminates at 400°C and concurrently produces charcoal. Production of wood vinegar integrated with charcoal production from wood/waste wood can also be carried out in a special kiln constructed of fire-resistant bricks and fire-resistant brick sand. This kiln has a 2.5 m^3 input capacity per batch. In this kiln, the condensation of the smoke/gas fraction into liquid mass (wood vinegar) takes place using a smoke/gas-collecting tool of stainless steel/metal with cylindrical shape and further connected to the sloping pipes. The unique thing is that the pipe can be made of either rather-expensive steel/metal or merely from cheap-priced bamboo.

3.2.2 Sawdust and oil-palm shells as raw material

Sawdust and oil-palm shells can be carbonized into charcoal. The carbonization is imposed using a so-called direct burning process of those two materials. The burning is performed in the steel-constructed reactor kiln of cylindrical shape, the base part of which is provided with a special chamber for the initial firing process. This chamber is connected with a blower to supply fresh air. Meanwhile, the reactor kiln is connected to a water-cooling unit to condense the emitted smoke/gas fractions. With sawdust or oil-palm shells, wood vinegar production proceeds until the temperature reaches 300–400°C, while carbonization for charcoal still continues beyond that temperature to a particular point where it is ultimately terminated and then followed with a cooling process.

3.2.3 Coconut shells as raw material

In charcoal manufacture from the carbonization of coconut shells, a drum kiln is used. This drum kiln can make use of a recycled drum formerly used as kerosene container with a 200 L capacity. By installing a smoke/gas-collecting tool and cooling pipes, an integrated production of coconut-shell charcoal and its corresponding wood vinegar can be achieved. This drum kiln has an input capacity of 90 kg of coconut shell per batch. Efficiency of coconut-shell conversion into charcoal runs at about 45%.

3.2.4 Other developments of integrated charcoal kilns

Other developments of charcoal kilns for integrated charcoal and wood vinegar production also promise interesting prospects in term of wood/waste wood utilization as well as environmentally friendly products. Table 10 elaborates further on integrated production of wood vinegar from particular ligno-cellulosic materials, e.g. small-diameter wood, waste wood, sawdust, oil-palm shells, etc. In a development related to simple communities as well as government endeavors, wood charcoal and coconut-shell charcoal have been produced and exported to various countries world-wide.

Table 10 Integrated production of wood vinegar and charcoal from several kinds of woody or ligno-cellulosic biomass

No	Kinds of woody / ligno-cellulosic biomass	Types of kilns	Charcoal			Wood vinegar production ($kg\cdot t^{-1}$)
			Production ($kg\cdot t^{-1}$)	Yield (I) (%)	Yield (II) (%)	
1	Mangrove	Dome shape	250.5	27.9	26.0	211.0
2	*Acacia*	Dome shape	146.8	22.1	26.5	165.3
3	*Hevea brasiliensis*	Dome shape	192.8	30.2	34.7	206.0
4	*Calliandra callothyrsus*	Portable	–	18.4	36.9	–
5	*Schiima wallichii*	Japan	91.0	18.4	15.0	112.8
6	Waste wood	Dome shape	128.1	24.8	40.6	209.8
7	Waste wood	Japan	190.6	24.1	11.9	94.0
8	Sawdust	Blow	163.8	19.2	23.0	178.6
9	Coconut shell	Drum	273.7	31.6	15.3	132.6
10	Oil-palm shell	Steel	190.0	20.1	30.5	286.0

Source: Nurhayati et al. (2002).

3.3 Gasification technology

There are several kinds of gasification technology and those which have been implemented in Indonesia are as follows:

3.3.1 Combustion gasifier

Utilization of heat as emitted from the burning of rubber wood was implemented in the combustion-gasifier system, which is merely a direct heating process for the drying of cacao seeds after their fermentation. The drying takes place by placing cacao seeds on the big pan and underneath direct heating is turned on, the so-called combustion-gasifier system. In this system, rubber wood is completely burnt, thereby releasing heat/energy that is collected in a chamber and then mixed with air in three stages such that the heating temperature decreases to 75°C. The mixture is further blown to the drying unit for direct heating of chocolate seeds. In this way, the drying called for 27 kg of rubber wood which has theoretical calorific value of 4,108 calories per gram and a moisture content of 11.6%. As such, the drying through the combustion-gasifier (direct heating) system can decrease the moisture content of cacao seeds from 136.6% to 7.2% in 38.5 min. The conversion efficiency of this gasifier system from wood biomass can reach 56.9%.

3.3.2 Fluidized-bed gasification

The gas emitted from the wood burning in the fluidized-bed gasification system was experimentally used as a fuel for, among others, a boiler. The resulting gas was at first mixed with inert materials such as sand thereby forming what is called suspended gas, which reveals its advantages over the unsuspended gas, due to its high recirculation rate. The suspended gas was further separated from unwanted matters (e.g. ash, dirt and tar) and then passed into the gasification reactor in a semi-continuous run. Inside the reactor, the gas was ready for use as fuel in the so-called fluidized-bed gasification system.

Another development of fluidized-bed gasification system is called technology of FBB-CHP (fluidized-bed boiler for combined heat and power). This technology can make use of sawdust, further giving off FBB-CHP gas that can enter the commercial market. Empirically, it has been shown that the commercial FBB-CHP system could reach an input capacity of 700 kg of woody biomass per hour, generating 2,500 kg of saturated vapor per kg at 1.8 MPa pressure. The resulting saturated vapor was used to drive/rotate turbine blades thereby generating as much as 52 kW electricity, while the residual heat of the vapor was still beneficial for the drying of a specified volume of lumber, i.e. 600 m^3 per batch (Sugiyatmo et al., 1998). This technology socially demands some competent experts and skillful technicians/workers for its commercialization in small-scale endeavors.

3.3.3 Charcoal gasifier

This technique employs what is called a downdraft gasifier and has proved simpler than that of fluidized-bed system. The downdraft charcoal gasifier system consists of a gasification reactor, a gas-clarifier unit, a gasoline-powered motor and an electric generator. Gas that results from the burning of charcoal and after being separated from solid particles and tar is blown to the electric generator in which its turbine blades are propelled, thereby generating electricity. In the experiment, the resulting gas with this charcoal gasifier system characteristically contained 27% carbonmonoxyde, 4% hydrogen, 0.5% methane and 7% carbondioxyde (Hartoyo and Nurhayati, 1986). Gas conversion from charcoal (with its calorific value at 6,733 calories per gram, 2.5% ash content and 22.4% volatile matter) in the charcoal gasifier system that ran at 55 kg input charcoal capacity per batch could reach 51%–61% heat efficiency and as such managed 11.7%–14.1% efficiency in electricity generation. The system consumed 17.5–24 kg of charcoal per batch. It turned out that the use of charcoal rather than its corresponding wood equivalent for its conversion into electricity proved more satisfactory and effective. In this endeavor, 1 kg of charcoal could produce 0.9 kWh of electricity.

3.3.4 Biogas generated from thermophillic fermentation

Fermentation technology as implemented on organic garbage, such as rotten vegetations, market wastes and urban trash, could experimentally produce so-called biogas, which is beneficial to provide fuel for households or driving machinery in small-scale industries. Organic compounds in vegetation garbage procured from the market, separated from unwanted matters, such as plastics, wood, tin, etc. and then chopped into small-size pieces (approximately 2 cm in length) could be experimentally used for its conversion into biogas through a fermentation process (Nurhayati, 1990). The fermentor was equipped with an automatic agitator, a feeding system, pipes for inflowing water vapor, a dual electric generator, a boiler and gas collectors/containers made of balloons and an outflow door for sludge. Fermentation of organic garbage into biogas was assisted by particular microorganisms and proceeded at 45–50°C. Parameters that should be accounted for in the fermentation process were the amount of waste feed (kg per day), dry matter (per cent), ash content (per cent), water consumption by electric generator (L), production of biogas (m^3 per day), methane content (per cent), residual maters (kg) and water consumption in the fermentation reactor (L). The resulting biogas can be used as fuel for boilers or be converted into electric energy.

The amounts used or generated from the biogas experiment on vegetation garbage from the market as described above were as follows: garbage feeding at 478 kg per day, dry matter content 22.3%, ash content 38.9% and retention time 20.9 days. From this endeavor, the system produced biogas at a rate of 28.7 m^3 per day with 54.5% methane content. It could achieve 57% conversion efficiency. Besides generating biogas, concurrently this experiment/endeavor emitted hygen compost as additional beneficial product. To wrap-up, fermentation of organic garbage of as much as 23 t proved experimentally able to generate 1,380 m^3 of biogas and 16 t of hygen compost.

4 Conclusions and suggestions

Sources of woody or ligno-cellulosic biomass can be abundantly procured from forestry, crops estate (plantation) and the agriculture sector. Unfortunately, their utilization as fuel which has been, up till now, developed and used at the community level is still confined to a simple life style (i.e. firewood and charcoal burning) and prepared from wood, waste wood and coconut shells. Furthermore, the use of firewood as simple biomass fuel is still dominating due to their benefit over other kinds of woody biomass from crops estate (plantation) and the agriculture sector. Therefore, biomass products for fuel uses developed by more advanced energy conversion technology, rather than firewood, still need to be promoted.

Technologies of energy conversion from woody biomass ever enhanced or developed can consist of energy-safe kilns and stoves, carbonization, gasification and fermentation techniques. Such endeavors generate, among others: heat energy, charcoal, gas fuel for boilers, special gas that can be converted to electricity and biogas. Conversion technology developed in and by simple communities is carbonization that produces charcoal and wood vinegar as its by-product. Wood vinegar seems to have favorable future prospects, since its technology is environment-friendly and moreover affords efficient utilization of raw material. It has been indicated that wood vinegar can be used as an effective organic fertilizer, a bio-pesticide and as plant growth hormone, implying that two beneficial products (i.e. wood vinegar and charcoal) can be produced in one simultaneous operation/process.

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