A CONTINUOUS-FLOW RICE HUSK GASIFIER FOR THERMAL APPLICATIONS[1/]

by

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ABSTRACT

This paper describes a continuous-flow rice husk gasifier (CFRHG) designed and developed for various thermal applications such as cooking, drying, kiln firing, baking, and others. The technology follows the principle of a moving-bed, down-draft reactor converting raw rice husks into combustible gases that is rich in carbon monoxide (CO) and hydrogen (H_2).

Different sizes were built and tested in collaboration with the private sector both in the Philippines and in abroad. The gasifier units which were built, tested and evaluated have varying reactor diameter, ranging from 0.40 to 1.20 m with a corresponding power output of 35.7 to 321.2 kW_t. The rice husk consumption rate for the different reactor diameters tested ranges from 19 to 169 kg per hour. The specific gasification rate of the gasifiers was found to operate well at 150 kg/hr-m^2. The temperature of the gas leaving the reactor varies from 150° to 270°C for all the units tested. The flame temperature reaches as high as 400° to 800°C, depending on the size of the reactor. The bigger the size of the reactor diameter, the higher is the flame temperature. The parasite load varies from 4.2% for the smaller diameter reactor to 1.5% for the bigger model. Combustible gases are generated within 5 to 30 minutes for the different sizes tested. The heating value of the gas ranges from 1200 to 1400 kcal/m^3. And, only one person is needed to operate the small gasifier and two persons are needed for the big gasifier model.

Results of the tests showed that the CFRHG is convenient to use and its operation is easily controlled with the use of gas valves. There is no smoke emitted during operation. Black carbon content and tar emissions were found to be very minimal. The char produced can be used for agricultural application and the ash produced can be used for the production of low-cost construction materials.

The CFRHG technology can be produced at P1,500.00 per kW_t. Presently, the different gasifier models presented are installed in the Philippines, Indonesia, and Vietnam. In terms of payback period, investment cost for the CFRHG can be recovered within 2.4 to 5.3 months as compared with kerosene, diesel, and LPG fuels.

[1/] Paper presented during the 10th PCIERD Regional S&T Fora and Competition held at FNRI Training Room, DOST Compound, Bicutan, Taguig, Metro Manila on February 26, 2010.

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INTRODUCTION

Alternative energy sources, like the use of biomass, is becoming of interest to people from around the world. This is because the supply of fossil fuel is becoming scarce causing its price to be costly for domestic households as well as for industrial sector. If fossil fuel will be continually tapped, however, the cost to utilize it will be very expensive. In addition to this, emission of burnt gases brought about by the production of this fossil fuel poses a lot of problem not only to the economy but also to the environment.

Rice husk, which is one of the biomass fuel sources around the world, is still considered untapped. In the Philippines, about 2 million metric tons of rice husks are produced annually. And about 115 million metric tons is generated from various countries like China, India, Indonesia, and other countries in Asia where rice is predominantly grown. In the Philippine setting, this voluminous amount of agricultural wastes are commonly stacked at the back of rice mills, dumped and burned on roadsides, or used as filling materials. There are instances in which these wastes are used to produce carbonized rice husks. In the process of producing carbonized rice husks, however, tremendous amount of smoke is emitted making it inefficient requiring for immediate solution to make it environmentally sound.

Gasifying rice husks, that is burning it with limited amount of air, was found to be an effective means of generating heat that can be utilized for various thermal applications and, at the same time, mitigating smoke emission problem. Several studies in the past revealed that a bluish-flame gas can be generated from rice husks when gasified. Recent developments on rice husk gasifier, following an inverted down draft mode, underpins such claim that indeed a very clean gas can be produced from gasifying rice husks. However, most of the systems developed operate on a batch mode while most of the industry applications require a continuous mode. The need for a rice husk gasifier that operates on a continuous mode has inspired the Center for Rice Husks Energy Technology (formerly operating as Appropriate Technology Center), in 2005, to develop a moving-bed inverted-downdraft gasifier.

This paper describes the continuous-flow rice husk gasifier (CFRHG) designed and developed by the Center for various thermal applications such as cooking, drying, baking, and others. The advantage features of the technology and the limitations are briefly described in this paper. Also, the socio-economic impact and opportunities of the technology are presented herein. The environmental aspect, ease of adoptability and replication are likewise discussed as well as its replicability and contribution to the advancement of science and technology.

METHODOLOGY

The design and development of the different models of CFRHG technology was carried out one after the other at the clients' level. The process started by obtaining information and data needed for the design from the client before design calculations and drawing preparations were made. Actual visits to the facility were also done to gather further actual data needed in the design of the gasifier. After the design was prepared, the materials needed and the manpower required to build were estimated and then the unit was built either by the clients themselves or by sub-contracting with fabricators nearby. Testing and evaluations of the different gasifier models were done in close coordination with the client-owners to iron out or to fine tune the operation of the machine, according to their requirement. Based on the results of the testing, adjustments and modifications of some parts were made to meet the specific needs of each client.

The performance of the different gasifier models was evaluated by measuring various parameters during actual operation. The weight of rice husks used and the weight of burnt rice husks were taken at the start and at the end of each operation using an appropriate weighing scale. The temperature at the various locations of the gasifier was also taken using a thermocouple-type and infrared thermometers. The pressure draft was measured using a pitot-tube manometer; and the velocity and the flow of air and of gas were determined by calculations. The electrical power consumption of each of the motors was determined by taking the amperages and voltages using an AC- clamp meter.

During the test, the following data were gathered:

(1) Start-up time to generate the gas
(2) Weight of fuel used
(3) Amount of char produced
(4) Gas temperature leaving the reactor
(5) Air temperature leaving the char box
(6) Flame temperature
(7) Total electrical power consumption (blowers, scraper, conveyors, etc)
(8) Air and gas velocity
(9) Pressure draft (static and dynamic)

The following parameters were analyzed after each test:

(1) Fuel consumption rate
(2) Specific gasification rate
(3) Power input
(4) Power output
(5) Percentage char produced
(6) Percentage parasite load

All the results obtained were used in coming up with the standard tabulation of the performance of the different CFRHG models.

RESULTS AND FINDINGS

Description of CFRHG

The continuous-flow rice husk gasifier (CFRHG) is a thermal heating device that converts rice husks into combustible gas for various heating tasks. As shown in Figure 1, the gasifier consists of the following major components: (1) Fed Hopper, (2) Reactor, (3) Char Chamber, (4) Scraper, (5) Particle Separator, (6) Gas Burner, (7) Pressure Relief Device, (8) Blower, (9) Support Stand, and (10) Loading Platform.

The CFRHG design follows the principle of a moving-bed-type gasifier operating in an inverted downdraft mode. In this design, rice husks are gasified inside a cylindrical reactor by providing the fuel with limited amount of preheated air converting the carbon content in rice husks into combustible carbon monoxide (CO) and hydrogen (H_2) gases. As schematically shown in Figure 2, rice husks are fed onto the feed hopper at the top of the reactor and char is discharged from the bottom using a scraper. The gasifier has a grateless-type reactor thereby eliminating the problem of discharging the char during operation. Air is used to counteract the heat emitted from the gasifier and is used as primary and secondary air for gasifying rice husks and for burning the gas, respectively.

In big systems, loading of rice husks is facilitated using a bucket elevator and discharging of char is done using a screw conveyor, usually in 0.6-m gasifier reactor and above.

Performance

All the CFRHG models tested successfully operate on a continuous mode. Continuous operation is accomplished by simply loading rice husks onto the feed hopper while simultaneously discharging char from the char box. Rice husk fuel is easily ignited and produces combustible gases within 5 to 30 minutes. Almost no smoke is emitted from the gasifier during operation. One to two persons are needed to operate the CFRHG – i.e., to facilitate loading of fuel and unloading of char.

For the different models developed, as shown in Table 1, the thermal power output varies from 29,745 to 267,702 kcal/hr (i.e., 35.7 to 321.2 kW_t) for the 40- and 120-cm reactors, respectively. The rice husks consumption rate ranges from 19 to 169 kg/hr and specific gasification rate is 150 kg/hr-m^2, on the average. The temperature of the gas leaving the reactor varies from 150° to 270°C. Preheated air, with a temperature of 90° to 180°C, is mixed with the burning gas at the burner producing a yellowish-to-bluish flame in color having a temperature of 400° to 800°C. Gasifier efficiency ranges from 52.2 to 53.1 percent. Measurement of the parasite load shows that the percentage amount of electrical energy used per unit heat produced is up to 4.2%. Moreover, this amount decreases as the reactor diameter increases.

Generally, the gas coming out of the rice husk gasifier, as shown in Table 2, consists predominantly of CO, H_2, CH_4, CO_2, N_2, and water vapour. CO, H_2, and CH_4 are the combustible gases while the remaining gases are non-combustible. The amount of CO varies from 15 to 30% while H_2 is 10 to 20%. CH_4 is very much low

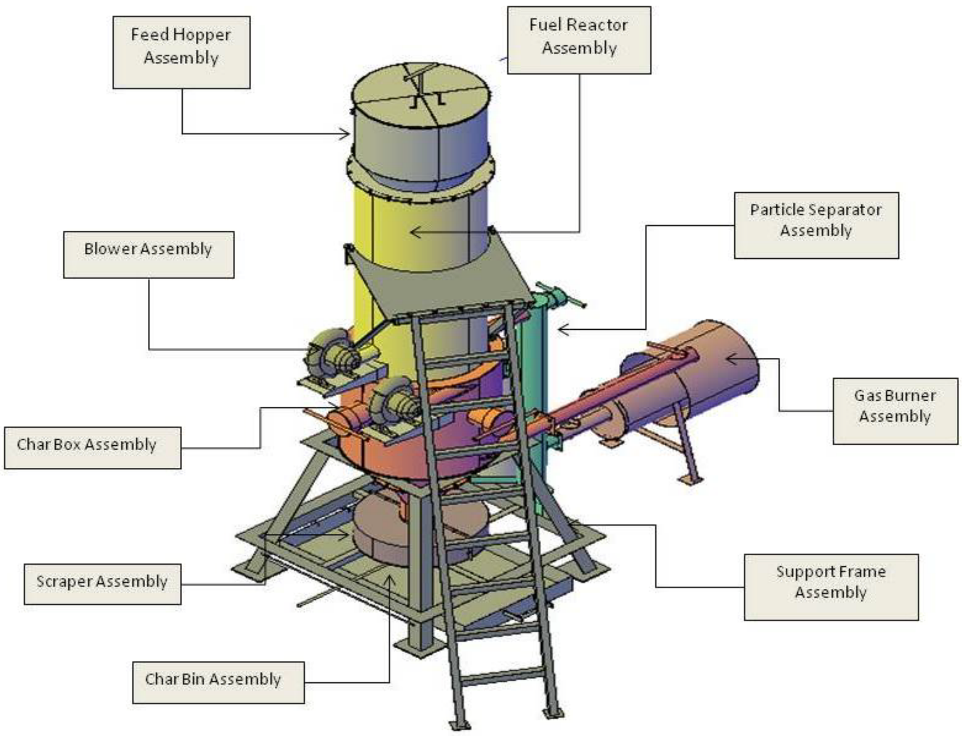

Figure 1. The CFRHG Parts Assembly.

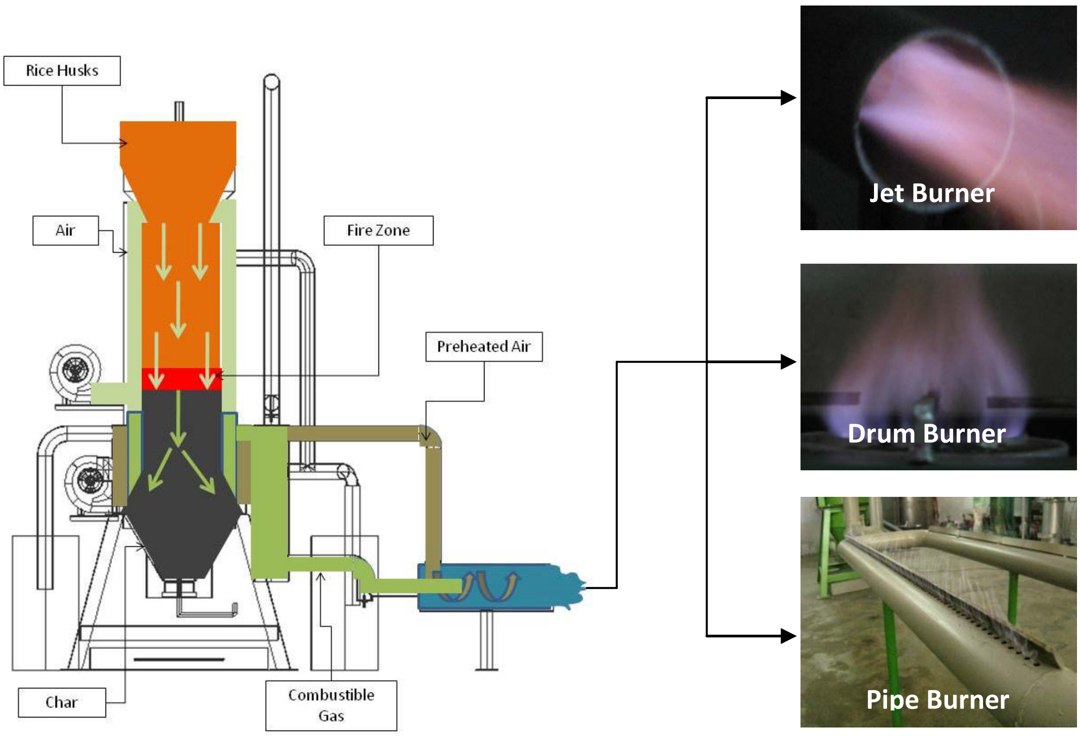

Figure 2. Schematic Drawing of the Operating Principle of the CFRHG Showing the Flame Produced in Three Different Types of Burner.

Table 1. Design and Performance Specifications of the Different Models of the CFRHG.

Parameters	Model				
	40D	60D	80D	100D	120D
Reactor Diameter (cm)	40	60	80	100	120
Start-Up Time (Min)	5-10	5-10	10-15	15-20	20-30
Heat Output					
kcal/hr	29,745	66,926	118,979	185,904	267,702
kW_t	35.7	80.3	142.8	223.1	321.2
Rice Husk Consumption (kg/hr)	19	42	75	118	169
Specific Gasification Rate (kg/hr-m^2)	150				
Specific Fuel Consumption (kg /kW-hr)	0.53	0.52	0.52	0.53	0.53
Gas Temperature (°C)	150 to 270				
Air Temperature (°C)	90 to 180				
Flame Temperature (°C)	400 to 800				
Gasifier Efficiency (%)	52.2 to 53.1				
Char Discharge Rate (kg/hr)	6	13	23	35	51
Electricity Consumption (kW)	1.5	2.5	3	4	5
Parasite Load (%)	4.2	3.1	2.1	1.8	1.5
Total Height (m)	3	4	5	6	7
Reactor Floor Area (m x m)	1.7 x 1.7	2.0 x 2.0	2.3 x 2.3	3.0 x 3.0	3.5 x 3.5

Table 2. Composition and Characteristics of Gas Produced from the Gasifier.

Gas Composition	
CO	15-30 %
H_2	10-20%
CH_4	2-4%
CO_2	5-15%
N_2	45-60%
Water Vapor	6-8%
Heating Value	1,200 to 1400 kcal/m^3
Black Carbon	10 to 50 ug/m^3
Tar	56 to 100 mg/m^3

since rice husks gasifier operates at relatively high temperature inside the reactor. The amount of CO_2, also known as the greenhouse gas, varies from 5 to 15% which is half of the amount derived when rice husks are burned by direct combustion. The heating value of gas ranges from 1200 to 1400 kcal/m^3, with measured black carbon content of 10 to 50 ug/m^3 and tar content of 56 to 100 mg/m^3.

The gasifier developed comes in variety of sizes and power output, depending on the energy demanded by the operation in which the technology is intended to be applied for. So far, 0.40- to 1.2-m reactors were built for various applications such as cooking, baking, water heating, and drying, shown in Figures 3 to 8.

The advantage features of the technology are: (1) the heat energy generated from the gasifier is in gaseous form and can be efficiently supplied for various heating tasks; (2) the operation is convenient for it does not require much attendance and the firing is controlled easily making it more suitable for sensitive applications like seed drying and food cooking; (3) the gasifier can easily be built even in a small shop; (4) the gas emitted from the burner contains less amount of black carbon, tars, CO_2, and other gases; and (5) the energy cost generated is cheap per kW_t.

Socio-Economic Impact and Opportunities

This technology can provide livelihood in the production and in the use of the CFRHG, particularly in rice producing regions. The CFRHG technology can primarily benefit both the manufacturing and the processing industries in utilizing it and also the suppliers in the locality. It can provide employment for 2 to 5 welders in building a unit of the gasifier for the period of one month, and for 1 to 2 persons in operating it, depending on the size of the unit.

Table 3 gives the production cost analysis for the different CFRHG models. A potential sale of P26,667.40 to 240,004.35 for materials will be available to local Hardwares and Suppliers in the country. For the labor, P10,290.00 to 92,500.00 will be available to local labor in the form of income per unit of the gasifier constructed. For those who will build and market the CFRHG can have a minimum profit of P6,324.80 or a maximum of P56,905.52 per unit. And, the government can realize a revenue (from tax payable) of P5,059.84 to 45,524.41, depending on the size, for every unit sold. Moreover, the continued utilization of this technology may result in an opportunity for farmers to have added income from the sale of their rice husks.

Table 4 shows the investment cost for the different CFRHG models which is P53,550.00 for the 40-cm reactor and P481,800.00 for the 120-cm. On the average, the investment cost is P1,500.00 per kW_t, which is 50 to 70% less than that of the commercially-available biomass furnaces. Payback period for the CFRHG considering a 40% shipment cost and operating time of 8 hours per day and 20 days per months is between 2.4 to 5.3 months. This would be higher if other costs are to be included.

Table 3. Production Cost Analysis for the Different Models of CFRHG.

Item	CFRHG Model				
	40D	60D	80D	100D	120D
Material Cos	26,667.40	55,978.80	106,633.90	166,612.65	240,004.35
Labor Cost	10,290.00	23,150.00	41,200.00	64,350.00	92,500.00
Overhead Co	3,200.09	7,197.46	12,796.07	19,993.52	28,800.52
	40,157.49	86,326.26	160,629.97	250,956.17	361,304.87
Total Produ	40,157.49	86,326.26	160,629.97	250,956.17	361,304.87
Selling and A	2,007.87	4,516.31	8,031.50	12,547.81	18,065.24
Total MC	42,165.36	90,842.57	168,661.47	263,503.98	379,370.12
15% of the	6,324.80	14,226.39	25,299.22	39,525.00	56,905.52
12% of the	5,059.84	11,381.11	20,239.38	31,620.48	45,524.41
Manufactur	**53,550.01**	**120,450.06**	**214,200.06**	**334,650.05**	**481,800.05**

Table 4. Operating Cost Analysis of the Different Models of CFRHG (As of February 2010).

Model			40D	60D	80D	100D	120D
Rated Output (kWt)			35.7	80.3	142.8	223.1	321.2
Investment Cost for the Gasifier (Php)			53,550	120,450	214,200	334,650	481,800
Shipment Cost of Unit, etc (Php) 1/			21,420	48,180	85,680	133,860	192,720
Total Investment Cost (Php)			74,970	168,630	299,880	468,510	674,520
Fixed Cost (Php/day)							
	Depreciation 2/		13.20	29.70	52.82	82.52	118.80
	Interest on Investment 3/		3.96	8.91	15.84	24.75	35.64
	Repair and Maintenance 4/		0.98	2.20	3.91	6.11	8.80
	Insurance 5/		0.44	0.99	1.76	2.75	3.96
	Sub-Total		18.58	41.80	74.33	116.13	167.20
Variable Costs (Php/day)							
	Fuel 6/		304.00	304.00	304.00	304.00	304.00
	Electricity 7/		108.00	180.00	216.00	288.00	360.00
	Labor 8/		250.00	250.00	500.00	500.00	500.00
	Grease, Oil, etc 9/		53.55	120.45	214.20	334.65	481.80
	Sub-Total		715.55	854.45	1,234.20	1,426.65	1,645.80
Total Costs		Php/day	734.13	896.25	1,308.53	1,542.78	1,813.00
Operating Cost		Php/hour	91.77	112.03	163.57	192.85	226.63
		Php/kW-hr	2.57	1.40	1.15	0.86	0.71
Savings per Day		Kerosene 10/	1,068.43	3,088.37	5,806.85	9,652.09	14,220.33
		Diesel 11/	706.74	2,288.83	4,379.12	7,405.79	11,003.17
		LPG 12/	858.46	2,624.23	4,978.03	8,348.08	12,352.73
Payback Period (Months)		Kerosene	3.5	2.7	2.6	2.4	2.4
		Diesel	5.3	3.7	3.4	3.2	3.1
		LPG	4.4	3.2	3.0	2.8	2.7

1/ Shipment cost of 40% of the IC
2/ Straight line method with 10% salvage value and life span of 10 years
3/26% of the investment cost
4/15% of the investment cost
5/3% of the investment cost
6/At P2.00 per kg
7/At electricy cost of P9.00 per kW
8/At a labor cost of P250.00 per 8 hour day
9/ At grease and lubrication oil, etc cost of P1.50 per kW
10/At a kerosene cost of P46.25 per liter and conversion ratio of 3.90 kg of rice husk per liter of kerosene
11/At a diesel cost of P39.15 per liter and conversion ratio of 4.13 kg of rice husk per liter of diesel
12/ At an LPG cost of P63.18 per kg and conversion ratio of 6.03 kg of rice husks per kg of LPG

Environmental Aspect

The CFRHG technology is considered to be environment-friendly since it utilizes a renewable energy source in which the by-product is re-usable. With this technology, the annual rice husk production of 2 million metric tons can be utilized for various thermal energy applications and the by-product can be utilized as valuable materials for agricultural and industrial uses. It does not emit harmful gases for it efficiently burns all the gases produced. It has high CO_2 reduction potential and very low black carbon emission (only 10 to 50 ug/m^3) as compared with other thermal generating devices.

Table 5 shows the savings and yearly potential sales of CO_2 from the use of CFRHG over the use of rice husks and other fuels by direct combustion. Compared with direct combustion of rice husks, the use of CFRHG may result in a savings of as low as 6.1 and as much as 54.5 tons of CO_2 per year for the different models with potential sales of US$ 61 to US$ 545 per year, considering a carbon credit of US$ 10 per ton of CO_2. For substituting kerosene fuel, a savings of 6.3 to 56.4 tons of CO_2 per year will be incurred with potential sales of US$ 63 to US$ 564 per year. If the gasifier is used to replace LPG, a yearly savings of 11.1 to 99.1 tons of CO_2 will be earned with potential sales of US$ 111 to US$ 991. Replacing the use of diesel fuel, a yearly savings of 15.7 to 139.3 tons of CO_2 will be gotten with potential sales of US$ 157 to US$ 1393.

The char, which is the by-product in the operation of the gasifier, can be used as carbonized rice husk for agricultural use or can be mixed with coal for biocoal pellet production. The ash, which is another by-product, can be processed further into locally-produced refractory materials or can be used as raw material in the production of cement-fiber board and geo-polymer products.

Ease of Adoptability/Utilization and Replication

The CFRHG units are presently used in various thermal applications such as frying, baking, drying, and other uses. Other applications of this technology, like heating boilers, firing kiln and even supplying gas to an internal combustion engine, are popularly sought by many clients from across the globe.

The design of the CFRHG is simple and does not require modern technique or state-of-the-art equipment to build. More importantly, it does not make use of high-tech component making its adoptability easy. It can be produced even in a small welding shop with the use of basic fabrication tools and equipment, or by subcontracting fabrication of its various parts. Furthermore, its operation is also simple that even the local folks can manage to operate it; thus, making its utilization easy.

At present, the CFRHG is being produced in the Philippines, Indonesia, Vietnam, and Malaysia. There are potential producers from other countries like India, Jordan, Egypt, Peru, Dominican Republic, and many more who have signified their intention to produce the CFRHG of varied sizes and for various applications.

Table 5. CO_2 Savings and Yearly Sales for Various Models of CFRHG.

CO_2 Savings from the Use of CFRHG Over Direct Burning of Rice Husks

Gasifer Model	40D	60D	80D	100D	120 D
RH Consumption, kg/hr	19.0	42.0	75.0	118.0	169.0
kg CO_2 per Hour	2.7	5.9	10.5	16.5	23.7
kg CO_2 per Day	21.3	47.0	84.0	132.2	189.3
kg CO_2 per Week	127.7	282.2	504.0	793.0	1135.7
kg CO_2 per Month	510.7	1129.0	2016.0	3171.8	4542.7
Tons CO_2 per Year	6.1	13.5	24.2	38.1	54.5
Sale per year (US$) 1/	61.00	135.00	242.00	381.00	545.00

Rice husks burning at 0.94 kg of CO_2 per kg of fuel.

CO_2 Savings from the Use of CFRHG Over the Use of Kerosene

Gasifer Model	40D	60D	80D	100D	120 D
RH Consumption, kg/hr	19.0	42.0	75.0	118.0	169.0
kg CO_2 per Hour	2.8	6.1	10.9	17.1	24.5
kg CO_2 per Day	22.0	48.7	86.9	136.8	195.9
kg CO_2 per Week	132.1	292.1	521.6	820.7	1175.4
kg CO_2 per Month	528.6	1168.5	2086.5	3282.8	4701.6
Tons CO_2 per Year	6.3	14.0	25.0	39.4	56.4
Sale per year (US$) 1/	63.00	140.00	250.00	393.00	564.00

Kerosene at 2.92 kg CO_2 per liter and conversion ratio of 3.92 kg of RH per liter of kerosene

CO_2 Savings from the Use of CFRHG Over the Use of LPG

Gasifer Model	40D	60D	80D	100D	120 D
RH Consumption, kg/hr	19.0	42.0	75.0	118.0	169.0
kg CO_2 per Hour	4.8	10.7	19.1	30.0	43.0
kg CO_2 per Day	38.7	85.5	152.8	240.3	344.2
kg CO_2 per Week	232.2	513.3	916.5	1442.0	2065.2
kg CO_2 per Month	928.8	2053.0	3666.1	5768.0	8261.0
Tons CO_2 per Year	11.1	24.6	44.0	69.2	99.1
Sale per year (US$) 1/	111.00	246.00	440.00	692.00	991.00

Lpg at 3.35 kg CO_2 per kg and conversion ratio of 3.92 kg of RH per kg of LPG

CO_2 Savings from the Use of CFRHG Over the Use of Diesel

Gasifer Model	40D	60D	80D	100D	120 D
RH Consumption, kg/hr	19.0	42.0	75.0	118.0	169.0
kg CO_2 per Hour	6.8	15.0	26.8	42.2	60.4
kg CO_2 per Day	54.4	120.2	214.6	337.6	483.5
kg CO_2 per Week	326.2	721.0	1287.6	2025.8	2901.3
kg CO_2 per Month	1304.7	2884.1	5150.2	8103.0	11605.2
Tons CO_2 per Year	15.7	34.6	61.8	97.2	139.3
Sale per year (US$) 1/	157.00	346.00	618.00	972.00	1393.00

Diesel at 2.94 kg CO_2 per liter and conversion ratio of 3.07 kg of RH per liter of Diesel.

1/ At US$ 10 per ton of CO_2

Replicability and Contribution to the Advancement of S&T

The CFRHG can easily be built and constructed. The technology is simple that it can be replicated even by just following the drawings.

This technology asserts a significant contribution to the advancement of S&T for it is the first continuous-type gasifier that uses rice husks with clean gas emission. Since the development of the fixed- bed rice husk gasifier, no other technology that operates on a continuous mode has been found available on commercial scale, only the moving-bed inverted-downdraft technology. Hence, making CFRHG an innovative gasifier technology.

The following are the distinct features of the CFRHG as compared with the other gasifiers previously developed:

1. No need of a dual reactor in order to have a continuous operation;
2. No problem on tar and black carbon emission because of its inherent design in which tar and black carbon are cracked before leaving the reactor;
3. No problem on char removal during operation since it is the first ever grateless-type gasifier;
4. No insulation is needed thereby eliminating the cost for insulating the system;
5. It makes use of the excess heat from the reactor and from the char chamber to improve gasification and combustion of gases; hence minimizing the problem on heat corrosion resulting in a prolonged life span of the gasifier unit;
6. It can be adopted to a variety of gas burners (either drum-type, jet-type or pipe-type) to meet various cooking and heating tasks requirements; and
7. The by-product of gasification can be used as source of carbonized rice husks for improving water holding capacity of the soil, as raw material for producing biocoal (CRH + biomass char) pellet fuel, as ingredient in producing low-cost refractory cement for heat insulation, as raw material for producing geo-polymer for low-cost construction material, and as raw material for producing cement-fiber board for low-cost housing.

CONCLUDING REMARKS

The CFRHG technology clearly demonstrates that rice husks can be efficiently gasified in a continuous mode following the principle of a moving-bed inverted-downdraft technology. Different reactor diameters of CFRHG of up to 1.2 meter work well in producing combustible gases using raw rice husks. The use of scraper eliminates the problem of char clogging during operation.

The technology can provide more benefits to the users, particularly in terms of convenience of operation and cost. Likewise, it can provide a greater socio-economic advantage to the locality in the production and in the utilization of the technology and to the government as well. It does not require advanced knowledge and high-tech component and equipment in the fabrication; thus, it can be easily built using locally available resources and manpower. It also addresses the environmental aspect of the country and of the world, in general, since it is considered a clean technology based on black carbon and CO_2 emissions, which are basically low. Its by-products can be further used as valuable commodity products for agriculture and construction sectors. More importantly, it can generate significant earnings from the sale of carbon credit, which, in the long run, can be more than enough to compensate for the cost of the CFRHG unit itself.

Moreover, the adoption of this technology in other countries simply indicates the significance of its contribution in the advancement of science and technology. It is the first ever continuous-type gasifier with clean gas emission thus far.

ACKNOWLEDGMENT

We would like to thank the following for their support during the implementation of this project: (a) Sampaguita Kropect Factory, (b) LASRI Rubber Processing Plant, (c) PT. Minang Jordanindo Approtech, (d) VINASILIC SJ, and (e) Biomass Energy System Technology - Philippines.

Above all, to the Almighty God who gave us the Wisdom and the Knowledge in successfully carrying out these projects.

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Figure 3. The CFRHG Model-40D Used for Drying Paddy Seeds in Nueva Ecija, Philippines.

Figure 4. The CFRHG Model-45D Used for Drying Shredded Plastics in Tangerang, West Java, Indonesia.

Figure 5. The CFRHG Model-60D Used for Paint Factory
In Tegal City, Central Java, Indonesia.

Figure 6. The CFRHG Model-80D Used for Drying Food Products
in Tarlac City, Philippines

Figure 7. The CFRHG Model-100D Used for Baking Rubber in North Cotabato, Philippines.

Figure 8. The CFRHG Model-120D Used for Torrefying Rice Husks in Vung Tau Province, Vietnam.