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RESEARCH ARTICLE

Caloric Value of Biomass based Power Plants, Life Cycle Assessment and Techno Economic of Different Crops for M.P. (India)

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Abstract

Solar radiation incident on green plant and other photo synthesis organism performs two basic functions such as temperature control for chemical reaction to proceed and the process of photosynthesis. The fundamental conversion process in green plant is photosynthesis which is process of combining CO_2 from the atmosphere with water and light energy to produce oxygen and carbohydrates[1].

$$X [CO_2] + Y [H_2O] + \text{light energy photosynthesis } X[O_2] + Y [Cx\ H_2O]$$

$Y [Cx\ H_2O]$ is used to indicate the carbohydrates.

The world population has increased at an explosive rate from 1.65 billion to just over 6 billion in the 20^{th}century, and continues to increase. In the same century, mankind has consumed over 875 billion barrels of oil and it is very likely that even more oil will be consumed in the present century. Annual energy use in developing countries has risen from 55 to 212 kg oil equivalent over the last thirty years, while developed countries use as much as 650 kg oil equivalent per person. In his synopsis 'Trilemma' Three major problems threatening world survival', foresees a three-fold challenge in the 21st century: how can we achieve economic growth, supply food and energy resources, while conserving the environment? To overcome the Trilemma, developing and introducing more efficient energy conversion technologies is therefore important, for fossil fuels as well as renewable fuels. This thesis addresses the question how biomass may be used more efficiently and economically than it is being used today. Wider use of biomass, a clean, renewable and CO_2 neutral feedstock may extend the lifetime of our fossil fuels resources and alleviate global warming problems. Another advantage of using of biomass as a source of energy is to make developed countries less interdependent on oil- exporting countries, and thereby reduce political tension. Furthermore, the economies of agricultural regions growing energy crops benefit as new jobs are created[1]. Biomass primary energy sources: Past, present and future in particular wood, has historically been an important energy source for fires, ovens and stoves. During the Industrial Revolution, coal displaced biomass because of its high energy content and because it is available in large quantities at low cost. At the beginning of the 20^{th} century, oil supplied only 4 % of the world's energy. Decades later it became the most important energy source. Especially developed countries are highly dependent on oil, which supplies about 96 % of their transportation energy. With world energy demand projected to rise by about 40 % from now to 2020, photosynthesis. Rajiv Gandhi Proudyogiki Vishwvidhalaya implemented the National Policy for Management of Crop Residues to protect the parali (crop residue). On December 10, 2015, the National Green Tribunal (NGT) had banned crop residue burning in the states of Rajasthan, Uttar Pradesh, Haryana and Punjab. Burning crop residue is a crime under Section 188 of the IPC and under the Air and Pollution Control Act of 1981. The Delhi high court had also ordered against burning residues, while Punjab government imposed a penalty of Rs 73.2 lakh farmers in 2016 for burning of crop residue[3].

Keywords: National Green Tribunal (NGT), *Parali*, Photosynthesis, Trilemma' Moisture content (MC), Volatile Combustible Matter (VCM)

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1. Introduction

1.1 Biomass Conversion Processes

The development of conversion technologies for the utilization of biomass resources for energy is growing at a fast pace. Most developing countries find it hard to catch up because the level of technology is beyond their manpower as well as their manufacturing and technological capability. Added to this is the unavailability of local materials and parts for the fabrication of these conversion units. Figures 1,2 shows the different methods for converting biomass into convenient fuel. Biomass conversion into heat energy is still the most efficient process but not all of energy requirement is in the form of heat. Biomass resources need to be converted into chemical, electrical or mechanical energy in order to have widespread use. These take the form of solid fuel like charcoal, liquid fuel like ethanol or gaseous fuel like methane. These fuels can be used in a wide range of energy conversion devices to satisfy the diverse energy needs. In general, conversion technologies for biomass utilization may either be based on bio-chemical or thermo-chemical conversion processes[3].

1.2 Thermal Application Including

- Cooking
- Drying
- Water heating
- Steam generation
- Electrical power generation
- Fuel for I C engine

1.3 Composition of Producer Gas Volumetric Composition of Producer Gas

$$\begin{pmatrix} CO\ 20-22\% \\ H_2\ 15-18\% \\ CH_4 2-4\% \\ CO_2\ 9-11 \\ N_2\ 50-54\% \end{pmatrix} + \begin{pmatrix} \text{Tar and particulate materials} \end{pmatrix}$$

Equation 1. Composition of producer gas.

1.4 Fuel Parameters

The tests and analyses just mentioned are in widespread use because they were developed for use in other industries. However, many more tests need to be developed specifically for gasification processes. This section addresses the effects of other fuel parameters on biomass gasification, illustrating the need for more specific testing procedures. The basic fuel parameters important in gasifier design are[3]

- Particle size and shape
- Particle size distribution
- Char durability and fixed-carbon content
- Ash fusion temperature
- Ash content
- Moisture content
- Heating value

Table 1. Agricultural Production Data, Ministry of Agriculture, http://agricoop.nic.in. The residue ratios and use patterns from the reports of taluk level studies sponsored by MNRE[6]

Crop	Production (million tons)	Types of residue	Production of main crop to residue ratio	Quantity of Residues(million tons per year)	Typical uses of residues
Rice	90	Straw	1.3	117	• As cattle feed in South and East India. • Generally burnt in the fields in North India
		Husk	0.3	27	As a fuel by small industry
Wheat	80	Straw	1.5	120	Mainly as cattle feed
Coarse cereals	30	Straw and husk	1.8	54	As cattle feed and fuel

Crop	Production (million tons)	Types of residue	Production of main crop to residue ratio	Quantity of Residues(million tons per year)	Typical uses of residues
Sugar cane	320	Bagasse	0.3	96	Mainly as a captive fuel by sugar plants, partly as raw material for paper making.
		Tops	0.05	16	As cattle feed
		Trash	0.07	20	Mostly burnt in the field
Coconut	14	Shell	0.13 kg per nu	0.2	Partly as domestic fuel.
		Fiber	0.2 kg per nu	2.8	Partly for making mattress, carpet etc
		Pith	0.2 kg per nu	2.8	No productive use. Disposal is a problem
Cotton	3.5	Stalk	3.0	10.5	Partly as domestic fuel.
		Gin Waste	0.1	0.35	As fuel for brick making and by small industry.
Oilseeds	20	Straw and husk	1.1	22	Domestic Fuel
Pulse	14	Straw	1.3	18	Partly as a domestic fuel
Jute/ Mesta	2.0	Stalk	2.0	4	Partly as fuel for processing tobacco leaves/domestic fuel
Total				510	

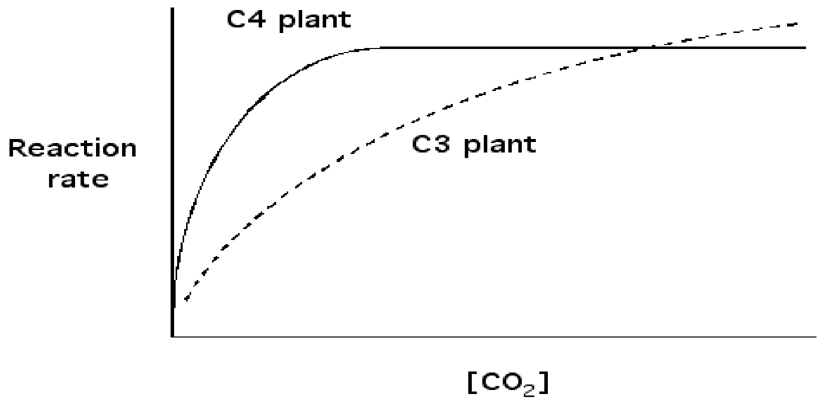
1.5 Techno-Economic and Life Cycle Assessments of Crops Base Residues from Biomass through Farmer

An impact assessment converts the inventory of emissions and wastes into impacts to the Environment through a consideration of environmental damage mechanisms. This study Looked at the life cycle impact assessment using the global warming potential and the Cumulative energy demand and increase the economics values of farmer's after selling the crops base residues for gasifier Power Plant[5].

1.6 Gasifier Model

Table 2. Specification of Gasifier Model

Gasifier Model	Cosmo Cp-10
Mode of Operation (power mode)	Cold & Clean Gas
Gasifier Type	Down Draft
Rated Gas flow	25 Nm^3 /hr
Average gas calorific value	1000 k cal/Nm^3
Gasification Temperature	1000-1200 degree centigrade
Output removal	Manual, once every six hours.
Fuel type & Size	Wood/woody waste with maximum dimension not exceeding 45 mm dia.
Permissible moisture content in Biomass	5-20 % (Wet basis)
Biomass charging	Online batch mode, by topping up once every two to four hours
Rated Hourly consumption	Up to 18 kg.
Auxiliary Consumption	.9KW(1HP)Pump+1.2KW(1.5 HP)Blower
Typical conversion efficiency	> 75 % with wood as fuel
Typical gas composition	CO- 19 %, H2-18 %, CO2d-10 %, CH4- upto 3 %, N2- 50 %
Engine Genset	11 kWe
Rated output (gross)	
Rated output (net)	10 kWe
Specific Biomass Consumption	Less than 17 kg/kWhr (Wood based)



Graph 1. C3 Plants and C4Plants.

Figure 1. 10 kW biomass Gasifier installed at energy park UIT-RGTU Bhopal.

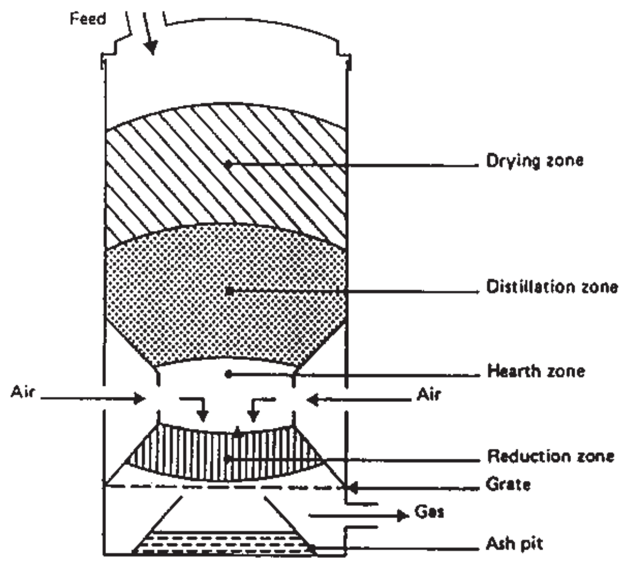


Figure 2. Downdraft Gasifier.

Figure 3. Photos of gasifier and generator set at RGPV Energy park.

1.7 Following Reaction Zone and Process in the Gasifier

Devolatilization zone: Biomass → char + volatile + tar

Devolatilization reduction: Volatile → Gas1 (CO, CO_2, H_2, CH_4 etc.)

Char Combustion: Char→ Gas2 (CO, CO_2)

There is also 10kWe downdraft gasifier available at Energy Park in Rajiv Gandhi Technical University, Bhopal (M.P.) for investigation and analysis of different woody biomass in the area of the research and development. This gasifier model shows Figure 3.

1.8 Dimension of Gasifier

Table 3. Dimension of Gasifier

S. No	Part of Gasifier	Dimension
1	Inner shell diameter (D1)	22cm
2	Outer shell diameter (D2)	26cm
3	Thickness of shell	0.7cm
4	Height of gasifier (H1)	115cm
5	Insulation diameter	32cm
6	Air nozzle diameter (di)	3cm
7	Length of air nozzle	10cm
8	Gas outlet diameter at inner shell (dg)	7 cm

Figure 4. **(a)** Crops residues bundle in farms **(b)** Crops husk

1.9 Specification of the Briquetting Plant

Table 4. Specification of the Briquetting plant

Model No.	Super 90
Technology	Ram and Die
Briquette diameter	90 mm
Briquette length	60-110 mm
Production capacity	1000 kg/h
Raw material size	1 mm to 10 mm
Finished product shape	cylindrical
Biomass type Agro residues	(Cotton stalks, Gram stalks, soy bean stalks and other agro residues)
Driving motors rating & rpm/Current consumption on load	Main motor :3PH 55KW 75HP /1475/50A Coupling motor :3PH 2.20KW 3HP/1430/6A

1.10 Briquetting plant

Figure 5. Compresse type Briquetting plant.

- Combustion zone. In the combustion zone, charcoal combusts with oxygen in the air from the inlet at the bottom of the gasifier[6].

$C+O_2 \rightarrow CO_2$, $\Delta H = +393.5$ kJ/ mole……………….(1)

$2H_2+O_2 \rightarrow 2H_2O$ + 242 MJ/Kg mole……………… (2)

Also, some other reaction occur but at a much lower rate.

- Reduction zone. By the release of CO_2 and heat from the combustion, reduction occurs. The main reaction here is CO being formed from CO_2-molecules and charcoal. This is an endothermic

Figure 6. Peddy type pellets from compresse.

reaction that hardly takes place at temperatures lower than 800 °C.

$C+CO_2 \rightarrow 2CO$ (Boudourd reaction) $\Delta H = 172.6$ kJ/mole………… (3)

- Pyrolysis In the third zone pyrolysis takes place. Pyrolysis is the degradation (lysis) of a material by heat (pyro). The absence of air in this zone, and the high temperature of the gas coming from underlying zones (between 200 °C and 500 °C) are needed for the gasification of the biomass[8].

Apart from charcoal, also various gas products are formed, mainly CO, CO_2, H_2O, H_2 and CH_4

2. Gasifier Fuels

Charcoal, wood, wood residues, agricultural residues and peat are some biomass fuels commonly used for gasification. Chemical, physical and morphological property differences of these fuels demand different gasification technologies or gasifier designs in order to smooth functioning of the system. The most important fuel properties can be identified as follows for stable and efficient operation of a gasifier with low pressure drop and production of high-quality gas. Several laboratory instruments are used to determine the following properties of Selected crops *Glycine max* (Soyabean) stalks, *Cajanus cajan* (Arhar) stalks, *Lens culinaris* (Masoor) stalks, Cotton stalks. The instruments used are bomb caloriemeter, furnace oven and electronic weight.

3. Proximate analyses of biomass fuels

3.1 Moisture Content

High moisture content of fuel reduces the thermal efficiency of gasifier since some heat is wasted for driving off the moisture which is otherwise used in reduction phase in converting thermal energy in to chemical energy or heating value of gas.

The desired moisture content for oue pilot gasifier is from 5-20 % But we tried to keep it as low as possible in order of 8–12 %.

The moisture of the biomass can be estimated by taking a small pre-weight sample whith an initial mass M is palced in drying oven in which a temperature of 110 °C is maintained After two hours mass is noted as M_e.

The moisture content is being calculated in percentage of biomass on dry basis is calculated as

$$M = \left(\frac{Mi - Me}{Mi}\right) x100$$

3.2 Volatile Matter Content

High volatile matter content of fuel demands special cleaning system and Special design in order to remove tars from producer gas when used in engine applications. So, the high quantity of volatile matter is not desirable as if tar can clog the cleaning equipment very frequently and need of cleaning arises frequently. The volatile matter of biomass is that component of the carbon present in the biomass, which, when heated, converts to the vapour. In almost all types of biomasses the amount of volatile matter which is a function of the carbon to hydrogen ratio is high and will be about 70-80 % of the weight of dry biomass. The amount of volatile matter is determined by heating a dried ground sample of biomass with an initial mass Mi in a closed crucible in an oven with a temperature of 600 °c for six minutes followed by heating the sample in an oven with the temperature of 900 °c for another six minutes and then its weight (Mf) is measured.

$$V = \left(\frac{Mi - Mf}{Mi}\right) X100$$

3.3 Ash Content

Melting or agglomeration of ash results in slagging or clinker formation. This adds much labour work and also excessive tar formation or blocking the gasifier with the risk of explosion even. The use of moving grates has added the advantage of ability to operation with fuels having high ash content The higher the amount of ash in a fuel, the lower is the calorific value of the fuel. The amount of ash is determined by heating a dry sample of biomass in a crucible in a furnace which is kept at 900 °C for 15 minutes so that all fuel is burnt completely. Sample is taken out of the furnace and the residue remaining in the crucible is ash. Measure the weight of the ash (Ms). Percentage ash content [a] is given by

$$A = \left(\frac{Ms}{Mi}\right) * 100$$

3.4 Fixed Carbon

The final step in proximate analysis is the determination of the amount of the fixed carbon [c] by using mass balance calculations. The amount of fixed carbon,

$$c = 100\text{-}(M+a+V)$$

3.5 Bulk Density

Fuels with high bulk density contain high energy content per unit volume and also require less space in fuel hopper. When the bulk density of fuel is low, it is difficult to flow under gravity and this result in low heating value of gas. Briquetting techniques as used now a days for achieving high bulk density as in case of agricultural residues.

Bulk Density of the testing materials was found out using weight of a given sample in a known volume the samples is placed in a cylinder container of known volume and uniform density is obtained by gently tapping the cylinder vertically down onto a table several times in the same manner .The excess on top of the cylinder is removed by sliding a string along the top edge of the cylinder .After the excess has been completely removed the grain sample is measured by analytical balance dry weight of the briquettes is determined from the top weight of the grain and the moisture content [Baba B. K *et al.*, 2012] Drying and storage of cereal grains. To overcome limitations of above fuel properties, suitable pretreatment of fuel is desired. Generally, pretreatment involves mechanical chipping for size reduction, screening to ensuring uniform size distribution, drying for moisture removal and densification for low bulk density fuels

3.6 Calorific Value of Feed Stock

The calorific value of a fuel is defined as the amount of heat evolved when a unit weight of fuel is completely burned and the combustion products such as CO_2 and H_2O are cooled of 298 °K. It is usually expressed in kilo joules. The calorific value of any given species of biomass is dependent on the moisture content and its density without slogging problem.

The calorific value of the different crop residues briquette was determined by using Bomb Calorimeter A sample of air-dried biomass with a known mass is burnt in an atmosphere of oxygen in a stainless-steel high-pressure vessel. known as a bomb. The bomb is a placed in a calorimeter which is highly polished outer vessel containing a known amount of water with a known temperature. The combustion products CO_2 and H_2O are allowed to cool to the standard temperature. The resulting heat of combustion is measured from the accurate measurement of the rise in the temperature of water in the calorimeter, the calorimeter itself and the bomb. The calorific value so estimated is the gross calorific value. Tests were done by oxygen bomb caloriemeter At RGPV Energy Dept Lab of Max temp of 300 ATP and having temperature recorded by Digital Beckman thermometer[9].

The calorific value of the briquette was determined by using the following formula

$$\text{Calorific value (Kcal/kg)} = \frac{(W+w)(T2-T2)}{X}$$

where,

W = weight of water in calorimeter (kg),

w = water equivalent of apparatus,

T1 = initial temperature of water (°C),

T2 = final temperature of water (°C),

X = weight of fuel sample taken (kg)

4. Gasifier

A downdraft gasifier of capacity 10KWe setup was installed in RGPV Energy Park to produce energy from various biomass materials. A three-cylinder four stroke engine was purchased and installed with gasifier in Energy Park of Energy Department RGPV Bhopal to conduct experimental work for testing different biomass material fuels.

The gasifier is connected to a GAS ENGINE running on 100 Producer Gas whose specification are given in table which is connected to the Ammeter and Voltmeter to show the Current and voltage generated during the working of generator on Gas Which eventually depend on the quality of gas Produced by gasifier using different biomass briquettes. In Final step we Are going to compare the energy input by gasifier each biomass of having a definite mass consumption rate and calorific value and in output energy is being calculated by

From gasifier and Bomb caloriemeter

Input energy = (Biomass Mass Consumption X Calorific value of sample Briquettes)

From Generator:

Output energy=Voltage X Current [1.16W =1Kcal/hr]

Overall efficiency=(Outputenergy)/(input energy)

4.1 Crops Base Residues Husk Generation from Crops

Table 5. Generating husk from crops by survey of villages

CROPS BASE RESIDUE (HUSK)IN Madhaya Pradesh				
s.no	**Grain production**	**COMMAN NAME**	**Grain Quantity Q/KG**	**Husk ProductionKG**
1	RICE	CHAWAL	1Q/100KG	20 kg
2	MUSTRED OIL	SARSO	1Q/100KG	150 kg
3	SOYABEEN	SOYABEEN	1Q/100KG	100 kg
4	WHEAT	GHEHU	1Q/100KG	100 kg
5	MAIZE (CORN)	MAKKA	1Q/100KG	60 kg
6	GRAM	CHANA	1Q/100KG	150 kg
7	GREEN GRAM	MUNG	1Q/100KG	55 kg
8	LENTIL	MASOOR	1Q/100KG	150 kg
9	BLACK GRAM	UDAD	1Q/100KG	55 kg
10	BEANS	MATAR	1Q/100KG	60 kg
11	DRY PEA /WHITE PEA	WHITE MATER	1Q/100KG	50 kg
12	CHICK PEAS	KAWALI CAHANA	1Q/100KG	140 kg
13	RED GRAM PIGEON PEA	ARAHR DAL	1Q/100KG	50 kg
14	PEARL	BAZARA	1Q/100KG	60 kg
15	SORGHUM	JOWAR	1Q/100KG	150 kg
HUSK QUANTITY IS MEASURE BY FARMAR OF MADHAYA PRADESH				

4.2 Testing of Biomass Briquettes

Table 6. Heating value and properties of biomass briquettes

Briquette	Diameter X Lenth (mm)	Bulk Density Kg /m^3	Moisture Content (%) As received	Volatile matter (%) Dry basis	Fixed carbon (%) Dry basis	Ash content (%) Dry basis	Calorific value (kcal/kg)
(Soyabean) stalks	90x20 90x40 90x60	480-520	10.84	79.14	11.92	8.94	4185
(Arhar) Stalks,	90x20 90x40 90x60	560-590	7.96	78.24	13.94	7.82	4228
(Masoor) Stalks	90x20 90x40 90x60	420-460	12.96	80.42	9.75	9.83	3828
Cotton Stalks	90x20 90x40 90x60	590-620	5.92	83.1	13.94	2.96	4465
Composite #1 Soya+Arhar	90x20 90x40 90x60	480-550	9.88	82.35	10.47	7.18	4005
Composite #2 Soya+Cotton	90x20 90x40 90x60	560-600	7.25	78.46	14.58	6.96	4275

Table 7. Engine Performance with respect to different biomass tested for generation of producer gas

Biomass briquette	Voltage (V)	Current (I)	Gasifier running time for (hrs)	Mass Flow rate to Gafifier (kg/hr)	Power Generated by generator (KW)	Power Generated / Month (KW)	Remarks
(Soyabean)	420	11	3 h 45 m	4.8	6.16	184	T_{max}=980 ºC $M_{biomass}$=18 kg
(Arhar)	420	11	3 h 45 m	4.54	6.17	186	T_{max}=980 ºC $M_{biomass}$=17 kg
(Masoor)	420	10	3 h 30 m	6.28	5.35	160	T_{max}=950 ºC $M_{biomass}$=22 kg
Cotton stalks	420	11	4 h	3.25	7.06	210	T_{max}=985 ºC $M_{biomass}$=13 kg
Composite #1 Arhar+Soya	420	11	4 h 20 m	3.57	6.84	205	T_{max}=940 ºC $M_{biomass}$=18 kg
Composite #2 Cotton +Soya	420	11	4 h 20 m	3.69	7.25	217	T_{max}=1010 ºC $M_{biomass}$=15 kg

4.3 Testing of Gasifier System

Experiment was conducted on 10 KWe PILOT downdraft gasifier at ENERGY PARK in RGPV developed for generating capacity of 11 KWe Generator with 6 different feedstocks to check the effect of feasiblity of feedstock on power generated by gas generator, power generated by producer gas generated by 3 different sizes and 4 different and 2 composite briquettes and efficiency of gasifier in terms of feed rate and of and power generated. The methods and instruments/equipments used to measure different fuel properties discussed earlier

5. Conclusion

This study support opinions regarding power generation capabilities, it is a lot of potential to replace wood and fossil fuels in lower-energy applications such as decentralized power generation and other similar applications.

The Government of India has various enabling policies to promote the development of the charging infrastructure network in Urban and rural area. A biomass gasifier is needed to ensure the efficient and timely implementation of Power supply in rural area and increase the development of Economical sustainability of (Electric Vichle) EV. Charging infrastructure optimally integrated within the electricity supply and transportation networks.

Potential to replace wood and fossil fuels in lower-energy applications such as decentralized power generation and other similar applications. This is the one Modal can be utilization of bio- wastage by product generated from Agriculture Crops.

This is Economical and Sustainable Modal for Development of Rural area for small scale commercial values.

The analysis of environmental damage mechanisms, an impact assessment translates the inventory of emissions and wastes into environmental impacts. This research after selling the base residues to the gasifier power plant, we looked at the life cycle effect evaluation utilizing the global warming potential and cumulative energy demand, and enhanced the economic values of farmers.

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