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ID 551 COST ANALYSIS FOR COMBUSTION OF RICE HUSK IN A FLUIDIZED BED COMBUSTION

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Abstract

The main aim of this study is to analysis the life cycle cost of utilizing the rice husk in a Fluidized Bed Combustion (FBC) for the electricity, heat and rice husk ash (RHA) production. The cost associated with investment cost, operation and management cost, fuel cost and electricity production cost were calculated. Different capacity range from 0.9, 1.25, 2.5, 5, 10 MWe of installed electricity production capacity in Fluidized Bed Combustion were calculated. The cost associate with full, half and quarter unit running of BFB to generate electricity were analysed.
The investment cost for installing 40MWe of BFB is 64 million dollar and the annual operating and maintenance (O&M) cost is 16 million dollar. The fuel cost using RH is 2.94 million dollar producing 81 tonnes of RHA. The result shows that 350 GWh annual energy can be produced in 40 MWe BFB using rice husk, which gradually decreases with decreasing the installed capacity. Further study on cost analysis of utilizing the rice husk as electricity and RHA production is suggested by repeating the applied method by using more detailed price. The use of rice husk can provide an opportunity to expand energy resources that can save fuel cost as well as income through sales and surplus electricity to the national grid.

Keywords: *Life cycle cost, fuel cost, Rice husk ash, electricity production, Rice husk, Bubbling Fluidized Bed*

Introduction

Rice husk is a by-product of rice which is widely available in many rice-producing countries like Nepal. The annual production of rice in Nepal is 5.23 million tonnes of paddy produced in the year of 2017 (The Kathmandu Post, 2017). The rice husk contain the 22% of the total paddy production, which is around 1.15 tonnes of rice husk. In Nepal, rice husk been used in various local needs such as a cooking fuel, briquette making, incubating the milk to make yogurt. However, the use of rice husk is less than the production; the rice husk is eventually dumped in the landfill.
Rice husk can be used as a source of energy as well as the supplementary cementous material. Thao et al. (2010) stated that the rice husk is an environmentally friendly fuel, which is carbon neutral and can be used for heat, steam, gases or liquid fuels. Rao et al., (2011) and Malhotra et al., (1996) mentioned that incineration of the husks under controlled conditions in temperatures can generates silica with the high amorphous content of approximately 90% or more. Therefore,
Rice Husk Ash (RHA) is a well-known pozzolan that could substitute for cement in the concrete.

The use of rice husk can provide an opportunity to expand energy resources that can save fuel cost as well as income through sales and surplus electricity to the national grid (Mai Thao, Kurisu, & Hanaki, 2012). In our previous study, we evaluated the potential of Greenhouse gas mitigation by utilization of rice husk in Nepal. The study (During et al., 2018) shows that the use of rice husk as supplementary cementitious material (SCM), power and heat production can save 272000 tonnes CO_2 in Nepal. While, using RH to produce power and heat production and silicon source can save 808 000 tonnes CO_2 per year (During et al., 2018). The cost analysis of utilizing the rice husk are equally important in decision-making process. To evaluate the cost effectiveness of rice husk utilization, a life cycle cost analysis was used. The main aim of this study is to analysis the life cycle cost of utilizing the rice husk in a Fluidized Bed Combustion (FBC) for the electricity, heat and rice husk ash (RHA) production.

Goal and scope

In this study, we look at the costs for install and maintain a power plant where the RH are combusted to RHA in Nepal. The goals are to estimate;

- The investment cost for different sizes of power plants with 0.9, 1.25, 2.5, 5, 10 and 40 MWe installed electricity production capacity with Fluidized Bed Combustion, FBC-technique.
- Fuel cost
- Operating and maintenance cost
- Price of electricity and RHA and cement

Scope of the study

The analyse do not include any other cost for RHA separation than ordinary ash separation. Cost for extra grinding of the RHA and collecting and storage of RHA is not included in this analysis.

Methodology

Rice husk is not new when it comes to transferring of low carbon technique to developing countries. The Clean Development Mechanisms, (CDM) in the Kyoto protocol have been used for many projects in India where rice husk is used for production of electricity and Certified Emission Reductions (CER). The amount of the CERs has been calculated according to the baseline for CO2 emissions from electricity production in India. In CDM projects, the CO_2 reduction have been focused on energy and not on cement replacement. The cost of using rice husk in electricity production and certified emission reduction (CER) are calculated based on Clean Development Mechanisms according to the Kyoto Protocols. In Nepal, standard production of energy is from hydropower and biofuels with small carbon footprint. Cement production have an average energy consumption of 5,4 GJ coal/ tonne of cement and a carbon footprint of 1.09 kg CO_2/tonne cement (During et al., 2018; OECD, 2018) in Nepal. A timeframe of 10 years was used for calculating of total costs and benefits from the investment without using any discount rate. The cost for FBC is referred from (Koornneef et al., 2007) which are recalculated for year 2019. Investment cost are taken from real projects in (Koornneef et al., 2007) and recalculated to the actual size of installed electrical capacity by a scale factor of 0.90.

Fluidized Bed Combustion (FBC)

In a FBC, a sand bed is blown by air from nozzles in bottom of the reactor, so the sand moves like a fluid in the bottom of the FBC (see Figure 1). There are two types of FBCs Circulated Fluidized Bed (CFB) and Bubbling Fluidized Bed (BFB). The main different is the velocity of air for fluidizing. The CFB have higher velocity more air and little higher steam temperature. The high air velocity lifts the sand bed and much of the sand are going with the flue gas and are separated and returned in the cyclone. For producing a cleaner RHA without sand it could be good with a lower air velocity as in the BFB but on other hand there will be less mixing of reactants and a little lower steam temperature, so the air velocity is a key parameter for the economy in the process and quality of the product

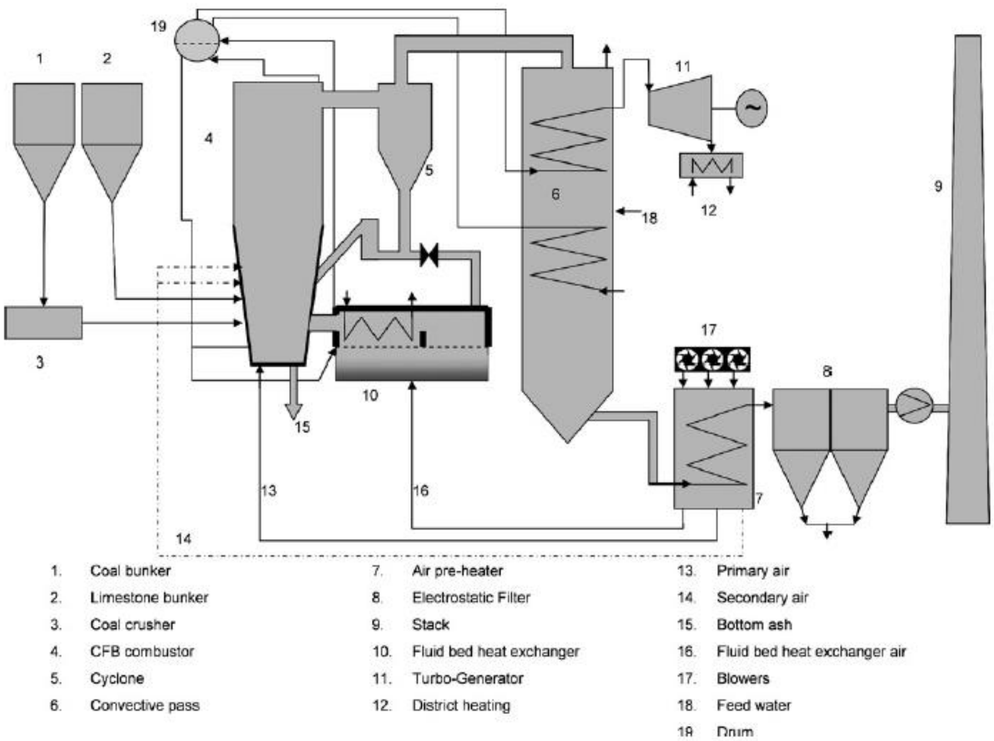

Figure 1. FBC process (Koornneef et al., 2007)

Advantages producing high quality of pozzolanic RHA in FBC are:

- Low temperature, not over 750˚C, keep the bio-based silica in an amorphous and reactive phase.
- Good mixing of reactants results in low rest carbon that in other casa could make a dark concrete and inhibit admixtures in the concrete.
- Low and stable temperature and flameless incineration give low emissions of NOx

- Good mixing lead to low emissions of hydrocarbons.
- Turbulent mixing with sand will grind the RHA and reduce water absorption of the RHA in the concrete and increase the workability and reduce needs of superplasticisers in the concrete.
- The process is continues process and have a high production rate.
- Combined heat and power production are possible.
- The FBC technique is mature, environmental and well documented.

Disadvantages

- Low temperature in the FBC could decreases the energy efficiency
- Sand from the bed could be mixed in the RHA.

Results and Discussion

Investment analysis

The cost data for fluidized bed combustion was referred from the study done by Koornneef. J et al. 2005. The investment cost 2005 for a BFB with 40 MWe (Mega Watt electricity capacity installed) was estimated as 1300 $/installed kWe.

Table 1 cost items

COST ITEMS	RANGE OF PERCENTAGES OF TOTAL INVESTMENT (%)
Boiler section	28–82
Fuel handling	4–23
Steam turbine section	7–15
Instrumentation and control equipment	2–5
Emission control	2–6
Balance of plant facilities	21–23
General plant facilities	10–15
Total EPC (engineering, procurement and construction)	**70–94**
Initial working capital	1
Contingency	6–12
Development fee	3–7
Start-up Owner's cost	1
Initial debt reserve fund	9
Total capital cost	**86–94**
Interest during construction	10
Financing fee	2
Total project	**100**

Present cost 2019

Present cost is calculated by using Consumer Price Index given by OECD (2018). In 12 years of period between 2005 and 20017, the index changes from 83.8 to 103.7 (average 2.3%/year). Therefore, we assume that the price for installing BFB in 2019 is 1,232 × price 2005. We use 1.232 × 1300 = 1600 $/kWe installed. The total investment cost is 1600 × 40000 =64 million $.

Size depending

Koornneef (2007) find that the size factor (SF) for BFB will be 0.64. If cost for one size is known other sizes can be calculated according equation 1, Cost 2 = Cost 1 * $(\text{Size 2/Size 1})^{SF}$. Based on the equation, the investment cost for different size of BFB is calculated (see Table 2).

Table 2 Investment cost for different sizes of BFB 2019

Size in MWe	Total Investment cost in million $
40	64
10	26.4
5	16.9
2,5	10.9
1.25	7
0.9	5.7

Operating and Maintenance, fuel cost and RHA produced

The annual operating and maintenance (O&M) cost is estimated to be 2.5% of total investment cost (Koornneef et al., 2007) that is 16 million dollar. The rice husk with heating value of 13GJ/ton was used as fuel to operate the FBC. The price of rice husk is 9.04 $/metric ton (0.7 $/GJ). Depending on size, availability and efficiency, the cost for fuel will differ. If the 40 MWe plant will run for 100% during the year end, the electrical efficiency is set to 30 % of the fuel cost per year. The annual operating and maintenance cost was calculated by C_f = Hour×Seconds× (Installed electricity/efficiency) ×C_{husk}, which would be 8765 hours ×3600 seconds× (40 MJe/0.3) x (0.7 $/1000) =2.94 million dollar/year. The total use of fuel is then 325000 tonnes of rice husk. The combustion of the rice husk produced approximately 25% of ash (Malhotra V.M. & Mehta P.K., 1996), which will be about 0,25 ×325 000= 81 000 tonnes of RHA.

Production of electricity and Heat

Total theoretical production of electricity per year for the 40 MWe BFB is 8765*40 = 350 GWh shown in Table 3.

The cross breakdown of different BFB with the capacity range from 0.9 – 500 MWe are shown in Table 3. This range is commercially available FBC in current market. The scaling up can be achieved either by adding multiple boilers or by increasing the boiler capacity (Koornneef et al., 2007).

Table 3. Cost breakdown of different BFB

Cost	BFB 40 MWe	BFB 10 MWe	BFB 5 MWe	BFB 2.5 MWe	BFB 1.25 MWe	BFB 0.9 MWe
Running 100% during the year						
Investment cost k $	64000	26400	16900	10900	7000	5700
O&M -k $	1600	660	423	273	175	142
Fuel cost k $	2940	735	367	183	92	66
RHA produced kt	81	20	10	5	2.5	1.35
Electricity GWh	350	87.5	43.7	21.9	10.9	5.4
Running 50 % during the year						
Investment cost k$	64000	26400	16900	10900	7000	5700
O&M -k $	800	660	423	273	175	142
Fuel cost k $	1470	349	174.4	87.2	43.6	33
RHA produced kt	40.5	10	5	2.5	1.25	0.94
Electricity GWh	175	44	22	11	5.5	4
Running 25 % during the year						
Investment cost k$	64000	26400	16900	10900	7000	5700
O&M -k $	1600	660	423	273	175	142
Fuel cost k $	735	184	91	46	23	16.5
RHA produced kt	20.25	5	2.5	1.25	0.625	0.47
Electricity GWh	87.5	22	11	5.5	2.75	2

The cost associate with 100 %, 50% and 25% running of BFB to generate electricity is given in Table 1. The obivious result shows that running 100% of BFB produce more electricity and less while running 25% of BFB for generating electricity.

Conclusion

This study focuses on the cost analysis of utilizing rice husk resources for electricity and RHA production. The cost associate with investment cost, operation and management cost, fuel cost and electricity production were calculated in different capacity range of FBC. Moreover, cost associate with 0.9, 1.25, 2.5, 5, 10 and 40 MWe installed electricity production capacity in Fluidized Bed Combustion were calculated. The cost associate with full, half and quarter unit running of BFB to generate electricity were analysed.
A timeframe of 10 years is used for calculating of total costs and benefits from the investment without using any discount rate. The cost data for fluidized bed combustion was referred from the Koornneef. J et al. (2005) studies. The investment cost for installing 40MWe of BFB is $64000 and the annual operating and maintenance (O&M) cost is 16 million dollar. The fuel cost using RH is 2.94 million dollar producing 81 tonnes of RHA. The result shows that 350 GWh annual energy can be produced in 40 MWe BFB using rice husk, which gradually decreases with decreasing the installed capacity. The study also shows that running 100% of BFB produce more electricity and less while running 25% of BFB for generating electricity. The use of rice husk can provide an opportunity to expand energy resources that can save fuel cost as well as

income through sales and surplus electricity to the national grid. Further study on cost analysis of utilizing the rice husk as electricity and RHA production is suggested by repeating the applied method by using more detailed price.

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