Effects of biomass densification on anaerobic digestion for biogas production

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Supplementary information for evaluating logistic cost

In this work, the scale of 3000m³ anaerobic digestor for biogas production was employed for evaluating logistic cost. According to our experiences, the suitable radius for transporting biomass of such scale plant was 5.0 Km in China, and it thereby was defined for the estimation. In addition, the consumed corn stover was estimated as approximately 3900 tons per years. The logistic cost was consisted of harvest, transportation, and storage. The detailed estimation of each item was listed as follows:

1. Biomass harvest includes the biomass collection from field, size-reduction and densification, and labor input.

1.1 Biomass collection cost was according to the local price of Chengdu, Sichuan, which was fixed at 80 Yuan/ton. The cost of biomass collection for briquettes and unbriquetted corn stover is same.

1.2 Size-reduction and densification   As for the corn stover, it was generally cut into 5-10 cm, and baled for subsequent transportation. As for the briquette production, the size was generally reduced to 30-50mm by a straw rubber. The size-reduced corn stover was briquetted afterwards. Electricity consumption for the unbriquetted corn stover and briquettes is estimated as 30 and 105 Kwh/ton, respectively, and current price for electricity is 0.25 Yuan/Kwh. Thus, the cost on size-reduction and densification for the unbriquetted corn stover and briquette production can be estimated as 7.5 Yuan/ton and 26.3 Yuan/ton, respectively.

1.3 Labor cost   The employed labor for collection and briquettes can be defined as same because the output efficiency of the baler and cutter for corn stover is close to the rubber and densification machine for briquettes. Labor efficiency is estimated as 3.0 ton/(day·labor) and the current price for labor is 150 Yuan/(day·labor). Thus, the labor cost for the unbriquetted corn stover and briquette production can be estimated as 50.0 Yuan/ton.

2. **Cost on biomass transportation** includes the fuel consumption and labor input. According to our experiences, the lorry with capacity of 20 tons (56 m³) is always employed for the biomass transportation. If the lorry is responsible for the bales, there are about 464 lorries for the total of 3900t corn stover. By contrast, there are 195 lorries for the briquettes. Based on the local price, it is 30 Yuan/km for renting the lorry (capacity of 20 tons), which includes the labor fees of loading and unloading the biomass, fuel consumption, and salary for driver. According to these information, the cost for transporting corn stover without briquetting could be calculated as

(464 lorries × 30 Yuan/(km·lorry) × 5.0 km) ÷ 3900 tons = 17.8 Yuan/ton; Using the similar calculation, the cost of briquette transportation is (195 lorries × 30 Yuan/(km·lorry) × 5.0 km) ÷ 3900 tons = 7.5 Yuan/ton;

3. **Storage cost includes the input for basic construction, fire-fighting equipment, land rent, and daily labor and operation cost.**

3.1 **Cost on the basic construction for storage.** The biomass pile for storage is generally designed as 6.0 m with lifetime of 10 years, and the price for constructing the storage place is estimated as 600 Yuan/m^2 according to local price. As for the unbriquetted corn stover, the area for the storage = (3900 tons ÷ 0.15ton/m^3 ÷ 6.0 m) × 1.2 = 5200 m^2, in which 0.15 ton/m^3 was the buck density of baled corn stover, and 1.2 is the coefficient for aisle. Thus, the cost on construction for storing the unbriquetted corn stover is estimated as (5200 m^2 × 600 Yuan/m^2 ÷ 10 years) ÷ 3900 tons = 80.0 Yuan/ton. Using the same calculation process, the area for storing briquettes = (3900 tons ÷ 1.2ton/m^3 ÷ 6.0 m) × 1.2 = 650 m^2, in which 1.2 ton/m^3 was the buck density of briquettes, and 1.2 is the coefficient for aisle. Thus, the cost on construction for storing briquettes is estimated as (650 m^2 × 600 Yuan/m^2 ÷ 10 years) ÷ 3900 tons = 10.0 Yuan/ton.

3.2 **Cost on the fire-fighting equipment.** In China, the fire-fighting is a mandatory requirement as the storage scale is higher than 1500 m^2. According to the communication with the senior engineer, Dr. Tao Luo, in Biogas Institute of Ministry of Agriculture in China, the total input for fire-fighting of a 5200m^2 storage area is approximately 1.5 × 10^6 Yuan. Thus, the cost on the fire-fighting of the unbriquetted corn stover storage is estimated as 1.5 × 10^6 Yuan ÷ 10 years ÷ 3900 tons = 38.5 Yuan/ton; As for the briquettes, the fire-fighting input could be reduced to approximately 2.0 × 10^5 Yuan. Thus, the cost on the fire-fighting of storing briquettes is estimated as 5.13 Yuan/ton according to the similar calculation.

3.3 **Land rent for storage.** Generally, the land rent for the storage place is 1.5 Yuan/m^2. Thus, the land cost for storing the unbriquetted corn stover is estimated as 1.5 Yuan/m^2 × 5200 m^2 ÷ 3900 tons = 2.0 Yuan/ton. Correspondingly, the land cost for storing briquettes is 1.5 Yuan/m^2 × 650 m^2 ÷ 3900 tons = 0.25 Yuan/ton.

3.4 **Labor and operation cost** generally includes the fees on repairing the basic construction and main equipment, and the labor salary for daily management. According to our experiences, the labor and operation cost is generally estimated as 5.0% of the total cost of the construction and the fire-fighting equipment. Thus, the labor and operation cost of storing the unbriquetted corn stover can be calculated as (80 Yuan/ton + 38.5 Yuan/ton) × 5% = 5.93 Yuan/ton; Based on the same calculation process, the labor and operation cost of storing briquettes is (10.0 Yuan/ton +5.13 Yuan/ton) × 5% = 0.76 Yuan/ton.