Analysis on Social Effect for Three Models of the Straw Power Plant Supply Chain

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Abstract. Crop straw power plant is environmental-friendly, but crop straw has low density, so the efficiency of the collection and transportation is very low, and per unit of weight crop straw reutilization will more expensive and make more pollution. In this paper, based on ABC (Activity Based Costing) and LCA (Life Cycle Assessment), the data of economic and environmental performance in the crop straw power plant supply chain are analyzed through quantitative calculation of cost and pollution of per unit weight. We find compression ratio in the pretreatment is key factor. Compression ratio is higher, economic and environmental performance is better, but it needs more investment. With straw supply uncertainty, compression ratio in straw supply chain needs balance.

Introduction

In China, there are government policies on prohibiting to burn in the open field for more years, and encouraging the reutilization of agricultural residue. The key is how to deal these wastes in weeks and how to balance the cost and pollution.

The reutilization of agricultural residue is researched by many scholars [1-4], especially in the straw supply chain. We have analyzed the environmental performance on straw supply chain on 2017 [5]. And after that we study scientific treatises in many fields, such as the model of biomass supply chain [6-8], collection pattern of biomass [9,10], logistics cost of biomass supply chain [11,12], management optimization of biomass supply chain [13-15] and synthetic evaluation on the biomass supply chain [16]. The researches focus on analysis and optimization for the whole of biomass supply chain, and by higher environmental performance on biomass treatment, the pollution of collection and transport is more effecting in the whole supply chain. Biomass include many materials and many ways of reutilization, So we choose the straw power plant supply chain that can deal with a large amount of straw, and use quantitative analysis to calculate the cost and pollution in collection, pretreatment and transport stage in the straw power plant supply chain.

Objectives and Scope

This paper calculates the cost of straw collection, pretreatment and transport, combines, this datum with data of pollution in the straw power plant supply chain we analyzed, assesses the social effects of the straw power plant supply chain.

The straw power plant supply chain includes straw collection, pretreatment, transport and storage. There have three scenarios.

In the first scenario, famers collect and deliver straw to the purchasing agency, and agents organize trucks to convey straw to the straw power plant. Straw is not compressed.

Figure 1. The first scenario.
In the second scenario, farmers collect and deliver straw to the purchasing agency, and agents organize machine to pretreat (compress) the straw. And then the compress straw is transported to the straw power plant. Straw is compressed into cuboid.

![Figure 2. The second scenario.](image)

In the third scenario, agents organize machine to collect, pretreat (compress) and transport the straw. Straw is compressed into cylinder in the field.

![Figure 3. The third scenario.](image)

The three scenarios are composed by three or four phases which are collection, collection and pretreatment in the field, transport in the field, pretreatment in the agency, transport to the plant.

**Model and Calculation**

**Models**

(1) **Collection Model**
This is the formula to calculate the straw collection by farmers.

\[
N = R \times S \times K \times \gamma \times \rho \tag{1}
\]

N is the straw collection by farmers (kg). R is crop yield per Hectare (kg/hm\(^2\)), S is farmland (hm\(^2\)), K is straw to grain ratio, \(\gamma\) is harvesting coefficient, \(\rho\) is utilization coefficient.

(2) **Pretreatment Model (in the field)**
These are the formulas to calculate the cost of pretreatment in the field.

\[
C_{2A} = E_{2K} \times V_{2K} + R_{2K} \times T \tag{2}
\]

\[
T = \left\lceil \frac{S}{R_{\text{ai}}} \right\rceil \tag{3}
\]

\[
V_{2K} = S \times G_{2K} \tag{4}
\]

\(C_{2A}\) is the cost of pretreatment in the field, \(E_{2k}\) is the unit price of fuel (¥/L), \(V_{2k}\) is the fuel consumption (L), \(G_{2k}\) is the unit fuel consumption (L/hm\(^2\)), \(R_{2k}\) is other unit price (¥/L, depreciation and maintenance), T is workdays, S is farmland(hm\(^2\)), \(R_{\text{ai}}\) is efficiency (hm\(^2\) per day), k is the type of current machinery.

(3) **Transport Model (in the field)**
These are the formulas to calculate the cost of transport in the field.

\[
C_{LT} = C_{LA} + C_{TA} + C_H \tag{5}
\]

\[
C_{LA} = Z \times D \times R_{LK} \times T \tag{6}
\]

\[
T = \left\lceil \frac{N}{Z} \right\rceil \tag{7}
\]

\[
C_{LT} = N \times D \times R_{LK} \tag{8}
\]
\[ R_{LK} = \frac{D \times G_{LK} \times E_{LK}}{Z \times D} = \frac{G_{LK} \times E_{LK}}{Z} \quad (9) \]

\( C_{LT} \) is the cost of transport in the field (¥), \( C_{LA} \) is the cost of vehicle on working (¥), \( C_{TA} \) is the cost of vehicle on depreciation (¥), \( C_{H} \) is the labor cost (¥). \( Z \) is load capacity (kg). \( D \) is distance (km). \( R_{LK} \) is the transportation rate (¥/kg·km). \( N \) is the straw weight collected by farmers (kg), \( G_{LK} \) is the unit fuel consumption (L/km), \( E_{LK} \) is the unit price of fuel(¥/L), \( k \) is the type of current machinery.

(4) Pretreatment Model (in the agency)
These are the formulas to calculate the cost of pretreatment in the agency.

\[ C_P = C_{PA} + C_M + C_{IN} \quad (10) \]

\[ C_M = C_H + C_{INM} \quad (11) \]

\[ C_{IN} = \sum i \frac{C_{IB}}{T_{IB}} \quad (12) \]

\( C_P \) is cost of pretreatment in the agency, \( C_{PA} \) is the cost of machinery on working (¥), \( C_M \) is the administrative cost (¥), \( C_{IN} \) is the construction cost (¥), \( C_H \) is the labor cost (¥), \( C_{INM} \) is the labor cost of the managers, \( C_{IB} \) is the price of constructions (¥), \( T_{IB} \) is service life.

\[ C_{PA} = E_{PAK} \times V_{PAK} + C_R + R_{PAK} \times T \quad (13) \]

\[ T = \lceil \frac{N}{R_{ai}} \rceil \quad (14) \]

\[ V_{PAK} = N \times G_{PAK} \quad (15) \]

\[ C_R = E_{RA} \times V_{RA} \quad (16) \]

\( E_{PAK} \) is the unit price of electricity (¥/kw·h), \( V_{PAK} \) is the electricity consumption (kw·h), \( G_{PAK} \) is the unit electricity consumption (kw·h/kg), \( C_R \) is the cost of rope (¥), \( R_{PAK} \) is other unit price (¥/day, depreciation and maintenance), \( T \) is workdays (day), \( R_{ai} \) is efficiency (kg/h), \( E_{RA} \) is the unit price of rope (¥/kg), \( V_{RA} \) is the rope consumption (kg), \( k \) is the type of current machinery.

(5) Transport Model (to the plant)
These are the formulas to calculate the cost of transport to the plant.

\[ C_{traf} = C_{fuel} + I + C_{load} + C_{depreciation} + C_{insurance} + C_{maintenance} C_{traf} = C_{fuel} + I + C_{load} + C_{depreciation} + C_{insurance} + C_{maintenance} \quad (17) \]

\[ C_{fuel} = D \times G_{fuel} \quad (18) \]

\[ C_{load} = C_{human} + C_{machinery} \quad (19) \]

\( C_{traf} \) is the cost of transport to the plant (¥), \( C_{fuel} \) is the cost of vehicle on working (¥), \( C_{depreciation} \) is the cost of vehicle on depreciation (¥), \( C_{insurance} \) is the cost of vehicle on insurance (¥), \( C_{maintenance} \) is the cost of vehicle maintenance (¥). \( D \) is distance (km). \( G_{fuel} \) is the unit fuel consumption (L/km). \( C_{load} \) is the cost on loading (¥), \( C_{human} \) is the labor cost on loading (¥), \( C_{machinery} \) is the cost of machinery working (¥).

(6) Pollution Model
Part 2.1.2 of “Emission Analysis of Air and PM Pollution on Straw Power Plant Supply Chain based on Life Cycle Assessment”.

Parameters
(1) Collection Parameter
The rice output is 9000kg per hectare, the straw to grain ratio is 1.0, the harvesting ratio is 60%, and the reutilization ratio is 75% [17-19].
(2) Pretreatment Parameter (in the field)
In China, each farmer had small arable land, so it is worked by small machinery. Thought searching in Alibaba platform, online and phone consultation, we filter 14 machines in 9 brands, and after analyzing statistics, the size of bundle is Φ0.5 m×0.8 m, 20kg/bundle.

Using Keyang DK100-70 and Dongfeng304 as an example, the machinery prices are ¥19800 and ¥38000, service life are 5 years and 10 years and salvage is 5%. The unit price of rope is ¥8.5/kg, each bundle needs 50g rope.

(3) Transport Parameter(in the field)
Thought searching in Alibaba platform, online and phone consultation, we filter 5 machines in 5 brands, and after analyzing statistics, Using Shifeng tricycle as an example, the machinery prices are ¥16000, service life are 10 years, the unit fuel consumption is 0.04L/km.

(4) Pretreatment Parameter(in the agency)
After analyzing statistics, Using Keyang DK2 as an example, the machinery prices are ¥3280, service life is 5 years and salvage is 5%. The unit price of rope is ¥8.5/kg, each bundle needs 50g rope, density of bundles is 200kg/m³, the electricity consumption is 18.5kw. Output of bundle is 2000kg/h, working machine needs 4 labor. The unit price of electricity is ¥0.5335/ kw·h.

(5) Transport Parameter(to the plant)
Thought searching and analyzing statistics, Using Dongfeng 210 truck as an example, the machinery prices are ¥260000, service life are 10 years, the insurance fee is ¥11549, the maintenance fee is ¥15000, the unit fuel consumption is 0.25L/km.

(6) Pollution Parameter
Part 2.2 of “Emission analysis of air and PM pollution on straw power plant supply chain based on life cycle assessment”.

**Calculation**

(1) Cost
According to equation (2) to (4), the cost of pretreatment in the field is ¥47.2/10³kg.
According to equation (5) to (9), the cost of transport in the field is ¥33.47/10³kg.
According to equation (10) to (16), the cost of pretreatment in the agency is ¥57.58/10³kg.
According to equation (17) to (19), the costs of transport to the plant are ¥142.47/10³kg in the first scenario, ¥28.49/10³kg in the second scenario and ¥44.74/10³kg in the third scenario.

In the first scenario, if the price of agency is ¥150, the total cost is ¥292.47.
In the second scenario, if the price of agency is ¥150, the total cost is ¥236.07.
In the third scenario, the best proportion of machine in the field, tricycle and truck is 1:2:1, the total cost is ¥125.83.

(2) Pollution

<table>
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<th>CO₂</th>
<th>CO</th>
<th>HC+NOₓ</th>
<th>SO₂</th>
<th>PM</th>
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<td>249.459</td>
<td>552.143</td>
<td>13.674</td>
<td>12.976</td>
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<td>the second scenario</td>
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<td>11.768</td>
<td>11.902</td>
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<td>the third scenario</td>
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<td>182.508</td>
<td>319.740</td>
<td>9.828</td>
<td>16.264</td>
</tr>
</tbody>
</table>

(3) Analysis
Now the price of the power plant is ¥280.
In the first scenario, the total cost is above the price of the power plant.
In the second scenario, the upfront investment is ¥110500. For working 250 days, the total income every year is ¥253580, the rate of return is 23.85%.
In the third scenario, the upfront investment is ¥347800. For working 30 days, the total income every year is ¥70700, the rate of return is 20.33%.

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Conclusion

In three scenarios, the first scenario has the highest pollution and the lowest rate of return, the second scenario has the lowest pollution and the highest rate of return, the third scenario is between them. We can find compress rate of straw is the key factor. The compress rate is higher, the social effect is better. On the other hand, higher compress rate need more investment. With straw supply uncertainty, more investment comes higher risks.

References


