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Study on the effect of biogas project on the development of low-carbon circular economy

—A case study of Beilangzhong eco-village

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Abstract: With Beilangzhong eco-village as an example, the effects of the biogas project on the reduction of greenhouse gas (GHG) emission and its economic effects are analyzed. The results show that 1833.45t GHG (CO_2 equivalent) was reduced, and an income of 1,117,000 Yuan (RMB), a net income of 958,500 Yuan (RMB), was gained by biogas sales, alternative energy, comprehensive utilization of anaerobic fermentation residues and the reduction of GHG emission, so the biogas project can greatly promote the establishment of low-carbon circular economy mode and sustainable development of ecological agriculture in Beilangzhong eco-village.

Keywords: biogas, Beilangzhong, eco-village, low-carbon

1. Introduction

Biogas projects started in the 1970s and it was developed during the early stage to solve energy shortage in rural areas of China. In recent years, the biogas project in large and medium-sized poultry and animals has developed fast. By the end of 2008, the number of the household biogas pools in the whole country is 30.5 million and the number of large and medium-sized biogas project dealing agricultural wastes is 39,500 (2700 biogas projects in large and medium-sized poultry and animals); they are playing an important role in solving the problems of pollution in the process of agricultural production. Having experienced the process of energy-environment-ecology-low carbon-cycle, biogas project in China has gradually formed its typical energy ecological model: "pig-biogas-fruit" in South China and "four in one" in North China, and the most representative technology is "making three improvements in a pool" and "three constructions in a pool". Biogas project make the farmers transforming their kitchens, toilets and pigsties, which achieves improving their living environment, making changes in energy and agricultural production structure, and raising their income. At the same time, biogas-linked energy ecosystem including the pretreatment system of livestock excrements and sewage, anaerobic fermentation system, centralized biogas supply system and the comprehensive utilization system of anaerobic fermentation residues is an integrated ecosystem, which effectively combines planting, breeding and comprehensive utilization

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of agricultural wastes.

At present, the biogas projects in China plays an important role in addressing the pollution control of agricultural wastes, efficient utilization of resources and promoting development of circular economy. Biogas has a higher calorific value; it can replace fossil fuels, such as coal, oil, natural gas, and some biomass energy, like firewood and straw, which can reduce GHG emissions. The Chinese Government pointed out in China National Program to Address Climate Change released in 2007 that the energy structure should be improved, renewable energy should be vigorous developed, and particularly biogas project should be strengthened to control GHG emissions [1]. All these have put forward ideas and measures for us to search low-carbon economic development mode, realizing the diversified utilization of renewable clean energy and sustainable development of agriculture in China.

With the rapid development of large-scale farms and the centralized farming communities, the manures and sewages in the farms, if not effectively treated and used, may become one of the main causes for the emission of three major GHG (CO_2, CH_4 and N_2O). With the shift of energy consumption structure and the establishment of low-carbon energy system, China has carried out extensive research and established a large number of demonstration projects and eco-village. As the new low-carbon economy development model in rural areas, nearly 50 biogas projects in large and medium poultry and animal plants with centralized biogas supply was set up only in Beijing from 2007 to 2009. Developing biogas in countryside can exploit energy resources, and its fermentation residue can be used as organic fertilizer, which can not only improve soil fertilization, reduce the use of pesticides and chemical fertilizers and improve crop yield and quality, but also be important for reducing GHG emissions and forming a highly efficient agricultural ecological circular system.

Since 2002, Beilangzhong eco-village, on the outskirts of Beijing, has constructed biogas project to treat manure and sewage in the swine farm. So far, biogas is supplied to 528 households in the village, and anaerobic fermentation residue is used as the fertilizer of flowers, fruit and grains; the whole system realizes zero-emission.

In this study, the positive role of biogas projects in realizing low-carbon circular economy in Beilangzhong eco-village system is analyzed from the two aspects: alleviating energy shortage in rural areas and reduction of GHG emissions.

2. Material and methods

2.1 Study site

Beilangzhong Village, located at Zhaoquanying town, Shunyi district, Beijing, is 30km away from the urban area. It has a climate of seasonal temperate semi-humid monsoon and an annual mean temperature of 11.5℃. There are 528 households, 1500 residents in the village. Beilangzhong, with swine-breeding as one of its pillar industries, is honored as “the first pig-breeding village in the suburbs of Beijing”. With the breeding scale constantly expanding, the pig-breeding industry has experienced the development from courtyard breeding to breeding community and finally the intensified breeding farm. In 2006, the breeding stock of swine-breeding farm in Beilangzhong Village reached 6500 heads. After the establishment of the biogas project, the excrements and sewages have realized zero emission. A Beilangzhong eco-village system has been gradually formed with the biogas project as the link and swine-breeding as the principal industry.

2.2 Biogas project of Beilangzhong

In order to solve the problem of environmental pollution created by excrements and sewages, the village invested 5,000,000 yuan to establish biogas project and biogas supply system in two phases from 2002 to 2004, which was designed to process excrements and sewages with high concentrations and comprehensively utilize biogas energy. USR adopted in the first phase has a capacity of $464m^3$ and daily biogas yield of $140\text{-}600m^3$; UASB in the second phase has the capacity of $557m^3$ and daily biogas yield of $130\text{-}580m^3$. The biogas is provided to 528 households for daily use by the biogas pipe network, which is helpful for reducing coal and electricity consumption, realizing energy conservation and carbon emission reduction, and developing low-carbon circular economy mode. The main body of biogas project is constructed with the assemble technology of enamelled pressed steel, with the method of high-pressure dry storage of gas. The project is designed to have a life time of 30 years.

2.3 Analysis method

In this study, the reduced GHG emission of the biogas project is calculated, including operating energy consumption, substitution conventional energy emission and excrement discharge. The effects of the comprehensive utilization of biogas project on the ecological environment and sustainable deveopment of Beilangzhong Village is analyzed. Then the cost and income of the biogas project is calculated so as to find out the role and effect of biogas project on the development of low-carbon circular economy in the village. The income mainly includes the direct and potential marketing income, such as the fertilizer income, the environment income, etc.

3. Discussion

3.1 Analysis of GHG emission reductions on biogas project

3.1.1 Operation energy consumption and emission of the biogas project

According to the statistics of proper operation, the annual power consumption of the two phases is respectively 21920kW·h and 27360kW·h, totaling 49280kW·h; the annual coal consumption to maintain the mesophilic anaerobic fermentation temperature and the thermal consumption for pretreatment of raw material is calculated as 100t. According to the GHG emission factors of various energy resources in Table 1, 280123.46kg CO_2, 292kg CH_4, 4.10kg N_2O are considered to be discharged annually during the normal operation of the biogas project.

Table 1 Factors for GHG emission factor of common energy resources[1]

Item	CO_2	CH_4g/kg	N_2Okg/TJ
Straw	1130 g/kg	4.56	4.00
Coal	2280g/kg	2.92	1.40
Biogas	748 g/kg	0.023	/
Liquefied petroleum gas	3075 g/kg	0.137	1.88
Electricity	1057.7 kg/kwh	/	/

3.1.2 Substitution conventional energy emission

The total biogas yield in the Beilangzhong biogas project is 182,500m^3/yr. Before that, villagers used fossil fuels, such as coal, liquefied petroleum gas, etc. The household energy consumption in the Beilangzhong village before and after the construction of biogas project is shown in Table 2. The amount of fossil energy used before and after the project is 95.4% and 74.9% respectively. The GHG emissions factor of biogas is far lower than that of coal and petroleum. Therefore, before the project, 3425.37t CO_2, 4077.79kg CH_4 and 47.95kg N_2O was discharged for the household energy consumption annually, and while the project was completed, the GHG discharge is 1562.95t CO_2, 1581.92kg CH_4 and 22.14kgN_2O. The discharge of CO_2, CH_4 and N_2O is declined by 54.37%, 61.21% and 53.83% respectively.

Table 2 The household energy consumption of Beilangzhong Village

Item	Energy quality	Quantity	Heat-value	Energy(GJ)
Before biogas project	Electricity	166300 kW·h	3.598 MJ/(kW·h)	598
	Massive coal	540 t	29.288 GJ/t	15816
	Honeycomb coal	855.47 t	20 GJ/t	17109
	Liquefied petroleum gas	22.05×10^3kg	44.8 GJ/t	988
After biogas project	Electricity	156200 kW·h	3.598 MJ/(kW·h)	562
	Coal	540 t	29.288 GJ/t	15816
	Biogas	182.5×10^3 m^3	26.01 MJ/m^3	4747
Remaining				13386

3.1.3 Emission reduction in excrement

The GHG discharged mainly by excrements in rural areas is methane; therefore N_2O emissions can be ignored in the estimate of reduced emissions in manure management. Swine manure and sewage is used as the raw material for the anaerobic fermentation so as to make a significant contribution for avoiding the direct emissions of CH_4. CH_4 emissions are calculated with the method recommended in *IPCC National Greenhouse Gas Inventories Good Practice Guidance and Uncertainty Management*[2]. According to the annual emissions of 1.18kg CH_4 by each pig[3], if all manures are used for the biogas project, then the annual CH_4 emission reduction is 7.67t.

Anaerobic fermentation residues contain a large number of nutrient elements necessary for the plant growth, such as nitrogen, phosphorus, potassium, and some bioactive substances with important regulatory roles. Studies indicate that 56.7%-64.7% CH_4 emissions can be reduced by using anaerobic fermentation residues of poultry manure for rice farming compared with compost. In general, this part of emission reduction depends on the use of anaerobic fermentation residues and the fertilizer applied previously, etc., which can not be accurately estimated, so they are not taken into consideration when the emissions of the biogas project are calculated. Be can see by the above calculations, biogas project has become an effective measure to achieve energy conservation and emission reduction in rural area, by the combination of different technologies such as manure and sewage treatment technology, engineering control technology, centralized gas supply technology, as well as comprehensive utilization technology of biogas and its residues. Biogas as a renewable, clean energy and can an alternative energy can improve the traditional coal-based energy structure in the countryside, and effectively reduce GHG emissions. In Beilangzhong village, biogas project can reduce GHG emissions by 1833.45t per year (CO_2 equivalent).

3.2 Cost-benefit analysis of the biogas project

3.2.1 Operating cost analysis of the biogas project

The total investment of Beilangzhong biogas project is 5 million Yuan, and the operating costs of the project include project depreciation, maintenance, power consumption, energy expenditure on maintaining the anaerobic fermentation temperature and heating, salaries, etc. Depreciation cost is calculated with composite life method with 30 years as its service life and the salvage value rate of 5%; maintenance, equipment abrasion and other updates investments are calculated at 10% of the depreciation cost. The total power consumption in operation is 49280kW·h, which charges by 0.55 Yuan/kW·h in accordance with the electricity price for agriculture in China, so the annual electricity consumption totals 27,104 Yuan. The annual coal consumption for heating is 100 tons, the price of which is 450 Yuan/t; the monthly salary of 8 management personnel is 900 Yuan/person. As a result, the operating cost of the biogas project can be calculated to be 158,500 Yuan/yr (excluding depreciation and maintenance costs).

3.3.2 The direct economic benefits of biogas project

The construction and normal operation of the biogas project has ensured stable energy supply for the villagers, changed traditional energy structure, and improved the life quality of the villagers. The direct economic benefits are mainly from biogas sales, which is 182,500 Yuan if the price of biogas is 1 Yuan/m^3.

3.3.3 The potential economic benefits of biogas project

The potential economic benefits of biogas project include those generated from replacing other energies by biogas and substituting for chemical fertilizer with anaerobic fermentation residues, and environmental benefits gained through GHG emission reduction. According to Table 2, since the biogas project is completed, 10,100 kW·h electricity, 855.47t honeycomb briquette and 22.05t liquefied petroleum gas has been saved each year. When calculated with the electricity price at 0.55 Yuan/ (kW·h), honeycomb briquette at 290 Yuan/t, liquefied petroleum gas at 6.21 Yuan/kg, 208,100 Yuan can be saved each year since the use of biogas. All above potential benefits have won the support from villagers for the further widespread utilization of biogas in the future.

Anaerobic fermentation residues contain many major elements, such as nitrogen, phosphorus, and potassium, necessary for plants. The content of ammonia nitrogen (NH_3-N), available phosphorus (P_2O_5) and available potassium (k_2O) is 563-1163mg/kg, 667-847mg/kg and 1130-1450mg/kg respectively. The equivalent chemical fertilizers of 51,000 m^3 biogas fermentation residues and the benefits of saving fertilizer while calculated with the above minimum content can be seen in Table 3. The benefits of yield increased in flowers, fruits, and grains by using anaerobic fermentation residue are not considered here, and only the cost of substituted chemical fertilizers is calculated. The conversion price of fertilizer is calculated according to the average market prices of chemical fertilizer in 2009, and 469,600 Yuan is saved annually by replacing chemical fertilizer with anaerobic fermentation residues.

Table 3 Analysis of fertilizer saving benefits

Fertilizer source	Concentration (ton)			Standard consumption (ton)			Quantity (ton)	Price (Yuan/ton)	Fund(Ten thousand Yuan)
	NH_3-N	P_2O_5	K_2O	NH_3-N	P_2O_5	K_2O			
Anaerobic	0.056	0.06	0.11	28.71	34.02	57.63	51000	——	——

fermentation residue		3	67	3						
Chemical fertilizer	Ammonium bicarbonate	17	——	—	15.40	0	0	90.60	624	5.65
	Diammonium phosphate	18	46	—	13.31	34.02	0	73.95	2728	20.17
	Potassium chloride	——	——	60	0	0	57.63	96.05	2200	21.13
	Total								——	46.96

Environmental benefits refer to benefits obtained from reducing GHG emissions during the operation phase of biogas project. Since the biogas project is completed, the annual reduced emissions of GHG are 1833.45t (CO_2 equivalent). Calculated at the international market price (1t CO_2=15 Euros), the annual environmental benefits are € 27,500, or￥256,800.

It can be drawn from the above calculation that, since the biogas project is completed, the revenue from biogas sales is 182,500 Yuan per year. The net profit is 24,000 Yuan/yr by deducting the operating costs (158,500 Yuan/yr, excluding depreciation and maintenance costs). If the potential benefits are taken into account, which includes 208,100 Yuan from replacing the conventional energy with biogas, 469,600 Yuan from the comprehensive utilization of anaerobic fermentation residue, 256,800 Yuan from GHG emissions reduction, then the total revenue is 1.117 million Yuan, a net benefit of 958,500 Yuan. The yield increased after the application of anaerobic fermentation residue is not calculated in the paper.

4. Conclusion

The reduction of GHG emissions is realized in Beilangzhong Village during the construction and normal operation of the biogas project. The comprehensive utilization of biogas and its residue has helped realizing the resourcization and innocuous development of the whole eco-village system, accelerating diversified sustainable development of ecological agriculture in the village, and promoting the development of low-carbon circular economy. Practice has proved that the development of the biogas project can bring unparalleled environmental, economic, and social benefits and has good development potential and widely public acceptance. The development mode of biogas-linked eco-village system in Beilangzhong represents the trend of new village construction in the future of China, and better low-carbon circular mode will be further perfected depending on further enhancing technology in the future.

Acknowledgements

The work is supported by National Key Technology R&D Program of China (No.

2008BADC4B03, 2008BADC4B15) and Special Funds for Basic Scientific Research of China Agricultural University.

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