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From Passive to Active: The Paradigm Shift of Straw Collection

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This paper takes the centralized biogas production project in the energy utilization of straw as a hypothetical item in investigation to discuss the straw collection mode based on the wishes of farmers. Through surveys of farmers in Shandong and Hebei provinces, under the current straw collection price, we found that 85% of farmers have the willingness to actively collect and transport straw, and the longest distance for active transportation is 3.22 km. The willingness of farmers to actively transport is not only affected by personal characteristics, family characteristics, and current energy consumption habits, but also the characteristics of behavioral intervention variables such as knowledge, attitude, and practice of environmental protection also significantly affect the distance of farmers' active transportation. The behavioral intervention variables of these non-economic factors can be interfered and improved through multiple conventional propaganda tools. Therefore, it is necessary to establish a collection and storage point construction model based on the willingness of farmers to realize the transformation of the straw collection model from passive to active. This method also has an important reference value for most straw energy utilization projects. It will have an important impact on the planning, design, and operation of the project.

Keywords: paradigm shift, Contingent Valuation Method, willingness to transport, straw collection, centralized biogas production

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INTRODUCTION

In November 2018, the United Nations Intergovernmental Panel on Climate Change (IPCC) issued a "Special Report." The report pointed out that in order to achieve the goal of global warming below 1.5°C by the end of the century, the world must achieve zero carbon emissions around 2050 (Intergovernmental Panel on Climate Change [IPCC], 2018). In order to achieve this ambitious goal, the Special Report pointed out that the only options are to promote biomass energy with negative emission and carbon collection and storage. On September 22, 2020, the Chinese government clearly stated at the 75th United Nations General Assembly that carbon emissions will strive to reach the peak before 2030, and strive to achieve carbon neutrality by 2060. Carbon emissions will be an important binding indicator for China's social and economic development in the future. Carbon reduction in vast rural areas is an important part of China's goal of achieving carbon neutrality. In recent years, with the development of China's rural economy and the improvement of farmers' lives, important changes have taken place in the energy structure of rural life (Han et al., 2018). Traditional cooking energy such as straw has been gradually replaced by coal, natural gas, and electricity (Yan et al., 2020).

Biomass energy is a zero-emission carbon energy throughout the life cycle (Tokimatsu et al., 2017). The development of biogas energy in China's rural areas has obvious economic, social and environmental benefits. Provide clean energy for rural households to replace scattered coal, reduce greenhouse gas emissions. Among them, the biogas is not only "carbon neutral," but also a rare full life cycle carbon negative emission energy (Li et al., 2017). The reason is that the main component of biogas is CH_4. CH_4 is a greenhouse gas with a warming effect much greater than CO_2. In a natural state, organic waste, especially human and animal manure, will be fermented in an oxygen-deficient environment, such as water or accumulation, to produce a large amount of biogas, which is directly discharged into the atmosphere. If engineering measures are taken to collect organic waste and produce biogas in a closed anaerobic fermentation tank, and then use energy, it can effectively block a considerable part of the natural formation and emission of biogas CH_4 (Fu et al., 2021).

The utilization of straw energy is an important way to improve the comprehensive utilization of straw and the clean energy supply in rural areas, and it is an effective way to solve environmental problems. In 2017, the comprehensive utilization rate of straw nationwide exceeded 82%, and including utilization modes of fertilizer, feed, fuel, crop matrix, industrial raw materials (Ma et al., 2019). The main clean energy utilization technologies related to rural energy for straw energy include rural large and medium-sized biogas, biomass pyrolysis gasification, biomass molding fuel and other modes. The centralized biogas production (CBP) mode is the future biogas development model in rural China (Chen et al., 2014).

The CBP mode refers to use crop straw as the primary raw material, and supply biogas to farmers through a pipe network. This model usually uses natural villages as the unit, and the system scale is hundreds of households. Compared with domestic biogas digesters, CBP can provide more stable and sufficient biogas energy and a more complete follow-up service and management method (Hengeveld et al., 2014). Under the premise that natural gas cannot cover rural areas, biogas has the comparative advantage of centralized supply. Wang et al. (2016) pointed out that the development of CBP should be further encouraged and continue to reduce support for domestic biogas digesters. Song et al. (2014) believed that CBP are suitable for developed regions where people live close together. Wang et al. (2017) took the straw biogas project in Gengguantun, Cangzhou City as an example, and calculated that the centralized biogas supply project can reduce a net emission of 3.56 t per ton (dry mass) of straw and 11.50 kg/m^3 of biogas used.

For the straw utilization project represented by CBP, the link of collection, storage and transportation has always been a bottleneck. Straw collection, storage and transportation are the key link for off-field utilization. For farmers, collecting freight is laborious and not motivated. For companies, they have straw utilization technology but suffer from no raw materials available. In addition to speeding up the research and development of straw collection, storage, and transportation technology and related equipment, it is also necessary to establish a complete market operation mechanism for straw collection, storage and transportation and research related incentive mechanisms, and explore new models of straw collection, storage and transportation systems (Gao et al., 2019). At present, farmers can choose to dispose of straw by self-processing, purchase by purchasers, purchase by cooperatives, and purchase by enterprises. Compared with the other three methods, self-processing requires farmers to spend more time and labor costs, which can be regarded as labor-consuming methods, while the other three methods are regarded as labor-saving methods.

Farmers selling straw are facing extremely strong market constraints. Active, is to fully mobilize the enthusiasm and initiative of farmers, so that farmers can participate in straw collection and transportation. Passive, means that farmers are not very enthusiastic about straw collection, and straw collection is mainly driven by third parties such as brokers. Straw storage can adopt two modes: scattered and centralized storage. The decentralized storage model encourages users to actively collect. According to the quality and variety requirements of the biogas plant for raw materials, farmers are allowed to provide raw materials to the fuel plant in stages and quantitatively. The centralized storage mode requires a larger storage space. The production plant centrally stores the raw materials collected from farmers. In order to meet the project's raw material collection volume, it is necessary to establish a collection and storage station within a certain collection and storage radius. There are three ways for farmers to sell straw: one is the door-to-door purchase by an intermediary, the other is transportation and sale by their own tractor, and the third is the sale by hired tractor.

The location of the collection and storage site is the most important link in the straw collection, storage and transportation system. The overall consideration should be given to the support methods in the various links of straw collection, storage, transportation, and use, and in accordance with the principle of nearby utilization, to reduce the cost of collection, storage and transportation, and establish a policy that includes government promotion, straw utilization enterprises and purchasing and storage organizations as the axis, broker participation, market-oriented operation system. The collection cost was found to be the most sensitive factor in the Artificial model. The storage cost was found to be the most sensitive factor in the Mechanical model (Sun et al., 2017). Huo et al. (2016) took the North China Plain (Feicheng, Shandong) as an example to establish a continuous supply model based on field collection-centralized storage-utilization, and determined the location and number of straw collection and storage stations. He also analyzed the cost and energy consumption of 5 links, including field collection, primary transportation, storage at the collection and storage station, secondary transportation, and raw material loading and unloading (Huo et al., 2016). China's rural official organizations to collect agriculture straw in a centralized way and to share benefits with farmers (Luo et al., 2018) we develop a straw collection and transportation model using transfer stations and propose a method to calculate the corresponding transportation costs based on China's specific agricultural and rural transportation conditions in this paper. Transportation cost calculations and location optimization for each transfer station are carried out in ArcMap (Cao et al., 2016). Wang et al. (2021a) suggested that should according to the transportation distance, the requirement of agricultural residue pretreatments and brokers' participation to influence the decision of the centralized transportation patterns.

If the enthusiasm of farmers can be mobilized, the efficiency of purchasing and storage enterprises will be greatly improved. This requires a full understanding of the farmers' willingness to collect and transport and influencing factors, and the construction of a purchasing and storage model based on the wishes of farmers. This requires two issues to be resolved: what is the longest distance of farmers' willingness to transport, and what influencing factors need to be intervened to mobilize farmers' participation. Regarding the survey method of willingness, the Contingent Valuation Method (CVM) is currently commonly used. At first, CVM was mainly used for the investigation and evaluation of the value of ecological products. In recent years, its application scope has been expanded to daily necessities, location selection of public facilities etc. (Choi and Koo, 2018; Zhu et al., 2019). In the study of rural residents' willingness for the CBP project, it is necessary to consider the individual characteristics, socioeconomic factors, and some non-economic factors of rural residents, so we use the CVM method for research. Significant positive behavioral intervention will greatly increase the enthusiasm of farmers. The "Knowledge, Attitude, Practice" model divides human behavior change into three continuums of knowledge, attitude, and behavior, where knowledge (knowledge and learning) is the foundation, attitude (belief and attitude) is the driving force, and practice (behavior change process) is the goal. The "Knowledge, Attitude, Practice" model has conducted a large number of status quo surveys and intervention studies, and has been found to have significant effects in behavioral intervention studies (Sharifzadeh and Abdollahzadeh, 2021).

Based on the above description, we proposes the following hypotheses:

Hypothesis 1 (H1): Families with means of transportation are more motivated.

Hypothesis 2 (H2): Behavioral intervention variables affect farmers' willingness to transport.

METHODOLOGY

Survey Regions

In order to study the straw collection paradigm based on farmers' wishes, we chose to conduct research and data collection in Shandong and Hebei provinces (**Figure 1**). First of all, the two provinces are the most important production provinces in the North China Plain, rich in straw resources, and have built a large number of CBP demonstration projects. Secondly, the population of the two provinces is close to 1/7 of China's population, which is one of the most densely populated areas in China, and the current air pollution problem is relatively serious. The construction of clean energy in this region will be the first area for China to break through in the future.

Survey Methods

We collected the questionnaires from July to November 2018 in Daiyue District and Feicheng City of Shandong Province, Linxi County, Weixian County and Linzhang County of Hebei Province. The survey includes four aspects (**Table 1**).

First, the basic information of respondent's personal characteristics, including: gender, age.

Second, the basic information of respondent's family characteristics, including: family population size, education level,

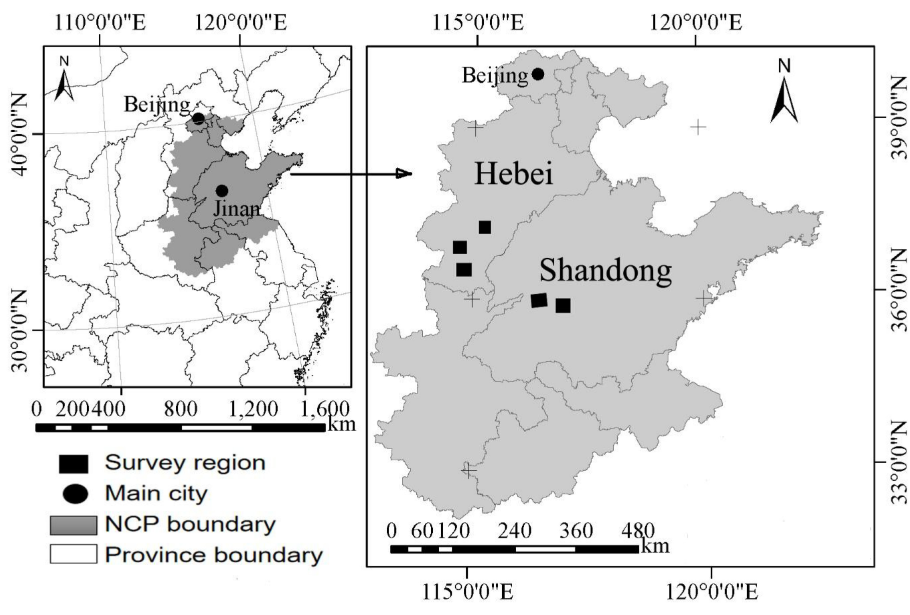

FIGURE 1 | The survey regions.

TABLE 1 | The variables and descriptive statistics.

Variable		Definition	Code	Value setting	Mean value	Std. err.
Dependent variable		WTT	WTT	Number	3.22	2.03
	Individual characteristic	Gender	Gen	Male is 1	0.59	0.49
		Age	Age	Years	50.17	11.45
		Education	Edu	Years	7.43	2.98
Independent variable	Family characteristic	Family population size	Popu	Number	5.78	2.16
		Cultivated land area	Area	Unit: Mu (Chinese land unit, 1 mu = 666.67 m^2)	12.90	41.74
		Children under the age of 10	Age 10	Number	1.26	0.99
		Older people over 65 years of age	Age 65	Number	0.73	0.79
		Is there a village cadre?	Cad	Yes is 1	0.04	0.20
		Family income 2017	Inc	Number	32205	24470
		Household expenditure 2017	Exp	Number	20478	14851
		Transport vehicle	Veh	Yes is 1	0.42	0.49
	Life energy characteristics	Is there solar water heaters?	Sol	Yes is 1	0.59	0.49
		Is there household biogas?	Bio	Yes is 1	0.11	0.31
	Behavioral intervention	Knowledge	Kno	Score	4.98	3.16
		Attitude	Att	Score	3.09	2.12
		Practice	Pra	1 = mainly clean energy 2 = clean and traditional energy half 3 = mainly traditional energy such as coal and firewood	1.95	0.74

cultivated land area, the number of children under 10 years old, whether family members serve as village cadres, the number of elderly people over 65 years old, annual family income in 2017, family expenditure in 2017, whether to have transport vehicle. In particular, transport vehicles, in the survey, we define transport vehicles as: fuel or electric transport vehicles with more than three wheels for agricultural production and life.

Third, household life energy characteristics variable, including: whether to have solar water heater at home, whether to have household biogas at home.

Fourth, the behavioral intervention variable by the survey of environmental protection "Knowledge, Attitude and Practice (KAP)," which is a behavioral intervention theory. "Knowledge" as "understanding of any given topic," "Attitude" as "feelings toward it, along with predetermined opinions" and "Practice" as "ways in which they demonstrate their knowledge and attitude through their actions (Kaliyaperumal, 2004)." Nowadays, the "KAP" have often been used in the consumer and environmental sectors (Ahamad and Ariffin, 2018; Almasi et al., 2019). There are no clear rules on how best to conduct a KAP survey, as the methods vary according to the subject and purpose of the study (Vandamme, 2009).

Fifth, the farmers' willingness to transport (WTT). In order to ensure that the interviewed farmers can accurately understand the question under investigation, we ask the investigator to first spend 1 to 5 min introducing the CBP project and model, the advantages and disadvantages of the project and product to the interviewee. The questionnaire used a double-border dichotomy (Bateman et al., 2001). Each questionnaire takes about 30 min. We mainly lead the team through the staff of the local agricultural authority, and let them provide the respondents according to our requirements.

In the specific investigation work, our first question is "If a CBP project is built to provide residents with concentrated biogas, will it be supported?" The respondents chose the answer "Yes" or "No." If respondents answered "Yes," proceed to the WTT survey section. Before the WTT survey, the respondents were first informed that the current purchase price of straw is 200 yuan/ton. If the respondents themselves or their family members are willing to take the initiative to transport the straw to the straw collection station, he can accept the distance from collecting straw to transporting it to the collection station. What is the maximum distance? The answer option directly answers the kilometers.

Variable Definition

The WTT is chosen as the dependent variables, separately. In the process of investigation, the investigators will make a special explanation that the acquisition price of straw is the current market price.

In the independent variable part, most of the questions come directly from the inquiries of the respondents, and some independent variables are obtained by means of proxy variables.

Income variables and expenditure variables are in the form of proxy variables. Because income is a relatively private issue in China's traditional concept, and most farmers also lack accurate statistics on income and expenditure. Therefore, these two variables are mainly estimates of the main sources of income such as the occupation, planting and breeding of the respondents. Expenditure variables also refer to the number of households to support, household spending on bulk consumer goods, etc.

Regarding the acquisition of the "KAP" variable, a more complex approach is taken. First, for the "knowledge" variable, we set 10 questions about environmental protection, and scored from 0 to 10 according to the number of questions answered by the respondents. Second, for the "attitude" variable, this variable was obtained by the following method: We asked respondents about the importance of environmental protection relative to income and health, and asked respondents to make a comparison and differentiate between income, health and environmental protection, a total of 10 points. For example, if environmental protection is given 3 points, the respondents' attitude score is 3 points. Third, we obtain the "Practice" variable using household energy preference as a proxy variable. Therefore, we use a preference value to represent this practice: if they prefer clean energy, such as liquefied gas/electricity, we define it as 1; if they prefer traditional energy such as coal and firewood, we define it as 3; clean energy and traditional energy, we define it as 2. The lower the preference value, the cleaner the current energy practice.

Descriptive Analysis

We collected 389 questionnaires. Among them, 38 questionnaires have missing data or self-contradictory filling. After detailed statistics, we finally obtained a total of 351 valid questionnaires. The sample efficiency rate is 90.23%.

The surveyed area has a temperate continental climate with four distinct seasons and long sunshine hours. Therefore, in terms of household energy utilization, the installation rate of household solar water heaters is not low, reaching 58.97%. However, due to the temperate zone, household biogas has poor efficiency and high maintenance costs. Only 10.54% of households have household biogas, and most biogas digesters are basically abandoned.

In addition to the hot water provided by solar water heaters, 11.95% of the sources of hot water are electric water heaters, 51.00% are coal-based, 11.68% are fuelwood, and 7.41% are liquefied gas. There is still huge space for improvement.

With the popularization of new media methods, the channels for farmers to obtain information and knowledge are becoming more and more diversified. "TV\Newspaper\Books" channel accounted for 48.22%; "Village Committee" channel accounted for 20.56%; "Mobile and Internet" channel accounted for 13.96%. There are also a small number of channels, such as "relatives and friends," "agricultural technical service personnel," "agricultural material dealers" and so on.

Model

In CVM studies, Tobit econometric model (censored regression model) was used to analyze the determinants of WTT and the maximum amount of distance that individuals are willing to transport. Zero-response data are inevitable in WTT surveys. Tobit model is often assumed as the true distribution of willingness bidding censored at zero and is better suited in case of data with many zeros than ordinary least squares regression analysis which may be biased and inconsistent parameter estimates the regression. Tobit model reveals both the probability of WTT and the maximum WTT of the respondents. Following the Tobit model (McDonald and Moffittt, 1980), a standard one-equation censored model can be defined as:

$$WTT_i^* = X_i\beta + \varepsilon_i,\ \varepsilon_i \sim N(0, \sigma^2),$$
$$WTT_i = \begin{cases} WTT_i^*,\ if\ WTT_i^* > 0 \\ 0,\ if\ WTT_i^* \leq 0 \end{cases} \tag{1}$$

Where for the ith individual, WTT_i is the latent (unobservable) WTT for construction of straw collection site; WTT_i is the observed actually maximum WTT for construction of straw collection site and is censored at 0; X_i is the vector of independent variables that are hypothesized to influence WTT theoretically; b is the unknown parameter vector to be estimated; and εi is the error term which is assumed to be normally distributed with the mean zero and constant variance sigma square (σ^2). The standard Tobit model provides the expected value of WTT_i (Tobin, 1958):

$$\begin{aligned} E(WTT_i) = &\Pr(WTT^* \leq 0) \cdot E(WTT_i|WTT_i = 0) \\ &+ \Pr(WTT^* > 0) \cdot E(WTT_i|WTT_i > 0) \\ &= Xi\beta F(Xi\beta/\sigma) + \sigma f(Xi\beta/\sigma) \end{aligned} \tag{2}$$

Where F represents the cumulative distribution function of a standard normal random variable, f represents the normal density function and s represents the standard deviation. In addition, the expected value of WTT for observations with positive WTT bids (Amemiya, 1973) is:

Tobit model can be used to determine both changes in the probability of being above zero (i.e., the discrete decision of whether to pay) and changes in the values of WTT for the whole sample and the observations which are above zero (McDonald and Moffittt, 1980). Afterward, the marginal effect of an independent variable on the expected value of WTT among the entire sample in the model is given by:

$$E\ (WTT_i|WTT_i > 0) = Xi\beta + \sigma\lambda \mid (Xi\beta/\sigma) \tag{3}$$

The change in the expected WTT value of those observations with positive WTT bids is:

$$\partial E\ (WTT_i)/\partial Xi = \beta F\ (Xi\beta/\sigma) \tag{4}$$

$$\partial E\ (WTT_i/WTT_i > 0)/\partial Xi = \beta\ [1 - \lambda(Xi\beta/\sigma)\ (Xi\beta/\sigma - \lambda(Xi\beta/\sigma))] \tag{5}$$

Where $\lambda(X_i\beta/\sigma)$ is the inverse Mills ratio, $[f(X_i\beta/\sigma)/F(X_i\beta/\sigma)]$. The change in the probability of eliciting positive bids is:

$$\partial \Pr(WTT_i > 0)/\partial Xi = \partial F(Xi\beta/\sigma)/\partial Xi = f\ (Xi\beta/\sigma)\beta/\sigma \tag{6}$$

RESULTS

Measurement Results

Before conducting the econometric analysis, we first performed a multicollinearity test for each independent variable. The mean variance inflation factor (VIF) is equal to 1.75. Among them, the VIFs of both income and expenditure variables are above 3. Income represents a household's source of income. Consumption level reflects consumption level. Therefore, to avoid multicollinearity, we keep only the expenditure variable.

Relying on the Tobit model and using Stata 15.0 measurement software, the regression analysis of WTT was carried out. The χ value is 148.12, and the *p*-value is 0.0000. The log likelihood is −671.18. The overall effect is good. The measurement results are detailed in **Table 2**.

Calculation of Willingness to Transport

The distance that participants can accept from collecting straw to transporting it to the straw collection station is 3.22 km.

Result Analysis

The measurement results basically verify our previous hypothesis.

The impacts of individual characteristics: According to this survey, considering individual characteristics, the variables of age have significant influence and negative correlation on WTT. This indicates young people have a higher WTT.

The impacts of family characteristics: In terms of family characteristics, "Children under 10 years old" has a significant influence and positive correlation on WTT, which indicates that the child is important to a family's life improvement decision. The more children under the age of 10 in the family, the higher WTT. The "Over 65 years old" is not significant, explaining that families with elderly people are not strong in their desire to improve their lives. The influence of whether has "village cadres in the family" is not significant. However, the family "population" have significant impacts, but the coefficient of "population" is negative.

It is clear that families with transportation vehicles have a higher WTT. This is consistent with the hypothesis.

The impacts of life energy characteristics: The results show that households with solar water heaters have a higher WTT. However, whether the family has biogas or not is not related to the WTT.

The impacts of behavioral intervention theory variable: The three non-economic variables of environmental knowledge, attitude and practice are equally significant in WTT, and the coefficients are in the same direction. The coefficient of knowledge and attitude is positive, indicating that the higher the cognitive score for environmental protection, the more positive the WTT. Cognitive theory shows that all the processes or activities of people to obtain and use information are the first to perceive information, then identifying the content of the information, generating willingness and finally changing the behavior. According to cognitive theory, the influence of knowledge, attitudes and household energy preferences on the purchasing willingness of rural residents should be comprehensive. It can be interpreted from the regression results in **Table 2** that the degree of awareness of environmental protection has a significant positive impact on the WTT, that is, the higher the awareness of environmental knowledge, the higher WTT. Similarly, respondents' emphasis on environmental protection has also increased the WTT. Results can be obtained that it is an effective measure to change household energy preferences and increase residents' WTT by raising public awareness of environmental awareness through publicity activities such as education and attaching importance to cultivate individual attention to environmental protection.

TABLE 2 | Tobit model measurement results.

Classification	Variables	WTT	
		Coeff.	Std. error
Individual characteristic	Gen	0.27	0.19
	Age	−0.02***	0.01
	Edu	0.01	0.03
Family characteristic	Popu	−0.14***	0.05
	Area	0.00*	0.00
	Age 10	0.33***	0.11
	Age 65	0.01	0.12
	Cad	0.22	0.25
	Exp	0.00	0.00
	Veh	0.89***	0.19
Life energy characteristics	Sol	0.63***	0.19
	Bio	−0.07	0.31
Behavioral intervention	Kno	0.08***	0.03
	Att	0.14***	0.05
	Pra	−0.48***	0.13
	_cons	3.70***	0.67

Number of obs. = 351; non-selected = 0; LR chi^2 (14) = 148.12; Prob > chi^2 = 0.0000.
Coeff. is estimated coefficient.
, *, coefficient is significant at 10, 5, and 1% probability levels, respectively.*

DISCUSSION

It is necessary to establish a collection and storage point construction model based on the willingness of farmers to realize the transformation of the straw collection model from passive to active. In the context of the policy of banning straw burning, farmers as rational economic agents (Nie et al., 2021), due to labor cost and time constraints and other restrictive factors, the best choice for farmers in various decentralized utilization behaviors is to directly return straw to the field (Yang et al., 2018). Moreover, most farmers return all the straw to the field directly after harvest, thus avoiding the cost of straw collection. As the executors of these behaviors, farmers need to bear the cost of straw collection (Wang et al., 2021a), and the private benefits they get are less than the social benefits. Under the current cost-benefit accounting of the comprehensive utilization of straw, the private benefits obtained by farmers are even negative, that is, the collection costs are too high and the benefits are too small (Yang et al., 2020).

Therefore, rational farmers will choose not to collect straw (Wang et al., 2021b). The transportation willingness of farmers studied in this article is a rational choice made by farmers on the premise of fully respecting the choices of farmers. It is also the critical point from passive to active.

Intervention in the behavior of farmers can increase initiative awareness and increase willingness. In the process of the utilization of crop straw resources, due to the differences in the goals, understanding and interest orientation of the government, enterprises and farmers in the use of straw resources, there is a game relationship among various stakeholders (Wen and Zhou, 2018). The fundamental driving factor affecting straw collection is the economic benefits of straw collection. In the survey, it was found that the reason why farmers are willing to recycle straw is that they believe that recycling straw can reduce environmental pollution caused by incineration, reduce the use of chemical fertilizers, and increase income. Environmental protection education intervention can significantly improve farmers' cognitive level, improve attitudes and change behaviors. Tools such as TV\newspapers\books have more obvious effects on farmers' intervention. Although the impact of different interventions on farmers is different, the more intervention methods for farmers, the better the effect. These intervention methods are simple, easy to implement, low cost, and effective, and can be widely promoted in rural grassroots.

However, there are still 24.58% of farmers who are unwilling to recycle straw. The reason for their unwillingness is mostly that the amount of straw is too small and they are too old to be able to recycle straw. This has a lot to do with the current aging phenomenon in rural China (Zhan et al., 2021). Most of the young and middle-aged people in rural areas go out to work (Zou et al., 2018). Only the left-behind elderly are left at home, and the elderly do not have enough time and energy to collect straw, so they are unwilling to recycle straw.

This paradigm shift has important reference value for areas with high agricultural vehicle ownership. The transportation fee increases with the increase of the collection radius, which is the most variable factor in the variable cost. The cost of straw supply includes raw materials, labor, fuel collection power, transportation fuel power, equipment depreciation and maintenance, management and other costs (Wu et al., 2021). Analyzed by cost category, labor cost ranks first, followed by raw material cost, and then the cost of collecting and transporting fuel and power (Sun et al., 2017). Labor cost and fuel power increase with the increase of transportation distance. Therefore, in areas where the number of agricultural vehicles is high, the willingness of farmers is relatively high, but the increase in other costs is also an interference factor that needs to be considered in an overall plan.

It has reference value for projects that require straw collection. At present, China's straw as an energy source is mainly used in direct-fired power plants, straw briquette fuel plants, and straw gasification stations. The cost of raw material supply is a common problem for all kinds of straw energy utilization projects. This kind of straw collection, storage and transportation model based on the wishes of farmers, such projects have common reference value. Especially for large straw consuming households such as biomass power plants, the selection and setting of sites at all levels (Cheng et al., 2020), and the distribution of interests of various stakeholders in the process of straw collection, there is great significance for the sustainability of the project by mobilizing the enthusiasm and initiative of farmers.

The development of low-carbon agriculture depends on the awakening of ecological awareness of agricultural producers based on economic incentives. Agriculture has a huge potential for carbon emission reduction and carbon sequestration (Wang et al., 2021c). Due to objective factors such as large straw production, wide coverage, and scattered resources, coupled with the high cost of returning straw to the field, limited local financial investment, and incomplete policy systems, the comprehensive utilization of straw needs to overcome many difficulties. Therefore, it is necessary to adopt a paradigm shift based on the transportation willingness of farmers to explore and strengthen the introduction of market forces and release farmers' willingness to participate in the form of economic incentives (Li et al., 2021). From another point of view, this is also paying for the increase of carbon sinks in the agricultural system by means of ecological compensation (Xiong and Li, 2019).

What is interesting, households equipped with household biogas should be high proportion of clean energy households according to the assumptions, but WTT are not significant. This is because the construction of household biogas is mainly driven by subsidies from the Chinese government (Sun et al., 2014). Ignore the willingness of farmers to participate actively.

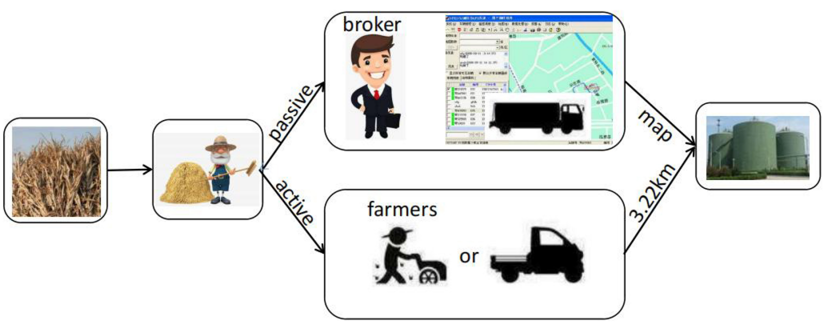

FIGURE 2 | Shift of straw collection mode from passive to active.

As a result, household biogas almost failed in China. This also contradicts the importance of farmers' willingness to the success or failure of the project.

CONCLUSION AND POLICY IMPLICATIONS

This paper takes the centralized biogas production project in the energy utilization of straw as an example to discuss the straw collection mode based on the wishes of farmers. Through surveys of farmers in Shandong and Hebei provinces, under the current straw collection price, we found that 85% of farmers have the willingness to actively collect and transport straw, and the longest distance for active transportation is 3.22 km. The willingness of farmers to actively transport is not only affected by personal characteristics, family characteristics, and current energy consumption habits, but also the characteristics of behavioral intervention variables such as knowledge, attitude, and practice of environmental protection also significantly affect the distance of farmers' active transportation. The behavioral intervention variables of these non-economic factors can be interfered and improved through multiple conventional propaganda tools. Therefore, it is necessary to establish a collection and storage point construction model based on the willingness of farmers to realize the transformation of the straw collection model from passive to active (**Figure 2**).

This research has important policy implications for the construction of most straw energy utilization projects. First, the establishment of a collection and storage point construction model based on the willingness of farmers and the transformation of the straw collection model from passive to active will have an important impact on the planning, design and operation of the project. Secondly, although there are still some farmers who are unwilling to participate, intervening in farmers' behavior can increase their awareness and willingness to take the initiative to transport. Third, the paradigm shift of this collection mode has important reference value for areas with high agricultural vehicles. Fourth, the development of low-carbon agriculture depends on the awakening of farmers' ecological awareness based on economic incentives. Fifth, it also has reference value for other similar projects that require straw collection.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

QW: conceptualization, methodology, validation, formal analysis, investigation, writing—original draft preparation, and visualization. YY: resources, data curation, writing—review and editing, supervision, project administration, and funding acquisition. Both authors were involved in preparing the manuscript.

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