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The disposal and willingness to pay for residents' scrap fluorescent lamps in China: A case study of Beijing

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ABSTRACT

The generation of scrap fluorescent lamps in China has increased greatly in recent years, and the improper disposal of mercury-containing waste has posed a major risk to residents' health. This paper describes research based on a sample from China to investigate the disposal and willingness to pay for scrap fluorescent lamps in households. We estimated that 4.19 million scrap fluorescent lamps are generated from households in Beijing per year. Most residents cannot recycle due to a lack of recycling facilities, and 34.7 kg scrap mercury is out of control. We found that 68.6% of Beijing residents are willing to pay extra fees to dispose of scrap fluorescent lamps safely, and the average value is 1.98 CNY/lamp, which is twice the value of the subsidiary standard that the government gives to treatment plants. We found that the length of residence period, cognition of hazardous waste and the understanding of extended producer responsibility (EPR) are the dominant factors that affect residents' payment decisions. Governmental departments should consider establishing a special fund to ensure the safe disposal of household scrap fluorescent lamps by installing recycling facilities in communities and by subsidizing recycling enterprises.

1. Introduction

The total number of fluorescent lamps (CFLs) exceed 1 billion in China in 2011 because of the implementation of the "green lighting" project from 2008 (Reynolds et al., 2012; Yang and Ji, 2014). With the following phase-out plan of incandescent lamps (ILs) issued by National Development and Reform Committee (NDRC) (NDRC, 2011), the ownership of FL has almost reached a level equal to levels in developed countries (Zhao et al., 2012). This is leading to a large quantity of scrap fluorescent lamps (FLs) from household. The FLs save energy and reduce emissions (Lee et al., 2014; Schleich et al., 2014), but the mercury in FLs is a type of highly toxic heavy metal (Cain et al., 2007). The actual amount of mercury in each FL (Zhou and Bukenya, 2016), which is produced with traditional liquid mercury injection process, is approximately 60–120 mg in China (Sun and Liu, 2003). If discarded improperly, one scrap FL can pollute at least 30 tons of water, which will cause great harm to the soil, the atmosphere and the human body (Pant and Singh, 2014; Guo et al., 2013). So scrap FLs has been listed as HW29 mercury waste in the "National hazardous waste list" (EPA, 2008).

However, scrap FLs generated from households were not disposed properly, which became a potential environment risk. When compared to other Waste Electrical and Electronic Equipment (WEEE), the economic value of scrap FLs is relatively low, which is unattractive to recyclers (Cheng and Hu, 2012). So most of the scrap FLs were combined with household garbage as ordinary household waste. Many FLs are broken during transport, landfilling or incineration; therefore, large amounts of mercury elements flow into the environment (Hu and Cheng, 2012).

There is no technical difficulty in the treatment of scrap FLs (Kujawski and Pospiech, 2014; Manomaivibool, 2015; Wu et al., 2014). However, the difficulty lies in how carry out uniform reclaim, who can afford the disposal costs and how much they should be subsidized for each scrap FL (Zhang et al., 2016). Some scholars have noted that, according to the "polluter pays" principle in China, producers and users that cause environmental pollution should be responsible for recycling (López-Mosquera et al., 2015; Peng et al., 2014). Regarding disposal expenses, China should refer to the disposal experiences of hazardous wastes in developed countries (Lee et al., 2015; Saphores and Nixon, 2014) and subsidize professional

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recycling organizations with household garbage disposal fees that are paid by residents (Silveira and Chang, 2011). However, some environmental economists think that it is difficult to implement a law to stipulate that the consumer should pay for the disposal of scrap FLs (Ying et al., 2015). Based on the conflicting opinions about the disposal fund, we considered that as the main users of FLs and the direct disposers of scrap FLs (Asari and Sakai, 2011), residents play an important role in the process of recycling(Afroz et al., 2013; Babaei et al., 2015).

The ownership of FLs in Beijing, as the capital of China, is enormous but unknown, and the scrap FL treatment system is also ineffective (Liu et al., 2015; Zheng, 2010). We conducted a survey on households in Beijing. First, we gathered information on the current recycling situation of household scrap FLs in Beijing, which mainly included the source. Then, we collected and analyzed the data to investigate the current users of FLs in Beijing households, their recycling behaviors, the awareness to participate in and the willingness to pay for recycling. Finally, we provide suggestions to implement FL recycling policies.

2. Methodology

2.1. Questionnaire Design

2.1.1. Explanation of the subject of the Research

Research team members carried out the questionnaire survey in the central business district of Beijing in July 2015. To provide respondents with a clear knowledge of the concept of FLs and to avoid misunderstandings, we provided a distinction between FLs and other types of lamps. Detailed interpretations of the various types of lamps are listed in the questionnaire, as shown in Fig. 1.

2.1.2. Selection of Research Subjects

Currently, the scrap FLs that generated from government institutions and state-owned enterprises in Beijing are transported to hazardous waste disposal centers through unified collection (Zheng, 2010). However, scrap FLs from households, which is the main source of scrap FLs, became the main problem due to a lack of unified recycling. Therefore, “household” is set as the basic research unit in this research.

2.1.3. Design of Questionnaire

The questionnaire has four parts. Part one describes the socioeconomic characteristics of residents and families, and it includes respondents’ gender, age, the number of people in the family, the household income, individual income and the resident period. Part two describes the current disposal situation, which includes the number of all types of lamps in the household and the disposal mode of scrap lamps. Part three inquires about recycling awareness, which includes household understanding of FLs and recycling, the cognition of the danger of FLs and the attitudes to participate in recycling. Part four explores the willingness to pay, which includes the acceptance to pay extra fees for recycling scrap FLs and to use certain payment modes, the reasons for refusing to pay, the relationship between identity and the willingness to pay and the limit of average willingness to pay.

2.1.4. Survey mode

Many traditional methods can conduct this survey, such as face-to-face interview, telephone interview, and mail (Yoo and Kwak, 2009). The study cost of these methods descends orderly, but the quality of return questionnaire also falls sequentially. To achieve the highly reliable results, we choose the face-to-face interviews with well-trained interviewers. Through direct explaining, our interviewers help the respondents fill the questionnaire and avoid some misunderstanding or missing. Moreover, we recheck the questionnaires after they are returning from the interviewers.

2.2. Sample Size and Distribution

The research area is limited to six districts in downtown Beijing, which are in the central area of Beijing. According to the Beijing Statistical Yearbook in 2015, these typical regions of Beijing have 2.871 million residents (BJMBS, 2015). To obtain the random sample of the general study objective, it is first assumed that the overall distribution of the survey has a normal distribution. The computation formula adopted in this research is as follows:

For repeated sampling or infinite population sampling without repetition

$$n = \frac{{Z_{1-\alpha}}^2 \cdot p \cdot (1-p)}{d^2} \tag{1}$$

For the limited population

$$n = \frac{N \cdot {Z_{1-\alpha}}^2 \cdot p \cdot (1-p)}{(N-1)\cdot d^2 + Z_{1-\alpha}^2 \cdot p \cdot (1-p)} \tag{2}$$

where α is the significance level, $Z_{1-\alpha}$ is the corresponding quartile at different confidence levels under normal distribution. p is the value that can be chosen by requirement, d is the value of confidence interval, and N is the overall total. It is easy to draw the conclusion that, when N approaches infinity, the result of Formula (2) approaches the result of Formula (1).

Because the number of households is known and there is no sample repetition in this study, the calculation method of Formula (2) should be used. Based on the calculation of the sample size calculated at a 95% confidence level, the total number of households in the six main urban areas in Beijing is expressed as $d = 5\%$, $Z_{1-\alpha} = 1.96$, $p = 0.5$, $N = 2.871$ million. According to final result, the sample size should be at least 385(384.1087). We gave out 500 questionnaires to achieve better results and to account for the possibility that some of the questionnaires that are returned may be invalid.

2.3. Estimation of scrap generation

We estimate the scrap generation of FLs based on our survey data. Many previous studies predicted the WEEE generation amount based on the data for their sales and lifetime, such as marketing supply method(A), Stanford method, consumption and use approach, time-step method. (Araújo et al., 2012; Li et al., 2015; Song et al., 2016; Tan and Li, 2014) However, the sale and consumption records of FLs are unavailable from the official statistics department. So based on the sample data for the household ownership and lifetime of FLs, we choose to estimate the scrap FLs generation with the stock-based model. (Tian et al., 2015; Zhang et al., 2012) It is assumed that there are n kinds of FLs, and the stock of in-use FLs has reached a stable level. The G_t represent the scrap generation of one city in year t and is given by Formula (3):

$$G_t = \sum_{i=1}^{n} \frac{S_t^i \cdot}{L^i} \cdot H_t \tag{3}$$

where S_t^i represent the average stock of FL i per household in year t, the H_t represent the number of households in year t, and L^i represent the average lifetime of FL i.

2.4. Analysis of Factors that Influence Willingness to Pay

To obtain the influencing factors of the willingness of households to pay for scrap FLs, we used the binary logistic regression

Compact Fluorescent Lamp (CFL) Fluorescent Lamp Tube (FLT) Incandescent Lamp (IL)

Fig. 1. Pictures of Various Types of Typical Lamps.

model. This is a regression analysis method where the dependent variables are the binary classification variables (Ami et al., 2014). There is no requirement for independent variables to be qualitative.

Before the binary logistic regression, assumptions were used to explain variables such as "are you willing to pay for recycling scrap FL?" If the respondent answers "yes", then Y=1; if the respondent answers "no", then Y=0. The independent variables that affect Y are written as $X_i(i = 1,2 \cdots m)$ (Wang et al., 2011).

The conditional probability of incidents is written as $P(y = 1|x_i) = p_i$, which provides the logistic regression model. The expression is shown as follows:

$$p_i = \frac{1}{1 + e^{-(\alpha + \sum_{i-1}^{m} \beta_i x_i)}} = \frac{e^{\alpha + \sum_{i-1}^{m} \beta_i x_i}}{1 + e^{\alpha + \sum_{i-1}^{m} \beta_i x_i}} \quad (4)$$

$$1 - p_i = 1 - \frac{e^{\alpha + \sum_{i=1}^{m} \beta_i x_i}}{1 + e^{\alpha + \sum_{i=1}^{m} \beta_i x_i}} = \frac{1}{1 + e^{\alpha + \sum_{i=1}^{m} \beta_i x_i}} \quad (5)$$

$$\ln\left(\frac{p_i}{1 - p_i}\right) = \alpha + \sum_{i=1}^{m} \beta_i x_i \quad (6)$$

Where p_i represents the probability of the respondents' willingness to pay for recycling scrap FLs and$p_i/(1 - p_i)$ is the proportion of incident occurrence. If the value is positive (because $0 < p_i < 1$), the logarithmic transformation is calculated. We can obtain the linear mode of the logistic regression model as shown in the formula, of which β_i represents the regression coefficient of explained variables, and α represents the regression intercept.

2.5. Measurement of Average Payment Limit

To obtain the average payment limit of households that were paying for scrap FLs, we used the Contingent Value Method (CVM) to carry out quantitative research. This method was formulated in the 1960s and can be used to evaluate the use value and non-use value of various types of resources and environments (Arrow and Solow, 1993). CVM can meet the demand of economic and consumer preference utility theory. The results can fully reflect the subjective feelings that individuals have for products, find the surplus value of every consumer and provide reasonable suggestions. CVM can also measure the economic value of environmental quality improvement, provide quantitative instruments that aid in decision-making for natural resources and environmental protection and overcome the existing defects of current economic models that cannot quantitatively measure the value of environmental goods (Zhan and Zhang, 2012).

The existing methods for measuring payment limits include discrete CVM (using selective questions in the questionnaire) and continuous CVM (using open questions in the questionnaire). For discrete CVM, the specific amount is set by the researchers, and the respondents simply need to select either "yes" or "no" to show their willingness to participate (Song et al., 2012). The discrete CVM method's level of difficulty for respondents is relatively low, but the researchers greatly influence the value range of options. Because the researchers control the answer options, uncertainty may occur, which may significantly affect the accuracy of the final results.

To obtain an accurate conclusion, we used continuous CVM. When respondents fill in open questions for CVM, they are free to mark the highest amount that they are willing to pay. CVM also makes data analysis easier. However, the only drawback of continuous CVM is that when the respondents are uncertain about the amount to write as their maximum level, they are likely to fill in inappropriate answers, which interferes with the final result in the analysis (Keramitsoglou and Tsagarakis, 2013).

2.6. Correction method of the investigation results

To improve the actual reliability of the final result, we adopted two methods. First, we used the Bilateral Average Correction Method (BACM) in the summary column of the final result. In EXCEL 2013, we deleted all of the answers in the highest and the lowest 5% of the data by using the formula TRIMMEAN function. With this function, we kept only 90% of the data and then calculated the average revised value. Second, in measuring the real payment limit that residents can accept, we set up two similar questions to determine the absolute costs of willingness to pay (CNY) and the percentage of relative prices (%). Then this WTP percentage multiplied by the average price of new FLs, we should get another collated value (CNY), which can determine whether the two sets of results are approximate and whether the final statistical results are real and effective.

3. Results and discussion

3.1. Characteristics of respondents

3.1.1. Sample Distribution and the Number of Valid Questionnaires

The questionnaire was administered in the six administrative districts in Beijing: Dongcheng, Xicheng, Chaoyang, Fengtai, Shijingshan and Haidian District. The sample location, the household number, the proportion and the sample size are shown in Table 1. Meanwhile, the number of valid questionnaires that were returned from all of the six districts and the valid proportion are shown. The total valid proportion was 97%.

Table 1
Research Sample Distribution and the Number of Valid Questionnaire Returned.

District	Location	Household Number(10,000)	Distribution Proportion	Sample Size	Valid Number	Valid Proportion
Dongcheng District	In the Mid-Eastern Region	34.46	12%	60	55	92%
Xicheng District	In the Mid-Western Region	47.21	16%	82	82	100%
Chaoyang District	In the Eastern Region	76.51	27%	133	130	98%
Fengtai District	In the Southern Region	45.4	16%	79	77	97%
Shijingshan District	In the Northern Region	14.02	5%	25	24	96%
Haidian District	In the Western Region	69.51	24%	121	116	96%
Total		287.1	100%	500	484	97%

Table 2
Socioeconomic characteristics of residents.

Variable	Group	Sample size	Sample proportion	Description	Average value	Standard deviation
Age	18-30	280	56.11%	24	31.85	10.68
	31-40	119	23.85%	35		
	41-50	66	13.23%	45		
	51-70	34	6.81%	60		
Gender	Female	269	53.9%	0	0.4609	0.49897
	Male	230	46.1%	1		
Family size	1	1	0.2%	1	3.7695	1.01445
	2	27	5.4%	2		
	3	221	44.3%	3		
	4	106	21.2%	4		
	5	125	25.1%	5		
	6	19	3.8%	6		
Education level	Below high school	12	2.4%	1	4.004	1.11
	High school	40	8.0%	2		
	College	73	14.6%	3		
	Undergraduate	225	45.1%	4		
	Graduate	107	21.4%	5		
	PhD	42	8.4%	6		
Family monthly income	<5000	20	4%	1	3.9519	1.56701
	5001–10000	86	17.2%	2		
	10001–15000	115	23%	3		
	15001–20000	86	17.2%	4		
	20001–25000	61	26.3%	5		
	25000以上	131	12.2%	6		

3.1.2. Residents' socioeconomic characteristics

After analyzing the basic information of the respondents, we found that the average age of the respondents was 31.85, the proportion of females was 53.9%, the average number of people in each family was 3.77, the average education level was undergraduate; the average household monthly income was 15,000 to 20,000 CNY. The socioeconomic characteristics of the respondents are shown in Table 2.

3.2. The generation of residents' scrap FLs

3.2.1. Household ownership of FLs

This survey collected data on household ownership of FLs, and the results are provided in Fig. 2. These figures show that ownership distribution follows normal distribution. The household ownership of various types of lamps was 4 to 18, and the average value was 10; The ownership of CFLs was maintained at 2 to 10, and the average ownership was 5.87, accounting for approximately 61% of the total number of lamps. When FLTs are added, the total ownership of FLs is maintained at 4 to 13 per household, and the average ownership is 8.78 per household, accounting for approximately 88.5% of the total number of lamps. Finally, the average household ownership of traditional ILs is 1.2 per household. These data reveal that ILs have basically been absent from household user market preferences, and FLs have become the most utilized lamps.

The average household size of Beijing is 2.5 persons (BJMBS, 2015), so the total number of household was estimated as 1.15 million. A calculation of the average household ownership of FL and the household number shows that the total ownership of household FL is 10.1 million.

3.2.2. The service life of the FLs

The life span of FLs is negatively correlated with the scrap generation amount. The life span distribution of CFLs and FLTs was 2.46 and 2.33 years, respectively. (See Fig. 3) The former is slightly longer than the latter because the current average quality of CFLs is higher.

3.2.3. The scrap generation amount of FLs

According to average stock and average life span of FL per household, we estimate that the annual scrap generation of CFLs and FLTs are 2.39 and 1.25, respectively. The total scrap generation reaches 3.64 FLs per household. Meanwhile, according to the number of households in Beijing, by conservative estimation, the amount of local household scrap FLs is 4.19 million annually.

3.3. The residents' scrap FL disposal

3.3.1. The disposal method after scraping

As shown in Fig. 4, the proportion of special recyclers is only 8%, and the proportion of households who return FLs to the retailer is 2%. Though both are proper ways to treat FLs safely, only 10% of households utilize these methods. The primary ways that residents dispose of waste can be divided into two categories: putting waste into classified garbage bins (57%) and throwing waste into unclassified garbage bins (26%). The sum of these two disposal methods, which are not proper disposal methods, accounts for 83% of the total disposal quantity. This indicates that FL treatment is still inadequate. However, more than half of the residents indicated that they would put scrap FLs in a classified dustbin that is designated with a classification signs. This shows that more than half of the res-

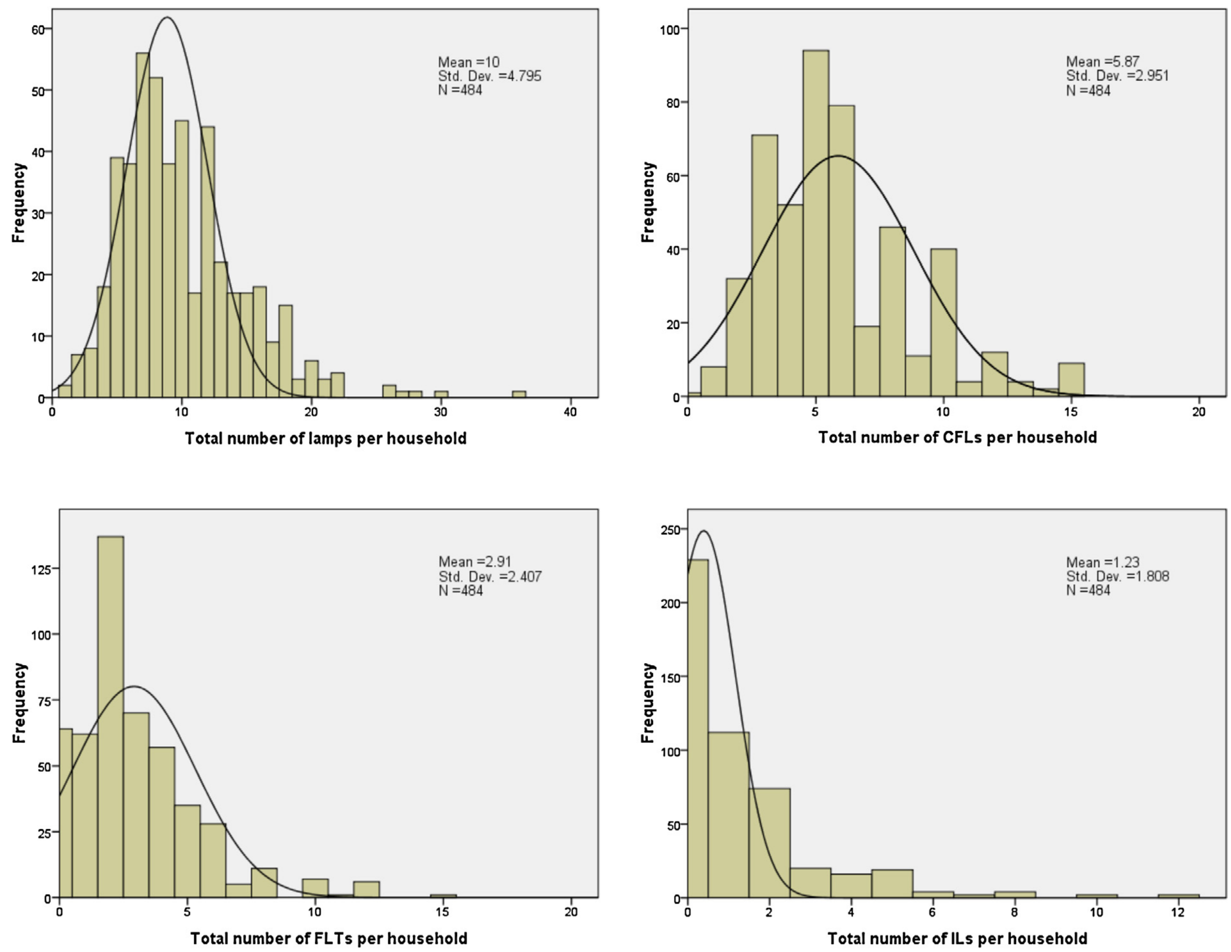

Fig. 2. The ownership of 3 types of lamps per household in Beijing.

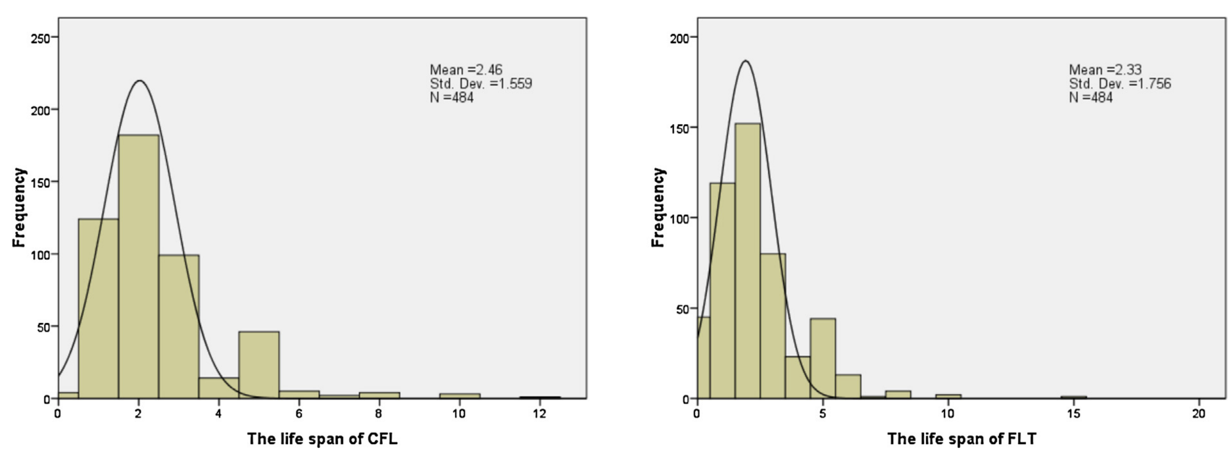

Fig. 3. The household life span of CFLs and FLTs.

idents are conscious of the need for environmental protection and are willing to contribute to the proper disposal of garbage. However, because there are no special facilities for recycling scrap FLs in most of the residential areas, the residents can only put scrap FLs in the garbage bins.

3.3.2. Mercury pollution by FL

According to Fig. 5 and based on the estimated value of total scrap FL output of 4.19 million annually, 83% of FLs are disposed into household garbage. As a result, at least 3.47 million scrap FLs from households in Beijing are disposed into household garbage.

The mercury content in FLs has been measured many times before; however, Table 3 shows that the results differ (Taghipour et al., 2014; Qi et al., 2009; Sun and Liu, 2003). Generally, the range of the mercury content is under 50 mg per lamp.

Because the mercury content in FL is falling continuously, we presumed it as 10 mg mercury/lamp. So it is estimated that the mercury content in the scrap FLs from households is approximately 34.7 kg per year.

Table 3
Mercury content in FL.

No.	Mercury content (mg)	Resources of materials
1	≤2.5 (P ≤ 30W) ≤1.5 (Low Mercury) ≤2.5 (Trace Mercury)	《Performance requirements of self-ballasted FL for general lighting GBT 17263 2002》
2	41(T12,D38 mm, 40W) 12(T8,D26mm, 40W) 60–120(liquid mercury)	Mercury pollution of FL and prevention(Taghipour et al., 2014; Qi et al., 2009; Sun and Liu, 2003)
3	≤5	《Limit requirements of poisonous and harmful materials in lighting productsQBT2940-2008》
4	25–45(T12, D36 mm) 20(T5, D16 mm) 10 (CFLs, D10mm)	The recycling disposal method of scrap FL and countermeasures (Qi et al., 2009)
5	5–8(FL)	The current situation of scrap FL recycling in Beijing and comprehensive utilization strategies (Zheng, 2010)
6	40 5-10(new technology)	Mercury risk from FL in China: Current status and future perspective (Hu and Cheng, 2012)
7	2–3	The national electric light source quality supervision and inspection center
8	0.1–50	Determining heavy metals in spent compact fluorescent lamps(CFLs) and their waste management challenges: Some strategies for improving current conditions (Taghipour et al., 2014)

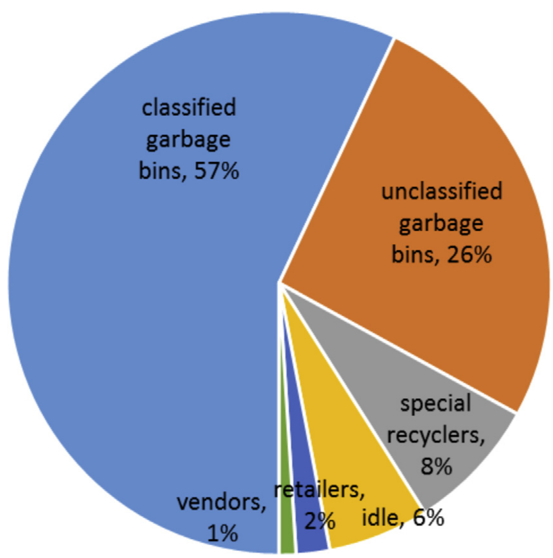

Fig. 4. The disposal method of scrap FL.

3.4. The residents' willingness to pay for recycling

3.4.1. Awareness of FL recycling by residents

We surveyed residents to determine their awareness of FL recycling. The survey shows that 10% of residents are not familiar with the dangers of fluorescence, and 38% of the residents believe the harmful of scrap FLs is similar with other common household garbage. The data shows that nearly half of residents still do not know that FLs contain mercury. The remaining residents know that FLs contain mercury and understand the dangers of mercury. In total, the results show that households in Beijing have inadequate cognition of the harm of FLs, and the government needs to strengthen education in this aspect.

The primary factors that residents consider when disposing of scrap FLs are discussed. Over 60% of the residents who were surveyed think that convenience is the most important factor that affects their chosen method of disposal. In addition, only approximately 30% of the residents consider environment protection to be a priority. Only 6% of the residents regard economic efficiency as the most important factor. These results indicate that the primary barrier to proper scrap FL disposal is that finding professional recycling points is difficult and residents' only other option is to throw the lamps in the garbage bins.

The questionnaire that was provided to participants explained that the government may provide support for FL recycling. The recycling methods that residents were willing to accept are shown. Approximately 67% of residents choose to hand these scrap lamps to fixed community recycling collection points, which is the most convenient and the most expensive way. Another 18% of residents would prefer online booking to schedule door-to-door FL recycling. This indicates that the internet develops quickly, especially online shopping, which changes residents' shopping concept and affects FL recycling.

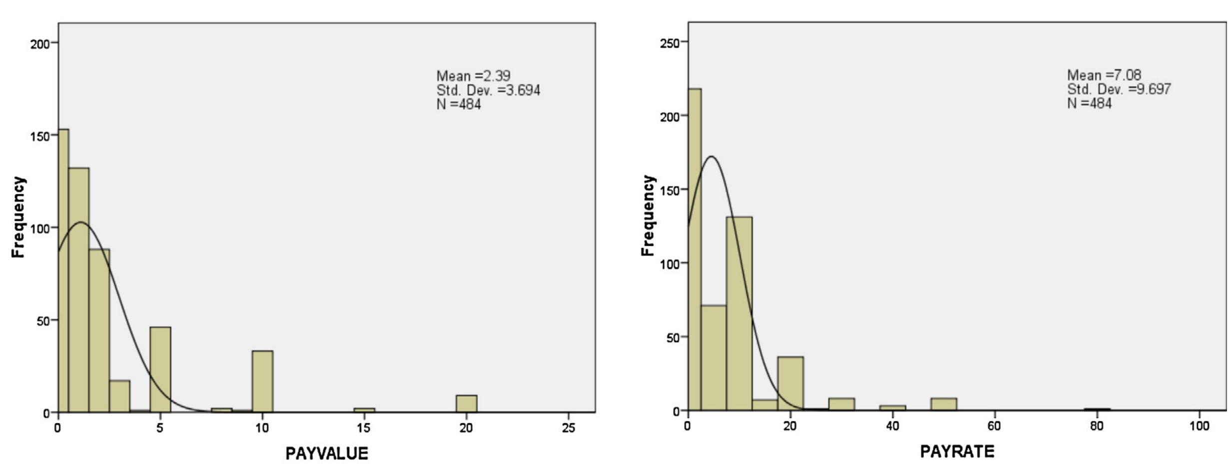

Fig. 5. The distribution of residents' absolute and percentage payment limits.

3.4.2. The acceptability and preferred payment method for recycling

We surveyed residents to determine their willingness to pay for FL recycling. The results indicate that 38.2% of the residents who were surveyed are willing to pay additional fees initially to support the disposal of scrap FLs. Another 30.4% of residents indicated that they accept to pay the fees if a mandatory regulation was implemented. Only 31.4% of residents indicated that they reject to pay for FL recycling services.

From the results, we can also clearly understand the payment modes of the residents who are willing to participate. The first mode is allocating municipal garbage disposal charges to residents every month, which means increasing household garbage fees appropriately, and this method accounted for 42% of those who were surveyed. The second mode involves adding the disposal charge to commodity prices, namely paying for recycling fees when buying the item to be recycled, and this mode accounts for 35% of those who were surveyed. The third mode involves paying the recycling fee when giving scrap FLs to the specified recyclers after scrapping, and this mode accounts for 24% of those who were surveyed. These data show that when residents choose payment modes, they primarily consider the convenience of the mode. Most survey respondents chose to add the scrap FL disposal expenses to other costs. Therefore, the government should add the FL recycling fee to the fees that are already paid by residents. This payment collection method is not only convenient for residents but will also help the government manage payment collection.

The survey found that residents refuse to pay for FL recycling services for several reasons. First, 66%of residents recognize FL recycling as the responsibility of the government's environment protection department. Second, 52% of residents think that this FL recycling fee should be the responsibility of the recycling or manufacturing enterprises. This shows that most residents think that this problem is caused by the inadequate environmental facilities of the enterprises when recycling and producing. Third, 48% of residents think that enterprises gain profits in the process of recycling or disposal. They believe that scrap FLs are also a type of resource and has a certain value; therefore, their profit should be used as scrap FL disposal fees. This indicates that the residents know the value of scrap products but are unfamiliar with the recovery cost.

We only know the common reasons why the residents reject to pay and list them as the options in the questionnaire, but the optional reasons why citizens accept to pay are unknown based on previous research. Therefore, to avoid affecting the respondents by our subjective options, we change our idea from surveying the reasons to analyzing the relationship between positive answer and the socioeconomic characteristics of the respondents with binary logistic regression.

3.4.3. Binary logistic regression of willingness to pay

The willingness to pay and the socioeconomic characteristics of the respondents were incorporated into the model, and then the "enter" method was used. The regression analysis result is shown in Table 4.

Generally, the main influence factors of Beijing residents' willingness to pay for scrap FL recycling can be divided into three categories: the positive influence factors are the length of residence period, cognition of hazardous waste and the understanding of EPR. The government can start with these factors to formulate the corresponding incentive mechanisms to promote the recycling of scrap FLs and other electronic waste.

First, the significance test value of the length of residence period is less than 0.001, which is the most significant factor affecting the willingness to pay, and the coefficient is positive. It shows that as the living time increase, the residents prefer to pay more to improve their living environment. Second, the significance test value of cognition of hazardous waste is also less than 0.001. It shows that the deeper the respondents understand the pollution risk of scrap FLs, the higher their willingness to pay. This is related to the improvement of environmental protection consciousness in modern society and the attention to environmental deterioration. Third, the significance test value of EPR is less than 0.01, which shows that understanding of EPR has a significant impact on the willingness to pay. If residents understand EPR more fully, then they are more willing to pay for recycling services. Therefore, to increase consumers' willingness to pay, the government should promote and ensure the smooth implementation of EPR.

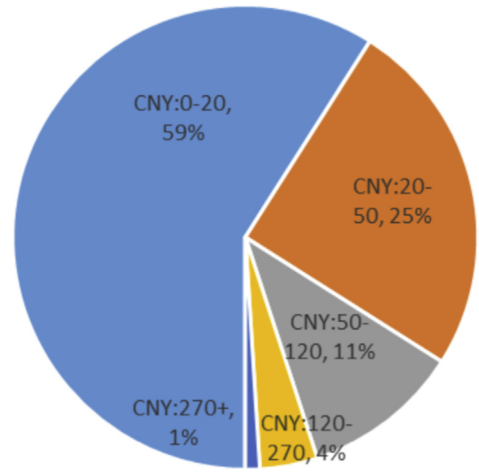

Fig. 6. The price distribution proportion of FLs purchased by residents.

3.4.4. The residents' average payment limit

This study analyzed the payment limit for scrap FL recycling with SPSS. The actual distribution and the normal fitting curve are shown in the left of Fig. 5. The figure shows that the average payment limit is 2.39 CNY/lamp. By adopting BACM to eliminate the extremely high value and low value, the modified average payment limit is 1.98 CNY/lamp. However, the current subsidy that the government provides to recycling enterprises is only 1 CNY/lamp, so the current payment limit of the research is approximately twice the amount of the government subsidy.

Because the brands, models and power wattage of the FLs used in households are all different, there may be a difference among the prices of the FLs. This will affect the residents' payment limits for the disposal fee of every FL. Fig. 6 shows the price distribution of the FLs that were purchased by residents in July 2015 from "www.etao.com". More than half of the prices are below 20 CNY, but the average unit price is approximately 30 CNY.

After surveying the absolute limits, this study surveyed the price relative percentage of payment limits as double checking. The actual distribution and normal distribution fitting curve is shown in right part of Fig. 5. The acceptable payment limit of most of the residents is mostly lower than 15% of the current price of FLs, and the average limit is 7.08% of the FL price, but the average payment limit adjusted after BACM is 6.17% of the FL price.

According to the results of the two methods calculated above, with percentage payment limit (6.17%) divided by the average price (30 CNY/lamp), we conclude that the collated value is 18.5 CNY/lamp, which is close to the average payment limit (1.98 CNY/lamp). Therefore, the payment limits that are obtained in the two research methods above are real and effective.

Table 4
Binary logistic regression results of willingness to pay.

	B	S.E.	Wald	df	Sig.	Exp(B)
Gender	−0.443	0.275	2.599	1	0.107	0.642
Age	0.007	0.015	0.224	1	0.636	1.007
Education	0.025	0.125	0.039	1	0.843	1.025
Family income	0.000	0.000	0.320	1	0.572	1.000
Length of residence	0.683	0.095	51.533	1	0.000	1.979
Family size	−0.059	0.134	0.192	1	0.661	0.943
Cognition	2.053	0.235	76.527	1	0.000	7.795
Law	0.226	0.298	0.571	1	0.450	1.253
EPR	0.743	0.271	7.491	1	0.006	2.101
Disposal	0.111	0.187	0.350	1	0.554	1.117
Constant	−8.363	1.283	42.512	1	0.000	0.000

4. Conclusions

Accompanied by the high ownership of FLs in the residents' households, the scrap FLs, which contain mercury, have become a potential threat to the environment. Through the survey in this paper, we estimate the generation and disposal of scrap FLs in Beijing. Also, we analysis the residents' awareness and WTP for recycling scrap FLs. The annual production of scrap FLs was estimated to be 4.19 million, and 3.47 million FLs were directly disposed into household waste. We found that 62% of residents are affected by the convenience of disposing scrap FLs, and most of them hope that particular recycling points can be set up in communities. 68.6% of residents are willing to pay extra fees for recycling scrap FLs, which will be added to the garbage disposal fee per month. The length of residence period, cognition of hazardous waste and the understanding of EPR are the dominant factors that affect residents' payment decisions. Finally, we conclude that the payment limit of residents is 1.98 CNY or 6.17% of the current price.

From the data mentioned in the paragraphs above, we know that although large amounts of scrap FLs are produced by households in Beijing each year, residents cannot participate in recycling due to a lack of recycling facilities. Currently, most residents are willing to pay extra fees to dispose of scrap FLs safely, and the payment limit is higher than the subsidiary standard that the government gives to enterprises. The government should establish disposal funds that be used to subsidize the recycling costs of WEEE. Manufacturers of electrical and electronic products and agents of imported electrical and electronic products should disperse the WEEE disposal funds in accordance with the provisions. Then this special fund should be spent on installing recycling facilities in communities and subsidizing recycling enterprises.

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