Consumer Preferences for Electricity from Bioenergy and Other Renewables

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Abstract: *This study ascertains residential electricity consumers' support and willingness to pay for electricity from renewable sources. Then, willingness to pay for specified renewable energy sources (solar, wind, landfill wastes, bioenergy from fast growing crops, and bioenergy from forest products wastes). Effects of demographics and environmental behaviors are estimated.*

Background

Bioenergy uses renewable feedstocks such as fast growing agricultural crops and trees or forest products wastes to produce electricity. The development of bioenergy has the potential for providing new markets for farmers and job creation in rural areas. Use of biomass as an electricity feedstock reduces sulfur and nitrogen emissions from coal-fired utility plants when cofired with coal. Bioenergy development could also potentially make use of crop residues left in fields and wastes from forest products now landfilled. Biomass comprises about half of the nation's consumption of renewable energy and biomass generating capacity is currently about 1 percent of overall generating capacity (Energy Information Administration). While bioenergy currently comprises half of renewable energy consumption, most of the planned capacity for renewable energy projects is in wind energy development (Bird and Swezey).

Renewable energy sources, including biomass, have impacts on the environment. Biomass generated electricity does produce CO_2, SO_2, and particulates emissions, but it is considered carbon neutral. Biomass generated electricity emits about $1/100^{th}$ the sulfur

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emissions that coal generated electricity does. Hydroelectric, wind, and photovoltaic do not produce CO_2 or SO_2 emissions. Hydroelectric power, however, faces environmental barriers related to dam construction. Wind machines can be noisy, have significant visual impacts on the landscape, and result in migratory bird deaths (National Wind Coordinating Committee). For example, in Vermont, proposed ridge line development of wind projects met with some opposition among residents (Miles). Photovoltaic costs are relatively high and long term effects of cell disposal are an issue.

Many estimates comparing costs of renewables have shown photovoltaic to be least cost competitive. Biomass generated sources are cost competitive with wind and landfill gas power. Guey-Lee found that utility renewable energy prices paid by utilities to non-utilities were 8.78 cents per kWh relative to an average utility-to-utility price of 3.53 cents per kWh. Among renewable sources, prices paid by utilities to non-utilities were 6.86 cents per kWh for conventional hydro, 11.77 cents per kWh for landfill gas, 11.64 cents per kWh for wind, 15.80 cents per kWh for solar, 9.67 cents per kWh for wood/wood waste, 6.27 cents per kWh for municipal solid waste and landfills, and 12.31 cents per kWh for other biomass. Additional estimates of electricity costs from biomass-fired plants range from 6.4 cents to 11.3 cents per kWh (Energy Efficiency and Renewable Energy Network; Oak Ridge National Laboratories). Thus, while bioenergy has significant environmental advantages over coal-fired generation of electricity, it is more expensive on a per unit basis.

Many utility companies offer green pricing programs, where consumers can purchase blocks of electricity from renewable sources, paying a premium to cover the added costs of the renewable energy. More than 300 utilities have either implemented or announced plans to offer a green pricing program to electricity consumers (Green Power Network).

The purpose of the study is to ascertain residential electricity consumers' views on electricity from bioenergy and other renewable sources. The sources examined include: solar, wind, landfill gas, bioenergy from fast growing crops, and bioenergy from forest products wastes. Consumers' support and willingness to pay premiums for energy from bioenergy sources are evaluated. Differences in willingness to pay across sources of renewable energy are also investigated.

Prior Studies

BioenergyProduction

Biomass for bioenergy can include any organic matter that is available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, wood and wood residues, animal wastes, and other waste materials. Example sources of dedicated biomass production for electricity include switchgrasses or hybrid poplar. Sources of feedstocks for bioenergy can also include forestry or agricultural waste or by-products, such as wood chips, stalks of cotton, soyhusks, or sawdust. Estimates are that as a waste or residue of forest products industries, biomass could provide about three to five percent of electricity generated in the United States. However, as an energy crop grown on 20-60 million acres, along with the waste or residue uses, biomass could supply between seven and twenty percent of electricity generated in the United States (Hughes). Analysis by Walsh, et al. indicated that at a farmgate switchgrass price of less than $44/dry ton, switchgrass could be produced at a profit greater than existing agricultural uses on nearly 17 million hectares (41.9 million acres) of cropland in the U.S. This quantity of biomass

production could displace an estimated 253 million barrels of oil or supply an estimated 7.3 percent of U.S. electricity needs.

Green Power Pricing

Findings from a number of studies have suggested that consumers are willing to pay more on their monthly electricity bills for electricity from renewable sources (Farhar and Coburn; Farhar and Houston; Farhar; Tarnai and Moore). While the aforementioned studies' estimates of percentages of those who would pay ranges from 30 to 80 percent, actual customer participation in ongoing green power programs has been as high as 4 percent, but generally participation rates are closer to 1 percent (Swezey and Bird). This disparity in percentages suggests overstatement of preferences for renewable energy. Wiser suggests that attitudinal surveys may tend to overestimate the market for renewables. Wiser also suggests that consumers may have concerns about the veracity of the claims of green marketers. Previous research in environmental certification suggests reasons why consumers may not support green products include that they do not believe environmental certification will work to improve the environment, other causes are of higher priority than the environment, companies should be regulated rather than using voluntary certification, or voluntary certification could lead to regulation (Jensen, Jakus, English, and Menard). Similar to the market for environmentally certified products, the reasons a person may support green power but being unwilling to pay a premium include an inability to pay more, a belief that it does not cost more to provide a green product, or a belief that manufacturers should not charge higher prices even if it costs more to make certified products.

Bioenergy and Other Renewable Energy Sources

Findings from prior studies have suggested that differences in preferences exist between types of renewable energy sources (Farhar; Farhar and Coburn). Findings from these studies suggest more favorable attitudes toward wind or solar power than bioenergy sources. For example, Farhar found that only 26 percent placed "Biomass" in their top three choices of renewable energy for their utility to develop compared with 69 percent for "Wind". About 53 percent of the respondents stated that they would be willing to pay at least $4 a month more for electricity generated from biomass, but 65 percent said they would be willing to pay $6 per month more for wind power. Farhar and Coburn found in a study of Colorado homeowners' preferences for energy that only 1.5 percent listed biomass as their top choice, while 33 percent listed solar cells as their top choice.

The aforementioned studies provided important information about preferences for renewable energy, but they did not use modeling that would account for influences of socio-economic, demographic, or attitudinal factors on willingness to pay (WTP) for different types of renewable energy. Farhar used non-linear regression and the R^2 value to find the "best fit" curve for overall WTP for renewables, but not by renewable energy source. In the studies by Farhar and Farhar and Coburn, only summaries of attitudinal questions and percentages willing to pay specified prices were provided for the potential sources of renewables.

Study Methods

A survey was conducted by mail in Spring/Summer of 2003. Prior to the field survey, a pretest survey of 50 randomly selected residents was performed. The results from the pretest were used in field survey development. For the field survey, a sample of 3,000 Tennessee residents was randomly drawn. A survey, cover letter, and information sheet were mailed to

individuals in the sample. About two to three weeks following the first mailing, a second mailing was sent to all non-respondents to the first mailing. Copies of the survey, cover letters, and information sheets can be obtained from the authors.

'Yea-Saying' Bias and WTP

Because prior estimates of percentages willing to pay more for renewable energy are significantly higher than actual green power program participation rates, methods to potentially diminish upward bias in willingness to pay estimates were employed in this study. Methods that may be used in an attempt to diminish upward bias is to ask study participants to treat the hypothetical scenario as realistically as possible and to remind the respondents of their budget constraint (Kotchen and Reiling; Cummings and Taylor). Both of these methods were employed in the survey.

Another method to help diminish potential upward bias is that participants are allowed to express support for the public good (renewable energy sources) without having to pay a premium. By allowing respondents to express support for renewable energy without requiring a price premium, bias associated with 'yea saying' may be reduced (Blamey, Bennett, and Morrison). When respondents are offered this option, they may perceive less pressure to provide a "socially responsible" response of willingness to pay more for renewables, producing a more realistic estimate of consumers' behavior in the marketplace. Findings from recent research regarding WTP for environmentally certified hardwoods using methods to diminish 'yea saying' bias produced a percent of consumers willing to pay that was much lower (20 to 40 percentage points) than previous studies not using these methods (Jensen, Jakus, English, and Menard).

Survey Content

The survey content was divided into three sections. First, respondents were asked about their support for and willingness to pay some positive amount for energy from renewable sources. Respondents were reminded that there may be many reasons why someone would be willing to pay more for electricity from renewable sources as well as many reasons why someone might not be willing to pay more for green power. Respondents were also reminded of their limited budgets to pay for many goods and many environmental and charitable causes, including renewable energy. Respondents were offered the options to support and pay more for renewable energy, support but not pay more for renewable energy, and to not support renewable energy. If a respondent indicated they supported and would pay some amount more for energy from renewable sources, he or she was asked questions regarding current participation in a green power program and willingness to pay for renewable energy from several specified sources including bioenergy.

The second section contained questions about consumers' willingness to pay for renewable energy from specified sources. These sources included solar, wind, landfill gas, bioenergy from fast growing crops, and bioenergy from forest products wastes. Respondents were asked to read an information sheet that compared land use, emissions, and other environmental impacts across the types of energy sources prior to responding. The sample was evenly divided among five premium levels for a 150kWh block of green power (about 12-15% of a typical household's electricity needs). These premium levels were $1.65, $3.75, $4.50, $6.00, and $13.00. These premium levels and the block of electricity sold were based on data from existing green power programs and did not differ by source of power. A referendum

format was used where respondents were asked to indicate whether they would be willing to purchase the block of power at the specified premium level.

The third section included questions about socioeconomics and demographics, such as age, education, and income. Respondents were also asked about environmental behaviors including contribution to environmental organizations and participation in home energy audits. Respondents were also asked to indicate their highest and lowest monthly bill during the past year.

Economic Modeling

The effect of demographic characteristics of respondents on the support for and willingness to pay for electricity from renewable sources was estimated using an ordered logit model. The possible outcomes (Support and Pay, Support but Not Pay, and Do Not Support) and their probabilities can be expressed as follows:

$$\Pr(\textit{Support and Pay} = 1) = \Phi(a_1 + ßX)$$
$$\Pr(\textit{Support and Pay} = 0) = \Phi(a_2 + ßX) - \Phi(a_1 + ßX)$$
$$\Pr(\textit{Do Not Support}) = 1 - \Phi(a_2 + ßX)$$

where α, and β are parameters to be estimated and Φ is the logistic distribution (Greene). The matrix *X* includes demographics and several other factors.

The effects of demographics on willingness to pay for renewable electricity from crops and from forest products wastes are modeled with binomial logit models. The matrix Z includes demographics. A variable measuring the price premium for renewable electricity, *R*, is included in each of the estimated equations for Crops and Forest Products Wastes. The probabilities of a respondent saying they would pay more for renewable energy from one of these sources, given they stated they supported and would pay more for electricity from renewables is:

$$a.\ \Pr(Crops = 1 \mid Pay = 1) = \Phi(d_1 + g_1 Z + j_1 R)$$
$$b.\ \Pr(ForestWastes = 1 \mid Pay = 1) = \Phi(d_2 + g_2 Z + j_2 R).$$

While the magnitudes on coefficients from each logit model cannot be interpreted directly, the sign of each coefficient can. The significance of the overall model is evaluated with a chi-square likelihood ratio test (LLR).[1] The significance of the coefficients is evaluated with t-tests. The estimate of willingness to pay is calculated as:

$$WTP = (d + g Z) / - j .$$

The demographic characteristics included in each model are age of the respondent, gender, education level, and household income level. Variables indicating whether the respondents had ever contributed to an environmental organization and whether they had ever participated in an energy audit were also included. The average of the respondents' estimates of their highest and lowest electricity bills for the year was also included in the models.

Results

Opinions on Renewable Electricity

Respondents were asked to indicate their views on electricity from renewable sources. Respondents could select that they supported electricity from renewable sources and were willing to pay more, that they supported electricity from renewable sources but were not willing to pay more, or that they did not support electricity from renewable sources regardless of cost. The results are presented in Table 1. The majority of the respondents supported electricity from renewable sources but were not willing to pay any more (54.48 percent).

[1] The Log-Likelihood Ratio Test (LLR) compares the log-likelihood function of the model if only the intercept were included with the log-likelihood of the model and is calculated as LLR (Restricted to Intercept)-LLR (Not Restricted).

Table 1. Opinions on Electricity from Renewable Sources.

Opinions	Percent of Respondents (N=402)
I support electricity from renewable sources and am willing to pay more for it.	38.31
I support electricity from renewable sources but am not willing to pay more for it.	54.48
I do not support from renewable sources regardless of how much it costs.	7.21

Those who supported and would pay more were asked whether they currently purchased electricity from renewable sources (for example through a green power program). While these respondents had indicated a willingness to pay, less than 5 percent indicated they currently purchased electricity from renewable sources (Table 2). This number was quite low compared with actual availability of green power. About 70.53 percent of the respondents resided in areas where green power programs were available (N=414).

Table 2. Purchase of Electricity from Renewable Sources.

Purchase of Electricity from Renewable Sources	Percent of Respondents (N=147)
Yes	4.76
No	77.55
Don't Know	17.69

Those who stated they supported electricity from renewable sources and would pay more were then asked about willingness to pay more each month for specific types of renewable energy. In each case, greater than 80 percent stated they would pay the premium provided. The mean percents of individuals who would pay more for each of the types of renewable energy were compared. The results are shown in Table 3. For the purposes of comparison, only observations where responses were provided to each of the questions about renewable energy

sources were used. A comparison of the means revealed that a higher percentage of the respondents would pay for solar and wind energy than bioenergy from crops or forest wastes. The mean percent of individuals who would pay more for landfill gas was not statistically different from the mean percent who would pay more for bioenergy from crops. Means with like letters in the column to the right are not significantly different. For example, crops and forest wastes both have the letter "c" beside them. This indicates that these two means are not statistically different from each other.

Table 3. Willingness to Pay for Specific Sources Comparisons of Means.

Renewable Energy Source	Percent Responding Would Pay More (N=144)	
Solar	90.97	a
Wind	90.28	a
Landfill Gas	88.89	ab
Crops	84.03	bc
Forest Wastes	82.64	c

Model of Support for and Willingness to Pay for Renewabe Energy

As shown in Table 4, the ordered logistic model for support and willingness to pay was significant using the LLR test. The model correctly predicted 68 percent of the responses. Educational attainment had a positive influence on support and willingness to pay for electricity from renewable sources. Respondents in the $60,000 to $75,000 income category were more likely than others to support and be willing to pay for renewable sources. If an individual had contributed time or money to an environmental organization, this also had a positive influence. Neither gender nor age significantly influenced support and willingness to pay. Having had a home energy audit or electricity bill level did no significantly influence support and willingness to pay.

Table 4. Ordered Logistic Model of Support and Willingness to Pay.[a]

Variable	Estimated Parameter	Wald Chi-Square	
Intercept 1	-.7303	.2940	
Intercept 2	2.5931	3.6414	*
Age	-.0280	.2881	
Age Squared	.000204	.1829	
Male	.0523	.0424	
High School Graduate	.6999	3.8370	*
Some College	.9499	6.7154	***
College Graduate	1.1255	7.8280	***
Household Income $45,001-60,000	-.0187	.0029	
Household Income $60,001-75,000	.6774	3.3010	*
Household Income $75,001-100,000	-.2150	.3209	
Household Income Greater than	.1708	.2039	
Contributed to Environmental	.9090	10.2766	***
Participated in Home Energy Audit	.3127	1.2926	
Average of Highest and Lowest	-.00012	.0041	
N=339			
LLR Test	42.0435	***	
Percent Correctly Classified	68%		

[a] ***=significantly different from zero at a=.01, **=significantly different from zero at a=.05, *=significantly different from zero at a=.10

Model of Willingness to Pay for Green Power from Forest Wastes

The logistic model of willingness to pay for electricity from forest wastes is displayed in Table 5. The model was not significant overall, but correctly classified 79.6 percent of the observations. Neither premium level nor income significantly influenced willingness to pay for electricity from forest wastes. Age, gender, and education level affected willingness to pay. Being male or being a high school or college graduate had positive influences on willingness to pay. All else equal, the likelihood of being willing to pay a positive premium increased with age until age 55.25 years, when the likelihood begins to decline with age.

Table 5. Logistic Model of Willingness to Pay for Electricity from Forest Wastes. [a]

Variable	Estimated Parameter	Wald Chi-Square	
Intercept	-9.9204	7.2299	***
Premium	-.0676	.7730	
Age	.4232	8.0745	***
Age Squared	-.00383	7.5981	***
Male	1.4744	5.6929	**
High School Graduate	1.8382	2.6533	*
Some College	1.4744	1.9988	
College Graduate	2.4419	4.3775	**
Household Income $45,001-60,000	.0525	.0031	
Household Income $60,001-75,000	-.7519	.6970	
Household Income $75,001-100,000	-0.8614	.8311	
Household Income Greater than $100,000	-1.4266	2.0578	
Contributed to Environmental Organization	-0.6027	.7592	
Participated in Home Energy Audit	-0.5354	.6519	
Average of Highest and Lowest Electricity Bill	-0.00242	.2854	
N=127			
LLR Test	18.3726	*	
Percent Correctly Classified	79.2%		

[a] ***=significantly different from zero at a=.01, **=significantly different from zero at a=.05, *=significantly different from zero at a=.10

Model of Willingness to Pay for Green Power from Crop Sources

The estimated logistic model of willingness to pay for electricity from crops is displayed in Table 6. The model was significant overall and correctly classified 82.9 percent of the observations. Neither premium level nor gender significantly influenced willingness to pay for electricity from crops. Age, education level, and income affected willingness to pay. Being a high school or college graduate had positive influences on willingness to pay. Incomes of $60,000 to $100,000 also had positive influences. Likelihood of being willing to pay increased with age until age 50.51 years when it began to decline. Contribution to an environmental

organization had a negative effect on willingness to pay. Neither having had a home energy audit or average bill had a significant influence on willingness to pay for electricity from crops.

Table 6. Logistic Model of Willingness to Pay for Electricity from Crops. [a]

Variable	Estimated Parameter	Wald Chi-Square	
Intercept	-9.3136	4.8091	**
Premium	-.0650	.6785	
Age	.4394	7.3432	***
Age Squared	-.00435	6.6973	***
Male	.5094	0.5424	
High School Graduate	2.7058	3.0892	*
Some College	1.4085	1.2883	
College Graduate	2.4006	2.8683	*
Household Income $45,001-60,000	-1.6292	2.0825	
Household Income $60,001-75,000	-2.0301	2.9246	*
Household Income $75,001-100,000	-2.6807	4.8570	**
Household Income Greater than $100,000	-1.5897	1.3171	
Contributed to Environmental Organization	-1.4673	4.2336	**
Participated in Home Energy Audit	-.9851	1.8470	
Average of Highest and Lowest Electricity Bill	-.00597	1.5045	
N=126			
LLR	23.0972	**	
Percent Correctly Classified	82.9		

[a] ***=significantly different from zero at a=.01, **=significantly different from zero at a=.05, *=significantly different from zero at a=.10.

Estimates of Willingness to Pay

The coefficients on the premiums in each of the models were not statistically different from zero. However, if the coefficients were used to calculate price willing to pay (among those stating they would be willing to pay more for energy from renewable sources) using the formula, then price for the 150 kWh block of electricity from forest wastes would be $25.65 (N=127) and

the price for electricity from crops would be $34.56 (N=126). If these conditional prices are then multiplied by the percent of respondents stating they would be willing to pay more for renewable energy (38.31), then the unconditional prices are $9.82 for electricity from forest wastes and $13.24 for electricity from crops per month. These estimates are equivalent to 6.51 cents per kWh and 8.83 cents per kWh respectively. Caution should be used with these estimates because the price coefficients were not significantly different from zero.

Conclusions

The results from this study suggest that the percentage of residential electricity consumers who are willing to pay premiums for electricity is much lower than found in prior studies, at 38 percent compared with estimates as high as 60 percent. Findings from this study suggest that there is a slightly lower preference for electricity from crops or forest wastes than for electricity from solar or wind sources. However, percents responding positively for electricity generated from crops and electricity generated from landfill wastes are not statistically different. This finding is similar to those from prior studies.

Generally, those who would be willing to pay more for electricity from renewable sources are more highly educated, middle income individuals who have contributed time or money to environmental organizations. If male gender, income of $60,000-$75,000, and having contributed to an environmental organization is used as a profile, this profile of respondent has over an 80 percent chance of stating they would be willing to pay more for electricity from renewable energy sources. It should be noted, however, that this profile constitutes are relatively small share of the sample (less than 5 percent).

Those who were willing to pay more for electricity from forest wastes are in their 50's, male, and a college graduate. Those who were willing to pay more for electricity from crops

were in their 50's, high school or college graduates, of middle income ($60,000 to $100,00), and had not contributed time or money to an environmental organization.

The results from this study do suggest that there is a potential market demand for electricity from forest wastes and crops, however, the market likely to be smaller than that for wind or solar power. The results with regard to contribution of time or money to an environmental organization suggest that this may have a negative influence on potential consumers' views of bioenergy.

Because a significant price response was not found, a wider range of premiums should be used in future research. The premiums used in this study were based on premium levels currently used in the industry. Another explanation for the lack of price responsiveness is that the survey did not adequately control for the yea-saying bias despite the use of the Blamey *et al*. method successfully used in the past. In this case it is possible that those respondents self-selecting into the "support and willing-to-pay more" category simply did not focus on price. Subsequent research will examine the open-ended responses for the "why are you willing to pay?" and "why are you not willing to pay?" follow-up questions to ascertain the degree to which any bias may be present.

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