AN ANALYSIS OF THE RESIDENTIAL PREFERENCES FOR GREEN POWER-THE ROLE OF BIOENERGY*

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BACKGROUND AND INTRODUCTION

Production of bioenergy, using renewable biomass for energy, on a commercial scale could expand industrial consumption of agricultural commodities, adding rural jobs and increasing economic activity in rural regions. Bioenergy uses renewable resources such as fast growing agricultural crops and trees or forest products wastes to produce electricity. Biomass, any organic matter available on a renewable or recurring basis, constitutes about half of the nation's consumption of renewable energy and about 3 percent of total consumption. Biomass electricity generating capacity is currently about 1 percent of overall generating capacity (Department of Energy, Energy Information Administration). In the future, sources may include co-firing of biomass in existing coal fired boilers and the introduction of high-efficiency gasification combined-cycle systems, fuel cell systems, and modular systems. Currently, the majority of new renewable energy projects are being focused on wind energy, rather than bioenergy sources (Bird and Swezey).

Biomass generated electricity is not an emission free fuel source, producing carbon dioxide (CO_2), sulfur dioxide (SO_2), and particulates emissions, but it is considered carbon neutral (doesn't produce net CO_2 emissions that contribute to global warming). Compared with coal or natural gas, biomass generated electricity emits significantly fewer sulfur emissions, about $1/100^{th}$ that of coal. Hydroelectric, wind, and photovoltaic do not produce CO_2 or SO_2 emissions, but hydroelectric

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power faces environmental barriers related to construction of dams, wind machines can be noisy and have significant impacts on the landscape, and photovoltaic costs are relatively high.

Estimates of costs of generating electricity by renewable sources vary across studies and time frame under consideration. Guey-Lee evaluated the cost of renewable electricity generation compared with conventionally generated electricity for 1995. Utilities purchase about 53 percent of the renewable electricity generated by non-utilities. Most of this energy from non-utility generating sources is wood and wood waste (41.1 percent), while only a small portion is from other biomass (1.6 percent). Guey-Lee found that utility renewable energy prices paid by utilities to non-utilities were 8.78 cents per kilowatt-hour (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. Other estimates of electricity costs from biomass-fired plants are 9 cents per kWh (Department of Energy, Energy Efficiency and Renewable Energy Network) and 6.4 to 11.3 cents per kWh (Oak Ridge National Laboratory). Thus, while bioenergy has significant environmental advantages over conventional methods of generating electricity, it is more expensive on a per kWh basis.

The purpose of the study is to ascertain residential electricity consumers' willingness to pay (WTP) for electricity from bioenergy and other renewable sources. This study expands on prior research by dividing bioenergy into two sources: bioenergy from agricultural crops and bioenergy from forest products wastes. Other sources examined include solar, wind, and landfill wastes. The willingness to pay is compared across sources. The effects of demographics, such as income and education, on willingness to pay are also examined. Willingness to pay estimates for bioenergy from crops and forest products wastes are developed for two example demographic profiles.

PRIOR STUDIES

Biomass for bioenergy can be derived from any organic matter that is available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops (crops used for bioenergy feedstock) and trees, agricultural food and feed crop residues, aquatic plants, wood and wood residues, animal wastes, and other waste materials. Example sources of biomass for electricity include combustion of 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. It has been estimated that as a waste or residue from 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).

Buyer Behavior Studies

A variety of studies have found consumer willingness to pay (WTP) for electricity from renewable sources or from sources than would produce less harm to the environment than conventional sources (Farhar (1999); Farhar and Coburn (1999); Farhar and Houston (1996); Rowlands et al.; Tarnai and Moore; Zarnikau). While the aforementioned studies estimates of percentages of those who would pay ranges from 30 to 93 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). The disparity in percentages of actual participation versus the willingness to pay indicated in the studies suggests positive response bias skewing assessments of the market for renewable energy.

Studies have also evaluated opinions and willingness to pay for electricity across a several renewable sources. Findings from a previous study suggested that differences in renewable energy preferences exist across fuel sources (Farhar, 1999). While 69 percent of the study respondents placed "Wind" in their top three choices, only 26 percent placed "Biomass" in their top three choices of renewable energy for their utility to develop. Among potential energy resources for their utility to use, 93 percent somewhat or strongly favored solar power, while 64 percent and 59 percent somewhat or strongly favored landfill gas and forest waste, respectively. 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. In contrast, 65 percent said they would be willing to pay $6 per month more for wind power.

Farhar and Coburn (1999) studied Colorado homeowners' preferences for energy. The homeowners were provided the choices of solar cells, wind power, active solar (domestic hot water systems), passive solar houses, large scale hydropower, burning municipal solid waste, small-scale hydropower, landfill gas, biomass power, ground source heat pumps, or other. Given these choices, only 1.5 percent listed biomass as their top choice, while 33 percent listed solar cells as their top choice.

Wiser suggests that attitudinal surveys may tend to overestimate the market for renewables. Farhar and Houston note percentages expressing WTP tend to be higher in surveys than in reality when provision of a public good is involved, with incentives to "free ride" being expressed in the actual market for green power. Potential upward bias in WTP estimates may be ameliorated if study participants are asked to treat the hypothetical scenario as realistically as possible and if they are reminded of their budget constraint (Kotchen and Reiling; Cummings and Taylor). Zarnikau found that while an increased percent of respondents willing to pay some amount more following an intensive exposure to information about energy resource issues, the actual premium amount was lowered. Zarnikau concluded that informed dialogue about energy alternatives would lead to a broader level of interest in supporting these resources at a modest level.

Upward bias in WTP for a public good, such as renewables, may also be diminished if participants are allowed to express support for renewables 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', perceived pressure to provide a "socially responsible" answer, may be minimized (Blamey et al.). Thus, producing a more realistic estimate of consumers' behavior in the marketplace. Therefore, it is important to identify potential reasons why a consumer may not support use of green power of a particular type or may not be willing to pay a premium for it.

STUDY METHODS

Survey

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 conducted. The results from the pretest suggested no significant design problems. For the field survey, a sample of 3,000 Tennessee residents was randomly drawn. A survey, cover letter, and information sheet about the renewable energy sources under study were mailed to individuals in the sample. About three weeks following the first mailing, a second mailing was sent to all non-respondents to the first mailing.

The survey contained 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 that their budget is allocated between many goods and many environmental and charitable causes, and that green power is but one. 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. If a respondent indicated he or she supported electricity from renewable sources but would not pay more, or that green power was not supported regardless of its cost, the respondent was instructed to skip forward to demographic questions.

The second section contained questions about consumers' willingness to pay for renewable energy from several sources, including solar, wind, landfill wastes, bioenergy from fast growing crops, and bioenergy from forest products wastes. Prior to answering the second section questions, respondents were asked to read an information sheet comparing land use, emissions, and other environmental impacts across the specified renewable energy sources and coal. The sample was evenly divided among five premium levels for a 150kWh block of green power to be purchased on the respondents' monthly electric bill ($1.65, $3.75, $4.50, $6.00, and $13.00). The premium levels and the block of electricity sold hypothetically were based on data from existing green power programs and did not differ by source of power. For each group, 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, income, and home ownership. Respondents were asked about recycling, contributions to environmental organizations, or home energy audits. Respondents were also asked to indicate their highest and lowest monthly bill during the past year.

Economic model

If a respondent was willing to pay some premium for electricity from renewable sources the *PARTIC*=1, otherwise *PARTIC*=0. If a respondent was willing to pay the specified premium on their monthly utility bill for a particular renewable energy source, then *PAYPREMj*=1, otherwise the variable was zero, where j= *Bioenergy-Forest Products Waste*, *Bioenergy-Crops/Fast Growing Trees, Wind*, *Solar*, or *Landfill Wastes*. Three possible outcomes exist; the respondent is not willing to pay any premium (*PARTIC* =0, $PAYPREM_j$ =0), the respondent would pay some nonzero premium less than the suggested premium (*PARTIC* =1, $PAYPREM_j$ =0), or the respondent would be willing to pay at least the suggested premium (*PARTIC* =1, $PAYPREM_j$ =1). Assuming the logistic distribution function, $e^a/(1+e^a)$, the probability of WTP is as follows (Kriström):

$$
\begin{aligned}
F_{WTP}(A) &= 0 && \text{if } A<0 \\
&= [1+\exp(a)]^{-1} && \text{if } A=0 \\
&= [1+\exp(a - ßA)]^{-1} && \text{if } A>0.
\end{aligned}
$$

Given that ß is positive, then the mean WTP=ln[1+exp(a)]/ß. The variance on the WTP can be estimated using the delta method (Greene). The model shown above can be extended to include other socioeconomic, demographic, and attitudinal measures about the environment and energy use. If Z is used to represent the matrix of these variables, and ? is used to represent the estimated parameters associated with Z, then the term a can be substituted with a + ?*Z* in the logistic distribution for F_{WTP} and in the calculation of WTP.

Zarnikau and Roe et al. found linkages between willingness to pay for green power or decreased air emissions and education and income levels. Zarnikau found male gender, and younger age to have positive influences on willingness to pay a premium for utility investments in renewable energy. Roe et al. found that affiliation with an environmental organization influenced willingness to pay for decreased air emissions. In this study, income and male gender are hypothesized to have a positive influence on willingness to pay, as is having some college education. Age is postulated to have a negative influence on willingness to pay. Contribution to environmental organizations, recycling, and participation in home energy audits are hypothesized to have positive influences on willingness to pay. Urban location is hypothesized to have a positive influence on willingness to pay.

RESULTS

A total of 421 responded to the survey. Among the respondents, 38.05 percent were willing to pay something more for renewable energy. Among the specified renewables, about 30.68 percent were willing to pay something more for energy from crops, 30.38 percent for energy from forest products wastes, 32.45 percent for energy from landfill wastes, 33.92 percent for solar energy, and 34.51 for wind energy.

Spike models were estimated for each of the renewable energy sources. Only the models for bioenergy for crops and for bioenergy from forest products wastes are presented for purposes of brevity. The results from these estimated models are displayed in Table 1. Of the 421 respondents, 335 responded to all questions needed to estimate the willingness to pay models. The values in parentheses below each coefficient are the standard errors of the estimates.

As can be seen in Table 1, the coefficient on *Premium* was significant in both models. The coefficient on Income $25,000 or less was significant and negative in the models. The coefficient on Income from $60,001 to $75,000 was significant and positive in both models. Having a college education and contribution of time or money to an environmental organization had positive influences willingness to pay. The coefficient on county population was positive and significant. Other variables, such as age, gender, recycling, and having had a home energy audit, were not significant in any of the models and were omitted.

Table 1. Estimated Spike Models of WTP for Bioenergy from Crops and from Forest Products Wastes[a]

	Fast Growing Crops		*Forest Products Wastes*	
Intercept	-1.5608	***	-1.5844	***
	(.3523)		(.3616)	
Premium	-.0617	***	-.0649)	***
	(.0121)		(.0126)	
Income $25,000 or less	-.6711	*	-.7500	***
	(.3900)		(.4051)	
Income $60,001 to $75,000	.5903	*	.6166	*
	(.3345)		(.3320)	
At Least Some College Education	.7968	**	.8376	**
	(.3455)		(.3577)	
Contribution of Time or Money to Environmental Organization	.8225	***	.9483	***
	(.2748)		(.2695)	
County Population (10,000)	.0007	*	.0006	*
	(.0004)		(.0004)	
LLF	267.8647		268.3115	
N	335		335	
% Correctly Classified				

[a] ***=significant at a=.01, **=significant at a=.05, *=significant at a=.10.

Using the estimates from the models presented in Table 1, the estimates of willingness to pay can be calculated. The estimates of willingness to pay are presented in Table 2. The estimates are calculated at the sample means and for two profiles. The two profiles were developed based on the signs and significances of the coefficients on the variables in the model. The first profile is income $25,000 or less, not college educated, not a contributor to an environmental organization, and living in a county with 100,000 population. The second profile is income $60,001 to 75,000, college educated, contributor to an environmental organization, and living in a county with a population of 600,000. The willingness to pay for bioenergy from crops calculated at the sample means is $7.19 per month, for Profile 1 is $1.77 per month and for Profile 2 is $22.31. For bioenergy from forest products wastes, the estimates of willingness to pay are $6.87, $1.52, and $22.70 respectively. Based on the estimated standard errors and confidence levels, profile 1 has a

WTP that is statistically lower than the mean, while profile 2 has a WTP that is statistically higher than the mean.

Table 2. Willingness to Pay Estimates for Bioenergy from Crops and Bioenergy from Forest Products Wastes at Sample Means and for Two Profiles.

	Willingness to Pay for	
	Bioenergy from Crops	***Bioenergy from Forest Products Wastes***
Sample Means		
WTP	7.1925	6.8717
Standard Error	1.4237	5.8355
Upper CI	8.6162	12.7072
Lower CI	5.7688	1.0362
Profile 1		
WTP	1.7710	1.5167
Standard Error	0.8780	0.8135
Upper CI	2.6490	2.3302
Lower CI	0.8930	0.7032
Profile 2		
WTP	22.3130	22.6692
Standard Error	5.9236	5.8355
Upper CI	28.2366	28.5047
Lower CI	16.3894	16.8337

The willingness to pay estimates for each of the renewable energy sources, including solar, wind, and landfill wastes, their estimated standard errors, and upper and lower confidence intervals are presented in Table 3. Each of the WTP estimates was statistically different from zero at the 95 percent confidence level. From Table 3, it can be seen that while the estimates of WTP for bioenergy from forest products wastes and from crops are $6.87 and $7.19, respectively, the WTP for electricity from wind sources is $15.48. The confidence intervals suggest that there is no statistical difference in WTP between bioenergy sources or between either of the bioenergy sources and landfill wastes. However, the confidence intervals do indicate that WTP for energy from solar or wind sources is statistically greater than WTP for bioenergy at the 95 percent confidence level.

Table 3. Estimates of Willingness to Pay, Standard Errors, and 95 Percent Confidence Intervals.

Energy Source	*WTP*	*Standard Error*	*Lower CI*	*Upper CI*
Bioenergy from Forest Products Wastes	6.8717	1.4055	5.4662	8.2772
Bioenergy from Crops	7.1925	1.4237	5.7687	8.6162
Landfill Wastes	9.7459	2.3978	7.3481	12.1437
Solar	12.7088	3.3224	9.3864	16.0312
Wind	15.4817	4.4544	11.0273	19.9361

For those who would not pay more for the specified sources of renewable energy, the responses regarding reasons why they would not pay more were obtained. The most common reason, in general, was that they respondent supported energy from renewable energy, but they were not willing to pay any more. Only about 7 percent of the respondents did not support the concept of electricity from renewable energy. However, for those who were supportive of renewable energy and stated they were willing to pay something more, the reasons why they were not willing to pay more for energy from specified sources was examined. Commonly cited reasons for not being willing to pay more for wind were the visual appearance of the windmills and concerns about bird migration/deaths. A commonly cited reason for not being willing to pay more for solar was concerns about disposal of the solar cells. For landfill wastes, the primary reason was a concern over air emissions from burning. For bioenergy from crops, environmental impacts of agriculture and displacement of acreage for food were listed. For bioenergy from forest products wastes, deforestation and concerns air emissions from burning were cited.

CONCLUSIONS

The results from this study indicate 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 90 percent. Findings from this study suggest that there is a somewhat lower preference for electricity from crops or forest wastes than for electricity from solar or wind sources. However, there is no statistical difference between WTP for bioenergy and energy from landfill wastes.

The results suggest about a $5-6 per month gap in willingness to pay between solar and bioenergy sources (about $.03-.04 per kWh). There is about an $8-9 per month difference in willingness to pay for wind compared with bioenergy sources (about $.05-.06 per kWh). When the WTP estimates are compared with estimated costs of generation from prior research (Guey-Lee; Department of Energy, Energy Efficiency and Renewable Energy Network; Oak Ridge National Laboratory), gaps between WTP and costs appear to be greatest for solar and bioenergy sources.

The results also indicate that income and education levels, contribution to environmental organizations, and urbanization influence willingness to pay, suggesting potential for target marketing of electricity from renewable sources. Because this study was confined geographically to one state, capabilities to examine effects of geographic location were limited. Future research should examine WTP across regions of the United States. Furthermore, future research might also examine how investment in local green power projects versus purchases off green power markets affect willingness to pay for bioenergy.

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