Willingness to Pay for Wind versus Natural Gas Generation of Electricity

Kofi Nkansah and Alan R Collins

In 2009, West Virginia enacted an Alternative and Renewable Portfolio Act (APRA) to broaden its energy use for electricity beyond coal. A choice experiment survey was conducted to assess West Virginians' willingness to pay (WTP) for 10 percent of electricity generated from wind energy versus natural gas. Results showed that residential consumers preferred electricity generated from wind, with annual per-capita WTP averaging from $19.25 to $26.75. Given the subsequent repeal of the APRA in 2015, we propose implementation of a voluntary green pricing program as an alternative policy to increase the share of renewable energy in West Virginia's energy portfolio.

Key Words: choice experiment, natural gas, renewable portfolio standard, wind energy

Introduction

Energy consumption in the United States is dominated by fossil fuel use. This dominance is evident in the power sector; fossil fuels accounted for about 65 percent of total energy use to generate electricity in 2014 (US Energy Information Administration 2015). As a consequence, emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulphur dioxide (SO_2) have been identified as major externalities associated with fossil fuel electricity generation (European Commission 2003, Machol and Rizk 2013). These externalities affect the environment and may have dire consequences for human health.

Sundqvist (2004) examined studies published over the past two decades and estimated the mean external costs of fossil fuel electricity ranged from 21.59 cents/kWh (for coal) to 7.29 cents/kWh (for natural gas). From this same research, external costs were found to be much lower for most renewable

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energy sources, with wind and solar energy at 0.42 cents/kWh and 1.0 cents/kWh,[1] respectively. With statewide average retail prices of electricity (2014) ranging from 7.13 to 17.05 cents/kWh, it can be asserted that the external costs of electricity generated from fossil fuels are as great as or at least represent a substantial portion of the full cost of electricity.[2]

Obviously, the current market prices of electricity generated from fossil fuel are below their true social cost of its production (Borchers, Duke, and Parsons 2007, Sundqvist 2004, Sundqvist and Söderholm 2002). A combination of the externalities associated with fossil fuel electricity, plus an awareness of climate change issues by politicians and consumers, have become motivating factors behind the need to pursue cleaner energy sources to replace fossil fuels in the United States (Bhattacharyya 2011). Up until the recent introduction of the Clean Power Plan by the Environmental Protection Agency, policy efforts aimed at increasing the share of renewable energy and cleaner fossil fuel alternatives in United States primarily occurred at the state level. The renewable portfolio standard (RPS) has been the policy instrument of choice. As of 2015, thirty-seven states and the District of Columbia have implemented some form of RPS.[3]

In West Virginia, over 90 percent of electricity is generated from coal. In 2009, the state of West Virginia adopted the Alternative and Renewable Portfolio Act (ARPA).[4] This policy required at least 10 percent of electricity supplied to consumers to be generated from renewable and/or alternative energy sources (cleaner non-renewable energy sources) by 2015. In addition to the typical sources of renewable energy, a variety of non-renewable energy sources (including natural gas and energy from clean coal technology), along with renewable credits traded within the PJM market (regional electricity transmission organization for West Virginia, the District of Columbia and thirteen other States), also qualified under the policy to meet the 10 percent standard. This legislation is notable among RPS policies in that it included alternative energy sources in addition to renewable energy sources.

[1] The mean external costs of electricity generation presented in this study have been converted from 1998 US dollars to 2014 US dollars. Conversions were based on the average consumer price index for the year 1998 and 2014.

[2] Average retail price of electricity does not include Alaska (17.46 cents/kwh) and Hawaii (33.43 cents/kwh).

[3] The RPS is a policy instrument which mandates electricity utility companies to provide a designated share of electricity from renewable sources in their energy portfolio. As of 2015, twenty-nine states and the District of Columbia have adopted an enforceable RPS. Furthermore, eight states have adopted some forms of voluntary programs with goals that are not enforceable by law (Database of State Incentives for Renewables and Efficiency, 2015).

[4] The West Virginia Alternative Energy Portfolio Standard (ARPA) was subsequently repealed during the 2015 West Virginia State legislature. When this study commenced in 2012, the ARPA was to be implemented in January 2015. The merits of this repeal and other policies to promote renewable energy will be discussed in the conclusions and policy implications section of this study.

One aspect of the ARPA policy was to limit the use of natural gas as an energy source to satisfy the RPS mandate to only 10 percent of the total renewable or alternative energy share (i.e., up to 1 percent out of the 10 percent requirement in 2015). As states like West Virginia struggle to find the right path to diversify its energy portfolio, knowledge of public acceptance of renewable and/or alternative electricity and the public's willingness to pay (WTP) a premium for these electricity generation sources is crucial to establishing viable markets for renewable energy. In addition to West Virginia, the States of Michigan, Ohio, and Pennsylvania also have included cleaner fossil fuel sources of electricity generation as potential energy sources that could be used to satisfy the requirements of their RPS policies. As natural gas and other cleaner fossil fuel alternatives become abundant, other states with adequate reserves of these alternative energy resources may also consider adding them to their current RPS energy mix. Thus, assessing the value consumers place on electricity generated from these cleaner alternative sources of electricity generation has applicability outside the State of West Virginia.

The main objectives of this study are to evaluate residential electricity consumers' WTP for renewable electricity (wind energy) relative to natural gas (a cleaner fossil fuel alternative) and the validity of limiting natural gas use in meeting the 10 percent requirement of the ARPA.[5] In addition to estimating households' WTP for electricity generated from wind relative to natural gas, households' attitudes towards the ARPA mandate were also assessed. Without prior information about consumers' preferences and WTP for electricity generated from wind compared to natural gas, limiting natural gas energy to 1 percent in the ARPA mandate will be validated if the results of this study find that there is an overwhelming preference for wind energy and consumers are willing to pay a positive premium for electricity generated from wind energy relative to natural gas. However, in 2015, the ARPA mandate was repealed by the state legislature. In light of this repeal, an alternative green pricing policy will be explored if the findings of this study show that respondents in both counties were willing to pay a positive premium for electricity generated from wind energy relative to natural gas energy.

The remainder of this paper is broken down into five major sections. First, a brief literature review of consumers' WTP for green and alternative sources of electricity will be presented. The gap in literature that this study sought to accomplish will also be presented in this section. A description of the study

[5] On average, residential demand for electricity in United States was estimated to be approximately 37 percent of the total electricity consumed in the country in 2013 (US Environmental Protection Agency 2015). This study is limited to residential consumers of electricity because the ARPA mandate required only utility providers with 30,000 residential customers to satisfy the provisions of the mandate.

area will follow in the second section, and the third section will include the survey development and implementation. This section will be followed by a section on econometric modeling of utility derived from choices made and a discussion of results. Lastly, this paper will present a conclusions and policy implication section.

Literature Review

A number of non-market valuation studies have sought to estimate the value consumers place on renewable electricity and its attributes (Ek 2006, Groothuis, Groothuis, and Whitehead 2008, Krueger, Parsons, and Firestone 2011, Ladenburg 2009, Ladenburg and Dubgaard 2007, McCartney 2006). Most of these studies have focused on wind power as a renewable electricity generation source and its attributes (Aravena, Martinsson, and Scarp 2014, Ek 2006, Groothuis, Groothuis, and Whitehead 2008, Krueger, Parsons, and Firestone 2011, Ladenburg and Dubgaard 2007). Non-market valuation studies that estimate consumers' value for attributes of wind power have prominently featured visual impacts, landscape change, wildlife impacts, and noise as important externalities associated with wind power (Álvarez-Farizo and Hanley 2002, Krueger, Parsons, and Firestone 2011, Ladenburg and Dubgaard 2007, Meyerhoff, Ohl, and Hartje 2010).

Only a few studies have sought to estimate the value consumers place on other renewable energy sources and cleaner alternative fossil-fueled electricity generation sources (Borchers, Duke, and Parsons 2007, Navrud and Braten 2007). Using a nested logit model, Borchers, Duke, and Parsons (2007) investigated the differences in consumers' WTP, given five renewable energy sources (generic green energy, solar, wind, biomass, and farm-methane). These authors found that, on average, consumers were willing to pay $17.00 per month for a generic green energy that will provide 25 percent of the household's electricity from renewable sources. In terms of specific green energy sources, consumers were willing to pay $21.54, $15.47, $12.38 and $10.59 per month for solar energy, wind, farm methane, and biomass, respectively.

Navrud and Braten (2007) also found that consumers' WTP for cleaner sources of electricity relative to coal in Norway was greater for electricity generated from wind (114.39 NOK to 659.50 NOK) than for natural gas (10.76 NOK to −907.17 NOK). Conversely, consumers required a compensation for electricity generated from hydropower (−173.17 NOK to −348.03 NOK) compared to coal. Navrud and Braten (2007) concluded that consumers perceived wind energy to be more environmentally friendly than hydropower, which requires alteration of aquatic systems due to dams.[6]

[6] As at 2015, 1 USD = 8.66 NOK. Navrud and Braten (2007) WTP values reflect 2005 Norwegian Krone purchasing power. 1 USD (2005) = 1.22 USD (2015).

A limited number of studies have sought to assess the impact of an existing renewable or fossil fuel electricity generation development within the vicinity of a consumer's residential location on the consumer's WTP for a proposed renewable electricity facility. Based on our literature review, only two studies have attempted to explicitly determine how an existing renewable electricity facility influences consumers' WTP for a proposed renewable electricity generation facility (Ladenburg and Dubgaard 2007, Navrud and Braten 2007).

The impact of existing wind development on consumers' WTP for electricity generated from wind was examined by Ladenburg and Dubgaard (2007) in Denmark. They found that respondents who could see an existing wind farm from offshore locations, or who had a summer house at a location with an offshore wind farm within view, were willing to pay a much higher premium for a reduction in disamenities derived from wind turbines located near shore.

Navrud and Braten (2007) found that a sample of respondents at rural locations with an existing wind farm development were willing to pay a positive premium for electricity generated from wind relative to imported electricity generated from coal. However, rural respondents' WTP for wind electricity was approximately 90 percent lower than the WTP values of respondents sampled in urban areas where no wind farm existed. Conversely, urban respondents required compensation for electricity generated from natural gas, while rural respondents were willing to pay a positive premium for electricity generated from natural gas.

Based on a thorough review of literature, this research is the first that has included comparisons of the differences in consumers' WTP for electricity generated from wind relative to natural gas between two populations that were sampled based on the types of electricity-generation facilities that already existed within their county of residence (both coal-fired and wind farm facilities vs. only coal-fired facility). If a statistically significant difference in WTP for electricity generated from wind relative to natural gas exists between the two populations, then perhaps respondents' prior experience with an existing source of electricity generation facility may be part of the factors influencing their WTP for a newly proposed, cleaner source of electricity generation.

Methods

Study Area

West Virginia, with its vast deposits of coal, accounted for about 12 percent of the total US coal production in 2012 (US Energy Information Administration 2015). In terms of estimated recoverable coal reserves, West Virginia ranks 4th in the country with 1,714 million short tons (US Energy Information Administration 2015). In 2012, the coal mining industry contributed about 16.27 percent of the total state GDP (National Mining Association 2014).

Current estimates (2015) put the share of total electricity generated from coal in West Virginia at approximately 94.1 percent. The remaining generation sources are all just under 2.0 percent, including conventional hydroelectric, wind, and natural gas (US Energy Information Administration 2017a). Of the top ten electricity power stations in the state by generation, the top eight are coal, the ninth is natural gas, and tenth is wind. About 56 percent)of the total electricity generated in West Virginia is exported out of state (US Energy Information Administration 2012).

Two economic factors are changing the electricity sector in West Virginia: (1) tripling of natural gas production in West Virginia between 2011 and 2015 due to extraction from the Marcellus Shale Formation, along with historically low natural gas prices; and (2) the increasing cost competitiveness of wind energy, which has 2022 projected levelized costs per MWh lower than natural gas (US Energy Information Administration 2017b). Based on these factors, natural gas and wind have the potential to become major portions of the state's future energy portfolio. Thus, these energy sources were selected for comparisons between a cleaner alternative energy source (natural gas) and renewable (wind) electricity generation in this study.

The selection of counties in West Virginia to be surveyed was based on two criteria: (1) a county with an existing coal-fired electricity generation facility, and (2) a county with both wind energy and coal-fired electricity generation facilities. These criteria were employed to assess if existing electricity generation facilities located near respondents have an influence on the value they place on electricity generated from renewable energy and cleaner fossil fuel alternatives. Monongalia and Grant Counties were selected as the two counties that met our sampling criteria. The location of the two counties within the state is presented in Figure 1. Monongalia County is located in north-central West Virginia on the border with Pennsylvania. In this county, there are four coal-fired power plants in operation.[7] The US Census Bureau classifies Monongalia County as part of a metropolitan statistical area (MSA) which includes neighboring Marion County. Grant County, on the other hand, is a more rural county located in the eastern part of West Virginia (Figure 1). Currently, two coal-fired power plants and a wind farm are operational within the county.

Survey

The design, testing, and administration of the final survey closely followed the "tailored design method" (Dillman 2011). Using the survey development

[7] Even though there are no wind turbine facilities in Monongalia County, there are wind turbines on the ridges at the northern border of Monongalia County and the state of Pennsylvania. As a result, about 24 percent of the sampled population indicated that they sometimes or frequently experience wind at their residence on a daily basis. Therefore, Monongalia County cannot be considered a county free of the disamenities that may be associated with a wind farm.

Figure 1. West Virginia County Map

methods of Krueger, Parsons, and Firestone (2011), three semistructured interviews and an intercept interview session were conducted with an initial draft questionnaire. After modification of some questions, three pretest sessions were conducted between March and May of 2012. During pretesting, important aspects of survey design, including how the questions were understood by respondents, survey length, total number of questions included, questions structure, and possible survey language bias, were discussed (Dillman 2011, Krueger, Parsons, and Firestone 2011).

The final questionnaire included four main sections. These sections included questions covering: (1) knowledge, awareness, and support for the ARPA policy in West Virginia, (2) attitudes towards existing electricity generation facilities located within the state (coal-fired power plants and wind farms), (3) a choice experiment (see next section), and (4) sociodemographic characteristics of respondents.

A sample of 1,500 homeowners and renters from each county were randomly selected to participate in the survey. Mailing lists were obtained from USADATA, Inc. The survey was conducted between November 1, 2013 and March 15, 2014. An invitation to participate, either by mail or online, was sent out as the initial contact in both counties. A cover letter introduced the purpose of the survey, how the respondent was selected to participate, and the importance of his or her contribution to shaping future policy on renewable and alternative energy in West Virginia.

The invitation letter that was sent to the Monongalia County respondents offered the option to participate online or request a mail survey. Even though respondents in Grant County were given the option to participate online, a paper copy of the survey was mailed along with the invitation letter, given that a lack of high-speed Internet in a rural county was likely. This way, participants could either respond online using a unique access code or complete and return the mailed survey. Including reminders, six contacts were made with the sample population of Monongalia County and five with the Grant County sample.

Choice Experiment

The choice experiment was designed based on the assumption that the ARPA was to be enforced starting in 2015. As a result, a choice design with no option for a status quo or opt out was presented to respondents. Thus, respondents faced a decision of either selecting wind or natural gas energy to generate 10 percent of the electricity supplied to their residence. Based on discussions during the semistructured interview sessions and an extensive literature review on consumers' WTP for renewable electricity, three attributes were selected for the choice experiment design: (1) energy source, (2) proximity of electricity generation facility relative to the respondent's residence, and (3) an additional fee to be added to the respondent's monthly electricity bill.

Three levels of proximity as an attribute of electricity generation were selected. These levels were categorical measures of near, moderate, and far locations relative to a respondent's residence. To give respondents a sense of what each of these three categorical measures entailed, each proximity level included a description of estimated visual, pollution, property value, and noise impacts from electricity generation externalities of wind and natural gas facilities (Rowe et al. 1995).

To quantify the monetary value that respondents place on electricity generated from wind versus natural gas, an additional fee on respondent's monthly electricity bill was included as the monetary attribute of the choice experiment design. This additional fee was presented as the premium that consumers would have to pay for 10 percent of the electricity supplied to them to be generated from either wind or natural gas. The use of an additional fee on a consumer's monthly electricity bill as the monetary attribute resonated very well with respondents during the semi-structured interviews and pretesting sessions. Monthly fee levels ranged from \$1.00 to \$15.00, representing 1 percent to 14 percent of the average monthly electricity bill in 2012 for residential customers in West Virginia.[8]

[8] Different intervals of monthly fees between \$1.00 and \$15.00 (incremental intervals of \$1.00, \$2.00, \$3.00 and \$5.00) were tested during the semistructured interviews before the final

Table 1. List of Attribute and Levels Used in Choice Experiment Design

Attributes	Levels
Energy source	Wind, natural gas
Proximity	Near, moderate, far
Additional monthly fees	\$1.00, \$2.00, \$5.00, \$10.00, \$12.00, \$15.00

Table 1 summarizes the three attributes and their levels used in the choice experiment design. During the choice experimental design phase, it was assumed that externalities derived from a wind farm would be significantly different from those derived from a natural gas-fired electricity generation facility. As a result, a labeled choice experiment (either wind or natural gas) was presented to respondents (see Table 2 as an example of choice questions). In designing choice combinations or sets, a full factorial choice design was considered, but the total number of choice sets that resulted from this design was enormous. With two levels of energy sources, three levels of proximity, and six levels of fees, an orthogonal main effect design was used to develop choice combinations following a SAS source code authored by (Kuhfeld 2005). This resulted in thirty-six choice combinations with two alternatives in each combination.

Even though number of choice sets resulting from the orthogonal main effect design was much smaller than a full factorial design, the ability of each respondent to answer all thirty-six questions in a survey was regarded as unrealistic. Thus, the thirty-six choice combinations were randomized with twelve blocks of three choice sets per block. Each respondent was randomly assigned to a block.

Even though the monetary value placed on proximity as an attribute was an important aspect of this choice experiment, no attempt was made to eliminate choice combinations in which the fee attribute for the farthest location was not higher than the fee attribute of the near or moderate locations. This decision was made because the choice options for this study were presented as labeled options and not generic. For an example, the perceived externality derived from a natural gas-fired power plant at a moderate location from a respondent's residence cannot be assumed to be higher than a wind farm located far from the respondent's residence.

attribute levels of \$1.00, \$2.00, \$5.00, \$12.00, and \$15.00 were included in the choice experiment design. The outcome of the discussion on monthly fee attribute levels was to include at least two values marginally close to \$0 (payment that would have been attributed to a status quo choice if included) and two values marginally close to the maximum monthly fee of \$15.00 (\$12.00 and \$15.00). The final attribute levels used in the choice experiment were levels that resonated well with the semistructured interview group and pretest groups.

Econometric Model

Individuals derive utility from their choices. Modeling a respondent's utility for our choice experiment followed the random utility theory. This theory asserts that the utility derived by an individual from making a choice is not directly

Table 2. Sample Choice Questions[a]

Energy Source	Wind	Natural Gas
	Far away	Moderate distance
Location of power plant relative to your residence (refer to the Appendix for comparisons of near, moderate and far away)	*Distance*: At least 19 miles or greater *Visual*: Turbines are too far away to see *Noise*: None *Property value*: None *Pollution* (*environment and health*): None	*Distance*: Between 2 and 19 miles *Visual*: Medium visibility of stack and smoke *Noise*: None *Property value*: None *Pollution* (*environment and health*): High health effects: Five times greater than residential locations that are far away
Cost (an increase in your current monthly electricity bill)	$15	$15
I will choose (*please check only one*)	❒	❒
	Near	Near
Location of power plant relative to your residence (refer to the Appendix for comparisons of near, moderate, and far away)	*Distance*: Within 2 miles *Visual*: High visibility of turbines *Noise*: Disturbance can occur *Property value*: Moderate decline in value (1%) within 0.5 miles *Pollution* (*environment and health*): None	*Distance*: Within 2 miles *Visual*: High visibility of Stack and Smoke *Noise*: None *Property value*: Moderate decline (1–2%) within a mile *Pollution* (*environment and health*): High health effects: Five times greater than residential locations that are far away
Cost (an increase in your current monthly electricity bill)	$1	$5
I will choose (*please check only one*)	❒	❒

Continued

Table 2. Continued

Energy Source	Wind	Natural Gas
	Moderate distance	Far away
Location of power plant relative to your residence (refer to the Appendix for comparisons of near, moderate, and far away)	*Distance*: Between 2 and 19 miles *Visual*: Medium visibility of turbines *Noise*: None *Property value*: None *Pollution* (*environment and health*): None	*Distance*: At least 19 miles or greater *Visual*: Minimal visibility of smoke if at all visible. Stack may be too far away to see *Noise*: None *Property value*: None *Pollution* (*environment and health*): Low health effects compared to locations that are at near and moderate distances
Cost (an increase in your current monthly electricity bill)	$5	$10
I will choose (*please check only one*)	❐	❐

Currently, 100 percent of your electricity comes from coal energy. Assume you have the opportunity to choose a renewable or alternative electricity source and where it is generated (location of the facility). This energy source will fulfill 10 percent of the electricity supplied to your home. Which of the following options will you choose?

[a]Each of the three choice set panels above were presented on as a separate question on a different page in the survey packet or web screen (online version).

observable. However, a substantial portion of this utility can be elicited through the use of a carefully designed stated preference method. However, there will always be a stochastic part of an individual's utility that will remain unexplained (Louviere 2001). The systematic component of utility derived by the n^{th} individual based upon the two labeled forced choice options presented in each choice set (wind power-i^{th} alternative or natural gas power-j^{th} alternative) can be expressed mathematically as:

(1) $$U_{in} = \beta X_{in} + \alpha_i S_n + \varepsilon_{in} \quad (i = 1, 0)$$

(2) $$U_{jn} = \gamma X_{jn} + \varepsilon_{jn} \quad (j = 1, 0)$$

where β and γ are vectors of choice specific parameter estimates associated with the corresponding vectors of attributes X for the i^{th} and j^{th} alternatives, respectively. S_n is a vector of the observed n^{th} individual's traits (demographics, characteristics, and attitudes) that are estimated as α_i in equation 1. Because this vector of individual respondent traits is invariant with homogeneity of degree of zero, it is estimated for the choice of the i^{th} alternative relative to the j^{th} alternative. In other words, the individual's invariant traits (S_n) were interacted with the alternative specific constant for the choice of the wind option only. Such invariant observed n^{th} individual's traits are interpreted relative to the choice of the j^{th} alternative. Equations 3 and 4 explicitly outline the systematic components of the utility models (all variables included) used to in this study.

$$(3)\quad U_{in} = \text{ASC\_WIND}_i + \alpha_{i1}\text{SEE\_WIND\_H}_n + \alpha_{i2}\text{SUPPORT\_ARPA}_n + \alpha_{i3}\text{INVEST\_LESS POLLUTION}_n + \alpha_{i4}\text{NEG ATTITUDE COAL}_n + \alpha_{i5}\text{NEG IMPACTS WIND}_n + \alpha_{i6}\text{GENDER}_n + \alpha_{i7}\text{AGE}_n + \alpha_{i8}\text{4 YEAR COLLEGE}_n + \beta_1\text{FEES}_{ni} + \beta_2\text{WIND\_MODERATE}_{ni} + \beta_3\text{WIND\_FAR}_{ni} + \varepsilon_{in}$$

$$(4)\quad U_{jn} = \beta_1\text{FEES}_{nj} + \beta_4\text{NGAS\_MODERATE}_{nj} + \beta_5\text{NGAS\_FAR}_{nj} + \varepsilon_{jn}$$

The coding techniques, a brief explanation, and summary statistics for each of the invariant traits included in equations 3 and 4 are presented in Table 3. An individual's invariant independent variables estimated as α_i represent interaction terms between the alternative specific constant for the wind alternative (ASC_WIND$_i$) and the n^{th} individual's invariant traits. These respondents' traits include support for the ARPA policy (SUPPORT_ARPA), frequency of sighting wind turbines (SEEWIND_H), attitudes towards electricity generated from coal (NEG ATTITUDE COAL), perception on the negative impacts of electricity generated from wind (NEG IMPACTS WIND), and the need to invest in less polluting electricity generation sources (INVEST_LESS POLLUTION). Demographic variables that capture respondents' age, education level (4 YEAR COLLEGE), and gender were also included as traits.

Based on an extensive literature review on consumers' WTP for green energy, we expected that the likelihood of choosing the wind option would be lower for individuals with an existing wind farm development within sight of their residence and/or with perceptions of negative impacts from wind electricity. Conversely, it was expected that respondents who expressed a negative attitude towards electricity generated from coal would derive a positive utility from the wind option choice and thus be more likely to choose this option. Literature on consumers' WTP for green energy (Borchers, Duke, and Parsons 2007, Krueger, Parsons, and Firestone 2011) show conflicting results for the impacts of demographic variables such as age, gender, and education on the utility that individuals derive from green energy programs. As a result, no specific expectations were placed on the impact of these variables prior to model estimation. Intuitively, respondents who agreed to the statement, "it's important to invest in power plants that generate the least amount of pollution," were expected to derive a positive utility from the choice of wind

Table 3. Definitions of Variables Included in Estimated Models

Variable	Description	Coding	Mean	Min	Max
WIND_MODERATE[a]	Electricity provided by wind turbines at a moderate distance from current residence	−1, near residence (reference case)	0.086 (M)	−1	1
$n = 584$ (M)		1, attribute level present	−0.023 (G)		
$n = 707$ (G)		0, attribute level not present			
WIND_FAR[a]	Electricity provided by wind turbines at a distance far from current residence	−1, near residence (reference case)	0.082 (M)	−1	1
$n = 584$ (M)		1, attribute level present	−0.038 (G)		
$n = 707$ (G)		0, attribute level not present			
NGAS_MODERATE[a]	Electricity provided by a natural gas-fired power plant at a moderate distance from current residence	−1, near residence (reference case)	0.041 (M)	−1	1
$n = 343$ (M)		1, attribute level present	0.011 (G)		
$n = 443$ (G)		0, attribute level not present			
NGAS_FAR[a]	Electricity provided by a natural gas-fired power plant at a distance far from current residence	−1, near residence (reference case)	0.155 (M)	−1	1
$n = 343$ (M)		1, attribute level present	0.122 (G)		
$n = 443$ (G)		0, attribute level not present			

ASC_WIND[a] $n = 927$ (M) $n = 1150$ (G)	Alternative specific constant for choosing wind option over natural gas option	1, wind choice 0, natural gas choice	0.630 (M) 0.615 (G)	0	1
FEES[a] $n = 927$ (M) $n = 1150$ (G)	Additional monthly cost for choosing an option to be added to current monthly electricity bill (USD)	Continuous variable in dollars: $1.00 to $15.00	6.861 (M) 6.318 (G)	1	15
SUPPORT_ARPA[b] $n = 312$ (M) $n = 389$ (G)	Respondent support for the current RPS in WV	1, support 0, neutral or do not support	0.430 (M) 0.329 (G)	0	1
SEEWIND_H[b] $n = 312$ (M) $n = 389$ (G)	Respondent frequently or sometimes see a wind turbine from my residence	1, frequently or sometimes 0, never	0.240 (M) 0.717 (G)	0	1
INVEST_LESS POLLUTION[b] $n = 312$ (M) $n = 389$ (G)	Respondent agreed to the statement, "It's important to invest in power plants that generate the least amount of pollution"	1, strongly or somewhat agree 0, neutral, somewhat, or strongly disagree	0.811 (M) 0.751 (G)	0	1
NEG ATTITUDE COAL[b] $n = 312$ (M) $n = 389$ (G)	Negative attitude towards electricity generation facilities that utilize coal as energy source	1, very negative or somewhat negative 0, neutral, somewhat or very positive	0.295 (M) 0.136 (G)	0	1

Continued

Table 3. Continued

Variable	Description	Coding	Mean	Min	Max
NEG IMPACTS WIND[b]	Given seven categories, the number of times wind was selected as the electricity generation source with the most negative impact	Continuous variable in percentage	26.511 (M)	0	100
$n = 312$ (M)			29.012 (G)		
$n = 389$ (G)					
GENDER[b]	Gender	1, female	0.490 (M)	0	1
$n = 312$ (M)		0, male	0.465 (G)		
$n = 389$ (G)					
AGE[b]	Age	Years	64.846 (M)	27 (M)	98 (M)
$n = 312$ (M)			61.512 (G)	23 (G)	96 (G)
$n = 389$ (G)					
4 YEAR COLLEGE[b]	Completed a 4-year college degree or graduate degree	1, at least 4 years of college	0.603(M)	0	1
$n = 312$ (M)		0, less than 4 years of college	0.267 (G)		
$n = 389$ (G)					

[a]Choice observations summary statistics. Total observation (Monongalia County; $N = 927$) and (Grant County; $N = 1150$).
[b]Unique respondents summary statistic. Total respondents (Monongalia County; $N = 312$) and (Grant County; $N = 389$).
[(M)]Monongalia County sampled population summary statistic and [(G)]Grant County sampled population summary statistic.

relative to natural gas. Lastly, no prior expectation was placed on the variable that captured respondents' support for the ARPA mandate in the utility model since both wind and natural gas qualified as energy sources that could be used to satisfy this mandate.

The alternative specific variable (ASC_WIND) measured the value of the choice between electricity generated from wind relative to natural gas. The additional fee parameter for the choice of an alternative (FEES) was estimated as a generic parameter (β_1) for both utility models and was expected to be negative. Because externalities associated with electricity generated from a natural gas-fired facility and wind farm were assumed to be different, parameters that captured proximity to electricity generated from wind (β_2, β_3) and natural gas (β_4, β_5) were estimated as alternative specific parameters. The unexplained random components of utility associated with the n^{th} individual's choice are represented as ε_{in} and ε_{jn}, respectively.

The distribution of the random component in the utility function was assumed to be independently, identically distributed (IID) type I extreme value (EV1). The assumption of IID for the random component of the utility function is the starting point for most choice model derivations as a result of the simplistic nature of the models it presents (Louviere 2001). The IID assumption led to the use of a logit-based utility model for the estimation of choice probability in this study. In order to include individuals' specific invariant variables (case specific) as predictors of choice probabilities, a conditional logit model that allows for interaction of individual respondent traits with the alternative specific constant of the option chosen was used to estimate the utility models presented in this study. The use of conditional logit required a restrictive assumption of independent of irrelevant alternatives (IIA) on choices (Greene 2012). This assumption means that when one of two options is chosen, its relative probability is not affected by the addition or removal of the other alternative.

WTP for 10 percent of a respondent's electricity to be generated from wind as the energy source relative to natural gas was estimated with an implicit price formulation below following Hensher, Rose, and Greene (2005):

(5)
$$\text{Implicit price (WTP)} = -\left(\frac{\beta(\text{non market attribute})}{\beta(\text{market attribute})}\right) = \left(\frac{\beta(\text{non market attribute})}{-\mu}\right)$$

where β is the coefficient of the energy source attribute and μ is the parameter estimate of fees. When linearity in attributes exists, then the estimated WTP for a non-monetary attribute according to the implicit price formulation represents the trade-off that a respondent would be willing to make between the non-monetary attribute and the monetary attribute (Bergmann, Hanley, and Wright

2006). Respondents' mean WTP for 10 percent of electricity generated from wind relative to natural gas was computed using the delta method. The delta method assumes that WTP is asymptotically normally distributed.

Results

Survey

After accounting for out-of-scope (undelivered questionnaires or invitations) and ineligible respondents (selected respondent was not an electric utility customer), the effective response rates were 27.0 percent in Monongalia County and 35.0 percent in Grant County. In terms of survey mode (online vs. mail), as expected, the response rate for the online survey was higher within the Monongalia County sample population compared to the Grant County population (11.0 percent vs. 4.6 percent). Conversely, the response rate for the mail survey was almost twice as high within Grant County compared to Monongalia County.

Table 4 presents summary statistics of demographics for the sample and county populations. As occurs frequently with surveys, older and more

Table 4. Summary of Sample and Population Demographics

	Monongalia County Surveyed Respondents	Population Demographics Monongalia County	Grant County Surveyed Respondents	Population Demographics Grant County
Total county households	1,500	36,449[a]	1,500	4,449[a]
Education (percentage share with at least 4 years' college education)	56% ($n = 371$)	37.3%[b]	26% ($n = 485$)	10.9%[b]
Median age (years)	67 ($n = 372$)	29.1[a]	64 ($n = 480$)	44[a]
Median household income (per year)	$50,000–$74,999 ($n = 354$)	$41,326[c]	$35,000–$49,999 ($n = 447$)	$40,250[c]
Percentage of females	52% ($n = 373$)	48.5%[d]	47% ($n = 496$)	50.4%[d]

[a]US Census Bureau: State and county quick facts (2008–2012).
[b]Reflects observations age 25 and above.
[c]US Census Bureau Data 2010.
[d]US Census Bureau: State and county quick facts (2013).

educated respondents were oversampled in both counties. Over-representation of certain demographics within a sample relative to the population, particularly demographics such as age and education, occurs frequently in surveys (Firestone and Kempton 2007). The sampled population in both counties was weighted against age and education level in order to account for sampling bias in the conditional logit model for each county's population. The weighting factors used to account for the sampling bias in both counties are presented in Table 5.

A majority of respondents in both counties (59 percent in Grant and 56 percent in Monongalia) indicated that they had not heard of the state's ARPA policy. After this policy was described to respondents, support for the goals of the policy was greater than non-support in both counties (30 percent vs. 22 percent in Grant and 41 percent vs. 24 percent in Monongalia). However, sizable numbers of respondents in both counties responded "not sure" about supporting the policy. Respondents were also asked about their general attitudes towards electricity generation facilities that use wind energy, natural gas, or coal as an energy source. At least 50 percent of respondents in both counties had a positive attitude towards all three sources of electricity generation. Most importantly, the majorities of respondents in both Grant County (54 percent) and Monongalia County (53 percent) had positive attitudes towards wind farms.

The West Virginia electricity market remains a fully regulated monopoly where consumers do not have a choice of electricity provider or generator. Respondents were asked to indicate their level of agreement with the statement: "each consumer should be able to choose the electricity generation source that he or she prefers." A majority of the respondents in Grant County (61 percent) and Monongalia County (51 percent) agreed (strongly to somewhat) with this statement. Respondents also were asked about their level of agreement with the statement "I am concerned about pollution created by electricity generation." Again, majorities of respondents in both Monongalia County (74 percent) and Grant County (62 percent) agreed (strongly to somewhat) with this statement.

An overwhelming majority of respondents in both Monongalia County (81 percent) and Grant County (72 percent) agreed with the statement, "It is important to invest in power plants that generate the least amount of pollution." Yet, when asked if they agreed with the statement, "I would be willing to pay more for electricity that is generated with less pollution than current energy sources (mainly coal)," only 37 percent of Monongalia County respondents and 18 percent of Grant Country respondents agreed. This result indicated that there is a disconnect between respondents' opinions on WTP for cleaner electricity generation sources versus the need to invest in cleaner electricity generation sources.

Table 5. Summary of Weighting Demographics of Populations

	Monongalia County			Grant County		
Age and Education Levels	**County population (%)**	**Sample population (%)**	**Weight (county/ sample)**	**County population (%)**	**Sample population (%)**	**Weight (county/ sample)**
Age 25 to 64, bachelor's or higher	30	26	1.13	9	17	0.52
Age 25 to 64, less than bachelor's	53	21	2.45	66	39	1.67
Age 65 plus, bachelor's or higher	3	34	0.09	3	10	0.26
Age 65 plus, less than bachelor's	15	18	0.82	23	34	0.68

Table 6. Conditional Logit Estimation Results

Variable	Monongalia County sample	Grant County sample
WIND_MODERATE	0.120 (0.140)	−0.099 (0.102)
WIND_FAR	0.294** (0.119)	0.307*** (0.084)
NGAS_MODERATE	−0.173 (0.106)	−0.207** (0.081)
NGAS_FAR	0.656*** (0.134)	0.4267*** (0.084)
ASC_WIND	1.821*** (0.780)	1.147* (0.609)
FEES	−0.084*** (0.015)	−0.094*** (0.012)
SEE_WIND_H	0.861** (0.437)	−0.494** (0.244)
SUPPORT_ARPA	0.590* (0.323)	0.096 (0.255)
INVEST_LESS POLLUTION	−0.119 0.397	0.417 (0.273)
NEG ATTITUDE COAL	0.631* (0.378)	0.681** (0.340)
NEG IMPACTS WIND	−0.043*** (0.007)	−0.025*** (0.005)
GENDER	0.409 (0.307)	0.101 (0.224)
AGE	−0.013 (0.011)	0.0003 (0.008)
4 YEAR COLLEGE	0.227 (0.294)	−0.121 (0.248)
NUMBER OF OBSERVATIONS	927	1150
LOG LIKELIHOOD	−444.39	−633.04
PSEUDO R-SQUARE	0.269	0.172
Info. Criterion: BIC	1.062	1.18673

***1 percent significance, **5 percent significance, *10 percent significance.
Cluster robust standard error in parentheses.

Regression Results

In order to simulate compliance with the ARPA, respondents were given the forced choice of choosing either a natural gas-fired power plant or a wind farm to generate 10 percent of the electricity supplied to their residence. The majority of respondents in both counties (62 percent in Monongalia and 60 percent in Grant) chose electricity generated from wind. In the econometric analysis, a pooled model of both counties and two separate county models were estimated. The null hypothesis of equality between the two county models was rejected at a 95 percent confidence interval. As a result, separate county models are presented in Table 6. Because each individual sampled was presented with three choice sets, the standard errors of the conditional logit models presented in Table 6 were estimated as cluster robust standard errors.

Two alternative model specifications were investigated. The first examined the effect of choice options order on choices made by respondents. With this model, we sought to assess if the position of a particular choice set in a survey block systematically affected the econometric model results. We found no statistical evidence of a choice option order effect. Secondly, in order to relax the IIA assumption of the conditional logit model and allow for preference variation across the sampled population (β is not fixed), mixed logit models for both counties were estimated. None of the standard deviations from the mixed logit models for either county were statistically significant. Moreover, a log-likelihood ratio test showed that the mixed logit models for each county did not statistically perform any better than their corresponding conditional logit models. As a result, the conditional logit models for each county were retained as the final models in this study (Table 6).

As expected, the location of the electricity-generating facilities impacted a respondent's utility. Siting of wind turbines at a location farther away (WIND_FAR) from a respondent's residence in either county contributed positively to the utility derived from a choice of the wind option relative to a near location (Table 6). Similarly, respondents in both counties derived a positive utility from a choice of natural gas power when such a facility is located at the farthest location away (NGAS_FAR) from their residence. However, the parameter estimate that captured the utility derived from the choice of natural gas power located at the moderate location away (NGAS_MODERATE) from the respondent's residence was negative and statistically significant only within Grant County. Based on the relative magnitude of NGAS_MODERATE (−0.207), it can be asserted that the negative utility derived from the choice of natural gas power located at a moderate location away from a respondent's residence is lower than the negative utility derived from the base case location of a near location.

The alternative specific parameter estimates captured the utility gained by choosing wind energy over natural gas (ASC_WIND). Coefficients were positive and statistically significant in both models. All things being equal, respondents derived a positive utility from a choice of the wind option relative to natural gas. An additional monthly fee that a respondent would have to pay on top of their current electricity bill was estimated as a generic parameter in equations 1 and 2. As expected, respondents derived a negative utility as the monthly fee attribute (FEES) associated with the option chosen increased in both county's models.

The parameter estimate that captured respondents' support for the ARPA policy (SUPPORT ARPA) was positive and statistically significant only in the Monongalia County model. This implied that Monongalia County respondents who supported the ARPA policy derived a positive utility from the choice of the wind option relative to natural gas, whereas ARPA support was not statistically significant among the Grant County respondents.

The variable that captured respondents' frequent of sighting wind turbines (SEEWIND_H) was statistically significant in both county's models. Interestingly, the impact of respondents' frequent sighting of wind turbines on the utility derived from the choice of wind option relative to natural gas was positive among the Monongalia County respondents and negative among

Grant County respondents. These conflicting results could be related to the presence of a large wind farm in Grant County. Grant County is one of the few counties with an existing wind farm facility in West Virginia. The closest wind farm location to Monongalia County is within the State of Pennsylvania, but the turbines can be seen on the mountainous ridges from some parts of Monongalia County.

All else being equal, individuals in both counties who expressed a negative attitude toward a coal-fired power plant (NEG ATTITUDE COAL) derived positive utility from the wind option relative to the natural gas option. Given seven categories of impacts (job creation, air quality, view of the landscape, property values, climate change, wildlife (birds and bats) and environment in general), respondents were asked to select the electricity generation source that they perceived to have the most negative impact for each category. All things being equal, as the number of times wind energy was selected as the energy source with the most negative impact among the seven categories presented (NEG IMPACT WIND), the utility derived from the choice of wind option relative to the natural gas decreased in both counties. In other words, there seems to be a linear relationship between the decline in utility derived from the choice of wind option and the number of times that wind was chosen as the electricity generation source with the most negative impact on the seven possible impacts presented. This result was not surprising, because from a random utility theory perspective, a favorable attribute of a choice profile invariably drives the utility derived from making that choice out of a choice set.

Lastly, none of the demographic variables incorporated in the models to explain respondents' choices were statistically significant in either county model. In other words, all things being equal, respondent's age, education level, and gender did not statistically affect the utility derived from a choice of the wind option relative to natural gas in both counties.

Willingness to Pay per Household for Electricity Generated from Wind

As indicated earlier, the mean WTP for 10 percent of electricity generated from wind relative to natural gas was computed using the implicit price ratio in equation 5. The results of respondents' WTP are presented in Table 7. At a 90 percent confidence interval, respondents in both counties preferred electricity generated from wind over natural gas. For Monongalia County, the mean monthly WTP for electricity generated from wind compared to natural gas energy was $21.79, while for Grant County, it was $12.19. While the mean WTP for 10 percent of electricity generated from wind relative to natural gas within the Monongalia County population was 44 percent higher than that of Grant County, this difference was not statistically significant due to overlapping confidence intervals. Thus, in both counties, there was a positive WTP for wind energy rather than natural gas. Considering consumers' overwhelming preference for the wind option relative to natural

Table 7. Mean Monthly WTP Per Household for Wind Energy as 10 percent of an Electricity Generation Source Relative to the Use of Natural Gas as an Alternative Electricity Generation Source

Monongalia County Mean WTP (90% confidence interval)	Grant County Mean WTP (90% confidence interval)
\$21.79 (\$5.52 to \$38.07)	\$12.19 (\$1.34 to \$23.04)

gas, and WTP a positive premium for 10 percent of electricity generated from wind relative to natural gas in both counties, it can be asserted that limiting natural gas energy to 1 percent of the total share of clean electricity mandated by the ARPA was a prudent policy strategy.

In order to estimate the overall social benefits derived from a choice of 10 percent electricity generated from wind rather than natural gas, the mean monthly WTP per household estimate was converted into an annual per capita dollar value. In computing the aggregate annual WTP per capita, the total number of households for each county was adjusted for survey non-response rates (Monongalia County: 73 percent and a Grant County: 65 percent). The adjusted total households' aggregate WTP per year were computed based upon an assumption that the mean monthly WTP of non-respondent households was zero. After accounting for non-response rate, the total households used to compute the adjusted aggregate WTP per year in Monongalia and Grant Counties were 9,841 and 1,571 households, respectively. These adjusted aggregate WTP were then divided by the total population in each county to compute mean annual WTP per capita.

On per-capita basis, the aggregated WTP per year for 10 percent of electricity generated from wind relative to natural gas among Monongalia County population was found to be 39 percent higher than the annual WTP in Grant County (Table 8). While this large gap is possibly due to the experiences with and opposition to wind energy from the residents in Grant County, this difference was not statistically significant due to overlapping confidence intervals. This result demonstrates that renewable electricity from wind

Table 8. Annual WTP Per Capita for Wind Energy as 10 Percent of an Electricity Generation Source Relative to the Use of Natural Gas as an Alternative Electricity Generation Source

Energy source	Monongalia County annual mean WTP per capita (90% confidence interval)	Grant County annual mean WTP per capita (90% confidence interval)
Wind	\$26.75 (\$6.78 to \$46.74)	\$19.25 (\$2.12 to \$36.37)
Total population (2010)	96,189	11,937

generates positive social benefits when compared to alternative energy from natural gas, even among a population that has already experienced both coal-fired and wind energy developments. This finding also validates the limitation of ARPA.

Conclusions and Policy Implications

This research sought to explain consumers' preferences and estimate WTP for renewable wind energy compared to natural gas energy for electricity generation in West Virginia. This study was motivated by the ARPA policy and its limit on natural gas as an alternative fuel to meet a 10 percent RPS standard. Survey results showed that more respondents supported the ARPA policy than opposed it. Also, respondents in both counties were willing to pay a positive premium per month (averages of $21.79 in Monongalia County and $12.19 in Grant County) on top of their current electricity bill for 10 percent of their electricity to be generated from wind rather than natural gas. We found positive social benefits derived from generating 10 percent of the electricity supplied to households from wind ($2.57 million annually in Monongalia County and $0.23 million in Grant County).

While these results showed public support for the ARPA mandate along with positive WTP and social benefits for wind energy, the ARPA was repealed by the 2015 West Virginia State Legislature. As West Virginia struggles to find a balance between a cleaner environment and its energy portfolio, it is hoped that the results of this study, being the first to estimate consumer WTP for renewable versus alternative electricity, will provide some insights about public preference for renewable and alternative energy sources. We hope these insights will enlighten future discussions on RPS or other policies to promote renewable energy within the state.

The ARPA policy was repealed for a number of reasons. Some of the claims made during the repeal of the ARPA were the negative impacts of this policy on consumers of electricity and the economy (West Virginia Chamber of Commerce 2015). In addition, legislators and lobbyists claimed there was the need to protect coal mining jobs that would be lost due to enforcement of an RPS and to avert any burdens from potential electricity bill increases (West Virginia Chamber of Commerce 2015). With survey results showing that majorities of respondents in both counties had not heard about this ARPA policy prior to this survey, limited public knowledge about this policy certainly helps to explain the ease at which the policy was repealed by the state's legislature without much public opposition or comments.

Now that the ARPA is repealed, and given the potential substantial social benefits from electricity generated from wind found in this research, a logical policy alternative to consider in the future would be a voluntary green pricing program for West Virginia consumers who are willing to pay a premium for renewable electricity. More than half of respondents believed that they should be given the option to choose their preferred source of electricity generation (Monongalia: 51.0 percent vs. Grant: 61.0 percent). These results confirm an earlier statewide study conducted by the Center for Business and Economic Research (2006) where 86.6 percent of respondents across West Virginia believed that electric utility customers should be allowed a choice to buy renewable and alternative energy. Providing consumers with a voluntary option to pay an additional premium on top of their electricity bill for renewable energy generation would provide economic incentives to increase the renewable electricity generation capacity within West Virginia. Moreover, in order to ensure the long-term sustainability of such a voluntary green pricing program, our results confirm that adding wind energy generation capacity is preferred over natural gas.

Nationwide, in 2015, over three-quarters of a million electricity customers purchased renewable energy under green pricing programs, mostly wind energy (O'Shaughnessy, Liu, and Heeter 2016). With price premiums in the range of \$0.01 to \$0.02 per kWh, green pricing premiums represent about 8 percent to 16 percent of a typical residential customer's electricity bill. The mean WTP for 10 percent of electricity generated from wind found in this study was within this range, with households willing to pay a premium of 11.5 percent and 20.5 percent, respectively, for Grant and Monongalia Counties.[9] Based on these results, it can be asserted that a voluntary green pricing program, if established in these two counties, has the potential to be sustainable in the long term.

Lastly, our survey consisted of only two county populations in West Virginia. The representativeness of respondents in these two counties compared to the rest of West Virginia was assessed using per capita income rankings. Monongalia County ranks among the top ten counties in the state, and Grant County falls within the bottom half of the ranking of 55 counties. Based on the relative per capita income positions of these two counties, Monongalia County and Grant County may be representative of counties with high and low per capita incomes around the state, respectively. As a result, mean WTP for 10 percent of electricity generated from wind, and respondents' preference for wind found in this survey was judged to be somewhat representative of the state as a whole. Nevertheless, future research should explore options to include the rest of the state in its sampling in order to extrapolate the results of this study to reflect the opinions and WTP for green electricity of consumers across the state with increased certainty.

[9] The percentage of WTP premiums are based on the average electricity bill per month for WV households in 2012 (\$106.15 per month).

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