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Consumer Preferences for Wood-Pellet-Based Green Pricing Programs in the Eastern United States

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Abstract: Co-firing wood pellets with coal is an attractive alternative energy generation method with economic, social, and environmental benefits for the US energy generation sector. One way to sustainably use wood pellets for co-firing is to create consumer-supported green pricing programs (GPPs). Our study surveyed residents of five states (Alabama, New Jersey, New York, Pennsylvania, and Virginia) to investigate preferences for the attributes of a hypothetical GPP. The study applied the Best Worst Choice method, which employs the Best Worst Scaling (BWS) and binary choice (BC) task. The BWS analysis showed that residents of all five states most value the flexibility of contracts, the location of energy generation, and the reduction of carbon emissions as attributes of GPPs. The BC analysis, however, showed that residents are willing to pay a premium for length of contract, followed by reduction of carbon emissions and variability of payments. This study shows that the adoption of optimal GPP attributes can create real customer value. The success of GPPs will depend on increasing enrollment and public support; hence, the next step will be to increase awareness levels and green consciousness through sensitization in the form of public education exercises and media campaigns. Such measures will serve to inform and educate residents on the benefits of GPPs and lessen the gap between intrinsic value and willingness to pay for select attributes.

Keywords: wood pellets; co-firing; best worse choice modelling; green pricing program; flexibility; variability

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Citation: Oluoch, S.; Lal, P.; Susaeta, A.; Smith, M.; Wolde, B. Consumer Preferences for Wood-Pellet-Based Green Pricing Programs in the Eastern United States. *Energies* **2024**, *17*, 1821. https://doi.org/10.3390/en17081821

Academic Editors: Peter V. Schaeffer and Martin Junginger

Received: 29 November 2023
Revised: 20 February 2024
Accepted: 20 March 2024
Published: 10 April 2024

1. Introduction

In the face of environmental concerns and depleting fossil fuel reserves, renewable energy has become a viable source of clean energy which can be used for the provision of energy security [1]. The United States (US) generates an estimated 24% of its energy from renewable sources, where 1.4% (or 56 billion kilowatt-hours (kWh)) of the total energy is generated from biomass [2]. Biomass is carbon neutral because the carbon dioxide (CO_2) emitted during combustion is equal to the amount previously absorbed during biomass growth [1]. The pelletization of woody residues (sawdust and wood chips) is one means of bioenergy production [3]. Wood pellets are more efficient than other conventional biomass products; their lower moisture content and greater energy density improve combustion efficiency, make transportation easier and more affordable [4]. The use of wood pellets has gained traction in many European countries; whereas, in the US, the market for wood pellet use is still not well established [5–7].

Coal generates approximately 19.3% of the US's electricity and is responsible for 1150 million metric tons of the nation's CO_2 emissions, making it one of the largest emitters among all fossil fuels [8]. Coal plants require a large capital investment and have a lifespan of up to 50 years; these factors make the direct replacement of coal plants with renewable energy infrastructure not fiscally viable [1,9]. Wood pellet combustion systems, however, are a relatively easy and affordable adaptation to existing coal plants with the potential to greatly reduce emissions per kWh of electricity generated [9]. As energy generation trends continue to shift toward renewable energy sources, utilizing wood pellets for co-firing at coal plants serves as a transitional path to make the energy transition feasible [1]. Cofiring involves the incorporation of biomass into the utility boilers of coal-fired power plants [10,11].

Co-firing wood pellets with coal offers both economic and environmental benefits as compared to traditional coal-based energy generation [1]. From an economic perspective, co-firing is less capital intensive as it utilizes existing coal-fired power plant infrastructure without further technological adjustments, resulting in savings that favor the biomass supply chain. The environmental benefits of co-firing with wood pellets include a reduction in the emissions of oxides of fossil carbon dioxide (CO_2), nitrogen (NO_2), and sulfur (SO_2), per unit of energy produced [11]. A good example of the of the potential carbon emissions reduction from co-firing is demonstrated in a study by Johnston and Kooten [12], which established that, for a 5795 MW coal capacity coal plant, co-firing could be reduced to 359 MW with the addition of 15% of wood pellets. Other studies have demonstrated that levels of co-firing between 5% to 15% can reduce CO_2 emissions by 5.4% to 18.2% [11]. Furthermore, co-firing minimizes wood and agricultural wastes, thus eliminating environmental disposal problems associated with additional costs such as landfill tipping fees [1]. A study in Alabama demonstrated that 10% co-firing will require 30–40 tons of wood pellets per hour which can increase the demand for wood and encourage the use of forest residues and other biomass products [13]. The affordability and adaptability of co-firing technology offers a potential means to reduce CO_2 emissions from coal plants [14,15].

While there is great potential for co-firing wood pellets in coal combustion plants in the US, 73% of domestic wood pellet production was exported to European markets in 2017 [7,16]. Competitive import prices have resulted in higher costs for domestic wood pellets, making co-firing less commercially viable [9,17]. Since the wood pellet industry has been largely influenced by export prices, it is not entirely understood how wood pellet consumption in the US would be valued. The fact that more than 80% of the forest resources in eastern US are privately owned acts as an additional barrier to the suitability of creating markets for woody biomass products [18,19]. The lack of support for evaluating the benefits of biomass is likely due to market failure, a lack of incentives, the strong markets for carbon, and a lack of information which could influence private landowners to participate in woody biomass energy generation [18]. Since the wood pellet industry has been largely influenced by export prices, it is not entirely understood how wood pellet consumption in the US would be valued. Owing to these uncertainties, it is important to understand how energy consumers would accept and value co-firing biomass with coal as a portion of the electricity provider's energy generation mix. The resulting information will be critical in developing biomass supply chains that support private landowners while promoting sustainable energy generation and enhancing consumer participation in the energy market. Exploring potential supporting policies that can assist and incentivize coal plants to adopt co-firing is critical to the understanding of biomass green pricing program (GPP) viability.

Production Tax Credit (PTC) is a federal tax incentive that allows up to USD 0.012 per Kwh of electricity generation in coal plants to be from biomass [15]. Despite this incentive, only 7.14% of the existing coal plants apply co-firing technologies as the PTC does not clearly specify co-firing guidelines [15,20], which underscores the importance of conducting further investigations into the low adoption rates of co-firing technology. Further, governmental intervention is required to make biomass co-firing economically attractive; we propose incorporating green pricing mechanisms to gain public support and increase the economic viability of co-firing plants.

Some US regions have developed legislation that mandates utility providers to offer GPPs to energy customers [21]. GPPs provide energy customers with the option to pay a premium on their energy bill so that a portion of their energy is generated from renewable sources. This premium covers the cost of any above-market renewable energy used and is based on the cost per kWh of green energy purchased by the energy consumer [21]. In most instances, the premium supports the development of renewables within the customer's local grid. In other cases, the premium may support renewable energy in the future [21,22]. GPPs are often associated with tax credit programs; when a customer pays a premium to increase renewable energy generation, they may be eligible for a tax credit per kWh of energy supported. These tax credit programs can offset upfront costs by 10 to 30% [22]. Hence, these programs allow energy providers to increase renewable energy generation and enable energy consumers to invest in renewable energy [22].

Correspondingly, renewable energy certificates (RECs) can be purchased from the energy provider, acting as a proof of credit for renewable energy delivery to the grid [23]. RECs are market instruments used to promote the environmental, social, and non-power attributes of renewable energy generation [24]. A REC is one megawatt-hour (MWh) of renewable energy electricity delivered to the electric grid [24]. RECs are used by energy providers to meet state Renewable Portfolio Standards (RPS) [24]. Other options available in the US deal with purchasing green energy from an alternate electricity supplier. These options depend primarily on the location of the electricity consumer and their access to alternate green energy grids. Examples include community choice aggregations (CCA) and community solar where communities collectively subscribe to a green power option as a bulk purchaser [25].

Many GPPs available throughout the US are provided by utility and third-party suppliers. Despite their availability, residential participation in GPPs is relatively low, particularly in the bioenergy sector of renewable energy [22,24]. Whereas the wind and solar markets have thrived over the last decade, the biomass market has mostly remained stagnant [25]. Amongst GPPs, wind represents 59–98% of the supported energy mix, while biomass is only 0–5% [26]. Since biomass holds potential for integration with current fossil fuel combustion systems, further investigations are required as a means to promote the transition to a larger renewable energy mix, particularly in regions of the US that still heavily rely on non-renewable energy sources like coal.

2. Background

Studies have been conducted to assess consumers' willingness to pay (WTP) for different renewable energy technologies. For example, Borchers et al. [27] applied a choice experiment to estimate consumer preferences and willingness to participate in green energy programs in the US, and found that consumers preferred solar, wind, biomass, and methane energy generation. Ek and Persson [28] used a REC as a payment vehicle to explore preferences for wind farm development in Sweden. They found that consumers are more likely to accept additional fees when wind farms are in recreational areas, locals' are involved in the planning and implementation, and there is a local ownership structure. Koto and Yiridoe [29] found that households in the Atlantic region of Canada were willing to pay a 14% premium on their monthly energy bill for wind power. Bae and Rishi [22] found that green energy consumers in South Korea prefer solar as opposed to fuel cell and wind and prefer renewable energy generation to be closer to their homes. A US study focusing on residential renewable energy consumers by Arpan et al. [30] found that political orientation was the most common predictor of message-induced hope, personal moral norms, and WTP. Knapp et al. [31] in a comparative study of stated and revealed preferences for residential programs in the US, found higher GPP participation rates in areas where consumers have stronger feelings about the environmental impacts of energy, and lower in areas where utilities charge higher green pricing premiums. A more recent study by Bae et al. [24] investigated consumer preferences for hypothetical green certificate programs in South Korea. They found that 67% of respondents were WTP a premium of USD 9.60–10.60 per month for a green certificate program. An economic assessment of co-firing rice straw with coal in Vietnam found that the value of co-firing was small;

however, when considering the social externalities like job creation and emissions savings, co-firing became an attractive option [17]. While several studies have explored renewable energy acceptability, none to our knowledge have explored public preferences for co-firing biomass with coal in US markets.

Despite the abundance of preference studies focusing on green energy, there is a lack of literature addressing essential features of energy conversion facilities. These are features, such as regularity, variability, and stability, that are essential for energy suppliers in developing renewable energy generation. Regularity refers to the periodicity of payment cycles for energy service provision; variability refers to how prices will change over the course of time; and stability refers to the mechanisms that ensure premium payment for a predetermined period or payment of fines for leaving the agreement [32]. By exploring energy consumers' valuation of these features, we can better address market uncertainty challenges that energy production facilities face. Discrepancies between consumers' stated preference for green energy and their revealed preferences are difficult to unravel [22,33]. Many of these discrepancies are associated with challenges involving marketing communications, effective branding, and the uncertainty or inconvenience of making a change [33,34]. While these factors are all important when it comes to customer interactions, they do not necessarily have any bearing on policy development, or the institutional changes required to support suppliers to integrate GPPs into their business models. A Best Worst Choice (BWC) model is one method that addresses such discrepancies by estimating inherent value and inferring actual value.

In this study, we apply the BWC model to estimate consumers' utility of GPP attributes, and their WTP a premium for co-fired wood pellet-based energy generation. BWC combines the Best Worst Scaling (BWS) and binary choice (BC) experiment methods to yield both attribute utility and WTP estimates as described by Oluoch et al. [35], Smith et al. [36], Soto et al. [37], Soto et al. [38], and Tanner et al. [39]. BWS is a stated preference method that applies random utility framework to estimate the importance by incorporating selection of best and worst attribute levels in each profile [40]. Applying this method can help to identify the priorities amongst potential green energy consumers as well as the associated risks associated with possible GPPs before they are launched. On the other hand, the BC experiment allows for consumers' WTP for attributes of a hypothetical GPP to be estimated. Assessing consumer preferences for green energy certificates can be critical in establishing amenable policies that can support renewable energy growth, while simultaneously supporting bioenergy use and reducing CO_2 emissions. The rest of the paper is structured as follows: Section 3 explains the methodological approach; Section 4 presents the results of the paired estimates for the BWS and estimation of BC tasks; Section 5 concludes the paper and discusses implications for policy makers.

3. Methods

3.1. Econometric Analysis

For this study, we focused on residents within selected states in the Northeast and Southeast, hereafter simply referred to as the Eastern U.S. A representative sample of $n = 2000$ residents from Alabama (AL), New Jersey (NJ), New York (NY), Pennsylvania (PA), and Virginia (VA) completed an online survey administered by Qualtrics, a third-party marketing company. It was important to elicit responses from these residents, as these states have existing/potential for co-firing plants that can incorporate wood pellets as a biomass energy source to generate green energy [41]. Furthermore, the biomass potential and the introduction of biomass GPPs are an under exploited markets in these states. Consequently, consumer preferences will be key to developing sustainable GPPs. Energy providers with co-firing plants stand to benefit from incorporating wood pellets into energy production as they can leverage REC subsidies that will serve to reduce the cost of energy production and increase consumer participation through GPPs.

Each respondent received six BWC tasks consisting of a single profile of attributes with three separate questions: (1) to select the best and worst attributes of a hypothetical GPP,

(2) to vote whether they would or would not support this program, and (3) to calibrate for hypothetical bias, by stating their level of certainty about their vote [42]. The first two tasks require separate conditional logit statistical analyses using the STATA 15 SE statistical software package. In the former task, the BWS paired estimation approach is applied to measure attribute importance, and the latter BC task is used to compute the WTP estimates. The third task is an extension of the BC that applies a cut-off to the certainty scales (1–10) to compute the WTP estimates, where responses that had certainty scores of 7 and below were excluded from the WTP estimates [38].

3.2. Attributes and Corresponding Levels

The attributes and their corresponding levels were developed based on the need to account for key features of GPPs for co-firing conversion facilities. Length of contract (LC), variability of payments (VP), flexibility of contracts (FC), reduction of CO_2 emissions (RC), location of energy generation (LG), and the green pricing premium payment (GP) were the six selected attributes identified from previous studies as having a large impact on consumer choice [19,24,25,28,43–48] (Table 1).

Table 1. Summary of attributes and levels used to create choice experiment questions.

Green Energy Attributes	Description	Levels
Length of contract (LC)	The contract length for the energy provision service that involves supply of electricity and a renewable energy certificate (REC).	6 months (6 M) 12 months (12 M) 24 months (24 M) *
Variability of payments (VP)	Variability of payments due to market factors can be accounted for by RECs that have a fixed premium or fluctuating premium.	Fixed premium (FP) Fluctuating premium ± 5% (F5) Fluctuating premium ± 10% (F10) *
Flexibility of contract (FC)	The electricity consumer has the option to opt out of the contract with or without a penalty.	Opt out of contract with a penalty (PEN) * Opt out of contract without a penalty (NOPEN)
Location of energy generation (LG)	The location of the energy provision service can be In State or out of state.	In State (IN-STATE) Out of state (OUT-STATE) *
Reduction in CO_2 Emissions (RC)	Co-firing conversion plants that incorporate wood pellets can result in local reduction of CO_2 emissions.	1–5% (LOW) * 6–10% (MED) 11–20% (HIGH)
Green Pricing Premium Payment (GP)	The payment vehicle in the form of a biomass renewable energy certificate (REC) added to the monthly electricity bill. With a charge for every Megawatt hour of electricity supplied to the consumer.	USD 10/MWh USD 20/MWh USD 30/MWh USD 40/MWh *

Note: * Indicates that the attribute levels (M24, F10, PEN, OUT-STATE, LOW and USD 40/MWH) were the omitted/baseline variables.

The LC attribute addresses regularity, which is the periodicity of payment cycles for energy service provision. The contract length for the energy provision refers to the duration for the service involving the supply of a given amount of electricity and an REC, after which the customer can opt out of the contract. Kaeznig et al. [46] used a similar attribute termed a 'cancellation period' where they used monthly, quarterly, semi-yearly, and yearly as their attribute levels. For their study, the attribute level yearly was considered as the omitted variable. For the simplicity of survey design, we designated LC levels as 6 months (6 M), 12 months (12 M), and 24 months (24 M). Owing to consumer aversion to longer contracts for most consumer goods, we designated 24 M as the omitted variable [25,45].

Price guarantee identifies how much consumers value price stability, which is measurable in terms of how long the price will remain stable [46]. For our study, this concept was captured as the VP attribute to account for how market forces beyond the control of the conversion facility, such as the cost of wood pellets, influence the price of green energy certificates. For this attribute, we applied the following levels: fixed premium (FP) and premiums fluctuating by (±5% (F5)) and (±10% (F10)) within the chosen contract length. The F10 was considered as the baseline variable due to customer aversion to higher percentage fluctuations in premium [25,26].

An important feature of most GPPs is that consumers have an opt out alternative [45]. For this study, the flexibility of contract (FC) attribute refers to mechanisms that allow green energy certificate buyers to enter a contract for a predetermined time frame and leave with the payment of a fine or without payment of a fine. For the attribute FC, we expected that the electricity consumer will have the decision to opt out of the contract with a penalty (PEN) or without a penalty (NOPEN) as attribute levels. The PEN level scale was designated as the omitted variable [26].

Location of generation has been applied in choice experiment studies by Kaeznig et al. [46] and Sagebiel et al. [48] as a measure of proximity of energy generation plants to the consumers. In the former study, they used regional European countries, whereas for the latter study they used a radius of less than 30 km and more than 30 km to represent local and non-local production of electricity as attribute levels. For our study, the location of energy generation (LC) attribute was applied to test for the domestic and regional importance/preference of energy generation. The corresponding attribute levels chosen were in-state (IN-STATE) and out of state (OUT-STATE), respectively. In our study, our omitted variable was the out of state attribute level.

Some choice experiment studies have applied reduction of fossil fuel generation/reduction in CO_2 emissions attributes [19,43,44,47]. For our study, we have used reduction of CO_2 emissions (RC) as an attribute to measure of respondents' preference towards the level of co-firing with wood pellets and the overall appeal of environmental quality. We set the levels for RC at 1–5% (LOW), 6–10% (MED), and 11–20% (HIGH) to reflect the ability of co-firing plants to reduce CO_2 emissions when wood pellets are used instead of coal. LOW was set as the omitted variable as it calls for the lowest intervention level to incorporate co-firing with coal.

The payment vehicle green pricing premium payment (GP) is the price above the normal electricity bill that consumers would pay for the biomass green energy certificate and is an implicit measure of WTP for attributes of GPPs. The attribute levels chosen (USD 10, USD 20, USD 30, and USD 40 per megawatt-hour (MWh)) were based on estimates on existing wind and solar RECs [24,25,28,46,48]. The omitted variable was USD 40/MWh as economic theory asserts that higher costs are generally less desirable.

The attribute levels from Table 1 resulted in 432 possible profiles ($3 \times 3 \times 2 \times 2 \times 3 \times 4$), which was an unfeasible number to apply to the BWC task. We used the R statistical software package version R.4.0.2 to obtain a fractional factorial design of 36 choice set profiles, divided into 6 blocks of 6 choice tasks. This is a D-efficient design (95.9%) that accounts for orthogonality, level balance, and minimum overlap.

3.3. Data Collection

The questionnaire consisted of three main sections. The first section was a brief introduction to the survey, which included background information on wood pellets, co-firing plants, and renewable energy certificates to highlight key GPP features. This section served to familiarize the respondents with terms used in the survey. This section also included introductory questions that assessed the respondent's knowledge of wood pellets, co-firing, and renewable energy in relation to features of green energy generation. In the second section, we introduced the BWC task, in which respondents were asked to identify the best and worst attributes, enroll to a hypothetical GPP, and identify their certainty level for desire to enroll (Figure 1). The third section solicited socioeconomic information about the respondent's demographic characteristics such as gender, age, education, occupation, household income, and place of residence.

(Check <u>one option</u> as the **<u>Best</u>** and one option as the **<u>Worst</u>**)

Best	Green Pricing Program (GPP)	Worst
☐	12-month contract	☐
☒	Fixed premium	☐
☐	Opt out of contract with a penalty	☐
☐	Energy generated in the State	☐
☐	Reduction of CO_2 emissions by 6-10%	☐
☐	Monthly premium payment of $20MWh	☒

Would you enroll in this green pricing program (GPP)

Yes ☒ No ☐

Extremely Uncertain	1	2	3	4	5	6	7	8	9	10	Extremely Certain
	☐	☐	☐	☐	☐	☐	☐	☒	☐	☐	

Figure 1. Example of a best/worst choice question for selecting attribute-level characteristics for hypothetical GPP for Alabama, New Jersey, New York, Pennsylvania, and Virginia. The first part illustrates the BWS component in which the attributes of the green pricing program are listed, and the respondent is tasked with choosing the best and worst attribute level. The second part illustrates the BC component represented by a referendum to enroll for this program. The third part is a certainty scale based on their vote to support/not support the GPP. In this GPP, the respondent chose (indicated with **x**) Fixed premium as the best attribute and monthly premium payment of $20 MWh as the worst attribute. The respondent also chose to enroll in the GPP and was certain by a scale of 8 to 10.

A pilot test was conducted with 60 respondents to test the length and clarity of the survey, the difficulty of the choice experiment tasks, and respondent fatigue [49]. The pilot test met the above stated threshold and responses were included in the final survey that was distributed to the sample population. To reduce sampling bias, the key demographic characteristics were balanced with pooled US Census 2019 data for the five states, as illustrated in Table 2 [35,38,50,51]. The online survey was administered by Qualtrics, providing modest compensation to survey participants in August 2020. Our target respondents were adult (18 years or older) residents of AL, NJ, NY, PA, and VA. Qualtrics sent out a total of 5421 invitations to potential participants, from which we received a total of 2000 complete responses (AL = 400, NJ = 400, NY = 400, PA = 400, VA = 400) resulting in a 36.9% response rate.

Table 2. Socio-demographic characteristics of survey respondents' vs. the pooled US Census for the five states (AL, NJ, NY, PA, VA).

Category	Sample Population (*n* = 2000)	US Census [a]
Median age (years)	39.50	39.62
Household size (people)	2.64	2.58
Education attainment (high school or higher %)	97.35	89.62
Female (%)	50.00	51.20
Median household income (USD USD)	*74,999.50*	*69,902.40*
Monthly power bill (USD USD)	123.32	122.15
Employment rate (%)	52.45	58.88

The sample mean is shown in italics, and the population mean and sample mean are not equal at the 5% level according to the Pearson χ^2 test. [a] US Census bureau 2019 [50].

4. Results and Discussion

4.1. State Socio-Demographic Variables

We conducted a Pearson chi-square test for socio-demographic variables (Table 2) to confirm the representativeness of our sample to the pooled US census data for the five eastern states. The null hypothesis for the equality of the means at the 5% significance level was rejected for the median income variable. There was no statistically significant difference reported for the other six socio-demographic characteristics, indicating a goodness of fit.

4.2. Introductory Questions

Some findings about the trends in respondents' awareness, knowledge, and enrollment in wood pellets, co-firing, and GPPs from the introductory questions are summarized as follows. A total of 33.57% of respondents from the Eastern states were aware of the sources from which their energy provider generates energy. A closer state-wise analysis reveals that respondents from AL had the greatest percentage at 38.5% followed by NY (37.5%), VA (36.75%), PA (29.50%), and NJ (25.50%), respectively. In addition, 28.56% of the Eastern state respondents were aware of existing GPPs in their respective states. A state-wise comparison revealed similar trends as the levels of awareness of existing GPPs were highest in NY at 39.5% and the lowest awareness level was found in AL at 22.75%. The low levels of awareness of existing GPPs in Alabama could be due to the lack of state mandated RPS for energy providers, thus reducing the momentum for developing GPPs, coupled with subsequent marketing that often increases awareness [52]. Even so, out of all the respondents in the five states, only 13.42% were enrolled in a GPP offered by their energy provider. The rates of enrollment in a GPP were highest in NY (23.75%), followed by VA (11.75%), AL (10.75%), NJ (10.50%), and PA (9.25%). The high enrollment rates in NY correlate with the higher production of renewable energy found there as compared to the other states, where NY produces 9.4 million MWh, followed by AL (4.6 million MWh), PA and VA (2.3 million MWh), and NJ (0.5 million MWh) [53]. The presence of a source of renewable energy may push the momentum towards developing GPPs. A National Renewable Energy Laboratory (NREL) technical report by Bird and Swezey [54] showed that GPPs enrollment rates were 1.3% in the US, whereas, by 2018, there was a total of 885,000 customers purchasing 8.9 million MWh of green power from utility GPPs, indicating an increase of 55.26% [25]. We further assessed the respondents' level of awareness of existing co-firing plants in the Eastern states. Our results show that only 22.64% of respondents were aware of the existence of co-firing plants in their state of residence, from which only 14.81% of respondents were aware of energy generation plants using wood pellets in co-firing technology to generate electricity.

4.3. Paired Estimates for BWS

In this section we analyze both the state-wise (AL, NJ, NY, PA, VA) and the pooled state estimates, which are a combination of total number of respondents from the five Eastern states. We used a paired estimation method that applies the best/worst pairs instead of the attribute level observations [55]. For the attribute estimation in the first step of the analysis, the 'GP attribute', was the omitted variable and used as a baseline/reference for the other attributes to avoid the dummy variable trap [55]. All attributes for the pooled estimates were positive and significant, meaning that the respondents valued all the attributes presented in the hypothetical GPP task (Table 3). The reduction of carbon emissions (RC) was the most valued attribute, followed by location of energy generation (LG), variability of payments (VP), flexibility of contract (FC), and length of contract (LC), respectively. Basu et al. [14] found that co-firing is a viable alternative to other CO_2 reduction technologies for conventional fossil fuel power plants; our findings show that, for consumer support, any GPPs designed to back co-firing plants must have a comprehensive carbon reduction approach. In the case of co-firing coal with wood pellets, the wood pellet to coal ratio should result in energy production that is carbon neutral, as seen in studies by Johnsten and Kooten [12], Kebede et al. [13], and Roni et al. [11]. A closer analysis of the state-wise attributes reveals that the LC, VP, and FC attributes were not significant for respondents from NJ, whereas LC was not significant in AL. It is plausible that these outcomes can be attributed to the lower GPP enrollment rates within respondents in these states as seen in Section 4.2. Although, these three attributes are key to the energy providers, they have an insignificant impact on AL and NJ residents' value of GPP in their states.

Table 3. Paired model conditional logit parameter estimates for hypothetical biomass GPPs.

	Alabama	New Jersey	New York Coeff (Std Dev)	Pennsylvania	Virginia	Pooled States
Attribute impacts						
LC	0.139 (0.093)	−0.131 (0.094)	0.424 (0.095) ***	0.299 (0.095) **	0.341 (0.095) ***	0.213 (0.042) ***
VP	0.328 (0.094) ***	0.071 (0.095)	0.478 (0.095) ***	0.324 (0.095) ***	0.519 (0.096) ***	0.342 (0.042) ***
FC	0.238 (0.086) **	0.063 (0.087)	0.279 (0.087) ***	0.202 (0.087) **	0.403 (0.087) ***	0.235 (0.039) ***
LG	0.348 (0.087) ***	0.350 (0.089) ***	0.534 (0.088) ***	0.429 (0.089) ***	0.556 (0.090) ***	0.440 (0.040) ***
RC	0.970 (0.094) ***	1.215 (0.096) ***	1.186 (0.094) ***	1.375 (0.097) ***	1.544 (0.097) ***	1.249 (0.043) ***
Level scale values						
M6	−0.559 (0.091) ***	−0.516 (0.092) ***	−0.270 (0.091) ***	−0.656 (0.093) ***	−0.577 (0.093) ***	−0.510 (0.041) ***
M12	0.308 (0.091) ***	0.448 (0.092) ***	0.338 (0.091) ***	0.477 (0.093) ***	0.449 (0.093) ***	0.400 (0.041) ***
FP	−0.875 (0.088) ***	−1.075 (0.090) ***	−0.859 (0.089) ***	−1.376 (0.090) ***	−1.110 (0.090) ***	−1.051 (0.040) ***
F5	0.187 (0.088) ***	0.319 (0.089) ***	0.101 (0.089)	0.359 (0.089) ***	0.273 (0.090) **	0.247 (0.040) ***
NOPEN	1.081 (0.074) ***	1.214 (0.076) ***	0.967 (0.074) ***	1.555 (0.076) ***	1.310 (0.075) ***	1.216 (0.034) ***
INSTATE	0.761 (0.075) ***	0.527 (0.077) ***	0.508 (0.074) ***	0.814 (0.077) ***	0.704 (0.077) ***	0.659 (0.034) ***
MED	0.450 (0.090) ***	0.292 (0.090) ***	0.325 (0.089) ***	0.398 (0.092) ***	0.299 (0.091) ***	0.346 (0.040) ***
HIGH	0.541 (0.091) ***	0.677 (0.091) ***	0.427 (0.089) ***	0.691 (0.092) ***	0.551 (0.091) ***	0.574 (0.041) ***
USD 10/MWH	−1.530 (0.104) ***	−1.346 (0.106) ***	−1.345 (0.105) ***	−1.683 (0.107) ***	−1.714 (0.106) ***	−1.512 (0.047) ***
USD 20/MWH	1.046 (0.104) ***	1.098 (0.106) ***	1.057 (0.105) ***	1.355 (0.107) ***	1.413 (0.108) ***	−1.183 (0.047) ***
USD 30/MWH	0.456 (0.104) ***	0.453 (0.107) ***	0.587 (0.104) ***	0.601 (0.107) ***	0.633 (0.106) ***	0.541 (0.047) ***
No. of observations	72,000	72,000	71,970	72,000	71,970	359,910
No. of respondents	400	400	400	400	400	2000
Log likelihood	−7421.826	−7421.826	−7711.252	−7355.097	−7421.699	−37,670.374

*** indicates significance at 1% level, ** indicates significance at 5% level. Note that the attribute REC and attribute levels (M24, F10, PEN, OUTSTATE, LOW, USD 40/MWH) were the omitted/baseline variables.

In the second step of the BWS analysis, we evaluated the results of the attribute level scaling. For the length of contract (LC) attribute, the pooled state estimates for the level scale reveal that the contract length of 6 months (6 M) had a negative coefficient relative to the baseline level scale of 24 months (24 M). The 12-month (12 M) contract had a positive coefficient, showing that a moderate duration contract was more important than contracts that were either too short or too long. While looking at the state wise contract length attribute levels, similar trends were observed for all the individual Eastern states. Gai et al. [56] found that dynamic contracts for community solar programs were most amenable to energy consumers in the US, where contract length options were consumer-led and variable depending on their specific needs to mitigate financial risk.

For the variability of payments (VP) attribute's level scale values, the results for the pooled state estimates show that the fixed premium level scale (FP) had a negative and significant coefficient as opposed to the fluctuating premium ± 5% (F5), translating to respondents valuing fluctuating premiums as opposed to fixed premiums. In the state-wise analysis, similar trends were observed for all the individual Eastern states except for NY respondents, where the F5 level scale was not significant. Perhaps, the higher enrollment rates in this state is attributed to consumers having a greater sense of the value of fixed premiums as opposed to fluctuating premiums. Fluctuating premiums account for changes in market trends such as the cost of wood pellets and operations [14]. From a co-firing energy plant perspective, this outcome should be an incentive to incorporate wood pellet-based co-firing and tap into green energy subsidies from consumer-based programs. Likewise, Kaenzig et al. [46] found that contract terms such as price guarantee (corresponding to our variability attribute) and cancellation period (corresponding to our contract length attribute) were more important in explaining consumer choices as opposed to the other attributes applied in their study. Other studies [31,46,57,58] show that low enrollment rates to GPPs can be attributed to deterrent premiums.

The level scale value for the flexibility of contract (FC) attribute was positive and statistically significant for both the state-wise and pooled estimates, indicating that respondents support GPPs with no penalties (NOPEN). This outcome was expected given that penalties detract customers from enrolling onto GPPs. Across all Eastern states, having an open agreement with no penalties held the most value in a consumer's choice to support a GPP. This finding is critical for developing an acceptable GPP; however, it does cause complications for the GPP provider. If the GPP provider were to not include a breach of contract penalty, it could lead to high participation with low retention. Studies have shown that incentives rather than penalties show higher retention rates in loyalty programs; our findings suggest that the use of contract breach penalties would be an inadvisable route. Respondents' preference for fluctuating rates poses a related challenge: with no breach of contract penalty there is an incentive to break the contract when rates increase. Incentives that address this attribute would be a key component for ensuring program retention [25,26]. On the contrary, Gamma et al. [59], performed a study investigating customer engagement in demand response programs. While investigating the role of reward and punishment in customer adoption in Switzerland, they found mixed results as punishment was as effective in engaging customers in sustainable technology innovation. However, their interpretations seem to agree with our findings, as they assert that customers will strongly favor their own personal benefit over the collective benefit, especially if the design of the program is based on self-serving reasons over collective benefits. Correspondingly, Swim and Geiger's [60] study on policy attributes, perceived impacts, and climate change policy preferences showed that participants preferred policies that use incentives over disincentives especially when polices target individuals.

The location of generation (LG) level scale values suggests a greater value for co-firing energy plants in the state (INSTATE) as opposed to out of state (OUTSTATE). The state-wise analysis shows that PA and AL have the highest parameter estimates, which corresponds to the fact that there is an existing workforce in the coal industry [61]. Respondents will value GPPs that provide direct benefits to their local environment and economy. Benefits such as reduced fuel costs, reduced emissions, and creation of a stronger locally based fuel supply. For the reduction of carbon emissions (RC) attribute, all the level scales were significant, showing that respondents value GPPs that result in a significant reduction in local emissions by 11–20% (HIGH), followed by 6–10% (MED) for the pooled states. The state wise analysis also reveals the same trend for the RC attribute levels as all respondents in the five Eastern states valued GPPs that result in higher levels of carbon reduction. Knapp et al. [31] conducted a comparative study of stated and revealed preferences for green electricity in the US. Their findings reveal that there are higher GPPs participation rates in areas where consumers have strong feelings about the environmental impacts of energy. Contradictory outcomes from Drake et al.'s [62] study on public preferences about the production of local and global ecosystem services lean toward preferences for achieving CO_2 reduction through national as opposed to local ecosystem services. Their study emphasizes consumer preferences for collective benefits of CO_2 emission reduction (global) over the proximity of the agent of benefit to their residence (local). This phenomenon is also known as not in my backyard (NIMBYism) [43].

Although we expected the premium payment for renewable energy certificates (GP) to have a negative utility with ascending costs, there was an exception as both the pooled and state-wise respondents valued moderate premium payment of USD 30/MWh as opposed to the lower premium payment of USD 20/MWh and higher payments of USD 40/MWh. Perhaps this outcome can be attributed to the benefits of GPPs reflected in the attractive attributes such as location, carbon emissions, flexible and variable premiums that customers find attractive and attach higher values to. This analysis further underscores the importance of conducting two tiered BWC modelling, as it explores the inherent value (utility) as well as the fiscal value of attributes.

4.4. Estimation of Binary Choice Task

By including a BC task, we can compare whether respondents give an intrinsic monetary value to corresponding attributes in the BWS analysis task. In this section we consider an analysis of the pooled eastern states and a calibrated model for WTP to further test for hypothetical bias (consequentiality). It is important to note in this section that the GPP payment (cost attribute levels) was converted into a single continuous attribute to facilitate the WTP analysis. The results displayed in Table 4 column 2 show similarities in terms of magnitude and signs to corresponding pooled states parameter estimates in Table 3. For instance, the parameter estimates for the level scales of the attributes flexibility of contract (NOPEN), in-state program location (INSTATE), and reduction of carbon emissions (HIGH) and (MED) in the BC task are comparable to the corresponding parameter coefficients in the BWS analysis. For the other attributes' levels scales, although all the signs were significant, there were some puzzling results in terms of expected signs. The length of contract (LC) attribute's the level scale in the BWS analysis task for the six-month contract (M6) had a negative sign whereas in the BC task, M6 had a positive sign for the combined Eastern states. However, for the 12-month contracts the M12 level scales were positive in both tasks. Similarly, for the variability of payments (VP) attributes, the levels scale fixed premium (FP) had a negative sign in the BWS analysis task and positive sign in the BC task, whereas, for the fluctuating premium (F5), the signs were positive in both tasks. These results suggest that, even for the same survey task, there may be subtle differences in the BWS measuring importance and the BC task that measured utility.

Table 4. Results from binary choice logit model and calibrated model estimations with parameter estimates and WTP values for hypothetical wood pellet green energy programs.

	Binary Logit		**Calibrated Model (Certainty Scale 7 Cut Off)**	
Attribute Level	**Parameter Estimates**	**WTP (USD)**	**Parameter Estimates**	**WTP (USD)**
M6	0.230 (0.042) ***	17.13	0.341 (0.050) ***	77.28
M12	0.097 (0.044) **	7.25	0.306 (0.053) ***	69.31
FP	0.122 (0.045) **	9.06	0.165 (0.054) **	37.37
F5	0.077 (0.045) *	5.74	0.112 (0.054) **	25.38
NOPEN	0.084 (0.036) **	6.28	0.151 (0.042) ***	34.30
INSTATE	0.069 (0.036) *	5.10	0.238 (0.042) ***	54.03
MED	0.116 (0.045) **	8.61	0.273 (0.055) ***	61.92
HIGH	0.209 (0.043) ***	15.55	0.447 (0.506) ***	101.33
GP	−0.013 (0.001) ***		−0.004 (0.001) **	
No. of respondents	2000			
No. of Observations	23,994			
Log likelihood	−8237.32		−12,016.41	

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Values in parentheses show standard errors. The attribute levels (M24, F10, Pen, Outstate, Low) were the omitted/baseline variables.

The marginal WTP measures represented in Table 4, column 3 show that the LC attribute attracted the highest WTP with M6 (USD 17.13) and M12 (USD 7.25) values, followed by reduction of carbon emission attributes with HIGH level attracting a WTP of USD 15.55 and MED (USD 8.61). This was followed by the variability of payment (VP) attribute with fixed premium at USD 9.06 and fluctuating premium $\pm$ 5% at USD 5.74. This result can be attributed to consumer aversion to the rising market trends for green energy certificates [24,46]. While the WTP values for NOPEN were USD 6.28 and USD 5.10 for IN-STATE, respectively, it is apparent from the results in Table 4 column 3 that there is a greater utility for energy generation in the state. Kaeznig et al. [46] found that location attributes had the strongest influence on customer choices when compared to monthly costs and electricity mix attributes. Consumers preferred electricity produced in their own region (Germany) as opposed to imports from other European countries. The reasons for these higher preferences can be attributed to local energy customers associating domestic power with a higher level of energy supply and security. Correspondingly, Bae and Rishi [22] found that consumers prefer green power plants that are closer to their homes. Sagebiel et al. [48] had similar findings with consumers having an additional willingness to pay for local suppliers of 3.72 Eurocent/Kwh. They concluded that locally produced electricity may reduce information and enforcement costs, as consumers can easily monitor how their electricity is produced, thus creating trust.

The level scale values used to measure length of contract suggest that longer contracts of 12 months (12 M) attract lower WTP as opposed to shorter contract lengths of 6 months (6 M) by up to USD 9.88. On the contrary, Kaenzig et al. [46], found that the contract length (cancellation period) had a minor influence on product choice whereas long-term price guarantee (a measure of variability) had some positive customer value. It is evident that even hypothetical green energy consumers are sensitive to financial commitments that are drawn over longer periods. For the carbon reduction (RC) attribute's levels, there was an increase in utility from (6–10%) MED to (11–20%) LOW of USD 6.94. This was an expected outcome, as respondents in all the Eastern states preferred GPPs that reduce carbon emission, given the fact that heightened global concern and the subsequent impetus to reduce global carbon emissions has successfully sensitized respondents on the importance of carbon emissions reduction. This outcome is consistent with other studies by Oluoch et al. [47], Soto et al. [37], and Susaeta et al. [19] who used carbon emission reduction as an attribute.

To adjust for the hypothetical bias (consequentiality) that is a common concern for stated preference WTP estimates, we applied a calibrated model as designed by Morrison and Brown [42]. The calibrated model applies cut-off values for certainty scales ranging from seven to ten with an assumption that the real WTP is closer to the calibrated model. For our case, we applied a cut-off of seven (Table 4, column 4). The binary logit WTP values for our calibrated model are higher than the observed WTP values. This outcome is consistent with observations from Morrison and Brown [42], which suggests that our WTP values were not over-estimated to surpass the real WTP. Furthermore, Whitehead and Cherry [63] assert that the tendency for hypothetical WTP can overestimate real WTP. They caution that approaches for measuring consequentiality should be considered as complements and not substitutes.

5. Conclusions

In the US, existing co-firing plants have an important role to play in energy generation despite emerging renewable energy technologies. Wood pellets, which are mainly exported, can be redirected for use in co-firing coal plants. One way to sustainably use wood pellets for co-firing is to create consumer supported GPPs. Our research investigates the public's preferences for the attributes of hypothetical GPPs. To estimate these values, 2000 respondents were surveyed using a BWC model for analysis. Low levels of awareness of (28.56%) and current enrollment (13.42%) in GPPs shows that there is a dire need for public education and exposure to promote GPPs. The BWC model, however, shows that respondents value attributes of GPPs despite low awareness levels, and are willing to pay a premium for certain attributes. Overall, the BWS analysis shows that residents in all five states highly value flexible contracts, in-state energy generation, and the reduction of carbon emission attributes. The results of the BC experiment, however, show that respondents are most willing to pay for a shorter contract length, followed by the reduction of carbon emissions, variability of payments, flexible contracts, and in-state energy generation, respectively. Based on these confounding results, we believe that there is not a one-size-fits-all solution for GPPs. Consequently, the focus should be on state or regional policy development as opposed to broad-based national energy policies.

From a policy standpoint, the outcome of this study demonstrates that energy consumer support for wood pellet co-firing energy generation can be achieved by creating GPPs to meet consumers' needs and creating real customer value. Decision makers can use this study's findings as evidence for the potential of biomass GPPs. An amenable policy could help support GPPs by removing bottlenecks that facilitate easier access to wood pellets across state lines and meet market demands resulting in biomass market price fluctuations. Regulating of the carbon market, providing suitable subsidies for co-firing companies that introduce GPPs, and increasing public education of GPPs are key to successful outcomes. Tax breaks and government assistance for independent marketers can further assist in making GPPs more popular among residents. Since there are few incentives for the production or application of biomass co-firing such as the PTC [15]. The introduction of GPPs as proposed in our study will introduce new avenues for income and motivation for utility companies to increase their utilization of biomass (wood pellets) for co-firing. As it stands, the only motivation for the use of the wood pellet is competitive coal prices. Consequently, incentives such as subsidies, low interest loans, grants, rebates, and financial plans for the retrofitting and conversion of plants to enable wood pellet co-firing, should be considered by decision makers to hasten the process of the adoption of wood pellets in co-firing. Currently, 17% of coal-fired plants may close due to failure to comply with existing RPS mandates. These closures may result in job losses and higher electricity prices [15]. GPPs as proposed in our study present a dual solution to coal power energy providers. These hypothetical programs provide a framework for supporting the transition from non-compliance to a more environmentally friendly co-firing wood pellet-based system to meet the RPS mandates.

For existing and prospective energy generating companies with co-firing capabilities, the results from this study suggest that there is an existing marketing potential, based on consumer willingness to pay for GPPs. Utility companies can take advantage of co-firing technologies by applying market strategies that weigh the intricate balance between the reduction of carbon emissions and ensuring suitable return on investments. Energy generating companies can benefit from the carbon offset tax credits resulting from wood pellet uptake for energy generation, thus making co-firing plants profitable and environmentally sustainable. Further benefits from consumers through enrollment to GPPs will assist in ensuring that biomass renewable energy certificates ensure a return on investment and meet carbon offset targets. Overall, our study suggests that there is potential for GPPs. The success of GPPs will depend on increasing enrollment and public support. In other words, the next step will involve increasing awareness levels and green consciousness through sensitization exercises such as public education and media campaigns to inform and educate the public on the benefits of GPPs. Energy consumers stand to benefit from participating in GPPs when energy providers develop programs that meet consumers' needs through a supportive policy framework by including favorable attributes. The information from this study and future studies revealing consumer preferences can further assist in developing optimal attribute packages to maximize enrollment into biomass based GPPs. The outcomes of this study can be used to build a mountain of evidence showing that GPPs can be mutually beneficial and sustainable for utilities companies, the environment, consumers, local communities, and private landowners. Consequently, independent power marketers and third-party developers can play a critical role in bridging the awareness and low enrollment gap by initiating aggressive awareness campaigns to promote biomass-based GPPs. From a marketing perspective, the potential for co-firing with wood pellets presents a business opportunity for landowners, residents, marketing companies, and the transportation sector. This opportunity can further stimulate local economies and provide a regional market for wood pellets in the US.

Author Contributions: Conceptualization, S.O., P.L., A.S. and B.W.; Methodology, S.O., P.L., A.S. and B.W.; Software, S.O., P.L., A.S. and B.W.; Validation, S.O., P.L., A.S. and B.W.; Formal analysis, S.O., P.L., A.S. and B.W.; Investigation, S.O., P.L., A.S. and B.W.; Resources, S.O., P.L., A.S. and B.W.; Data curation, S.O. and A.S.; Writing—original draft, S.O., A.S. and M.S.; Writing—review & editing, S.O., P.L., A.S. and M.S.; Visualization, P.L. and A.S.; Supervision, P.L. and A.S.; Project administration, A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by the United States Department of Agriculture (USDA) NIFA award 6142 and National Science Foundation (NSF) Award 1555123. The APC was funded by Northern Kentucky University (Biological Science Department).

Data Availability Statement: The data that support the finding of this study are available on request from the corresponding author due to ethical reasons.

Acknowledgments: The authors gratefully acknowledge the support of the Clean Energy and Sustainability Analytics Center at Montclair State University. The authors would like to thank the Clean Energy and Sustainability Analytics Center researchers for their support on research endeavors. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not reflect the views of the Montclair State University or USDA.

Conflicts of Interest: The authors declare no conflict of interest.

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