

Quantifying Social Preferences toward Woody Biomass Energy Generation in Montana, USA

Robert Campbell
University of Montana
robert3.campbell@umontana.edu

Tyron Venn
University of Montana
tyron.venn@umontana.edu

Nathaniel Anderson
USDA Forest Service, Rocky Mountain Research Station
nathanielmanderson@fs.fed.us

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1. Introduction

In 2009, about 83% of energy consumed in the US came from coal, oil and natural gas (EIA 2010). In order to reduce greenhouse gas (GHG) emissions and reliance on imported fossil fuels, the US government has passed legislation aimed at decreasing fossil fuels use through increased efficiency and increased production of renewable solar, wind, hydroelectric, geothermal and biomass energy (US 2005 Energy Policy Act and its 2007 amendment). About 2% of all energy generated in the United States (24% of renewable energy), presently comes from woody biomass (EIA 2010), and studies have found that woody biomass could eventually supply up to 10% of US energy needs (Zerbe 2006). A major barrier to market expansion of woody biomass energy in the United States has been its high production cost relative to fossil fuels (Gan and Smith 2006). However, there are significant negative externalities created by the extraction, transport, and combustion of fossil fuels for energy generation (National Academy of Sciences 2010), and potential positive externalities associated with woody biomass energy that if accounted for, may make woody biomass energy a socio-economically efficient option.

In order to place a dollar value on the externalities associated with energy generation, nonmarket valuation techniques are required. Nonmarket valuation studies have been used to quantify the value of a wide range of environmental goods and services associated with renewable energies. Studies have found positive willingness to pay (WTP) for various beneficial attributes associated with renewable energy sources, including reduced greenhouse gas emissions (Roe et al. 2001, Longo et al. 2008, Solomon and Johnson 2009, Susaeta et al. 2011, Solino et al. 2012), improved air quality (Roe et al. 2001, Bergmann et al. 2006), enhanced preservation of landscape quality (Álvarez-Farizo and Hanley 2002, Bergmann et al. 2006), reduced wildfire risk (Bergmann et al. 2006, Solino et al. 2012) and preservation of wildlife habitat and biodiversity (Álvarez-Farizo and Hanley 2002, Bergmann et al. 2006). Positive WTP has also been found for non-environmental attributes including energy security (Longo et al. 2008, Li et al. 2009) and rural employment (Solino et al. 2012).

There have been few studies to date that have focused specifically on public preferences for woody biomass energy generation. Susaeta et al. (2011) used a choice modeling exercise in Arkansas, Florida and Virginia to assess preferences for woody biomass electricity generation and its associated environmental effects. Respondents had positive (but statistically insignificant) WTP for improved forest health, reductions in CO₂ emissions and improvement of forest habitat from reduced wildfire risk. Some socioeconomic characteristics of respondents were found to be significant, with positive correlation between WTP and increased education level and knowledge of renewable energies. Because almost 90% of forest lands in the Southern US are privately owned, little of the woody biomass described in the Susaeta et al. (2011) study would come from public lands. In the absence of financial incentives, including markets for carbon, applications of the findings of this study to inform and influence private forest management and woody biomass energy generation appear limited. Solino et al. (2012) found positive WTP by people in Spain for reduced greenhouse gas emissions, reduced risk of forest fire and reduced pressure on natural resources associated with the utilization of woody biomass for electricity generation.

No past studies have evaluated preferences regarding woody biomass energy in the western United States, nor have previous studies evaluated preferences specifically toward feedstock generated by forest restoration treatments on public forests. The US West has unique geographic, ecological, and socioeconomic characteristics - perhaps the most significant of which in this context is the high proportion of public lands compared to other parts of the country. Public preferences are more relevant to, and can be more readily accommodated within, forest management policy in the western United States where public lands are abundant.

This study used choice modeling (CM), a non-market valuation technique, to examine public preferences toward the utilization of woody biomass from public forests for energy generation in Montana, USA. Preferences were characterized in terms of willingness to pay for increases in energy generated with woody biomass harvested from public forests and for potential effects of changes in public forest management and renewable energy policy on forest health, the prevalence of large wildfires, and air quality. Socioeconomic and attitudinal characteristics were utilized to explain preferences. By determining public willingness to trade-off woody biomass energy generation against important environmental attributes, the results of this study can inform public forest management and renewable energy policy in Montana.

This paper has six sections. In Section 2 a description of the geographic and socioeconomic characteristics of the study area are provided. Section 3 describes the development of the survey instrument used in the study. In Section 4 the econometric model used to analyze the data is described. Section 5 reports and discusses the results of the study, and in Section 6 the main findings are summarized.

2. Study area and co-benefits and costs of woody biomass energy

Montana's economy has historically relied heavily on agriculture and resource extraction through logging and mining, and the forest industry still accounts for a significant portion of economic activity in several counties in the state (McIver et al. 2013). As has been the trend throughout the West, Montana's economy is increasingly service oriented, fueled by tourism and migration based on natural amenities provided by the state's public lands and recreational opportunities (Rasker and Hansen 2000). The state is home to multiple national parks and national forests, which were the main attractant for 11 million travelers that visited Montana in 2013 (Grau et al. 2014). The state has a large, and expanding wildland-urban interface that allows residents to live amongst the natural amenities they desire, but also places their lives and homes at risk from wildfires (Rasker 2014).

With 23.3 million acres of forestland (Rummer et al. 2005) and 35% of land in the state under federal or state ownership, and Montana's economic reliance on resource extraction and amenity values from public forests; residents are likely to have strong preferences about public land management policy and practice.

In Montana, 9.5 million acres of forestland are classified as moderately or severely departed from natural fire regimes and could benefit from mechanical thinning treatments, prescribed wildland fire, or a combination of the two (Rummer et al. 2005). Forests that are departed from historic fire regimes

have increased tree density, structural homogenization, and fuels buildup (Taylor 2004), resulting from decades of wildfire suppression (Ryan et al. 2013). Forests that are departed from their historic conditions are less able to support native plant and animal species (Huntzinger 2003, Hiers et al. 2007), are less resilient to disturbances like insect and disease infestation, and more likely to experience unusually severe and damaging wildfires (Schwilk et al. 2009).

Prescribed fire or mechanical forest restoration treatments can increase the area of healthy forests that support a greater diversity of native plant and animal species, and are more resilient to human and natural disturbances like insect outbreaks, non-native invasive species, disease, wildfires and a changing climate (Swanson et al. 1994, Barrett et al. 2012). These treatments can also reduce the severity of large wildfires (Stephens et al. 2009) that can burn homes, damage important municipal watersheds, endanger firefighter and civilian lives, and blanket large areas with wildfire smoke. Some forestland can be treated with prescribed fire alone, but in cases where very high fuel loads are present, air quality restrictions are in place, or the forest is in close proximity to the wildland-urban interface, mechanical treatments may be required before, or in place of, prescribed fire (Rummer et al. 2005).

Existing and proposed legislation, like the Healthy Forests Restoration Act of 2003 and the Forest Jobs and Recreation Act of 2013 (specific to Montana), mandate increased amounts of timber harvest and restoration treatments on public forests, and encourage harvesting of woody biomass for energy generation (United States House of Representatives 2003 and 2013). Mechanical forest restoration treatments typically target small diameter trees with little or no value in traditional timber markets. A woody biomass energy market would provide an outlet for this material and provide needed funds to perform mechanical forest restoration treatments. However, harvesting woody biomass can also have a negative effect on forest health and biodiversity through reduced soil productivity (Thiffault et al. 2011), increasing opportunities for spread of invasive weeds, and increasing sediment runoff into streams (Shepard 2006). Additionally, in communities where woody biomass energy generation facilities are located, local air quality may be negatively impacted (Chum et al. 2011).

3. Choice modeling survey instrument

In order to determine which social and environmental effects associated with woody biomass energy generation are most important to residents of Montana, a focus group meeting was held in Missoula, Montana, in July of 2013. The meeting was attended by stakeholders from the United States Department of Agriculture Forest Service, Montana Department of Natural Resources, Montana Department of Environmental Quality, The University of Montana, The Montana Wilderness Association, the forest industry, wildlife and land conservation groups, and local recreation groups¹. The five most important attributes identified at this meeting were: homes powered with wood in the state (HOMES); unhealthy air days in “your” community (AIRDAYS); large wildfires in the state (WILDFIRES); forest health

¹ Representatives from tribal forestry, private forest owners, and environmental groups with a strong anti-biomass energy stance were contacted about attending the meeting, but were either unavailable or uninterested in attending.

in the state (FORESTS); and household monthly energy bill (BILL)². Each attribute was defined over a ten-year time horizon to provide a realistic time-frame in which to adopt and implement new forest management strategies, while also remaining relevant to respondents. The attributes are defined and their status quo and alternative levels reported in Table 1. A more thorough description is provided below for aid in interpretation of the results.

Table 1. Definitions of choice attributes and quadratic variables

Variable	Definition	Levels
<i>Choice attributes</i>		
HOMES	A measure of the amount of woody biomass energy produced per year	10000, 20000*, 30000, 50000
AIRDAYS	The number of days per year when air quality is unhealthy for sensitive groups	5, 10*, 15, 30
WILDFIRES	The number of wildfires per year that burn at least 1000 acres and threaten homes and watersheds	6, 9, 12*, 15
FORESTS	The percent of healthy forestland	10, 20*, 30, 60
BILL	Household average monthly energy bill	80, 100*, 120, 150, 200, 400
<i>Quadratic variables</i>		
HOMES_SQ	Squared value of HOMES	
AIRDAYS_SQ	Squared value of AIRDAYS	
FORESTS_SQ	Squared value of FORESTS	
BILL_SQ	Squared value of BILL	

Note: * indicates status quo attribute level

HOMES was defined based on feedback from focus group participants that numbers of homes powered would resonate more and be more easily interpretable than a unit of electricity or power generation such as kilowatt hours or British thermal units (Btus). The source of the biomass was described as wood produced by restoration treatments on public forests. The energy was described as electric or thermal energy produced by a mixture of both large and small-scale facilities and excluding heat produced by wood stoves for household use.

AIRDAYS was based on the average number of days over a five-year span that air quality was recorded as “unhealthy for sensitive groups” at United States Environmental Protection Agency monitoring stations throughout the state, representing the average number of days the average Montanan household is exposed to levels of air pollutant concentrations that are high enough to pose a health risk to older adults, young children and people with specific health concerns (EPA 2013). The definition included an explanation that it is also possible that long-term exposure to air quality that is

² A sixth attribute, “Rural Job Creation” was ranked as important and initially included in the survey, but was dropped after peer-review suggested that the survey was overly-complex. “Rural Job Creation” was dropped, rather than one of the attributes, but because market mechanisms exist which can be used to quantify the economic effects of job creation, unlike the other attributes which lack any market mechanism to capture their value to society.

unhealthy for sensitive groups may pose health risks to all member of the community and reduce life expectancy. Unhealthy for sensitive groups was preferred over the more drastic “unhealthy” as the measure for this attribute because the status quo level for “unhealthy” air days is very small across most of the state.

The WILDFIRES status quo level was determined using a GIS data set from the Monitoring Trends in Burn Severity project (MTBS 2012). The definition highlighted the average number of homes destroyed annually over the past decade in Montana but also stressed that majority of homes were destroyed by a small number of very destructive fires, that the number of fires that burn each year is highly variable, and that wildfires are an important beneficial natural disturbance necessary for healthy forest ecosystems.

The FORESTS definition emphasized the fact that healthy forests support a greater diversity of native plant and animal species and are more resilient to disturbances. Levels of forest health were defined in terms of percentage points, rather than land area because it was determined that such units would resonate better with respondents. The amount of healthy forests in Montana was determined using the Vegetation Condition Class classification system, which categorizes the level of departure of current vegetation conditions from a historic reference (Barrett et al. 2010).

The average household energy bill in Montana was used to define the status quo of the cost attribute (EIA 2011a). The annual equivalent of BILL was also provided in the choice sets to decrease the likelihood of respondents interpreting the amounts as inconsequential. Defining BILL in terms of a standard household expense, rather than a government tax or fee, was considered to be a good way to minimize protest responses from respondents who may have positive WTP for the attributes in the survey, but who are fundamentally opposed to tax increases.

Based on the five attributes and their levels ($4^4 \times 6^1$), there are 1,536 possible combinations. Using SAS statistical analysis software and the macros described by Kuhfeld (2010), an efficient fractional factorial experimental design was created with 48 alternative combinations of the attributes. An efficient design size with 48 alternatives had 2 non-status quo alternatives per choice set, four choice sets per respondent, and six survey blocks. The alternatives were combined into 24 choice sets, and a status-quo alternative was added to each choice set to provide a “no-change” option. Respondents were randomly assigned a survey with one of the choice set blocks.

The 16-page survey instrument contained four sections. Section 1 provided a short introduction and collected information on respondent residence and opinions about sources of energy generation, public lands management, and climate change. Section 2 provided background information about energy consumption in the United States, forest restoration treatments, and details about what woody biomass energy is, how it is generated, sustainable levels of production from public forests in Montana, and what costs and benefits have been associated with the harvesting and energy generation activities. Section 2 also collected more information about respondent attitudes toward energy and public lands³.

³ These questions were placed after the background information because they were more detailed than questions in section 1, and required the knowledge of some terms presented in the background information. In addition to

Section 3 defined the attributes and presented the respondent with the choice sets. In order to allow a wide variety of attribute level combinations to be presented, a statement was made reinforcing the fact that any combination of attribute levels was possible, even if they seemed unlikely to the respondent. Respondents were reminded to consider their budget constraints and alternative uses of their income. An example choice set is provided in Figure 1. Section 4 collected information about the respondents' experience with the survey and sociodemographic information, which allowed comparison between the collected sample and the general population of the state.

Figure 1. Example Choice Set

Attribute		Expected outcomes over 10 years		
		Strategy A	Current Strategy	Strategy B
Homes powered with wood in my state		30,000 homes	20,000 homes	10,000 homes
Unhealthy air days in my community		5 days per year	10 days per year	30 days per year
Large wildfires in my state		12 large wildfires per year	12 large wildfires per year	9 large wildfires per year
Forest health in my state		60% healthy forests	20% healthy forests	20% healthy forests
My household's monthly energy bill		\$200 (\$2,400 annually)	\$100 (\$1,200 annually)	\$120 (\$1,440 annually)
I would choose (select one only)		☐	☐	☐

A mixed-mode data collection strategy was employed to obtain a stratified random sample of the population of Montana. Respondents were contacted with an invitation letter mailed to their home

the collection of information, these question, and the questions in section 1 served to prepare respondents for the choice sets by framing the issue and reminding respondents of the alternative renewable energy options, alternative uses of public forestland, and alternative uses of scarce forest management resources.

explaining the purpose of the research and presented with either (a) a web address and password to complete the survey online, or (b) a notification that they would soon be receiving a physical survey packet in the mail, or (c) a web address *and* the option to wait and receive a physical copy in the mail. The sample was stratified according to three criteria to ensure coverage of rural residents, people who live in forested areas and people who live in air-sheds with a history of poor air quality. Residents of forested areas were identified using US EPA level III Ecoregions (EPA 2013). Poor air-quality air-sheds were identified as EPA non-attainment air-sheds, which have failed to meet national ambient air quality standards (EPA 2013).

Individuals in the internet-only group received an invitation in the mail with a link and identification number that allowed them to access the survey online. Individuals who had not completed the survey after about two weeks received a reminder post-card in the mail. The mail version of the survey was distributed using the four-contact method described in Dillman (2007), which is designed to maximize response rate and minimize non-response bias. Using the four-contact method, respondents first received an invitation letter. About a week later, they received the survey packet and a token gift (a \$2 bill in this case). If they returned the survey, respondents received a thank-you letter, if not; they received a reminder post-card encouraging them to complete the survey. If the respondent still did not return the survey, a second copy was sent with a more strongly worded cover-letter stressing the importance of the research and their response. Individuals in the mixed-mode group received an invitation letter with a link to the internet survey and were encouraged to complete the survey online; they were also informed that if they preferred not to complete the survey online, they could wait and receive a physical copy in the mail. Individuals that did not complete the survey online after about two weeks received a physical copy in the mail and further contacts as defined under the Dillman method.

4. Econometric model

Analysis of CM data is based on economic theory about consumer choice and utility maximization; specifically, random utility maximization (McFadden 1973) and the characteristics theory of value (Lancaster 1966). Based on the characteristics theory of value, an individual's demand for a given alternative is determined by the alternative's characteristic attributes.

Based on this theory, CM allows an environmental good comprised of multiple attributes to be valued according to preferences for each attribute. This makes CM ideally suited for quantifying the multiple environmental effects associated with utilizing woody biomass from public forests for energy generation. Random utility explains that the utility associated with a particular alternative from a choice set is composed of both an observable and a random component,

$$U_j = V(x_j, p_j; \beta) + \varepsilon_j \quad (1)$$

where U_j is the true but unobservable utility associated with the consumption of profile j , V is the systematic indirect utility function, x_j is a vector of the attribute levels associated with profile j , p_j is the cost of profile j , β is a vector of preference parameters, and ε_j is a random error term. An individual will only select alternative i over alternative j if the utility associated with alternative i is greater than the

utility from alternative j . Because the stochastic components are unobservable, the probability that an individual will choose alternative i from a choice set C is predicted as

$$P(i|C) = P(U_i > U_j) = P(V_i + \varepsilon_i > V_j + \varepsilon_j), \forall j \in C. \quad (2)$$

where the probability of an individual choosing alternative i over alternative j , is equal to the probability that the sum of systematic and stochastic elements of utility from alternative i are greater than the sum of systematic and stochastic elements of utility from alternative j . This can be rearranged to yield

$$P(i|C) = P(U_i > U_j) = P(V_i - V_j > \varepsilon_i - \varepsilon_j), \forall j \in C. \quad (3)$$

which states that the probability of choosing alternative i over alternative j , is equal to the probability that the difference between the random components of utility from alternatives i and j is less than the difference between the systematic components for those same alternatives.

By assuming that the errors in the regression can be described by a Gumbel distribution, a multinomial logit model can be specified. The MNL specification that describes the probability of selection in this case is

$$P(i|C) = \frac{\exp(\mu V_i)}{\sum \exp(\mu V_j)} \quad (4)$$

where μ is a scale parameter inversely proportional to the variance of the error term. By assuming constant error variance, this parameter can be set to equal one (Ben-Akiva and Lerman 1985). Two MNL specifications were fit in this study. The first model contained only the choice attributes, represented by equation (5). The second model specification, represented by equation (6), was expanded to include socioeconomic and attitudinal variables, and squared versions of the attributes to account for non-linearities in the relationships between changes in the attribute levels and likelihood of selecting a particular alternative. In the base model, the assumption is made that preferences are homogeneous across respondents. This assumption may not hold true because there are individual characteristics that are likely to explain some portion of the preferences that people have toward environmental goods. This preference heterogeneity is taken into account in the full model by including individual characteristics as explanatory variables. The squared term for the wildfire attribute was excluded from the final model because of statistical insignificance during earlier iterations of the model.

$$P_n(i|C_n) = \frac{\exp(\beta_{ni}X_{ni} + \alpha C_n + \tau Q_{ni})}{\sum \exp(\beta_{nj}X_{nj} + \alpha C_n + \tau Q_{nj})} \quad (5)$$

$$P_n(i|C_n) = \frac{\exp(\beta_{ni}X_{ni} + \lambda_{ni}X_{ni}^2 + \alpha C_n + \tau Q_{ni} + \gamma R_n X_i + \theta R_n C_n)}{\sum \exp(\beta_{nj}X_{nj} + \lambda_{nj}X_{nj}^2 + \alpha C_n + \tau Q_{nj} + \gamma R_n X_j + \theta R_n C_n)} \quad (6)$$

X_{ni} is a vector of terms for the attribute levels; β_{ni} is a vector of associated estimated coefficients; X_{ni}^2 is a vector of terms for the attribute levels, squared with associated coefficient λ_{ni} ; C_n is the cost attribute associated with each alternative and α is the associated coefficient; Q_{ni} is an alternative specific constant (ASC), taking a value of 1 for status quo alternatives and zero otherwise,

with an associated coefficient of τ ; and R_n is a vector of case-specific socioeconomic characteristics, that appear in the regressions as interaction terms, multiplied by the alternative-specific attribute-level variables, and having an associated coefficient of γ . The coefficients were estimated using maximum likelihood estimation. Tables 1 and 2 provide descriptions of all the variables used in the models.

The ASC accounts for variation in choice that is not explained by changes in choice attribute levels, average monthly energy bill, or socioeconomic characteristics. Sometime referred to as “status quo bias”, this phenomenon results in decision-makers selecting the status quo at a rate higher than would be predicted by an economic model of consumer decision making (Samuelson and Zeckhauser 1988). This paper uses the more neutral term “status quo effect” (SQE) to avoid the suggestion that this phenomenon is the result of some sort of flaw. There are numerous rational and psychological explanations for the presence of the SQE (Adamowicz et al. 1998, Boxall et al. 2009). Failing to account for the SQE can result in model estimates that overstate the effect of changes in attributes on respondent choices (Samuelson and Zeckhauser 1988).

In order to obtain policy relevant interpretations of the estimated coefficients, the marginal effects of each attribute must be calculated. Based on the models represented by equations (5) and (6), for attributes 1 through K the average household marginal willingness to pay for a one-unit improvement in the k th attribute can be estimated by equations (7) and (8), respectively

$$\frac{\beta_n}{\alpha} \quad (7)$$

$$\left(\frac{\beta_n + \sum_{m=1}^M \gamma_{nm} G_m}{\alpha + \sum_{m=1}^M \theta_{nm} G_m} \right) \quad (8)$$

where G represents the fraction of the population in Montana that falls into each of the m socio-economic or attitudinal categories (as reported in Table 2), and all other parameters are defined as above. Based on the method used by Han et al. (2008), equation (8) produces adjusted average household MWTP that corrects for the potential that survey respondents were not representative of the demographic characteristics of the study area as a whole.

Table 2. Sociodemographic and attitudinal variables with Montana and survey sample means

Variable	Definition	Montana (%)	Sample (%)
CLIMATE	dummy variable =1 for people who do not believe in man-made climate change	52.0 ^a	50.7
HIGHINC	dummy variable =1 for households with annual income > \$150k	5.1 ^b	5.0
COLLEGE	dummy variable =1 for individuals with at least a bachelor's degree	28.7 ^b	49.8
SENIOR	dummy variable =1 for people who are 65 years old or older	16.0 ^b	39.5

^a Source: Leiserowitz et al. 2015

^b Source: United States Census Bureau

5. Results

The survey effort yielded 540 total responses for the state of Montana. Of these, 478 contained completed choice set sets and were included in the data analysis. 5,433 internet-only invitations were mailed but 374 were returned as undeliverable. The 5,059 internet-only invitations that were delivered to homes yielded 300 survey responses and an effective response rate of 5.9%. With an effective response rate of 50%, the 343 mixed-mode survey invitations that were sent (310 were delivered) resulted in 154 returned surveys. 174 mail-only surveys were sent and 159 delivered to homes, yielding 86 returned surveys and an effective response rate of 54%.

The survey respondents were on average older, better educated, and wealthier than residents of the state as a whole (Table 2). Based on preliminary questions in the survey, respondents appeared to have an interest in issues related to the attributes in the choice sets. While only 41% of respondents stated in a preliminary question that they would be willing to pay higher monthly energy bills for renewable energy, 74% of respondents indicated that they supported higher amounts of woody biomass harvest from public lands to generate energy. 88% of respondents agreed that public forests are in need of restoration, either to conserve biodiversity, reduce risk of large wildfires, or minimize the impacts of insect and disease infestation. 63% of respondents felt that smoke from wildfires and the burning of slash piles negatively affected the health of people in their community, and 57% of people agreed that air pollution from cars, industry, power plants and wood stoves negatively affected the health of people in their community.

Table 3 presents the parameter estimates of the two model specifications. Because the MNL requires the assumption that errors are independently and identically distributed, errors in both models were clustered according to a unique identifier for each respondent to correct for the potential correlation amongst the errors for an individual completing up to four choice sets.

It was expected that increases in the level of HOMES and FORESTS would be associated with increased likelihood of an alternative being selected because higher levels of both attributes are benefits. Increases in AIRDAYS, WILDFIRES, and BILL, on the other hand, make the respondent worse off and are expected to decrease the likelihood of an alternative being selected. It was predicted that the sample strata would be significant determinants of respondent preferences but preliminary models indicated that they were not statistically significant predictors of CHOICE and they not included in the final model. The coefficients in the base model are all statistically significant at less than the 1% level and their signs are consistent with the expectations. The positive coefficient on the ASC in the base model is statistically significant, suggesting a significant SQE.

In the full model, the coefficients on choice attributes represent the preferences of base-case respondents. That is, the preferences for non-high income earners, who are not seniors, have less than a bachelor's degree in education, and do believe that humans are causing climate change through the burning of fossil fuels. All of the attribute coefficients in the full model had the expected sign and all but the WILDFIRES coefficient were statistically significant at better than a 1% level.

Table 3. Regression Analysis Results

	Base Model		Full Model	
	Coefficient	Std	Coefficient	Std
<i>HOMES</i>	0.0110 ^{***}	0.00256	0.0646 ^{***}	0.0151
<i>AIRDAYS</i>	-0.0421 ^{***}	0.00476	-0.0876 ^{***}	0.0232
<i>WILDFIRES</i>	-0.0378 ^{***}	0.0126	-0.0382 ^{***}	0.0253
<i>FORESTS</i>	0.0328 ^{***}	0.00190	0.166 ^{***}	0.0143
<i>BILL</i>	-0.00570 ^{***}	0.000520	-0.0142 ^{***}	0.00271
<i>ASC</i>	0.345 ^{***}	0.0671	0.0741	0.164
<i>HOMES X CLIMATE</i>			-0.0117 ^{**}	0.00576
<i>AIRDAYS X CLIMATE</i>			0.0311 ^{***}	0.0108
<i>WILDFIRES X CLIMATE</i>			0.0238	0.0267
<i>FORESTS X CLIMATE</i>			-0.0150 ^{***}	0.00436
<i>BILL X CLIMATE</i>			0.0000553	0.00100
<i>ASC X CLIMATE</i>			0.0954	0.163
<i>HOMES X HIGHINC</i>			-0.000535	0.00891
<i>AIRDAYS X HIGHINC</i>			0.00735	0.0148
<i>FORESTS X HIGHINC</i>			0.00366	0.00693
<i>BILL X HIGHINC</i>			0.00282 [*]	0.00150
<i>ASC X HIGHINC</i>			-0.0142	0.300
<i>WILDFIRES X HIGHINC</i>			0.0288	0.0443
<i>HOMES X COLLEGE</i>			0.00886	0.00586
<i>AIRDAYS X COLLEGE</i>			-0.0283 ^{**}	0.0110
<i>WILDFIRES X COLLEGE</i>			-0.0312	0.0276
<i>FORESTS X COLLEGE</i>			0.00715	0.00450
<i>BILL X COLLEGE</i>			-0.000329	0.00103
<i>ASC X COLLEGE</i>			0.219	0.168
<i>HOMES X SENIOR</i>			-0.0117 [*]	0.00599
<i>AIRDAYS X SENIOR</i>			0.00617	0.0109
<i>WILDFIRES X SENIOR</i>			-0.0621 ^{**}	0.0286
<i>FORESTS X SENIOR</i>			-0.00584	0.00452
<i>BILL X SENIOR</i>			-0.00147	0.00105
<i>ASC X SENIOR</i>			-0.0965	0.168
<i>HOMES_SQ</i>			-0.000742 ^{***}	0.000223
<i>AIRDAYS_SQ</i>			0.000936 [*]	0.000554
<i>FORESTS_SQ</i>			-0.00162 ^{***}	0.000173
<i>BILL_SQ</i>			0.0000176 ^{***}	0.00000513
<i>N</i>	5745		5661	
log pseudolikelihood	-1799.4		-1663.4	
likelihood ratio test ^b			p>chi2 = 0.000	

Note: ^{*} $p < 0.10$, ^{**} $p < 0.05$, ^{***} $p < 0.01$ Note^b: Null hypothesis of likelihood ratio test is joint insignificance of variables

Unlike the base model, the coefficient on the ASC is statistically insignificant in the full model. Testing highlighted that it was the addition of the quadratic terms that removed the statistical significance of the ASC. Coefficients for *HOMES_SQ*, *FORESTS_SQ*, *AIRDAYS_SQ* and *BILL_SQ* reveal statistically significant diminishing marginal effects of changes in the levels of the attributes on the probability of choosing a particular alternative. The failure of the base model to capture diminishing marginal utility appears to be the reason for the statistical significance of the ASC in that model.

The climate change opinion interaction terms reveal statistically significant differences in preferences between respondents who believe in man-made climate change and those who do not. The negative coefficients on *HOMES X CLIMATE* and *FORESTS X CLIMATE* and the positive coefficient on *AIRDAYS X CLIMATE*, reveal that respondents that don't believe that humans are causing climate change have a statistically significantly lower WTP for these attributes than respondents who do believe in man-made climate change. The positive and significant (at the 10% level) coefficient on *BILL X HIGHINC* reveals that high income respondents were less sensitive to increases in monthly energy bill. The negative and significant coefficient on *AIRDAYS X COLLEGE* suggests that respondents with at least a bachelor's degree are less likely to select a strategy where the number of AIRDAYS increased relative to the status quo. Negative coefficients on *HOMES X SENIOR* and *WILDFIRES X SENIOR* reveal that respondents who were older than age 65 were less willing to pay for increases in the number of homes powered with wood in the state, but were more sensitive than others to increases in the number of large wildfires.

5.1 Social willingness to pay

Table 4 reports the average monthly household MWTP for the base model and the full model, estimated using equations (7) and (8), respectively. A 95% confidence interval for each estimate was estimated with 500 bootstrap repetitions using the method described by (Efron and Tibshirani 1986). The confidence intervals highlight that all average MWTP estimates are statistically significantly different than zero for all attributes except the ASC for the full model. The MWTP estimates from the full model have been adjusted to represent the population of Montana and they are the focus of the remainder of the discussion.

Table 4. Marginal Willingness to Pay for Attributes per month

Attribute	Marginal Unit	Base Model		Full Model	
		Average household MWTP (\$)	95% confidence interval (\$)	Average household MWTP (\$)	95% confidence interval (\$)
HOMES	1000 homes	1.93	1.07, 2.78	4.02	1.89, 6.15
AIRDAYS	1 day/year	-7.40	-9.35, -5.44	-5.33	-8.49, -2.16
WILDFIRES	1 wildfire/year	-6.63	-10.82, -2.44	-3.01	-5.21, -0.81
FORESTS	1 percentage point	5.75	4.61, 6.89	10.88	6.45, 15.31
ASC	na	60.60	34.37, 86.84	11.90	-4.46, 28.25

The MWTP for each attribute is a useful measure that can facilitate estimation of the impacts of changes in the levels of provision of individual attributes. However, because the attributes are measured in different units, MWTP cannot be used to compare the relative magnitude of the marginal effect of the individual attributes. One way to interpret the estimates that facilitates more direct comparison between the attributes is to estimate WTP for a constant percentage point change in each of the attributes. Using results from the full model, Table 5 provides the MWTP for each attribute, aggregated across the 405,525 households in the state (United States Census Bureau), as well as the aggregate WTP for a 10% improvement in each of the attributes. Viewed through this lens, WTP for improvements in forest health is significantly larger than WTP for the other attributes, with an aggregate WTP of \$106 M annually to increase the level of healthy forests by 2 percentage points per year for the next ten years. WTP for a 10% increase in the number of homes powered with wood in the state has the second largest magnitude, at \$39 M per year over the next ten years. WTP for 10% improvements in AIRDAYS and WILDFIRES are \$26 M and \$18 M, respectively. To provide some context with which to interpret these aggregate MWTPs, the total average annual household expenditure on energy bills in Montana is about \$414 M⁴.

Table 5. Aggregate Marginal Willingness to Pay per year

Attribute	Aggregate MWTP (\$)	10% improvement from status quo	WTP for 10% improvement from status quo (\$)
HOMES	19,604,766	2,000 homes	39,209,531
AIRDAYS	25,957,848	1 day	25,957,848
WILDFIRES	14,685,864	1.2 wildfires	17,623,037
FORESTS	53,099,365	2 percentage point	106,198,730
ASC	57,967,876	na	na

6. Conclusions

Residents of Montana expressed willingness to pay for all of the attributes in this study associated with utilizing woody biomass from public forests for energy generation. These results suggest the potential for significant public benefits from forest restoration treatments and energy generation from woody biomass harvested from public forests. The largest MWTP was for increasing forest health, suggesting that the largest public benefits from forest restoration activities come from the improvement of forest health and biodiversity conservation. When combined with WTP for protection of homes and watersheds from large and destructive wildfires the benefits from forest restoration treatments are large even if woody biomass harvest is not part of the management plan. However, including the utilization of woody biomass for energy generation as part of a forest restoration management plan can add significant public benefits that are not captured otherwise. In addition, if a financial profit can be gained through the utilization of the biomass, more acres of treatment may be facilitated and more benefits associated with the forest health restoration and wildfire risk reduction may be gained. Preferences toward air quality impacts are strong, and although it is impossible to directly compare the magnitude of the MWTP across the attributes, when one considers the fact that it only takes three

⁴ Average household monthly energy bill Montana in 2011 was \$84.97 (US EIA 2011).

additional unhealthy air days per year to outweigh the magnitude of a one unit improvement across all three other attributes combined, it is clear that any management decisions that degrade air quality will have significantly reduced net benefits associated with them.

Analysis revealed that the stratifications used in the sample design were not statistically significant determinants of the preferences that respondents had toward changes in the attributes being valued. This suggests that even though there are geographic characteristics that relate closely to the attributes being valued, such as whether or not someone resides in an air-shed with poor air quality and whether or not they live in a forested area, they are not important determinants of preferences toward forest management policies or air quality impacts. Instead, preference heterogeneity for these environmental goods was explained more by individual attitudinal and sociodemographic characteristics. Additional modeling of the data is needed to further understand the characteristics that determine preferences toward these environmental goods, whether specific groups in the population have like preferences, and what economic efficiency and equity implications might arise as a result.

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