A Stated Preference Study of Electricity Generation in Western Canada

Jason Hawkins

Department of Civil Engineering
University of Calgary
2500 University Dr NW
Calgary, AB T2N 1N4
email: jfhawkin@ucalgary.ca

Abstract

This study examined the preferences for various forms of electricity generation among residents of western Canada (British Columbia, Alberta, and Saskatchewan). A stated preference survey was administered through an online system and 340 respondents provided feedback on their preferences based on the monthly cost to them, GHG emissions associated with the plant, and its distance from their residence. The results suggest heterogeneity of preference between the provinces. The results of this research will be used as the basis for a choice model of electricity generation under an assumption of distributed networks.

Keywords: Heterogeneous Preferences, Electricity Choice Sensitivity, Green Electricity

1. Introduction

Electricity generation accounts for 14% of anthropomorphic GHG emissions in western Canada (British Columbia, Alberta, and Saskatchewan) [1]. As such, it is an important industry if we are to mitigate climate change impacts. We all enjoy the benefits of access to electric energy and the services it makes possible. Conservation initiatives have raised awareness among the the public of the need to reduce their consumption of electricity, but it is unlikely this will provide the requisite reductions in generation-related emissions. Changes in generation technology will be required, especially in jurisdictions such as Alberta and Saskatchewan where generation has historically come from coal-fired power plants. This form of generation produces mean life-cycle emissions of 888 tonnes of CO_2 equivalents per GWhr of generation, which contrasts with 500 tonnes for natural gas and roughly 25 tonnes for most other conventional sources (e.g. nuclear, hydro, and wind). Recent changes to provincial and national policy in Canada have suggested a shift towards action on the contributions of electricity generation towards climate change. The Alberta government has begun a program to phase out the use of coal-fired plants in the province and replace them with a combination of one-third natural gas-fired and two-thirds renewable generation [2]. Renewable alternatives are becoming increasingly cost effective as more effort is focused on their development and improvement. For the purposes of this research, renewable energy will be defined as any source for which the input fuel can be replaced in the lifetime a human or any source which can be derived from an input energy source with a consumption time scale - at current rates - on the order of the lifespan of the earth. This would include hydro dams, wind turbines, solar panels, geothermal energy, and tidal sources. Many renewable generation methods are location-specific; tidal sources are not feasible for regions far from tidal bodies of water. The local availability of an input resource will often influence preference because its use will positively effect the local economy and have spill-over effects from construction and maintenance work.

This study builds a Random Utility Theory (RUT) model of electricity preferences in western Canada, with the aim of developing a choice model of the preferred electricity system under an assumption of distributed and "smart" electricity infrastructure in western Canada. The current centralized system of electricity provision is structured around large-scale generation sources located at remote sites, which are transmitted to consumptivie centres of population and industry. Consumers have minimal knowledge of spot prices, the current mix of online electricity sources, or their consumption patterns. This fails basic tenets of market economics as agents of demand are severely hampered in their ability to respond to supply price variation. The system has fallen behind generation technology availability and the ability of information technology (IT) to inform consumers of their consumption patterns. It is proposed that a distributed network, making use of current IT, would act similar to a transportation network. In transportation modelling, agents of demand (persons) are presented with a set of potential travel modes. Their mode choice is a function of the characteristics of each mode and the individual choice agent (e.g. income, sensitivity to environmental degradation, and willingness to engage in communal action by taking public transit). Similar characteristics would arise in electricity preference if we were to provide mechanisms of choice to individuals. In this type of model, the factors contributing to the choice of an alternative are normally ascertain via stated preference (SP) methods. This method was employed in the present research for its ability to measure preferences for alternatives not currently available in a region.// There is a wealth of research on preference for renewable generation alternatives. Preferences are typically determined through one of two methods, or a combination thereof. The first method, revealed preference (RP), is based on research in jurisdictions with renewable premium programs through which customers may choose to pay an additional monthly fee to support the construction of renewable sources of electricity. This option is available to retail customers in the study area through Bullfrog Power and in several local regions (e.g. Calgary and Edmonton) through local utility providers. This method has been used in previous studies [3] as a means of quantifying willingness to pay (WTP) for renewable alternatives. However, this is prefaced on an assumption of uniform and substantial, if not infinite, spending budgets. The second approach employed is an SP survey. In addition to the flexibility of this method discussed above, SP has the ability to draw-out the preferences of respondents irrespective of their budget constraints. This data could be utilized to determine the desire for government subsidy of renewable energy programs. To accomplish this task using RP data would require an income profile of current customers, which is unlikely to be made available.

2. Background

2.1. Regional Context

The study region consists of the three western-most province of Canada: British Columbia, Alberta, and Saskatchewan. This region was chosen because data was made available to the researcher from ENMAX Energy Inc. in Calgary, Alberta for 2014 across their service area and aggregated by postal code. Energy policy in each province is administered by provincial regulation and the generation mix varies substantially between provinces due to differences in regulation methods and available resources. British Columbia is a coastal province and has access to abundant water resources. This means that 86% of its electricity is sourced from hydro-electric dams, 7.4% from natural gas-fired plants, and the remainder from a variety of wind, solar, and tidal sources (ref). Alberta and Saskatchewan are land-locked provinces with significant fossil resources and no access to tidal waters. Alberta has seen a recent shift away from coal-fired plants with the construction of several new natural-gas fired plants. The current generation mix is 43.6% natural gas and 38.5% coal. Alberta has significantly increased its utilization of wind resources, especially in southern regions around Fort Macleod, and presently sources 9.0% of its generation from wind turbines. The remainder of the provincial generation comes from a combination of hydro and biomass plants. Similar to Alberta, Saskatchewan has high rates of coal (44.0%) and natural gas (29.4%) generation due to its access to these cheap feed-stocks. The province also has a large river system and utilizes it for 22.0% of its electricity needs. The remainder of generation in Saskatchewan comes from wind farms in its southern region.

2.2. Review of Literature

There is a large literature on the subject of preference for renewable electricity technologies and studies generally examine either the willingness to pay (WTP) for renewable alternatives or heterogeneity in the preference for renewable alternatives. Yoo and Reed [4] examine heterogeneity based on marginal cost over the respondent's existing utility bill and the number of jobs created to implement the technology. They find respondents show the strongest heterogeneity in their preference for solar, with this alternative being preferred by those who identify as environmentally conscious. Those who do not identify as environmentally conscious, are found to prefer wind power. All respondents are indifferent to biomass generation. Mozumber et al. [5] find a WTP of $10/month in New Mexico, or roughly 14% of an average monthly bill for a shift to 10% renewables and a willingness to bear a 36% increase in cost for a 20% share in renewables. They recognize these results as biased by the sample, which has an average age of 24, 38% of whom reported contributing to an environmental group. They use a factor developed by Champ and Bishop [3] to adjust for bias based on a study in Wisconsin in which they found a stated WTP of $100 per year, but actual payments which averaged only $59 per year.This study is focused on a proposed wind farm in eastern New Mexico, in the context of a state mandate to attain 10% renewable sourcing by the year 2010. They provide details on the benefits of the project and its potential to power 94,000 homes. There is no comparison with other forms of renewable generation or current forms of generation.

A study by Bergmann et al. [6] examines differences in the preferences of urban and rural residents in Scotland. A reference natural gas-fired plant is compared to one of a series of alternatives, which includes large offshore and onshore wind farms, a moderate size wind farm, and a biomass plant. The output of each plant and a measure of the size of the development is provided to survey respondents. They find urban residents value generation alternatives with low landscape impacts, which do not harm wildlife. Rural residents were found to be more strongly influenced by the number of jobs created and land requirement, as most of these jobs and generation sites would be located in rural areas. Several other studies were identified, which examine the WTP for renewable alternatives [7][8][9][10][**?**][11][12]. They find wind and solar are preferred over biomass, but there is no consensus as to the preference between wind and solar. It appears to be a decision based in local experience, relative costs and production rates, and the availability of each resource in the survey area.

3. Methodology

3.1. Survey Methods

This survey was implemented as a stated-preference (SP) choice experiment. SP experiments are a common method of eliciting preference in economics and planning fields [13]. This approach has the advantage of allowing for solicitation of preferences for alternatives not currently available to the survey respondent. This is an important feature for policy analysis of the desire for new forms of technology and the willingness-to-pay (WTP) of the citizenry. The choice experiment is typically framed as a comparison of two competing alternatives, with several attributes listed of interest to the researcher. It is assumed the chosen alternative is "liked" by the respondent and the unchosen alternative is "disliked". The attributes of the alternatives are randomly assigned across experiments to provide the necessary variation to estimate parameter values. Societal preferences can then be inferred from a large set of such choice experiments, administered to a sample of the target population. The results of the experiment can then be translated into utility functions for each alternative according to standard methods of Random Utility Theory (RUT).

RUT represents the utility of a particular good or service as a set of deterministic factors and a stochastic error component representing the unobserved component of utility. The set of deterministic factors are specified by the analyst so as to minimize the utility ascribed to stochastic error. The deterministic component of utility is decomposed into a set of attributes, with qualitative or quantitative levels, representing the available alternative for the good or service. The probability of an alternative can be specified as:

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \tag{1}$$

where P_{ni} represents the probability of individual n selecting alternative i, β' is an estimate of the unit measurable utility of the attribute x_{ni} for individual n, and $\beta' x_{nj}$ is the summation of the measurable utilities ascribed to all j alternatives by individual n. The exponential form of the function is the result of assuming a Weibull distribution for the error component and represents a general logit formulation.

3.2. Survey Design

The purpose of the present choice experiment was to ascertain the electricity generation preferences of residents of western Canada. It was administered as an online survey via an SP survey system developed for the purposes of this study. The survey was disseminated via a variety of methods of communication. The majority of responses were obtained through a "snowball" method of emails being sent to contacts in the study region, who were requested to forward the survey to their contacts who lived within the study region. Social media (Facebook, Twitter, reddit, and online forums) were utilized to distribute the survey to a wider group of respondents. Each respondent was first presented with an ethics disclosure and summary of the experiment purposes and outcomes, before being asked whether they would like to proceed with participation in the study. They were then taken through a series of choice experiments consisting of two hypothetical electricity generation plants (see Figure 1).
Each choice was randomly selected from a list of 9 alternatives and 3 attributes, described in Table 1, which represented 720 potential alternatives.

Alternatives were chosen based on existing sources of generation in the three jurisdictions and the most viable alternatives not currently present. Monthly costs provided a monetary quantification of WTP and were based on average monthly electricity charges available from the Alberta Ministry of Energy. The energy cost was presented to respondents, rather than the

Generation Source	Large Solar Cell Array	Coal-Fired Plant
Cost ($/month)	36	36
Direct Emissions	None	High
Distance from your residence (km)	7	63
	○	○

Figure 1: Figure caption

Table 1: Choice Alternative and Attribute Levels

Attribute	**Level**	**Units**
Alternative	Biomass Plant	NA
Alternative	Coal-Fired Plant	NA
Alternative	Natural Gas-Fired Plant	NA
Alternative	Hydro Dam	NA
Alternative	Large Wind Farm	NA
Alternative	Small Wind Turbine	NA
Alternative	Large Solar Cell Array	NA
Alternative	Small Solar Panel	NA
Cost	36	$/month
Cost	58	$/month
Cost	87	$/month
Direct CO_2 Emissions	None	$/month
Direct CO_2 Emissions	Low	NA
Direct CO_2 Emissions	Med-Low	NA
Direct CO_2 Emissions	Med-High	NA
Direct CO_2 Emissions	High	NA
Distance from Residence	0	km
Distance from Residence	7	km
Distance from Residence	18	km
Distance from Residence	63	km

total cost they would see on their monthly utility bill. This was done to compare the marginal costs of each generation source, absent of the inflation produced by non-energy costs (i.e. distribution, transmission, and administration), which were considered constant regardless of the generation source. For sources not presently available on the grid, the additional infrastructure costs would be incorporated into the marginal cost of energy and this effect could be assessed based on survey responses. The Ministry of Energy estimates the energy cost of electricity at $20-50 per month [14][**?**]. The costs presented to survey respondents were based on these estimates. Emissions were presented in a qualitative form because there is less familiarity among the public as to the quantitative value of emissions associated with each generation source. This provided a measure of the sensitivity of respondents to allowing emissions as a trade-off for cost or distance. It should be noted that all emission combinations were considered, including those that may appear unrealistic: a small wind turbine with high direct CO_2 emissions. Inclusion of the full set of alternatives prevents selection biases by the survey developer and provides a means of quantifying unrepresented preferences for a particular generation source. For example, a respondent might be presented with a small wind turbine with high emissions and a natural gas-fired plant with high emissions. *Ceteris Parabis*, the respondent may choose the natural gas-fired plant and express an inherent preference for this source. This type of preference can then be represented via the inclusion of alternative specific constants in the utility estimation. The final attribute considered in this experiment was the distance of the generation source from the respondent's residence. This metric has seen minimal consideration in electricity choice literature. It was included in the present study for three key reasons. Firstly, there has been increased interest in western Canada to explore renewable electricity generation. These sources can be readily scaled to the individual household level, meaning there is a higher probability of such sources being located near your residence. Secondly, advances in technology have made distributed electricity a viable alternative to our current grid system. Distributed electricity systems are characterized by small-scale generation sources operating at the community scale. As such, it is becoming increasingly important to measure the sensitivity of residents to having various sources of electricity generation constructed in their community. The details of the choice model resulting form this survey will be discussed at greater length in a future publication, but it is pertinent to the present study that distance from residence to the generation source is included in the survey question. A fundamental research question to be addressed via this research is the spatial structure of electricity generation as small-scale renewables become viable options.

A total of 340 people were surveyed across the provinces of British Columbia, Alberta, and Saskatchewan. This produced a total of 2040 usable stated preference pairs. Demographic characteristics of survey respondents were compared with statistical data on the regional demographics [?][?][?]. Respondents under the age of 40 were over-represented in the sample at 72% as compared to 40% across the model region. Reported incomes were disproportionately above $100,000 with 36% of respondents reporting household incomes above this threshold as compared to 11% of the population. The urban-rural composition of respondents was within an acceptable range of 5% of the population. The age of the sample was most likely biased by the avenues of dissemination and age profile of the researcher's contacts. Weights were applied to the model to compensate for deviation of the sample from the population distribution of age, income, urban-rural divide, and province of residence.

4. Results

A series of logit functions were built to examine the relative significance of each variable and the heterogeneity of preferences within the population. In each of the functions, utility was measured relative to the alternative constant for a coal-fired plant. Cost and distance were factored down by an order of magnitude so that parameters were applied per $10 and 10 km, respectively. The first model considered cost, emissions, and distance to be homogeneous in their importance across the survey population and alternative set. This formulation of utility suggested respondents were indifferent to a transition to natural-gas fired plants, relative to coal-fired plants, and all other forms of generation were preferred to coal (at a 90% CI). Nuclear plants were considered the most similar to coal-fired plants. An initial examination of the alternative constants for wind and solar alternatives suggested a difference in the parameters between large and small alternatives for both sources; however, a complete statistical analysis that accounts for correlations gave a t-statistic of 0.3 for both comparison by source size (significantly below the 1.65 threshold at a 90% CI). Distance sensitivity was not significant when considering all plants homogeneous, which indicated distance sensitivity may be source specific. From these results, it was estimated that an improvement in GHG emissions is valued at $28.80 per month by respondents for each level of improvement.

Table 2: Standard Logit - with Demographic Weights

Parameter	**Value**	**SE**
Cost ($ x10)	-0.02368	0.00779
Emissions (Level)	-0.06819	0.0168
Distance (km x10)	-0.005140	0.0111
Biomass Constant	0.6799	0.0919
Coal Constant (Fixed)	0.0000	0.000
Natural Gas Constant	0.07901	0.107
Hydro Constant	0.7456	0.104
Large Wind Constant	0.6936	0.0989
Small Wind Constant	0.4308	0.0968
Large Solar Constant	0.3770	0.0947
Small Solar Constant	0.6324	0.104
Nuclear Constant	0.1767	0.0946

The base model was adjusted to implement error terms for cost and GHG emissions. It was posited that sensitivity to these parameters would be heterogeneous because cost sensitivity varies by income and valuation of addressing environmental impacts is variable within the population. The error component, or mixed logit, representation of logit has been found to increase the ability of models to simulate preference. Error component logit allows the analyst to specify distributions for attribute parameters. This can be interpreted as allowing the utility each respondent ascribes to a particle attribute as varying across respondents. The general form of the error component model is represented as follows:

$$P_{ni} = \int \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} f(\beta) d\beta \tag{2}$$

where variables are defined as before and the logit function is integrated over a probability density function. Lognormal distributions were assumed for both cost and GHG emissions as it was assumed, despite heterogeneity in weighting, both increased cost and GHG emissions are uniformly viewed as negative. This formulation produced a 16% improvement in the model fit according to the ρ^2. The heterogeneity in both parameters was found to be statistically significant. A nested logit implementation was also explored for nesting structures of 1. renewable (biomass, hydro, large wind, small wind, large solar, small wind) and non-renewable (coal, natural gas, and nuclear) and 2. small-scale (small wind and small solar) and large-scale (biomass, coal, natural gas, large wind, large solar, and nuclear). It was determined there was insufficient similarity between alternatives to justify either of these nesting structures.

Table 3: EC Logit (Lognormal Parameters for Cost and Emissions) - with Demographic Weights

Parameter	Value	SE
Cost ($ x10)	-0.00721	0.00283
Error Component(Cost) ($ x10)	-0.01466	0.00670
Emissions (Level)	-0.03546	0.0530
Error Component(Emissions) (Level)	-0.07271	0.0392
Distance (km x10)	-0.0005320	0.0124
Biomass Constant	1.217	0.212
Coal Constant (Fixed)	0.0000	0.000
Natural Gas Constant	0..1028	0.118
Hydro Constant	0.8300	0.128
Large Wind Constant	0.4353	0.121
Small Wind Constant	0.4731	0.107
Large Solar Constant	0.3770	0.110
Small Solar Constant	0.7055	0.122
Nuclear Constant	0.1865	0.106

Taking into account the heterogeneity observed in the cost parameter, each of cost, emissions, and distance were broken out by income. Three income brackets were defined: <$50,000; %50,000-$99,999; and <=$100,000. Placing respondents into income categories improved the model fit by 29%, relative to the base case. Results suggested that cost is an important factor to low-income respondents, becomes more important in the middle income bracket, and less significant in the highest income bracket. This peaking in its significance could be a result of lower income respondents being younger and single, whereas the middle income respondents have families that place financial restrictions on them. Higher income earners placed less significance on the cost of electricity, as well as emissions and distance. This did not fit with the standard assumption of high income earners being averse to environmental ills in their neighbourhood and pushing such impacts into other areas. A potential cause for this observation may be the reference of parameters to the coal constant. The model provides a mean value of the parameter, whereas a higher parameter value for this constant among high income households would place the relative values of cost, distance, and GHG emissions below that of the coal constant. This was tested by running two restricted versions of the base model: once for respondents with household incomes below $100,000 and a second model for those with incomes of $100,000 or more. This analysis found high income households as having parameter estimates for cost and distance not significantly different from the coal constant (at 90% CI). This may be a consequence of the sample demographics. Many of the younger respondents were also found to report as being in the high income group. This suggested the presence of a group of young professionals in the sample who may still maintain a frugal student perspective in their responses. Such respondents may focus on the cost component of each alternative and place less weight on distance and GHG emissions relative to the prevailing assumption regarding high income households.

Table 4: Standard Logit (by Income Bracket) - with Demographic Weights

Parameter	**Value**	**SE**
Cost-LowIncome ($ x10)	-0.01821	0.0101
Emissions-LowIncome (Level)	-0.1184	0.0213
Distance-LowIncome (km x10)	-0.01448	0.0136
Cost-MidIncome ($ x10)	-0.04055	0.0161
Emissions-MidIncome (Level)	-0.06063	0.0382
Distance-MidIncome (km x10)	-0.05439	0.0273
Cost-HighIncome ($ x10)	-0.007594	0.0205
Emissions-HighIncome (Level)	0.1263	0.0453
Distance-HighIncome (km x10)	0.1190	0.0343
Biomass Constant	0.7227	0.0931
Coal Constant (Fixed)	0.0000	0.000
Natural Gas Constant	0.08046	0.109
Hydro Constant	0.7763	0.106
Large Wind Constant	0.7101	0.100
Small Wind Constant	0.4183	0.0984
Large Solar Constant	0.4220	0.0957
Small Solar Constant	0.6880	0.105
Nuclear Constant	0.1551	0.0962

The results of breaking the model out by income were checked against one broken out by age into three categories: 18-30 years of age; 30-50 years of age; and 50 years of age and over. The results of this analysis fit more closely with expectation. Only the youngest age category had a negative cost sensitivity significantly different from 0 (at %90 CI). Emissions are not considered a strongly negative factor for the youngest group, with a positive parameter relative to coal. Respondents over the age of 50 were found to show a strong aversion to emissions relative to their younger counterparts. There may be a health component associated with this difference.

Table 5: Standard Logit (by Age Brackets) - with Demographic Weights

Parameter	**Value**	**SE**
Cost-YA ($ x10)	-0.07773	0.0143
Emissions-YA (Level)	0.09870	0.0364
Distance-YA (km x10)	-0.002529	0.0261
Cost-MA ($ x10)	0.02159	0.0241
Emissions-MA (Level)	-0.01301	0.0508
Distance–MA (km x10)	0.1208	0.0273
Cost-SA ($ x10)	0.004421	0.0105
Emissions-SA (Level)	-0.1474	0.0212
Distance-SA (km x10)	-0.04137	0.0137
Biomass Constant	0.6787	0.0933
Coal Constant (Fixed)	0.0000	0.000
Natural Gas Constant	0.00712	0.109
Hydro Constant	0.6927	0.106
Large Wind Constant	0.6703	0.101
Small Wind Constant	0.3915	0.0981
Large Solar Constant	0.3660	0.0970
Small Solar Constant	0.5892	0.106
Nuclear Constant	0.1200	0.0963

A model was developed with alternative-specific constants broken out by province of residence. Alberta and Saskatchewan are fairly similar in their generation mix, but the British Columbia system is dominated by hydro dams. This model was developed to test for heterogeneity resulting from exposure to different electricity mixes and other local effects on preference. Cost, emissions, and distance sensitivity were assumed constant between provinces. Significant differences were found across most source-province pairs (at 90% CI), with the exception of natural gas between BC-AB and BC-SK, large solar array between BC-SK, and nuclear between BC-SK. A large difference was found in preference for biomass between British Columbia and Alberta. There is a wide set of possible explanations for this difference and the following is a non-exhaustive list. Both jurisdictions currently have biomass plants in operation (ref), but there may be differences in the proximity of respondents to plants and perceptions developed through local controversy. The definition of biomass may vary between the two provinces due to differences in the mass burned at plants and information presented to residents of each province. British Columbia may burn waste mass that would otherwise be land filled, while plants in Alberta may burn feed products that are perceived as having more valuable uses. This could induce a difference in the choice of respondents between these two provinces.

Table 6: Standard Logit (by Province of Residence) - with Demographic Weights

Parameter	**Value**	**SE**
Cost($ x10)	-0.01821	0.0101
Emissions (Level)	-0.1184	0.0213
Distance (km x10)	-0.01448	0.0136
Biomass Constant-BC	0.7227	0.0931
Coal Constant-BC (Fixed)	0.0000	0.000
Natural Gas Constant-BC	0.08046	0.109
Hydro Constant-BC	0.7763	0.106
Large Wind Constant-BC	0.7101	0.100
Small Wind Constant-BC	0.4183	0.0984
Large Solar Constant-BC	0.4220	0.0957
Small Solar Constant-BC	0.6880	0.105
Nuclear Constant-BC	0.1551	0.0962
Biomass Constant-AB	0.7227	0.0931
Coal Constant-AB (Fixed)	0.0000	0.000
Natural Gas Constant-AB	0.08046	0.109
Hydro Constant-AB	0.7763	0.106
Large Wind Constant-AB	0.7101	0.100
Small Wind Constant-AB	0.4183	0.0984
Large Solar Constant-AB	0.4220	0.0957
Small Solar Constant-AB	0.6880	0.105
Nuclear Constant-AB	0.1551	0.0962
Biomass Constant-SK	0.7227	0.0931
Coal Constant-SK (Fixed)	0.0000	0.000
Natural Gas Constant-SK	0.08046	0.109
Hydro Constant-SK	0.7763	0.106
Large Wind Constant-SK	0.7101	0.100
Small Wind Constant-SK	0.4183	0.0984
Large Solar Constant-SK	0.4220	0.0957
Small Solar Constant-SK	0.6880	0.105
Nuclear Constant-SK	0.1551	0.0962

The final analysis was a novel formulation based on the hypothesis that distance sensitivity is heterogeneous by the source of generation. The reasons for this heterogeneity range from the health effects of plant emissions, to aesthetic perceptions of locating a plant near one's residence. In this formulation distance was distinguished by the source of generation. In this analysis, only hydro was perceived positively relative to coal-fired power. Large-scale solar was also viewed positively, but narrowly failed the test for significance at a 90% CI. The results of the sensitivity test by generation source can be interpreted with a positive value meaning a preference for having the source further from one's residence and a negative value denoting a low sensitivity to a particular plant being near one's residence. With this interpretation, nuclear is considered the least desirable and preference is for it to be located as far as possible from residences. It is considered acceptable to have a large-scale solar array in close proximity to residences. However, results suggest small-scale solar is less desirable than its larger counterpart and coal-fired plants are the most acceptable for placement near residences. These results are in contrast to the expectation of the researcher. The size of the sample suggests this result was not the result of insufficient data. A total of 454 situations were presented to respondents with coal-fired plants included as an alternative, from which it was chosen 51% of the time. This choice rate is below only those of biomass, large-scale wind, and large-scale solar. It was suspected this discrepancy arose from preference among those in Alberta and Saskatchewan, where coal-fired power plants are dominant, for this source. The provincially-differentiated model was run again, with the biomass constant fixed the coal constant allowed to vary. This analysis showed a strong negative coefficient for coal in British Columbia (-1.032) compared to a statistically significant value of 0.4786 for Alberta and a value for Saskatchewan not significantly different from 0.000. In both cases, the difference of jurisdictions with coal-fired plants (Alberta and Saskatchewan) was statistically significant and positive compared with that of British Columbia.

Table 7: Standard Logit (distance by generation type) - with Demographic Weights

Parameter	Value	SE
Cost($ x10)	-0.01420	0.00809
Emissions (Level)	-0.04132	0.0180
Distance-Biomass (km x10)	-0.1340	0.0406
Distance-Coal (km x10)	-0.2673	0.0400
Distance-Natural Gas (km x10)	-0.06367	0.0345
Distance-Hydro (km x10)	-0.09498	0.0453
Distance-Large Wind (km x10)	-0.02340	0.0302
Distance-Small Wind (km x10)	-0.003398	0.0318
Distance-Large Solar (km x10)	-0.1057	0.0273
Distance-Small Solar (km x10)	-0.03545	0.0367
Distance-Nuclear (km x10)	-0.1202	0.0325
Biomass Constant	0.05009	0.121
Coal Constant (Fixed)	0.0000	0.000
Natural Gas Constant	-0.5054	0.138
Hydro Constant	0.2112	0.126
Large Wind Constant	0.1639	0.131
Small Wind Constant	-0.1047	0.129
Large Solar Constant	0.2023	0.133
Small Solar Constant	0.1197	0.130
Nuclear Constant	-0.4702	0.127

4.1. Environmental Bias in Respondents

Several demographic characteristics were obtained from survey respondents, but were not incorporated into the model. These factors still warrant discussion as to their effect on biases in the results. Previous studies on the subject have shown a strong bias towards environmentally-conscious respondents. Figure 2g shows a tendency of respondents towards liberalism, but a moderate sample of conservative respondents. Two questions were asked to describe environmental-consciousness of respondents:

- Have you given money to an environmental group in the past year?
- Do you currently pay a premium on your electricity bill for a renewable energy portfolio or purchase electricity through a renewables provider such as Bullfrog Power?

These data suggest %15 of respondents make contributions to environmental groups and %5 pay for a premium program for a renewable electricity portfolio. These rates are lower than those indicated in previous studies, but remain above the findings of Statistics Canada across the population. They reported charitable giving to environmental causes among %7 of the population [15]. It is suggested survey responses are biased by self-selection, but that this bias is sufficiently small to not warrant adjustment of results.

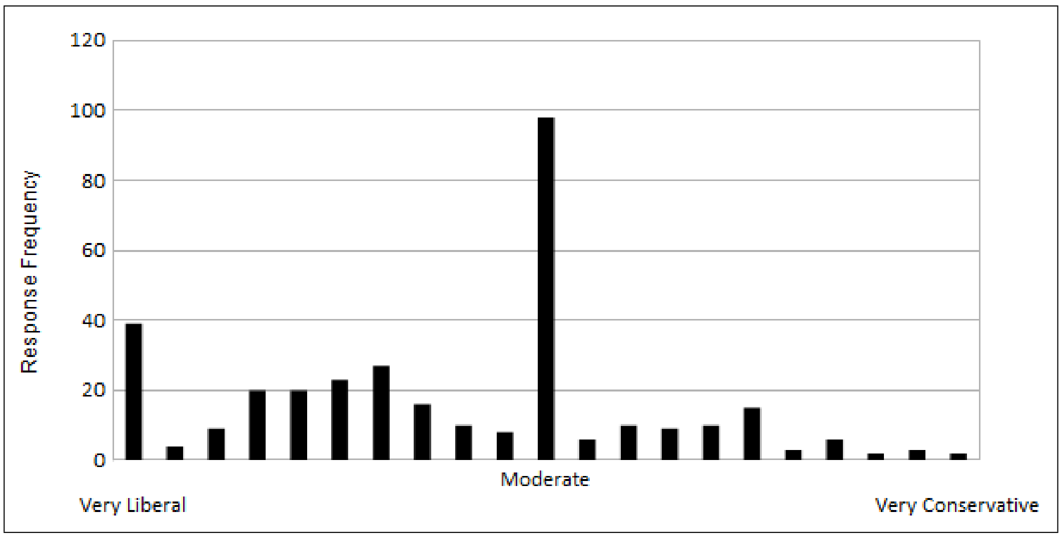

Figure 2: Figure caption

5. Conclusion and Future Work

The results of this study suggest a heterogeneity of preference between provinces, likely resulting from present exposure to sources of electricity generation. The validity of the ultimate objective of this research is questionable with the present data. Results for the sensitivity of respondents to distance do not show the relationships one would expect given previous survey results as to the generation preferences of the public. It is suggested that a number of changes may be necessary to the survey design to ensure more consistent results. Firstly, the use of a marginal price of energy may be misleading to survey respondents as this is not the price they see on their monthly bill. It may be advisable to present the total cost to respondents and draw-out the marginal cost of energy based on reporting from utility provides in post processing. Inconsistencies in the distance results may be a result of biases in the sample population or errors resulting from multiple responses by the same respondents. The current implementation does not provide a method of ensuring a single response from each respondent. A paper-based method would provide more confidence in the sample set. The sample size obtained is within the bounds of other studies in the literature, but a larger sample would allow for more statistically robust break-outs of the data by demographic group. It is also suggested a larger sample of more senior demographics be taken to reduce the weights applied to these samples in model estimation.

It is desirable to have robust results from which a choice model can be derived. The model described above, representing a distributed electricity network has potential as a source of insight for researchers and utility providers. Data representing the electricity consumption of ENMAX customers in Calgary, Alberta and its surrounding communities was provided to the researcher. This data has been expanded to a representation of the three provinces and a base choice model developed. The model allocates generation sources based on local preferences, the demand for electricity in the area, and existing generation sources requested by adjacent areas in previous steps of the model run. These types of results would provide a representation of a hypothetical network of small-scale and renewable generation, with the ability to address the climatic impacts of our current electricity system. Such a representation does not exist to the best knowledge of this author.

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7. Survey Link

https://elec-survey.herokuapp.com/electricity-preferences/start/

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