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Abstract. Use of renewable energy sources is one solution to decrease green house gas emissions and the use of polluting fossil fuels. Renewables differ in their environmental and societal impacts, and to design sound renewable energy policy, societies need to assess the trade-offs between alternative sources. To enable the evaluation and comparison of renewable energy production alternatives in Finland, this paper applies the choice experiment to elicit the monetary information on people's preferences for four renewable energy sources: wind power, hydro power and energy from crops and wood, and considers four impacts of energy production: effects on biodiversity, local jobs, carbon emissions and household's electricity bill. The nested logit analysis reveals that higher income, female gender, and young age increase the probability to choose renewable energy instead of the current energy mix. Wind power is, on average, the most popular renewable energy technology, but regional differences exist. The national aggregate willingness to pay for a combination of renewable energy technologies that corresponds to Finland's climate change and energy policy is over 600 million euros.

Keywords: Choice modeling, renewable energy, willingness to pay

1. Introduction

The European Union has promoted the use of renewable energy sources by several directives, the latest one establishing a common framework for the production and promotion of renewable energy sources in order to limit greenhouse gas emissions (European Parliament, 2009). Renewable energy sources differ in their environmental and economic impacts. Common features to all renewable energy sources are that they are more expensive than the current energy-mix, and none of them is solely beneficial for the environment. All of the four most common sources (wind power, hydropower, energy from wood and energy from crops) can replace CO_2 emissions but in different degrees. While the production of bio energy crops itself causes CO_2 emissions (Farrell et al., 2006), thus reducing the net substitution rate of CO_2, wind and hydropower production, once installed, is practically CO_2 free. What is more, bio energy crop production (such as corn, wheat or barley for ethanol) is a source of nutrient leaching and it reduces biodiversity (Lankoski and Ollikainen, 2011). Regarding energy from wood, using branches and stumps as a part of wood leads to increased leaching, reduced nutrient balances in forest soils and reduced forest biodiversity. Wind power is not environmentally innocent either. It causes negative landscape effects and is detrimental to bird and bat populations (Johnson et al., 2003; Kikuchi, 2008; Ladenburg and Dubgaard, 2007). Environmental problems of hydropower are well-known, too. It is harmful to all migratory fish stocks, dams create local problems and when the water flow in a whole river system is regulated for power production, negative environmental impact extend to the whole catchment area. (Håkansson et al., 2005)

Not only the environmental impacts of alternative renewables differ but so do local, regional and global economic effects. While hydro and wind power do not have permanent impacts on employment in local economies, energy production from wood or crop biomass does. In rural areas, bio energy crop projects may create new income sources and employment to improve the declining profitability of agriculture and replace the reducing agricultural jobs. Use of wood has similar local impacts. (Lauhanen and Laurila, 2007) Moreover, when energy wood is taken from pre-commercial thinning of stands, it improves profitability of forestry and may even improve biodiversity of commercial forests.

Due to many aspects associated with renewable energy resource promotion, societies face a true trade-off when choosing the most beneficial source of energy or a set of sources. To make a sound choice, societies must develop a good understanding on the environmental impacts of alternative sources and the citizens' valuation of these impacts and especially, the marginal rate of valuation between the sources. The choice experiment (CE) method suits well to the elicitation of trade-offs between different characteristics of renewable energy sources in a form that allows for studying implications of alternative energy policies in a concrete policy situation described in the questionnaire. Our case is based on implications of the European Union's renewable energy policy to the Finnish energy policy design. The EU aims to increase the use of renewable energy by 20% by the year 2020 and shifts this burden to its member states. Finland's aim is to increase the use of renewable energy from the current share of 25% to 38% by 2020. (European Parliament, 2009; Ministry of employment and the economy, 2008) This goal can be achieved with a combination of different sources.

In this study we examine the marginal valuation of environmental and economic impacts of four main sources of renewable energy: wind power, hydro power, bio energy crops and wood. The environmental impacts we consider are common to all four energy sources: the effects on the state of local biodiversity and the amount of replaced carbon emissions. The economic impacts comprise the amount of new local jobs created and the effect on the household electricity bill. In Finland, there is currently no monetary information available on the preferences of citizens for characteristics of renewable energy production alternatives and our study fills this gap. In addition to the effects of energy sources, we examine whether the label of the energy source matters, i.e. the citizens put the value on the fact that a particular energy source per se is produced. Using information on preferences, the social welfare effects of the potential future energy production alternatives are calculated. Also, our study reveals which characteristics of the respondent affect the willingness to pay.

Previous similar studies are especially Hanley and Nevin (1999), Bergmann et al. (2006, 2008), and Scarpa and Willis (2010). Hanley and Nevin (1999) focused on two energy sources, biomass and hydropower, and used a contingent valuation method to elicit people's willingness to pay. Bergmann et al. (2006) applied the choice experiment method to quantify people's preferences over the social and environmental impacts of hydro and wind power as well as biomass production, and focused in differences in preferences between rural and urban citizens (Bergmann et al., 2008). The attributes were the impacts of energy sources on landscape, wildlife, air pollution jobs and the electricity bill. Scarpa and Willis (2010) focused on the choices in households and small commercial buildings. They included micro-generation technologies, such as heat pumps, pellet stoves, micro-wind and others, and examined the determinants of their adoption. [1]

The rest of the paper is organized as follows. Section 2 presents the overview of the energy policy in Finland and discusses the alternative renewable energy sources. Section 3 reviews the earlier applications of valuation of energy externalities. Section 4 reports our application, section 5 our results and section 6 concludes and discusses.

2. Renewable Energy Policy Design in Finland

The policy frame for the Finnish energy policy was decided in January 2008 by the European Commission, which released the program for climate and energy aiming at mitigating the climate change by decreasing the greenhouse gas emissions by 20 % by the year 2020. The tool kit for this policy was three-fold: to renew the emissions trading system in EU, to decrease emissions in the sectors that are not involved in the EU emissions trading (such as traffic, construction, waste and agriculture), and to increase the amount of energy sourcing from renewable energy sources. To facilitate the increase in renewable energy production, binding national targets are assigned to all EU member countries. Their targets can be met using freely all available renewable energy sources. In addition to these tools, the share of bio fuels used in traffic should be no less than 10 %. (European Parliament, 2009)

The Finnish target is to increase the share of renewable energy sources in energy production from the 2007 level 25 % to 38 %. Given that the share of renewable energy in Finland is initially high, the new target is challenging and cannot be achieved just relying one source. In 2007, out of the total use of energy (411 TWh), 47% originated from fossil fuels (coal, natural gas, oil), 25 % of renewable energy sources, 17 % of nuclear power, 7 % from peat, and 4 % from other sources, e.g. importing electricity. (Statistics Finland, 2008)

Reaching the target for renewable energy production would need the increase in bio energy, energy from hydropower, wind and geothermal energy as well as the reduction in total energy consumption.[2] Of the total energy use, the share of hydropower is 11%. The estimated potential to increase hydro power is very limited: there are only few free water courses suitable to hydropower. Also, the current legislation denies constructing the major still freely floating rivers for hydro power. Thus, the hydro power production can be enhanced by building smaller rivers or fine tuning the annual water flows in the already built river systems. (Act on..., 1987; KTM, 2005a; KTM, 2005b) The role of wind power has been negligible in Finland; in 2006 wind power capacity was only 197 MW (about 130 wind mills). In 2010, Finland has launched a feed in law system to promote investments in wind power; the strategic goal is to increase productive capacity up to 2000 MW by 2020 (leading to 6 TWh production).[3] (Law of... 2010; Peltola and Holttinen, 2001)

Finland uses wood biomass based energy sources in a variety of different forms. Traditionally black liquor and other concentrated liquors from pulp manufacturing are used to produce energy in forest industry. Wood is used in combined heat and power plants, and wood and wood chips are also used in small-scale combustion plants in countryside. Wood and wood chips provide the greatest potential to increase the use of biomass. The official goal is to increase the use of wood from current 5 million cubic meters to 12 million cubic meters. Due to costly transportation costs a great share of this increase would take place in small-scale combustion and CHP plants. Thus, increased use of wood biomass would entail positive regional employment effects. (Lauhanen and Laurila, 2007; Ministry of employment and the economy, 2010; Statistics Finland, 2008) Environmental impacts of using wood biomass depend on from which source wood is taken in use. If wood residues come from sawmills, this only improves the production efficiency of forest and energy industries. The use of timber from pre-commercial thinning increases local forest rents and may even improve forest biodiversity. However, if branches and stumps are source of increased use of wood, this may lead to biodiversity damages and soil productivity decreases due to loss of nutrients. (Antikainen et al., 2007; Mälkki and Virtanen, 2003)

Bioenergy and biofuels can alternatively be produced from crops. An especially interesting bio energy crop in Finland is perennial reed canary grass, which is cultivated with low fertilizer input. Reed canary grass can replace peat in CHP production. Like wood, it provides a regional solution due to rapidly increasing transportation costs; the socially optimal transportation radius depends on relative prices and may extend over 100 kilometres from the power plant. Cultivation of reed canary grass reduces nutrient leaching relative to conventional crops; its impact on biodiversity is ambiguous (Lankoski and Ollikainen, 2008). As for bio fuels, the Finnish focus is on the second generation (cellular-based) technology to prevent competition with food production. The requested 10% increase in the share of bio fuels to 10% of all fuel consumption by 2020 makes 6TWh. If bio fuels are produced instead of reed canary grass from the straws of barley or wheat the environmental impacts remain roughly the same as in conventional cultivation. (Antikainen et al., 2007)

The energy sources we provide in the questionnaire are based on the potentials outlined above. We survey the citizens' opinions on environmental impacts of these renewable energy production technologies and on Finnish energy policy issues, their familiarity with renewable energy production and readiness to increase their consumption of renewable energy at the expense of the other consumption which refers to their willingness to pay for the increase in renewable energy production.

3. Method and application

The core of a choice experiment survey is a series of choice tasks in which the respondents state their preferences for environmental goods, i.e., future energy production in a hypothetical setting. The alternatives are described by selected environmental and societal characteristics (attributes), based on Lancaster's characteristics theory of value (Lancaster, 1966). The attributes are addressed several levels in order to find the effect of increase or decrease in the characteristics on people's valuation. In each choice task, the respondent compares the alternatives (combinations of attribute levels) and chooses the one that provides the highest utility. (Bennett and Blamey, 2001)

There are several econometric models available for the analysis of the choice data. For instance, the nested logit (NL) model, the generalization of the multinomial logit model, introduces two stages. In the upper level of the model, the choice between the branches 'Renewable energy' and 'Current energy mix' is done, and in the lower level follows the choice between the renewable alternatives. The idea of the NL model is to model the correlation between groups of similar alternatives, that is, by assumption alternative renewable energy sources have more in common than any of them has with ‘Current energy mix’. This solves the restriction of the simple multinomial logit model which assumes that respondents perceive all alternatives in one choice task similarly (independence of irrelevant alternatives, IIA), although this is unlike when a task consists of one status quo alternative and four renewable energy alternatives that similar by nature. The coefficients of the alternative specific constant (ASC) and attributes in the model reveal the tastes of an average respondent. The interactions of ASC with socio-demographic variables provide more information about the factors affecting the willingness to pay by revealing the differences compared to an average respondent. (Bennett and Blamey, 2001; Louviere et al., 2000; McFadden, 1981; Train, 2009)

The choice process is formally presented as follows. At the first stage, the utility functions for the branch choice (‘Renewable energy’ vs. ‘Current energy mix’) are: $U_{Rnewables} = \alpha_j + \sum_m \delta_m c_{mn} + \lambda_1 IV_{Rnewables} + \varepsilon$ and $U_{CurrentMix} = \lambda_2 IV_{CurrentMix} + \varepsilon$. The alternative specific constant (ASC) α_j, specified as one for renewable energy options and zero for the opt-out option, captures the average effect of unobserved factors. The respondent or attitude characteristics c_{mn} reflect the impact of these factors on the choice in the first stage, δ_m is the associated coefficient, and IV_s refers to the inclusive value (or scale) parameter and λ_s is the associated coefficient. In the second stage, the utilities for respondent *n* from alternative *j* are determined by $U_{nj} = \sum_k \beta_k x_{njk} + \sum_m \eta_m c_{mn} x_{njk} + \varepsilon$. In the utility functions for choice among alternatives, the coefficient β_k for attribute *k* represents the average tastes of the respondents, and x_{njk} is the value of attribute *k* for alternative *j* for individual *n*. The next term accounts for the respondent or attitude characteristics c_{mn} that are interacted with the attribute x_{njk} due to invariance across alternatives for each individual, and η_m is the associated coefficient. The error term of the random utility model is represented by ε . The ASC and the scale parameters, out of which the one for the upper level is specified as one and the one for the lower level is left to be estimated by the model, indicate the relative utility of 'Renewable energy' versus 'Current energy mix'.

When one of the alternatives is the current state (current energy-mix), the part-worths (willingness-to-pay estimates, WTPs) for alternative renewable energy sources and for any combination of attribute levels (the scenario) can be calculated with statistical analysis. For the selected improvement in scenarios (attribute combinations), the expected WTP of individual *n* follows the standard Hanemann (1982) utility difference expression, which assumes the constant marginal utility of income over the population: $E(WTP_n) = -1/\beta_p \left[\ln\left(\sum \exp(V^1)\right) - \ln\left(\sum \exp(V^0)\right)\right]$, where β_p is the parameter estimate of the cost, V^1 is the utility evaluated in the renewable energy case, defined as changes in attribute levels relative to the current energy mix, V^0.

During the design phase, the selection of attributes of renewable energy production was based on the views of the expert panel and on the pilot survey among citizens and university students in spring 2008. Table 1 presents the selected attributes: the impacts on local biodiversity and on local jobs, and the changes in carbon emissions and in the electricity bill. The levels of attributes, identified with help of literature (Antikainen et al., 2007; Halonen et al., 2003; Lauhanen and Laurila, 2007; Siitonen, 2008) and information from experts, correspond to potential impacts of particular renewable energy sources. The changes in carbon emissions related to the additional share of renewables, measured in terms of percentual reductions compared to the current energy mix being used instead, are based the emission coefficients and depend on which energy source the renewables are assumed to substitute.[4] Moreover, in the case of bio energy, the assumptions on emissions of transportation and burning biomass play a role. (Brännström-Norberg et al., 1996; Mälkki, 1999; Mälkki and Virtanen, 2003; Turkulainen, 1998)

Table 1. Attributes and levels in the choice tasks.

Attribute	Description	Alternative	Levels
Local biodiversity (BD)	Impact on local biodiversity in the proximity of energy production	Wind	no change, deterioration
		Crop	improvement, deterioration
		Wood	improvement, deterioration
		Hydro	no change, deterioration
Change in carbon emissions (CO)	Reduction in CO2 emissions, related to the additional share of renewable energy production (from 25% to 38%)	Wind	-99 %, -97 %
		Crop	-70 %, -60 %
		Wood	-95 %, -90 %
		Hydro	-99 %, -90 %
Local jobs (JOB)	Amount of new local jobs resulting from the energy option	Wind	800, 100
		Crop	1400, 400
		Wood	5000, 2500
		Hydro	500, 20
Change in electricity bill (PRICE)	How much more (in euros) one should pay for electricity bill yearly	All	5, 30, 80, 160

After the specification of the attributes and levels, the choice tasks were formed by combining the levels by the experimental design procedure. The full factorial design would allow for identification of main effects of attributes, that is the utility of each attribute irrespective of changes in other attribute levels, and the effect of interactions between all attributes, but forming all possible combinations of three 2-level attributes and one 4-level attribute in four alternatives would result in $32^4 = 1{,}048{,}576$ alternatives. Thus, a fractional factorial design was adopted as it allows for studying the main effects of each attribute which are the focus of this study.

An orthogonal design plan of 32 choice tasks was created with the software SPSS 15.0. The tasks were blocked into 4 blocks of 8 choice tasks such that each respondent faced 8 tasks (example in fig 1). The labels of the alternatives refer to alternative renewable energy technologies: energy from wind power, energy from wood, energy from crop, and energy from hydro power. The levels of the attributes were defined as the differences from the current energy mix. The attributes were the effect on local biodiversity, the change in carbon dioxide (CO_2) emissions, the effect on local jobs, and the increase in electricity bill. In the choice question, a dual response method was applied. First, the respondent chose the preferred option among four renewable energy options in a forced choice task. In the next question, an opt-out option was provided by asking whether s/he would actually prefer the current energy mix instead of any of the renewable energy options. This procedure ensures, in case of large number of opt-out choices, gathering information on relative attractiveness of renewable energy alternatives (see, Brazell et al., 2006) and forces the respondent to pay attention to attributes and levels when the opt-out option as an easy option is not present.

Figure 1. An example of a choice task including four alternative ways to produce renewable energy.

Characteristics	**Alternative 1: Energy from wind**	**Alternative 2: Energy from crop**	**Alternative 3: Energy from wood**	**Alternative 4: Energy from water**
Effect on biodiversity	no change	improvement	deterioration	no change
Increase in your household electricity bill	170 € / year	90 € / year	30 € / year	170 € / year
New longterm jobs	1000	200	2500	20
Change in CO2 emissions	-99 %	-50 %	-70 %	-99 %

Before a series of choice tasks, the respondents were informed about the current share of renewable energy (25 % in 2007), the target share of renewable energy (38 % in 2020), the current use of renewable energy (102 TWh in 2007), and the estimation of renewable energy needed in 2020 (118 TWh). The respondents were told that the following choice tasks are to map opinions on renewable energy sources and their effects on environment and society. In choice tasks, the changes in local biodiversity, CO_2 emissions, local jobs and yearly electricity bill associated to one renewable energy source are to be compared to the opt-out option: no increase in the share of renewable energy production and the continuing use of the current energy mix. The respondents were reminded about considering their budget constraint. In addition to choice tasks, the respondents answered a series of attitude questions concerning energy issues in general and the production of renewable energy in particular.

The data were collected in October 2008 by the internet panel of a professional polling company. The sample of 1304 respondents randomized by age, gender and geographical area was contacted. Due to non-response and missing values to relevant questions, 947 questionnaires were usable for the attitudinal and choice analysis.

4 Results

4.1 Socio-demographic characteristics and familiarity with energy production

Table 2 presents the mean average sample values of several socio-demographic characteristics and the corresponding average values from the statistical data in 2008 (Statistics Finland, 2011). The share of male respondents is 50.9 % and the mean age is 46.6 years. The mean annual household income is 45.5 thousands euro, the mean household size 2.51 persons, and 3.7 % of the respondents were unemployed and 20.8 % retired. The representativeness of the sample for the population was tested with the Independent samples t-test for age, income, and household size, while for the rest of variables the Pearson chi-square test was performed. At the 5 % level significance level, the evidence for the rejection of the null hypotheses of the equality of means was found regarding three variables. The share of people having the university degree was significantly higher in the sample (16.3 %) than in the population (6.7 %) ($\chi^2(1) = 14.74$, $p = 0.0001$) as well as the share of agricultural entrepreneurs (1.1 % vs. 0.2. %) ($\chi^2(1) = 4.06$, $p = 0.04$), while the proportion of rural residents was significantly smaller in the sample (24.7 %) compared to the population (40.7 %) ($\chi^2(1) = 10.61$, $p = 0.001$). While the bias towards high education in the sample likely results from the internet panel, the other two reflect the small scale agricultural entrepreneurship in Finland: there are citizens that are part-time farmers or private nonindustrial forest owners. No statistically significant differences appeared in the share of the residents in the largest Finnish cities (31.7 %). The randomization of the respondents according to geographical area seems to have resulted in corresponding shares of respondents in five Finnish provinces.

Table 2. The comparison of the sosio-demographic factors in the sample data and the corresponding population data.

	Sample	**Population**
Sample size	947	5 326 314
Gender (% of males)	50.9	49.0
Age (mean)	46.6	40.6
Annual household income (mean, in 1000 EUR)	45.5	48.8
Household size (mean)	2.51	2.09
Unemployed	3.7	4.4
Retired	20.8	23.1
High education (% university degree)	*16.3*	*6.7*
Agricultural entrepreneur	*1.1*	*0.2*
Residence in rural settlement (%)	*24.7*	*40.7*
Residence in city (Helsinki region, Turku, Tampere) (%)	31.7	26.4
Residence in... (%)		
Southern Finland province	42.2	41.2
Western Finland province	34.3	35.3
Eastern Finland province	12.1	10.7
Oulu province	7.9	8.8
Lapland province	3.4	3.5

The population data in 2008 are from Statistics Finland (2011).Marked with *italics* , the sample mean and the population mean are not equal at the 5% level according to the Pearson χ^2 test.

The experience of the respondents on power plants was reflected in two aspects: having seen them and living close to them. Excluding the answers ‘Cannot say’, according to both aspects, the hydropower plant was the most familiar since almost three fourths (72 %) stated having seen them and almost one fourth (23 %) lived in their proximity. The next most well-known plants in terms of ‘having seen’ were: wind power plant (67 %), fossil fuel (i.e. coal or gas) power plant (48 %), nuclear power plant (48 %), peat power plant (36 %) and biomass power plant (26 %). At the same time, about one fifth lived in the proximity of fossil fuel plant (19 %), biomass power plant (17 %), or peat power plant (16 %), and only tenth lived in the proximity of wind power plant (10 %) or nuclear power (10 %). One conclusion from these percentages is that the biomass production is rather little known. This is confirmed by the inspection of the shares of ‘Cannot say’ answers that were larger for bio energy production compared to other technologies, namely, as many as 19 % (12 %) were not sure whether they live close to (have seen) a biomass power plant. No more than 4 % of the respondents stated his/her job to be closely connected to energy issues.

As the increase in the production of renewable energy only applies to the electricity production, only those households whose heating is produced by electricity are ‘fully’ touched by our main survey question: the economic impact of the increase in the renewable energy production. To find out these people, the type heating system in respondents’ apartments was asked: 28 % of the respondents had direct electric heating and 8 % had storage electric heating. Meanwhile, a larger share of the respondents had either district heating (49 %) or warmed their apartment with oil (14 %).

As regards environmental and monetary issues related to the energy consumption of the respondents, not everyone had considered them. Almost two fifths (37 %) of the respondents did not know whether their household had bought renewable energy, while one fifth (22 %) stated that they have bought or are currently buying energy produced by renewable energy technologies. Most respondents (77 %) were aware of the magnitude of their current electricity bill.

4.2 Attitudes on energy issues

In order to investigate the relationships between the attitudinal variables reflected by statements concerning energy policy, the factor analysis was conducted with the statistical software SPSS 15.0. The correlated statements (variables) were combined into one factor representing the essence of original variables by the principal components analysis. The varimax rotation that minimizes the number of variables giving high scores to each factor was used for the simplification of the interpretation. (Statsoft, 2011) According to the scree test to decide on how many factors are retained, the 14 statements were reduced to four factors. Another commonly used criterion (the Kaiser criterion) suggests that the factors with the Eigen values larger than one are to be retained. Here the fourth factor with Eigen value of 0.999 was considered in the analysis.

Table 3 presents the loading of the statements (with question numbers most on the left) concerning the energy policy, the perceptions on the environmental and societal consequences of renewable energy production and the readiness to contribute to the increase in the share of renewable energy to the extracted four factors. The statements were assumed to associate with the factors for which they have the highest score. The factors reflect the continuum from the active climate protecting attitude to the opinion understating and neglecting the effect of GHGs on climate. The strict environmental attitude of factor 1 (named 'Climate activists') is revealed by the experience on buying renewable energy and the position that everyone should do the same regardless of the costs, emphasizing the significance of everyone's contribution in boosting the share of renewable of all energy use. Factor 2 ('Moderate supporters') reflects a combination of conservation-minded and pro-domestic renewable energy perspective emphasizing the opportunities of renewable energy production in promoting the lively countryside and the environmental sustainability and self-sufficiency of energy production as well as stating, in the question 3.2, the willingness to reduce own energy consumption as a means of GHG reduction. When looking at the loads of this statement about the readiness to reduce one's own energy consumption to each of four factors, in addition to being, in comparison to the loads of other statements, exceptionally and relatively equally loaded to all factors, it is the one dividing the factors into those of the positive attitude towards the increase in the production of renewable energy and the lack of support for renewable energy as a means for reducing the GHGs. The statement associates positively to factors 1 and 2 and negatively to factors 3 and 4.

Factor 3 (‘Technologists’) represents the view emphasizing technological solutions in conventional energy production (i.e. nuclear power plants) rather than the production of renewable energy as a promising alternative to reduce GHGs in Finland, and stressing the role of technical solutions and disregarding the consumer’s viewpoint when making energy policy decisions. While not considering the reduction of energy consumption an especially important goal, factor 3 still expresses care for climate by supporting competitive and market based measures to mitigate GHG emissions. In contrast to factors 1-3, factor 4 (‘Remiss about GHGs’) reflects the careless attitude towards environmental consequences of burning fossil fuels, the reluctance to pay for energy more than currently, and underlines the freedom of consumers to choose themselves the source of the energy they consume and the importance of the energy remaining cheap. These broad attitudinal scale of respondents suggest differences in marginal willingness to pay estimates for energy from renewable sources.

Table 3. Respondents' attitudes on energy policy issues and the loads of statements to extracted factors.

Question numbers and statements	**Extracted factors**			
	Climate activists	Moderate supporters	Technologists	Remiss about GHGs
3.6 Independent of costs, everybody should choose the energy resulting in the minor environmental impact	**,539**	,239	-,064	-,402
3.1 My household has bought / currently buys electricity produced from renewable energy sources	**,827**	,030	,099	,085
3.8 The impact of energy production on natural biodiversity should not be worse in the future than currently	,118	**,700**	,009	-,054
2.6 In case environmental friendly energy is more expensive due to, e.g. new investments, it is important to know what the additional money is used for	-,010	**,701**	,140	,036
2.5 The harmful effects of energy production on environment must be reduced	-,025	**,707**	,009	-,274
2.4 It is important to maintain the vitality of countryside by creating new jobs related to renewable energy sources	,179	**,624**	-,091	,179
2.3 In its energy production, Finland should be self-sufficient and independent of imports (e.g. coal, oil, natural gas, uranium, electricity)	,082	**,543**	,243	,129
3.2 I'm ready to reduce my own energy consumption to decrease the green house gas emissions (e.g. carbon dioxide)	,351	**,446**	-,304	-,296
3.4 To reduce green house gases (e.g. carbon dioxide), new production capacity of nuclear power must be built in Finland	,083	,070	**,663**	,239
2.2 Decisions on energy production are to be made by public administration based on research results instead of consumer viewpoint	-,073	,134	**,780**	-,113
3.7 Nobody should be forced to pay more for environmental friendly energy	-,076	,140	-,078	**,767**
3.5 The most important is that energy remains cheap	,030	,062	,183	**,735**
3.3 I'm ready to pay more for environmental friendly energy	,437	,261	-,040	**-,606**
2.1 Environmental problems stemming from energy production (air pollution, climate change) are exaggerated	,077	-,070	,401	**,464**

4.3 Willingness to pay for increased renewable energy production

The analysis of the choice tasks reveals the support for alternative energy production options and the factors affecting the probability that the respondent chooses a particular renewable alternative. In 7566 choice tasks, out of renewable energy alternatives, energy from wood was chosen the most often (1994 tasks, 26 %), followed by wind power (1544 tasks, 20 %), hydro power (720 tasks, 10 %), and energy from crop (675 tasks, 9%). The opt-out option (staying in the current energy mix) was the most popular, chosen in 2633 tasks (35 %). Out of 947 respondents, 163 (17 %) chose the opt-out option in all 8 choice tasks. This relatively high share of zero willingness to pays indicates, on average, the reluctance to pay more for the renewable energy, but not necessarily the opposition to renewable energy production. Unfortunately though, the potential protest answers, i.e. those who chose the opt-out option because they protested some element of the described scenario instead of having the true zero willingness to pay, could not be identified due to the lack of appropriate follow-up questions.

The econometric analysis of the valuation data was conducted with the software Limdep 9.0 Nlogit 4.0. In the linear-in-attributes nested logit (NL) model, the renewable energy alternatives are located in one branch and the current energy mix in another. The coefficients of the alternative specific constant (ASC), coded as zero for the current energy mix and one otherwise, and attributes in the model reveal the tastes of an average respondent. The levels of opt-out option 'Current energy mix' are coded as zeros for the carbon dioxide attribute, job attribute and price attribute. For the qualitative biodiversity attribute, the baseline level was no change, and two effects coded dummy variables were introduced: the improvement and the deterioration compared to the current energy production. The interactions of ASC with socio-demographic variables provide more information about the factors affecting the willingness to pay by revealing the differences compared to an average respondent.

Table 4 presents the results. First, all coefficients of the utility function (attributes and energy technologies) have expected signs: on average the general public opposes the deterioration of biodiversity and prefers the increase in jobs, the decrease in CO2 emissions, and the increase in biodiversity. Also, the higher the sum of the yearly electricity bill, the less probably the alternative is chosen. Second, the model reveals high preference for wind power followed by wood energy, while the preferences for hydropower and crop energy are much lower. Third, regarding the socioeconomic factors affecting these valuations, the respondents with income higher than the average, male gender, and age younger than the average elicited higher preferences for renewable energy sources. The geographical analysis of the place of residence revealed that, compared to the rest of Finnish population, the residents in Eastern Finland favoured bio energy technologies over other sources; wood more than biocrops.

Table 4. Results of the nested logit model (NL).

Variable	Coef	St.e	Sign
1 Utility function: Attributes			
Biodiversity Improvement	0,090	*0,030*	***
Biodiversity deterioration	-0,134	*0,042*	***
Number of jobs	0,000	*0,000*	***
Decrease in CO2 emissions	0,003	*0,001*	***
Increase in electricity bill	-0,002	*0,001*	***
1 Utility function: Energy technologies			
Wind power	0,443	*0,112*	***
Hydro power	0,325	*0,143*	**
Energy from crop	0,295	*0,149*	*
Energy from wood	0,381	*0,127*	*
2 Branch choice: Respondent characteristics			
Income *ASC	0,259	*0,064*	***
Male * ASC	-0,133	*0,049*	***
Old * ASC	-0,396	*0,057*	***
Eastern Finland residence * Crop	0,050	*0,028*	*
Eastern Finland residence * Wood	0,110	*0,037*	**
3 Inclusive value			
More renewable energy	0,162	*0,049*	***
Current energy mix (Fixed parametei	1,000	*0,000*	
Model statistics			
Number of obs (choice tasks)	7566		
Log likelihood	-10142.75		
Pseudo R	0,161		
Correct predictions	31 %		

Standard errors are in parentheses. ***(**)* significant at 1(5)10% level

Table 5 presents the willingness to pay estimates for attributes and for each renewable energy technology, calculated with the help of model coefficients. Moreover, we analyze the national benefits of the energy policy scenario that corresponds to Finland's Climate Change and Energy Strategy (Ministry of employment and the economy, 2008).

According to Ministry of Employment and the Economy (2010), the increase in the production of renewable energy by 2020 consists of wind power and energy from wood. The increase in renewable energy use is expected to be 18 TWh out of which roughly a third (6 TWh) is produced by the wind power and the rest by energy from wood. Regarding the environmental and employment effects, this scenario is based on the following assumptions. The wind and wood energy both cause positive and negative effects on biodiversity, thus we expect the impacts to cancel out. Regarding the employment effects, we weighted the middle points of the attribute levels according to the weighting of the renewable energy alternatives considered (wind and wood). For CO2 emissions, we assumed that the renewable energy production substitutes the average electricity production.

Table 5. Mean WTP estimates (in euros) and aggregate WTPs (in million euros) for branches (energy technologies), attributes and for a scenario.

Energy technology / Attribute	**Household WTPs (in euros)**	**Aggregated national WTPs (in millions of euros)**
Wood (Eastern Finland)	298	81
Wind (country)	270	685
Wood (country except Eastern Finland)	232	525
Crop (Eastern Finland)	210	57
Hydro (country)	198	502
Crop (country except Eastern Finland)	179	405
Biodiversity improvement	55	139
Biodiversity deterioration	-81	-205
One job more	0,02	0,1
Decrease in CO2	1,7	4
Scenario: Finland's Climate Change and Energy Strategy	249	632

The number of households is calculated by using the information on population amounts nationally and regionally and the average household size in Finland 2008 (Statistics Finland 2008).

The WTP estimates for energy technologies in table 5 are in the diminishing order starting from the technology for which the households are willing to pay the most. The residents in Eastern Finland are willing to accept, on average, a 298 € increase in their household's yearly electricity bill in order to substitute the current energy mix with the energy from wood. The next highest WTP was estimated for the nationwide WTP for wind power and the WTP for non-Eastern residents for energy from wood. These results highlight high preferences for wind and wood energy and an important potential role energy wood may have in Eastern Finland. Regarding WTPs for attributes, the WTP estimate for improvement in biodiversity is lower than the willingness to accept compensation for deterioration. This indicates that the respondents less willingly lose the current level of biodiversity than gain the higher level. The magnitudes of WTP estimates for one permanent employee and a one percent decrease in emissions of CO2 are small compared to other WTP estimates. The aggregated national WTP estimates in the rightmost column are the household estimates multiplied by the number of households in Finland (in Eastern Finland and in the rest of Finland) in 2008. The yearly benefit for the Finns from the implementation of the Climate Change and Energy Strategy is 632 million euros.

5 Conclusions

This choice experiment survey provided new information for the Finnish energy policy planning by eliciting citizens' preferences for environmental and societal attributes of four renewable energy alternatives: wind power, hydro power and bio energy from wood and crops. A broad scale of attitudes towards the GHGs, their effect on the climate change and the mitigation options revealed that the increasing use of renewable energy, though decided and promoted at the EU level, has no consensual basis on the citizens level.

The preferences for different technologies gave support for wind power and bio energy from wood at the expense of hydro power and bioenergy from crops. These findings lie at the heart of the Finnish energy policy and citizens' experience. Most of hydropower has been built and the negative impacts of regulating water reserves for power production and lost salmon fishing possibilities have been criticised. Forests in turn are plentiful and can provide locally a large sustained yield of energy wood for which current demand is low. A unanimous understanding is that increased use of wood is regionally beneficial and that in the long-run it would also promote forest industry thanks to improved quality of stands. Mistrust on bio energy production from fields is rather surprising given the large arable area and secondary role of northern agriculture in global food security.

Regarding significant regional differences in preferences for bio energy, the residents in Eastern Finland were most supportive of bio energy from crops and wood. This as one would expect as the Eastern Finland has the highest forest cover of land and thus high supply potential of energy wood. The same holds true for the fields assigned to reed canary grass. This recalls for paying attention to regional equity when implementing new energy policies. The citizens perceived impacts of energy production on biodiversity important, especially, the deterioration of biodiversity was strongly opposed. These findings underline the importance of linkages between national energy policy and national policies and strategies that aim at the development of rural areas and the enhancement of biodiversity.

This research allows for several conclusions on the Finnish renewable energy policy. The Finnish Climate Change and Energy Strategy (2008) is in line with citizens' preferences, as the energy from wood and wind power are the most preferred technologies among citizens. Obviously the citizens are strongly opposed to the increase in the use of hydropower, the issue which every now and then comes up in the discussion although building new hydropower plants would require the change in the legislation. Further, the citizens seem to be skeptical for the energy from crops, with an exception of the residents in Eastern Finland. Another significant regional difference was the support for energy from wood in Eastern Finland. These regional differences were expected, because bio energy has large regional economic impacts, and the forests are important only in Eastern and Central Finland. Wind power, although being a nationwide energy technology, in turn has only modest impact on employment.

Since the conduction of this survey in 2008, the European Union has tightened its targets for the increase in renewable energy production. Our results, though not fully applicable to this new situation, can provide suggestive information for decision-making on the future energy policy issues as well. The change in the overall climate change policy context and in the emerging role of forests in renewable energy production would demand for monitoring of the changes in citizens' preferences for renewable energy production and its environmental consequencies over time.

References

Act on the protection of rapids. 1987. Koskiensuojelulaki 23.1.1987/35.

Antikainen, R., Tenhunen, J., Ilomäki, M., Mickwitz, P., Punttila, P., Puustinen, M., Seppälä, J., Kauppi, L., 2007. Bioenergian tuotannon uudet haasteet Suomessa ja niiden ympäristönäkökohdat (The production of bioenergy in Finland: new challenges and environmental aspects). Reports of Finnish Environment Institute 11.

Bennett, J., Blamey R., 2001. The Choice Modelling Approach to Environmental Valuation. Edward Elgar, pp. 269

Bergmann, A., Colombo, S., Hanley, N., 2008. Rural versus urban preferences for renewable energy developments. Ecological Economics 65(3): 616-625.

Bergmann, A., Hanley, N., Wright, R., 2006. Valuing the attributes of renewable energy investments. Energy Policy 34: 1004-1014.

Brazell, J.D., Diener, C.G., Karniouchina, E., Moore, W.L., Severin, V. Uldry, P.-F., 2006. The no-choice option and dual response choice designs. Merketing Letters 17:255-268.

Brännström-Norberg, B.M., Dethlefsen, U., Johansson, R., Setterwall, C., Tunbrandt, S., 1996. Life-cycle assessment for Vattenfall's electricity generation. Summary Report. Vattenfall, Stockholm. 137p.

European Commission 2006. Energy Issues. Special Eurobarometer 258. Available: http://ec.europa.eu/public_opinion/archives/ebs/ebs_258_en.pdf. Accessed April 28, 2008.

European Parliament 2009. Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0028:EN:NOT. Accessed April 12, 2012.

Farrell, A.E., Plevin, R.J., Turner, B.T., Jones, A.D., O'Hare, M., Kammen, D.M., 2006. Ethanol can contribute to energy and environmental goals. Science 311 (5760), 506–508.

Halonen, P., Helynen, S., Flyktman, M., Kallio, E., Kallio, M., Paappanen, T., Vesterinen, P., 2003. Bioenergian tuotanto- ja käyttöketjut sekä niiden suorat työllisyysvaikutukset (Direct employment effects of bioenergy production and use). VTT Research Notes 2219. 51p.

Hanemann, W.M., 1982. Applied Welfare Analysis with Qualitative Response Models, Working Paper 241, Giannini Foundation of Agricultural Economics, University of California, Berkeley.

Hanley, N. , Nevin, C., 1999. Apprasing renewable energy developments in remote communities: the case of the North Assynt Estate, Scotland. Energy Policy 27: 527-547.

Hensher, D., Rose, J., Greene, W., 2006. Applied choice analysis: A primer. Cambridge University Press, UK, 717 p.

Håkansson C., Johansson P.-O., Kriström B., 2005. Salmon and hydropower: dynamic cost-benefit analysis. In: Aronsson T, Axelsson R, Brännlund R (Eds) The theory and practice of environmental and resource economics-essays in honour of Karl-Gustaf Löfgren. Edwar Elgar, UK.

Johnson, G.D., Erickson, W.P., Shepherd, M.F., Shepherd, D.A., Sarappo, S.A., 2003. Mortalityof Bats at a Large-scale Wind Power Development at Buffalo Ridge, Minnesota, American Midland Naturalist 150(2):332 – 342.

Kikuchi, R., 2008. Adverse impacts of wind power generation on collision behaviour of birds and anti-predator behaviour of squirrels. Journal for Nature Conservation 16: 44–55.

KTM, 2005a. Vesivoimatuotannon määrä ja lisäämismahdollisuudet Suomessa (The opportunities to increase hydropower production capacity in Finland). Energiateollisuus Oy.

KTM, 2005b. Pienvesikartoitus (Small Hydro Evaluation). Report for Ministry of Trade and Industry Dnro 58/804/2004. PR Vesisuunnittelu Oy.

Ladenburg, J., Dubgaard, A., 2007. Willingness to pay for reduced visual disamenities from offshore wind farms in Denmark. Energy Policy 35, 4059 – 4071.

Lancaster, K.J., 1966. A New Approach to Consumer Theory. The Journal of Political Economy 74(2):132-157.

Lankoski, J., Ollikainen, M., 2008. Bioenergy crop production and climate policies: A von Thunen model and case of reed canary grass in Finland. European Review of Agricultural Economics 35, 519-546.

Lankoski, J., Ollikainen, M., 2011. Biofuel policies and the environment: Do climate benefits warrant increased production from biofuel feedstocks? Ecological Economics 70, 676-687.

Lauhanen, R., Laurila, J., 2007. Bioenergian tuotannon haasteet ja tutkimustarpeet (Challenges and research needs of bio energy production). Metla Working papers 42.

Law of the subsidies for electricity produced from renewable sources. 2010. Laki uusiutuvilla energialähteillä tuotetun sähkön tuotantotuesta. 1396/2010.

Louviere, J., Hensher, D., Swait, J., 2000. Stated Choice Methods – Analysis and Application. Cambridge: Cambridge University Press.

McFadden, D., 1981. Econometric models of probabilistic choice. In Structural analysis of discrete choice data with econometric applications, ed. Manski, C. and D. McFadden, 479 pp. Cambridge: MIT Press.

Ministry of employment and the economy, 2008. Climate Change and Energy Strategy. http://www.tem.fi/files/20587/Climate_Change_and_Energy_Strategy_2008_summary.pdf . Accessed January 14, 2009.

Ministry of employment and the economy, 2010. Finland’s national plan for promoting energy from renewable energy sources pursuant to Directive 2009/28/EC. http://cc.europe.eu/energy/renewables/transparency_platform/doc/national_renewable_energy_action_plan_finland_en.pdf . Accessed March 22, 2012.

Mälkki, H., Hongisto, M., Turkulainen, T., Kuisma, J., Loikkanen, T., 1999. Vihreän energian kriteerit ja elinkaariarviointi energiatuotteiden ympäristökilpailukyvyn arvioinnissa. (Green energy criteria and life cycle assessment in assessing environmental competitiveness of energy products). VTT Research Notes 1974. 117p.

Mälkki, H., Virtanen, Y., 2003. Selected emissions and efficiencies of energy systems based on logging and sawmill residues. Biomass and Bioenergy 24: 321-327.

Peltola, E., Holttinen, H., 2001. Tuulivoimamarkkinat suomalaisen teknologiaviennin kannalta. (Windpower market and technology expert in Finland). VTT Energia Reports 45.

Scarpa, R., Willis, K., 2010. Willingness-to-pay for renewable energy: Primary and discretionary choice of British households’ for micro-generation technologies. Energy Economics 32: 129-136.

Siitonen, J., 2008. 4. Energiapuun korjuun vaikutukset metsälajiston monimuotoisuuteen. (Impacts of harvesting energy wood on forest biodiversity.) In: Kuusinen, M., Ilvesniemi, H. (Eds.) 2008. Energiapuun korjuun ympäristövaikutukset. (Environmental effects of harvesting energy wood.) Tapio and Metla publications. Pp. 30-35.

Statistics Finland, 2008. Electricity generation by energy source. http://www.stat.fi/til/ehk/tau_en.html. Accessed April 15, 2008.

Statistics Finland, 2011. http://www.tilastokeskus.fi/tup/tilastotietokannat/ index_en.html. Accessed April 18, 2011.

StatSoft, Inc. 2011. Electronic Statistics Textbook. Tulsa, OK: StatSoft. http://www.statsoft.com/textbook

Turkulainen, T., 1998. Tuulivoimalan elinkaariarviointi. (Life cycle assessment of wind power plant.) Lappeenranta University of Technology. 72p.

Train, K., 2009. Discrete Choice Methods with Simulation. 2nd ed. Cambridge: Cambridge University Press.

Footnotes

[1] In addition to above studies, an opinion poll on the energy issues (European Commission, 2006) revealed that citizens do not oppose the idea of paying more for energy originating from renewable sources. According to the survey results, 47 % of Finns were prepared to pay more for energy produced from renewable energy sources. 35 % of the total sample agreed on an increase up to 5 % and 12 % were prepared to pay even more. When in the split sample the possibility of reducing energy consumption was accounted as an alternative to reduce CO2 emissions, 60% of the respondents were not prepared to pay more but intended to reduce their energy consumption, while 18% stated the opposite.

[2] A parallel target for the increase in renewable energy sources in the EU strategy, the reduction in carbon emissions, may partly be aimed by using nuclear power. Moreover, the EUhas classified peat as a slowly renewable source of energy. We focus strictly on

renewable energy sources and do not include nuclear power as an option in this survey or peat in the bundle of renewable energy sources.

[3] Geothermal energy and solar energy are comparable to wind and hydro power in that they do not require substantial land input. These sources have a only small role in the Finnish energy-mix. Both as used in a scale, mostly to provide electricity in small houses and summer cottages.

[4] For instance, the GHG emission coefficient estimates (g/kWh) for wind power range from 3 to 8, while the coefficient is 340-850 for coal and 250 for average electricity production. When coal is substituted by wind power, the percentual reduction in GHG emissions is (850-8)/850*100=99.1.

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