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The valuation of non-market environmental impacts of wind and solar energy farms from a citizen and consumer perspective

J. Corbié[a]

[a]*Faculty of Technology, Policy and Management, Delft University of Technology. Student nr.: 4007018*

Abstract

The status-quo in prevailing literature derives the non-market environmental impacts from government financed renewable energy project through consumer-based stated preference methods, in which respondents are asked to trade-off environmental impact reductions with their after-tax private income. However, many scholars have argued that eliciting an individual's preference in their role as consumer may be a poor proxy of how they in their role as citizen advise the government how to spend tax money to reduce environmental impacts. So far, this citizen-consumer duality is only empirically derived for transport infrastructure projects. To the best of the authors knowledge, this study is the first to assess empirical differences between citizen and consumer preferences for (non-market) environmental impacts of government financed renewable energy technologies. This empirical knowledge gap is ameliorated by designing a citizen and consumer-based stated choice experiment where respondents are asked to make hypothetical choices between a wind and solar energy farm for a specific building site as a citizen or a consumer. The results indicate that to some extent citizens and consumers make different trade-offs between the environmental impacts of wind and solar energy farms. Moreover, the results infer that differences may lead to different policy recommendations in environmental valuation studies of similar renewable energy technology alternatives.

Keywords: citizen preference, (non-market) environmental impacts, wind energy farm, solar energy farm

1 Introduction

The status-quo in prevailing literature derives the non-market environmental impacts from government financed renewable energy project through consumer-based stated preference methods (Mattman et al. 2016). In these experiment, respondents are asked to make hypothetical choices on spending their private after-tax budget (while financed by taxes) to reduce environmental impacts.

There is an ongoing discussion on the use of such consumer-based approaches to estimate non-market environmental impacts. The basis of the discussion is labelled as the citizen-consumer duality (Vanhonacker et al., 2007) and pertains to the debate whether respondents behave as consumers or citizens in stated preference surveys and whether their willingness to pay (WTP) responses differ depending on these different roles (e.g. Alphonce et al., 2014; Howley et al., 2010; Ovaskainen & Kniivilä, 2005). Consequently, scholars contend that eliciting an individual's preference in their role as consumer may be a poor proxy of how they in their role as citizen advise the government how to spend tax money to reduce environmental impacts (Ackerman & Henzerling, 2004). Moreover, recent scientific contributions infer empirical differences between the way individuals in their role as citizen and as a consumer make trade-offs for government financed transport infrastructure projects (Mouter & Chorus, 2016; Mouter et al., 2016). For instance, in Mouter & Chorus, 2016) respondents are asked to choose between hypothetical routes options by trading-off travel time gains with previously collected tax money (citizen) or their private after-tax budget (consumer). In fact, they infer a statistically significant higher willingness to pay for travel time gains derived from government policy than from their willingness to pay from their after tax income. Despite prior scientific contributions suggesting that citizen and consumer valuation of non-market environmental impacts may differ, to the best of the author's knowledge, no research has empirically explored this in a renewable energy context.

Therefore, the main objective of this paper is to ameliorate this scientific gap in literature by gaining insights in how citizens and consumers make different trade-offs between the environmental impacts from government financed renewable energy projects.

1.1 Research question

The following research question is formulated to attempt to fill this scientific gap:

"To what extent do individuals in their role as a citizen and as a consumer make different trade-offs between non-market environmental goods and services of wind and solar energy farms?"

This research question is answered by designing and conducting two discrete choice experiments, where respondents are asked to make choices between a wind or solar energy farm for a specific a specific building site as a citizen and a consumer.

The choice alternatives differ on the following environmental impacts: 1) Number of households with visual hinder 2) Number of households that experience a noise level of 42 dB on the house façade 3) Amount of hectares replaced agricultural land 4) Amount of hectares of recreational land-use. Furthermore, the consumer experiment includes the cost attribute 'single increase in energy tax. The comparison of the citizen and consumer experiment instigates an answer to the research question.

1.2 Outline of the paper

To reach this goal, first, section 2 will outline the methodology. Then, section 3 presents the data collection method. Sections 4 and 5 discuss the results and policy implications. Finally, section 6 concludes and discusses the results.

2 Methodology

In order to identify differences between citizen and consumer, a definition is adopted from prior research. Mouter et al. (2016) derive that the conceptual difference between citizen and consumer preferences is that they are derived from a willingness to pay from public and private budget respectively. This differences is induced by the choice setting of individuals. For instance, Mouter & Chorus (2016, p. 318) indicate that citizens display their preference by "*supporting or opposing government policies in public spheres like elections, referenda, demonstration and social media*". Contrarily, consumers reveal their preferences in a market setting by purchasing and consuming goods and services (Orr, 2007).

Consequently, Mouter et al. (2016) define that citizen preferences are derived from an individual's preference to allocate government's (previously collected) tax money, while consumer preferences are derived from an individual's preference to spend their after-tax private budget.

In addition, Mouter & Chorus (2016) argue that such preferences can be derived from carefully framed stated choice tasks, replicating typical citizen and consumer choices. For example, Mouter et al. (2016) asked respondents to choose from several government transport investment programs with the same level of previously collected tax money budget. As a next step, respondents decide to which program they prefer to allocate that specific budget. This conceptualization omits the trade-off between infrastructure impacts and private after-tax budget and focuses on the trade-off *between* infrastructure effects, consistent for a public budget. This approach is adopted in this study to infer citizen preferences for the environmental impacts of renewable energy technologies. Besides this, the consumer experiments includes the exact same impacts, but asks for a monetary contribution for environmental impact reduction programs. The study focuses on wind and solar energy farms. Section 2.1 outlines the methodological (experimental) design choices that hold for both citizen and consumer experiment. Section 2.2 presents the citizen experiment and section 2.3 illustrates the consumer experiment.

2.1 Experimental design

A literature study gained insight into the relevant environmental impacts that may influence the choice of respondents for wind and solar energy farms. Expert discussion with spatial planners, researchers and economists attested the societal relevance of these factors. Subsequently, four scientific and societal relevant environmental impacts were selected: 1) Number of households with visual hinder 2) Number of households that experience a noise level of 42 dB on the house façade 3) Amount of hectares replaced agricultural land 4) Amount of hectares of recreational land-use. Next, a planned renewable energy construction site was selected as a case study (Drentse Monden and Oostermoer) to identify feasible wind and solar energy farm configurations with similar electricity output. This conceptualization was adopted to allow to compare environmental impacts with current environmental evaluation studies. The case study design yielded a feasible range of wind and solar energy farm land-use. Furthermore, a GIS analysis identified a feasible range of residents within 500 meters from the construction site (and thus identify as the visual and noise hindered residents). This was input for the experiment choice set design.

Since no prior research has attempted to design a citizen experiment in this context, a pilot study was conducted to pre-test the discrete choice experiment set-up. For the pilot-survey, a ‘basic plan four’ orthogonal design was designed with Ngene (ChoiceMetrics, 2012). This experimental design enables estimating seven utility parameters with three levels with 18 choice tasks. The insights from the pilot survey is threefold. First, extensive feedback reports on the survey set-up illustrated positive feedback on the respondent’ insight in the understandability of the introductory texts as well as the difficulty, realism and relevance of the choice situations. Second, a quantitative analysis of choice behavior identified an on average 60/40 ratio of choices for wind energy over solar energy. Furthermore, it was derived that attributes were perceived the ‘most important attribute’ for a minimum of 12% (agricultural land-use) and maximum of 46% (noise hinder) of the respondents. Third, the estimation of an multinomial logit model gained insights into utility parameters of the attributes. These utility parameters served as ‘prior’ estimates for the final survey experimental designs.

Two D-efficient experimental designs were generated with Ngene (ChoiceMetrics, 2012), with the prior input from the pilot survey. The experimental design enables to estimate a maximum of 11 parameters with four levels with 12 choice tasks. The pilot survey attribute levels were slightly adapted to improve ‘realism’ and prevent non-trading behavior. For instance, the attribute range of the relative high ‘noise’ utility parameter was limited as an attempt to reduce dominance.

Hence, the following attribute levels are chosen: number of households with visual hinder (0, 100, 200, 300), number of households that experience a 42 dB noise level on the façade (0, 50, 100, 150), amount of hectares agricultural land-use (Wind: 10, 20, 30 , 40 and Solar: 50, 100, 150, 200), amount of hectare recreational land-use (Wind: 5, 10, 15, 20 and Solar: 50, 100, 150, 200). To assist respondents in their choice, eye-level impressions of the visual hinder from wind and solar energy farms were designed and shown in the introduction of the survey. Furthermore, maps of the construction sites were included to outline the land-use of the choice situation alternatives.

2.2 Citizen experiment

The respondents from the citizen experiments were asked to advise the government on the allocation of the previously collected tax money to a wind or solar energy farm. The introductory text denoted that respondents should base this choice on the described attributes and assume that all other factors are constant (e.g. electricity output, ecological impact, energy bill). Furthermore, in order to induce generic answers for Dutch citizens, respondents were not informed about the exact location of the planned renewable energy farm. Also, consequentiality was added by denouncing that the government will use the results to manage environmental impacts for future renewable energy farm siting. Literature purports that consequentiality is an essential aspect of stated preference studies (Johnston et al., 2017) . The introductory text and example choice situation are depicted in figure 1.

Hinder:

The wind or solar energy farm can be placed in the vicinity of residential areas and may impact the direct living environment of households through visual hinder and noise hinder.

1. The number of households experiencing visual hinder: The wind or solar energy farm changes the unobstructed view on the landscape from households at the edge of the rim of a wind construction site (at the minimum required distance of 500 meters) or a solar construction site.
2. The number of households experiencing noise hinder: A solar energy farm does not produce sound, but a wind energy farm does. The maximum yearly averaged sound level of a wind turbine on the minimum distance to residents (500 meters) is 42 dB, measured on the façade of the house. The sound is not audible when the windows are closed. When the windows are open, this sound level is comparable to the sound of a refrigerator at a 1 meter distance. However, the type of sound is different: electrical appliances produce a monotonous sound, whereas the sound of a wind turbine is slightly zooming.

Land-use:

The construction of a wind or solar energy farm directly replaces land used for agriculture or recreation. The area directly replaced land is measured in hectares. One hectare is equal to two football pitches, whereas a hundred hectares (one kilometre by one kilometre) is equal to a small village.

3. The amount of hectares replaced agricultural land: The wind or solar energy farm replaces agricultural land. This land is located on private farm property.
4. The amount of hectares replaced recreational land: The wind or solar energy farm replaces recreational land. Recreational land is used for a range activities, such as running and nature recreational activities. A fenced solar energy farm forms a barrier between a residential area and the recreational area, impeding the accessibility.

The government wants to use the results of this experiment to support the decision-making process for the construction of wind and solar energy farms in the Netherlands, when the projects only differ on the indicated characteristics. Therefore, we ask you to assume that the projects do **not** differ on other aspects (e.g. electricity production, security of supply, electricity bill)

The government is interested in the general preferences of Dutch citizens for the development of wind and solar energy farms. Therefore, we do not reveal if the construction impacts your living environment or not. If combinations of characteristics seem illogic, we kindly request you to proceed making a choice based on the environmental impacts.

Please select the renewable energy farm you would recommend to the government.

	Project A: Onshore wind energy farm	**Project B: Grounded solar energy farm**
Number of households experiencing visual hinder	100 households	200 households
Number of households experiencing a sound level of 42 dB on the façade	50 households	0 households
Amount of hectares replaced agricultural land	10 hectares	150 hectares
Amount of hectares replaced recreational land	20 hectares	150 hectares

Figure 1: The citizen experiment attribute description and example choice situation

2.1 Consumer experiment

The consumer experiment survey design is predominantly consistent with the citizen experiment. However, several design alterations are included to induce a typical consumer choice setting. The fundamental difference is the inclusion of a cost attribute to infer an individual's trade-off between an environmental impact and their private (after-tax) budget. This cost attribute is defined as a 'one-time energy tax increase for all Dutch households'.

As a result, the respondents from the consumer experiment were asked to choose between three renewable energy farms: a planned wind energy farm, an alternative wind energy farm and an alternative solar energy farm. The planned wind energy farm design is the financial opt-out alternative under consistent environmental impacts. The two alternative renewable energy farms presented a reduction of environmental impacts for a specific tax increase.

The introductory text and an example choice situation is depicted in figure 2.

5. Single Energy Tax increase for all Dutch households: The alternative wind energy farm and the alternative solar energy farm have higher project costs than the planned wind energy farm. For instance, the installation of quieter wind turbines is more costly. The government considers a one-time Energy Tax increase in 2018 for all Dutch households to finance the alternative renewable energy projects because there is not enough regular budget to cover the extra costs. Mind that the tax increase only holds for 2018 and imposed in other years (2017 and 2019 and on). The project with the most votes will be built.

	Planned onshore wind energy farm	**Alternative onshore wind energy farm**	**Alternative grounded solar energy farm**
Number of households experiencing visual hinder	300 households	100 households	200 households
Number of households experiencing a sound level of 42 dB on the façade	150 households	50 households	0 households
Amount of hectares replaced agricultural land	40 hectare	10 hectares	150 hectares
Amount of hectares replaced recreational land	20 hectare	20 hectares	150 hectares
Single Energy Tax increase for all Dutch households in the Netherlands to finance the construction and maintenance costs	N/A	25 euro	45 euro

Figure 2: The consumer attribute description and example choice situation

3 Data collection

Both citizen and consumer surveys consist of two parts. First, the respondents were asked to read the introductory text and answer the choice situations. Second, the respondents are questioned on perceived survey understandability, realism and relevance as well as their perceived 'most important attribute'. A survey company (TNS NIPO) collected respondents data of Dutch citizens in the age 18 years and older.

No real representativeness was required, but rather a balance of gender, age, income. Table 1 presents an overview of the sample characteristics. Denote that socio-demographic information was not available for every respondent. Therefore, the sample size does not exactly coincide with the estimated samples in section 4.2.

Table 1: Sample descriptive results from the citizen and consumer experiment

	Citizen experiment		**Consumer experiment**	
	(n)	(%)	(n)	(%)
Gender				
Female	108	56%	90	52%
Male	85	44%	82	48%
Age				
18 to 29 yr	33	17%	26	15%
30 to 39 yr	25	13%	23	13%
40 to 49 yr	29	15%	32	19%
50 to 59 yr	46	24%	32	19%
60 + yr	60	31%	59	34%
Education				
Secondary education or lower	51	26%	47	27%
MBO	71	37%	57	33%
HBO/Bachelor University	52	27%	46	27%
Master University/PhD	19	10%	22	13%
Income				
€0 - €27.800	37	16%	43	25%
€27.800 - €41.200	52	23%	39	23%
€41.200 - €69.000	77	34%	40	23%
€69.000 - higher	59	26%	50	29%

4 Results

4.1 Descriptive results

A quantitative analysis of responses infers several insights in the general choice behavior and perceptions of the respondents. Table 2 summarizes the respondent's perceived 'most important attribute'. Denote that consistent with the pilot survey, most respondents perceive noise as the most important attribute in their decision (49.4% and 42.2% respectively). Furthermore, denote that 'tax payment' is selected by the second largest group as the most important attribute in their choice. This indicates the important role of costs in consumer experiments.

Table 2: Overview of percentage respondents selected attribute as 'most important aspect in their decision'

	Citizen	**Consumer**
Number of households experiencing visual hinder	24,5%	17,0%
Number of households experiencing a sound level of 42 dB on the façade	49,4%	42,2%
Amount of hectares replaced agricultural land	12,7%	8,3%
Amount of hectares replaced recreational land	13,5%	9,6%
Single energy tax increase for all Dutch households in the Netherlands to finance the construction and maintenance costs	N/A	22,9%

Besides this, Table 3 and Table 4 highlight the percentage of respondents non-trading for alternatives per experiment.

Table 3: Percentage of citizen experiment respondents non-trading per alternative

	Citizen
Wind energy farm	12,0%
Solar energy farm	25,7%

Table 4: Percentage of consumer experiment respondents non-trading per alternative

	Consumer
Planned wind energy farm	9,6%
Alternative wind energy farm	4,6%
Alternative solar energy farm	14,7%

Several insights can be gained from the non-trader analysis. First, the results illustrate that for both the citizen and consumer experiment a considerable amount of respondents categorize as non-traders for one of the choice options, which may indicate that too low attribute ranges were selected. Remarkably, in the consumer experiments, more respondents are non-traders for an alternative project than the status-quo. This may indicate a willingness to pay for the reduction of environmental impacts. Furthermore, denote that in both citizen and consumer experiment, most non-trading respondents choose solar energy farms, which may indicate unobserved motivations in favor of solar energy farms. However, the model estimates outlined in the next section enable a more elaborate analysis.

4.2 Multinomial Logit estimations

The Multinomial Logit model provides an efficient option to estimate and compare utility estimates from the attribute main effects (Train, 2003). All models are specified as linear-additive random utility models and utility is defined as shown in equations 1-5. Denote that this is a labelled experiment. Therefore, an alternative specific constant (ASC) is estimated, which enables to estimate unobserved preferences. Denote that the constants (labels) are estimated relatively to each other. This implies that for the citizen experiment ASC_{wind} is set to one and ASC_{solar} is estimated relatively to the other. For the consumer experiment the ASC_{plan} is set to one and both ASC_{wind} and ASC_{solar} is estimated relative to the opt-out planned wind energy farm alternative.

Furthermore, all attributes are estimated as alternative specific parameters. For example, wind energy farms induce a different type of visual hinder solar energy farms and are therefore estimated with separate parameter. The citizen utility is a linear function of the ASC solar, the number of households with visual hinder (WV or SV), the number of households with noise hinder (No), the number of hectares directly replaced agricultural land (WA or SA) and the number of hectares directly replaced recreational land (WR or SR). The consumer utility for an alternative is a function of the ASC wind, the number of households with visual hinder (WV or SV), the number of hectares directly replaced agricultural land (WA or SA), the number of hectares directly replaced recreational land (SR) and the ‘single increase in energy tax (WT or ST).

Citizen utility functions

(eq.1): $U(Wind) = ASC_{Wind} + \beta_{Wvis} * WV + B_{Wnoi} * NO + \beta_{WAgr} * WA + B_{WRec} * WR$

(eq.2): $U(Solar) = ASC_{Solar} + \beta_{Svis} * WS + \beta_{SAgr} * SA + B_{SRec} * SR$

Consumer utility functions

(eq. 3): $U(Plan) = ASC_{base}$

(eq.4): $U(Wind) = ASC_{Wind} + \beta_{Wvis} * WV + B_{Wnoi} * NO + \beta_{WAgr} * WA + B_{WRec} * WR + B_{WTax} * WT$

(eq. 5): $U(Solar) = ASC_{Solar} + \beta_{Svis} * WS + \beta_{SAgr} * SA + B_{SRec} * SR + B_{STax} * ST$

Table 5 summarizes the model fit parameters and the utility estimates. Several observations can be made. First, denote that the models report a low fit, expressed in the adjusted Rho-square. As a rule of thumb, a well-fitted model a rho-square value greater than 0.2 and rho-square higher than 0.4 are hard to find (Henscher and Johnson, 1981). Therefore, the MNL model’s ability to predict citizen and consumer choices between wind and solar energy farms is arguable. However, the model is still suitable to identify statistically significant attributes.

Second, mind that all parameter estimations have a logical sign. Third, the estimations illustrates that to some extent there are differences in the way citizens and consumers trade-off the environmental impacts of wind and solar energy farms. For instance, a citizen significantly cares for the visual hinder of wind energy farms, but the consumer does not. Contrarily, consumers significantly care for the agricultural land-use of solar energy farms, but the citizen does not.

Table 6 conveys that there are statistical significant differences across experiments for (statistically significant) attributes. For instance, the results deduce that consumers have a statistically higher preference for solar energy farms when all attribute values are zero. Furthermore, consumers derive a statistically significant larger utility from solar recreational land-use than citizens, but derive a statistically significant lower utility from solar visual hinder than citizen. Interestingly, citizens and consumers do not derive statistical significant different utility from noise hinder.

Table 5: MNL model fit and utility estimates

Context	Citizen experiment				Consumer experiment			
Observations:	2844				2616			
Individuals:	237				218			
Rho-square:	0,067				0,047			
Adjusted Rho-square:	0,063				0,043			
Estimates								
	Est	*Std. err*	*t-test*	*p-value*	*Est*	*Std. err*	*t-test*	*p-value*
ASC_Solar	0,411	0,202	2,040	0,04*	1,440	0,173	8,300	0*
ASC_Wind	0.00	Fixed	--	--	1,880	1,180	1,600	0,110
B_WNoise	-0,634	0,072	-8,760	0,00*	-0,507	0,190	-2,680	0,01*
B_WAgr	0,028	0,362	0,080	0,940	-0,824	1,520	-0,540	0,590
B_WRecr	0,075	0,713	0,110	0,920	-1,300	2,950	-0,440	0,660
B_WVis	-0,128	0,035	-3,640	0,00*	-0,175	0,116	-1,520	0,130
B_WTax	--	--	--	--	-1,720	0,459	-3,750	0*
B_ZAgr	-0,050	0,073	-0,680	0,490	-0,216	0,073	-2,980	0*
B_ZRecr	-0,001	0,001	-1,950	0,05*	-0,209	0,076	-2,750	0,01*
B_ZVis	-0,269	0,037	-7,330	0,00*	-0,158	0,038	-4,190	0*
B_ZTax	--	--	--	--	-0,562	0,227	-2,470	0,01*

Table 6: T-ratio test per attribute to establish

Attribute	***T-ratio****
ASC Solar	3,88
B_WNoise	0,62
B_WAgr	N/A
B_WRecr	N/A
B_WVis	N/A
B_ZAgr	N/A
B_ZRecr	-2,73
B_ZVis	2,11

*Defined as the difference from the consumer utility with respect to the citizen utility

5 Policy implications

The differences between the citizen and consumer preferences may have implications for analysts wishing to compare several renewable energy technologies in an economic valuation study. The conceptual difference between citizen and consumers leads to different unit of measurement for their preferences. The aggregated citizen preferences for a renewable energy project is measured in citizen utility per tax money budget. The consumer preferences can be estimated through marginal willingness to pay. The marginal willingness to pay can be calculated by estimating the marginal rate of substitution between the environmental effect attribute and the cost attribute. The formula for the marginal willingness to pay is given in equation 6.

(eq.6): $$marginal\ willingness\ to\ pay = -\frac{\beta\ nonmarket\ environmental\ attribute}{\beta\ monetary\ attribute}$$

Subsequently, the citizen and consumer preferences can be inserted in an environmental valuation of several renewable energy technologies. Several alternatives are formulated based on possible environmental impact reductions. The renewable energy technology alternatives are:

- Wind 1: noise hinder is minimized
- Solar 1: solar visibility hinder is minimized
- Solar 2: the agricultural land-use is reduced with 20%

Table 7 illustrates the citizen utility evaluation framework for the renewable energy farm alternative.

Table 7: Citizen utility evaluation framework

	Reference	Wind 1: Noise	Solar 1: Visibility	Solar 2: Agricultural land-use
ASC	**No**	**No**	**Yes**	**Yes**
Visual hinder	*(155)*	155 residents	**0 residents**	155 residents
Noise hinder	*(30)*	**0 residents**	0 residents	0 residents
Agricultural land-use	*(7,5)*	7,5 hectare	525 hectares	**420 hectares**
Recreational land-use	*(2,5)*	2,5 hectares	175 hectares	175 hectares
Utility	-0.35	-0.20	0.41	-0,01

Table 8 outlines the consumer welfare estimation framework for the renewable energy farm alternatives.

Table 8: Consumer welfare estimation

	Reference	Wind 1: Noise	Solar 1: Visibility	Solar 2: Agricultural land-use
ASC	No	No	Yes	Yes
Visual hinder	*(155)*	155 residents	**0 residents**	155 residents
Noise hinder	*(30)*	**0 residents**	0 residents	0 residents
Agricultural land-use	*(7,5)*	7,5 hectare	525 hectares	**420 hectares**
Recreational land-use	*(2,5)*	2,5 hectares	175 hectares	175 hectares
Welfare	€0	€ 8,84	€ 16,43	€ 33,58

A number of inferences can be deduced from these results. First, denote that the different unit of measurement for citizen preferences yields an expression in utility and not in monetary terms. Furthermore, observe that the differences in citizen and consumer preferences may lead to different policy recommendations based on the environmental valuation of similar renewable energy technologies. For instance, the citizen utility framework may recommend to concentrate research efforts on identifying effective policy measures that induce solar visibility hinder reduction. Contrarily, the consumer welfare estimation indicates that effective policy for agricultural land-use reductions should be designed. Denote that this analysis is for exploratory purposes and excludes a normative discussion on best policy measures.

6 Conclusion and discussion

The main objective of this research was to gain empirical insights into the extent to which citizens and consumers make different trade-offs between the environmental effects from government financed wind and solar energy farms. We reach this objective through the design of a citizen-based stated preference experiment and a consumer-based stated preference experiment, in which respondents are asked to choose between wind and solar energy farms based on four environmental impacts and a cost attribute: 1) number of households with visual hinder, 2) number of households with a 42dB noise level on the façade, 3) amount of hectares directly replace agricultural land, 4) amount of hectares directly replaced recreational land 5) a one-time energy tax increase for all Dutch households.

6.1 Conclusion

The major inference from this study is that to a certain extent citizens and consumers make statistically significant different trade-offs between the environmental impacts of wind and solar energy farms and that these differences may lead to different policy recommendations for similar government financed renewable energy technology alternatives. This conclusion is derived from three insights. First, citizens and consumer derive significant utility for different attributes. For instance, citizens derive significant utility for the visual hinder of wind energy farms, but the consumer does not. Contrarily, consumers derive significantly utility for agricultural land-use of solar energy farms, but the citizen does not. Second, citizens and consumers derive statistically significant more or less utility for (statistically significant) attributes across experiments. For instance, consumers derive a statistically significant larger utility from solar recreational land-use than citizens, but derive a statistically significant lower utility from solar visual hinder than citizen. Third, the conceptual difference between citizen and consumer preferences implies the use of different environmental evaluation frameworks and results in a different preferred renewable energy technology expressed in different units. The citizen utility evaluation framework compares the non-monetary contributions environmental impacts for a specific tax money budget and deduces a the relative highest utility for a solar visibility minimization. Consumer welfare estimation enables to gain insight into the increase in marginal willingness to pay from alternative renewable energy technology projects compared to a reference project and instigates that an agricultural land-use reduction alternative yields the highest welfare gains.

6.2 Discussion

To the best of the authors knowledge, this paper provides the first empirical insights into how citizens and consumers trade-off the environmental impacts from wind and solar energy farms.

The design of this research is in line with Mouter et al. (2016) who focus on the relative importance of infrastructure impacts by omitting a monetary attribute (by setting public budget as a constant). However, Mouter et al. (2016) also include project gains and derive marginal rates of substitution between impact (travel casualties) and gain (travel time reduction). The experiments designed in this study do not incorporate gains, primarily due to the lack of an intuitive and meaningful gain (such as minute travel time gain), for renewable energy technology projects. For instance, a renewable energy projects may increase the low-carbon electricity supply (in line with national sustainability policies) or induce reductions of greenhouse gas emissions (in line with long-term climate goals) if capacity replaces carbon emitting power plants. However, the meaningfulness of expression such as a low-carbon increase in 'megawatt hour' or greenhouse gas emission reduction in 'ton CO_2' is questionable. Therefore, it may be interesting to assess how a meaningful trade-off between infrastructure impacts and gains can be designed for renewable energy projects with consistent tax money budget.

In line with this, denote that the citizen and consumer experiments find significant relations and willingness to pay value for environmental impacts that are omitted or qualitatively assessed in environmental valuation studies like a (social) cost-effectiveness analysis (SCEA). For instance, the environmental impacts visual hinder and noise hinder are summarized as a qualitative ‘negative’ effect in the SCEA of the differences in societal impacts of a wind and solar energy farm (Warringa et al., 2016). Thus, policy analyst may alleviate the importance of environmental impacts in such comprehensive infrastructural impact studies. Especially since, as the results in this research indicate, the differences in citizen and consumer preferences can influence the policy recommendations based on environmental impacts. However, citizen preferences cannot directly be incorporated in an SCEA, instigated by a difference in electricity output per tax budget for wind and solar energy farms. It may be interesting to research how citizen preferences can be incorporated in an SCEA of projects with a different electricity output per tax budget.

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