



**Measuring the indirect costs associated with the establishment of a wind farm: An application of the Contingent Valuation Model**

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# Measuring the indirect costs associated with the establishment of a wind farm: An application of the Contingent Valuation Method

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## Abstract

Although a green energy source, the location of electrical generating windmills may cause a disamenity effect (negative externality). The establishment of a wind farm is known as a locally undesirable land use (LULU) and leads to the not-in-my-backyard syndrome (NIMBY). In an application of the contingent valuation method, a willingness-to-accept framework was used to estimate the aggregate annual compensation required to allow the construction of a wind farm near Jeffrey's Bay, South Africa. This compensation amounted to R490 695. A binary choice logit analysis found that retirement status, concern about climate change, concern about view-shed impacts and the offer amount are important predictors of voting for or against the project.

Keywords: Contingent Valuation Method, indirect cost, wind farm

## 1 Introduction

Over the past 40 years there has been recognition of the fact that human activity has reached a scale capable of influencing our environment (Davidson, 2005). Along with diminishing sources of known fossil fuel deposits, this growing environmental awareness has led to a search for alternative sources of energy, especially clean energies. There are a number of renewables currently receiving attention on the global stage, including wind, solar, thermal, hydro, biomass and tidal power. Technologies exist that are capable of creating electricity from all of these sources. Of all the potential renewable energy sources, wind energy has experienced the greatest growth worldwide over the past few years (Yue, Liu & Liou, 2001).

Although wind energy is a relatively well-established source of energy internationally, it has yet to penetrate the South African market, despite the potential due to South Africa's long coast-line and abundant open areas. Opponents of wind energy argue that there are local negative externalities (or indirect costs) associated with the location of wind turbines, which include the potential deterioration of scenic views and the disturbing noise created by the rotation of the turbines (Warren, C. R., Lumsden, C., O'Dowd, S., & Birnie, R., 2005). These externalities fall into the broad problem known as a locally undesirable land use (LULU). In turn, these locally undesirable uses of land may lead to the not-in-my backyard syndrome (NIMBY). It is argued that this syndrome may lead to inefficient resource allocation because the costs of the negative externality are borne locally while the benefits are distributed more broadly (O'Hare, 1977). A possible solution to the problem is compensating those affected by the local externality. In a study conducted by Groothuis, Groothuis & Whitehead (2008) a measure of the compensation required to allow wind generation windmills to

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be built in the mountains of Watuaga County, North Carolina, USA was estimated. The results of the study indicate that an amount of \$1.90 per month or \$23 per annum per household was required for the project to go ahead. Based on an estimated 18 540 households in Watuaga County, total compensation required equaled \$426,400. These results indicate that people are willing to accept a reduction in scenic view quality due to the construction of a wind farm, provided they receive adequate compensation.

The development of a wind farm, by Genesis Eco-Energy (Pty) Ltd, in close proximity to Jeffrey's Bay, South Africa, may be viewed by some as a LULU. The project is located on the Sunnyside dairy farm approximately 5km from Jeffrey's Bay on the slope of a hill north of the N2 highway connecting Port Elizabeth and Cape Town. The closest inhabited residential area is a suburb of Jeffrey's Bay called Wavecrest (Lochner, P., Dippenaar, S., Wren, S., Binneman, J., Holland, H., Illgner, P., Van Rooyen, C., & Malherbe, F., 2008). The selection of appropriately sized wind turbines is still under consideration. It is expected that machines of 1.8 to 2 MW will be installed. One turbine size is expected to be used for the entire wind farm. The final choice of the size of turbine will be based on ease of erection, availability, suitability to the wind regime and flicker effects (Lochner *et al.*, 2008). Table 1 below shows the details of the proposed project.

The wind measurement studies undertaken at the site indicate kilowatt hours (kWh) production will be relatively equally distributed both daily and seasonally (Lochner *et al.*, 2008). The wind turbines will be connected to the local Eskom grid via a new line (22kV capacity) of approximately 500m in length (maximum) which connects to the existing municipal power line of 66 kV that passes the eastern edge of the site. Certain sections of the existing power lines may require upgrades, but this will require only installing new conductors, not an entirely new line (Lochner *et al.*, 2008). Should the existing lines not be able to carry all of the load, it may be necessary to run a new 66kV line from the site to the main Eskom 132kV line that joins from the Melkhout substation (Lochner *et al.*, 2008).

The aim of this study was to provide the first formal attempt to quantify the compensation required to overcome the NIMBY syndrome associated with the establishment of a wind farm in South Africa; the specific wind farm being the one in Jeffrey's Bay, Eastern Cape. The compensation required is estimated by means of the contingent valuation method (CVM).

## 2 The Contingent Valuation Method

The contingent valuation method (CVM) has over time become one of the most often used non-market valuation techniques. The method employs either willingness-to-pay (WTP) questions to elicit individuals' preferences for improvements in public goods or willingness-to-accept (WTA) questions to elicit individuals' preferences for deteriorations in public goods (Mitchell and Carson, 1989). The Blue Ribbon Panel Report to the NOAA Panel on Contingent Valuation (CV) resolved that it is a reliable and useful technique (see Arrow *et al.*, 1993). The report also provided guidelines for good CV practice.

One of four elicitation methods can be employed in CVM studies, namely bidding games, open ended questions, payment cards, and dichotomous choice questions. A bidding game entails suggesting higher (lower) and higher (lower) amounts to individuals until their maximum WTP or minimum WTA (a point estimate) is reached (Mitchell and Carson, 1989: 99). An open ended question is one in which an individual is asked to state his/her maximum WTP or minimum WTA (no values are suggested in this case). The payment card method presents an individual with a range of values from which he/she is requested to select the one which contains his/her maximum WTP or minimum WTA. With the dichotomous choice format an individual is presented with a single payment/offer (WTP/WTA amount) to which he/she must either agree or disagree.

Once the WTP or WTA responses are collected, various parametric models (OLS, Tobit, logit, probit etc.) can be applied to estimate preference functions, which in turn are used to calculate

expected WTP or WTA values.

The economic theory underlying the application of the willingness-to-accept framework to the establishment of a wind farm can be explained as follows: assume a resident has the following utility function, utility =  $u(x(q), z)$ , where  $z$  represents a consumption good and  $x(q)$  represents quality of a scenic amenity that can be affected by the presence of wind turbines. This resident maximises his or her utility subject to a budget constraint  $y = px + z$  (where the price of  $z$  is normalised to one). Solving for the indirect utility function yields  $v(p, q, y)$  where  $y$  is income and  $p$  represents the price of the scenic amenity (Groothuis *et al.*, 2008). The WTA for a reduction in the quality of the scenic view amenity can be ascertained when

$$v(p^o, q^o, y) = v(p^o, q^1, y + WTA) \quad (1)$$

where  $p^o$  is the current price,  $q^o$  is the original amenity quality and  $q^1$  is the lowered amenity quality, and WTA is the willingness-to-accept welfare measure for lowering the quality of the scenic amenity (Groothuis *et al.*, 2008). In Equation (1), WTA is not income constrained. More specifically, WTA is added to income.<sup>1</sup>

### 3 Survey design

#### 3.1 Questionnaire development

The most important task in conducting a CVM study is the design of the questionnaire. With this in mind, every attempt was made to adhere to the guidelines recommended in the Arrow *et al.* (1993) report. These attempts are described below.

The survey was conducted via personal interviews and the pre-coded questionnaire, used as the survey instrument, was pre-tested by members of the research team. The questionnaire was subsequently refined and improved. A scenario was formulated to make the respondents aware of the effects of the proposed wind turbines. An accurate description of the project was presented to respondents and photographs of existing turbines were shown to the respondents. These photographs were pre-tested by members of the research team. The valuation question was posed as a vote on a referendum. More specifically, respondents were asked whether or not they would accept the establishment of the wind farm on the designated site in return for the specified compensation offer. Different WTA offer amounts were used, as “it is crucial that the arbitrarily assigned sums be varied across respondents” (Cameron, 1987). The contingent valuation question in the survey was:

“Suppose to compensate individuals for accepting the wind farm in their area, electricity bills would be reduced by R XXX each month per household. Suppose this proposal is on the next election ballot. How would you vote on this proposal?”

YES/NO

The rand amount was randomly filled in with one of six rand amounts (R1, R5, R15, R30, R50 and R75). Following the status quo approach, all “Don’t Know” responses were treated as “No” responses (Groothuis *et al.*, 2008).

Although it has been well documented that the WTP framework is the preferred format in CVM studies, the WTA elicitation method was employed in this study, given the perceived property rights of individuals in this particular context (Groothuis *et al.*, 2008). It has been suggested by Inhaber (1992) that due to a reluctance to infringe on perceived property rights (based on politicians’ concerns about remaining in office) the status quo becomes the default property right when choosing a project’s location that will give rise to the NIMBY syndrome. WTA thus becomes the appropriate

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<sup>1</sup>Conversely, WTP is the amount of income an individual would give up to make him/her indifferent between the original state and the revised state. The indirect utility function is given by:  $v(p^o, q^o, y) = v(p^o, q^1, y - WTP)$ . Accordingly, WTP is thus income constrained (i.e.  $y - WTP$ ). Due to the fact that WTA is not income constrained, its use as opposed to WTP may thus impart upward bias. The authors wish to thank an anonymous referee for pointing this out.

measure when individuals perceive that the status quo defines the property rights (Groothuis, *et al.*, 2008).

A follow-up question was included in the questionnaire in order to determine the reasons for all “no” responses. Non-responses to the WTA question were zero.

### 3.2 Data collection

Sufficient research funds were available to allow for a sample of 180 respondents, representing 5.4% of the target population, to be interviewed face-to-face during the period January 2010 to March 2010. The sample frame consisted of residents of the Wavecrest suburb (Jeffrey’s Bay) situated in close proximity to the proposed site and who would thus be directly exposed to the wind farm. There are 4 348 plots in the Wavecrest suburb, of which 3 349 are registered as developed plots. A representative sample of this population was chosen. The sample size for this population was determined by employing the following formula:

$$n = \frac{N}{1 + N.e^2} \quad (2)$$

where:  $n$  = sample size;  $N$  = population size and  $e$  = level of precision.

Using the formula in Equation (2), the sample size was determined with a level of precision of 7.25%. This level of precision ensures a representative sample from the population, because the generally accepted level of precision for representative samples is 10% or less (Fink, 2003).

## 4 Statistical results and discussion

### 4.1 Socio-economic, behavioural and attitudinal analysis of respondents

Table 2 below provides a summary of the socio-economic profiles of the sample of households who were interviewed as part of the questionnaire survey.

The average age of the respondent was 59 years. The average level of education for the respondents was 12.85 years. The average household size was 2.73 individuals and the average number of children per household was 2.25. The average respondent lived in Jeffrey’s Bay for 8.95 years. Of the respondents, 53.9% indicated they were retired, whilst 30.56% were formally employed. The average income of respondents was R131 889.88, whilst the average monthly expenditure on electricity was R490.37 per household.

The questionnaire also included certain key questions which allowed an analysis of the respondents’ behaviour and attitude towards the proposed wind farm project (see Table 3 below).

The majority of respondents (72.8%) indicated that they were aware of the project. Subscription to environmental and scientific publications was low (6.7%) among respondents. The levels of involvement with environmental organisations (conservation and protection groups, etc.) were very low - 2.2% of respondents were members of such organisations. Involvement with outdoor organisations (fishing, hiking and surfing clubs) were higher, but still not very prevalent (5.5% of respondents). Support for renewable energies was substantial (99.4%), whilst 83.9% of the respondents indicated that dependency on fossil fuels was a concern. Of the respondents, 84.4% indicated that climate change was a concern. Concern for the impacts on the views of area due to the establishment of a wind farm was limited (20.6%).

### 4.2 An analysis of WTA responses

Table 4 below reports the number and percentage of “yes” responses at each offer amount. At the lowest rand amounts, 86.67% indicated they would accept the offer. As can be expected, the percentage of “yes” responses increases as the offer amount increases.

Interestingly, the median WTA by respondents was only R1 and only 7% of respondents indicated that they would prefer a higher amount. An anonymous referee argued that this may suggest that most respondents did not care about the wind farm and few saw it as a problem.

### 4.3 Statistical model of WTA

Due to the referendum format of the WTA question where a respondent simply votes “yes” or “no” to a single rand amount, the probability they would accept a given rand amount is statistically estimated by means of a qualitative choice model such as a Logit model.

The logit model can be expressed more formally as:

$$Probability(Yes) = 1/(1 + e^{-\beta'X}) \quad (3)$$

where  $\beta'X_i = \beta_0 + \beta_1X_i$ . The  $\beta$ 's are coefficients to be estimated using the logit statistical technique and the independent variable,  $X_i$ , is the rand amount the household was asked to accept. Independent (explanatory) variables could include the WTA amount only or could include the WTA amount and a combination of socio-economic, behavioural and attitudinal variables. Logit models make use of maximum likelihood criterion in estimation procedures, as opposed to the ordinary least squares criterion (Gujarati, 2003).

Fourteen independent variables were originally included in the logit model (Dimitripoulos & Kontoleon, 2009; Groothuis *et al.*, 2008; Ladenburg, 2008; Kondouri, Kountouris and Remoundo, 2009). These were: age of respondent, years of education of respondent, number of children, household size, whether the respondent was a retiree, whether the respondent was employed, years the respondent had been a resident in the town, average monthly electricity bill, gross annual income, awareness of the project, concern about fossil fuel dependence, concern about climate change, concern about view-shed impacts and the WTA offer amount.

A complete statistical model inclusive of all the abovementioned attitudinal, behavioural and socio-economic variables was initially estimated. Following an inspection of statistically significant coefficients, a more parsimonious model (the reduced model) was estimated. The following coefficients were insignificant and were excluded from the final model: age of respondent, years of education of respondent, number of children, household size, whether the respondent was employed, years the respondent had been a resident in the town, average monthly electricity bill, gross annual income, awareness of the project and concern about fossil fuel dependence.

The reduced statistical model estimated was:

$$[\log(yes)/(1 - yes)] = \beta_0 + \beta_1(RETIRED) + \beta_2(CLIMATE CHANGE) + \beta_3(VIEW IMPACT) + \beta_4\log(OFFER) \quad (4)$$

where “yes” is the dependent variable and shows whether a person was or was not willing to accept the amount offered during the questionnaire survey. A yes vote was recorded with a 1, and a no vote with a 0.

In the interests of conserving space, only the reduced model with coefficients significant at the 90% level or better is displayed (see Table 5 below).

The statistically significant coefficients can be interpreted as follows:

- Retired: The retired variable’s coefficient is statistically significant at the 5% level. The positive sign indicates that if the respondent is retired he or she would be more likely to accept the compensation offered for the project to go ahead.
- Concern about climate change: This variable’s coefficient is positive and statistically significant at the 5% level. This means that if the respondent is concerned about climate change he or she would be more likely to agree to accept the compensation offered for the project to go ahead.

- Concern about view impact: The coefficient of this variable is statistically significant at the 1% level and its negative sign suggests that if the respondent is concerned about the impact of the wind turbines on views, he or she would be less likely to accept the compensation offered for the project to go ahead.
- Offer amount: The positive sign of this coefficient suggests that the respondent would be more likely to vote in favour of the project at higher offer amounts. The coefficient is statistically significant at the 1% level.

#### 4.4 Median and total WTA estimates

From Equation (3), Cameron (1987) provides a formula to calculate the median WTA. The formula is:

$$\text{Median WTA} = \exp^{(\beta_0/\beta_1)} \quad (5)$$

where  $\beta_1$  is the coefficient on the offer amount and  $\beta_0$  is the grand constant calculated as the sum of the estimated constant plus the product of the other explanatory variables times their respective median values.

Using the formula in Equation (5), median WTA per household was estimated at R12.21 per month or R146.52 per annum. The per month median WTA estimated using Equation (5) is substantially higher than the median WTA obtained from the sample data. This may be due to the fact that a small sample size was used in the study and the data was analysed using a maximum likelihood approach. To calculate the total indirect cost to the Wavecrest population of the establishment of a wind farm, the median household WTA estimate was multiplied by the number of households in Wavecrest (3349). The total monthly indirect cost associated with the project is R40,891.29, which translates into an annual figure of R490,695.48. The aggregate WTA estimation, however, constitutes only a partial analysis of cost. The capital, operating and maintenance costs of the wind farm project along with the indirect cost estimated in this paper need to be analysed and compared with the total benefit (financial and environmental) estimates if adequate holistic decision-making is to take place. More specifically, the aggregate WTA estimated in this study must be viewed as only one cost input into a comprehensive social cost-benefit analysis to determine the desirability of wind farms for wider society.

## 5 Conclusion

The premise of this study was that individuals who are negatively affected by the local externalities caused by wind turbines are willing to accept compensation in the form of lower electricity costs. This compensation could play a role in helping to eliminate the not-in-my-backyard (NIMBY) syndrome. This paper estimates the aggregate WTA (compensation) for the construction of a wind farm in close proximity to Jeffrey's Bay, South Africa to be R490,695.48 per annum. This amount can be considered an upper bound of the population's total WTA for two reasons: first, a fairly small sample size coupled with a maximum likelihood approach to data analysis was used in this study, and second, the median WTA estimated from the raw data was substantially lower than that estimated using the predictive model.

The study also shows that individuals' WTA is mainly influenced by two factors, namely concerns about climate change and concerns about view-shed impacts. The results suggest that individuals who are concerned about climate change have less of a NIMBY reaction to view-shed impacts compared to individuals who are not as concerned about climate change. Respondents, who are retired, are more likely to vote in favour of wind-powered electricity. The aggregate WTA estimated in this study must, however, be viewed as only one cost input into a comprehensive social cost-benefit analysis to determine the economic feasibility of wind farms for wider society.

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**Table 1: Project Specification**

CHARACTERISTIC	VALUE
Name	Kouga Wind Energy Project
Location	Sunnyside Dairy Farm, Jeffrey's Bay
Installed capacity	15MW
Project life	25 years
No. of turbines (turbine capacity)	8 (=2MW) to 30(=500kW)
Area required	20ha
Turbine height	75m
Blade length	45m
Annual capacity factor	30%
Electricity production	21462MWh
CO2 off-set	545000 tonnes

Source: Lochner *et al.* (2008)

**Table 2: Socio-economic profile of respondents**

Variable	Mean
Age (years)	59
Education (years)	12.85
Number of children	2.25
Household size	2.73
Retired (%)	53.89
Employed (%)	30.56
Resident (years)	8.95
Monthly electricity bill (Rand)	490.37
Gross annual income (Rand)	131 889.89

**Table 3: Behavioural and attitudinal profile of respondents**

Behaviour/attitude	% of respondents
Aware of project	72.78%
Subscription to scientific/environmental publication	6.67%
Member of environmental organisation	2.22%
Member of outdoor organisation	5.56%
Renewables should be government priority	99.44%
Concern about dependency on fossil fuels	83.89%
Concern about climate change	84.44%
Concern about wind turbines' harm to views	20.56%

**Table 4: Responses at each offer amount**

Offer amount	Yes	No	%Yes
R1	26	4	86.67%
R5	26	4	86.67%
R15	27	3	90%
R30	28	2	93.33%
R50	29	1	96.67%
R75	30	0	100%

**Table 5: Logit regression model of probability would accept compensation**

Variable	Coefficient	z-Statistic	Median
Constant	0.571764	0.510038	
Retired	1.809932	2.163313**	1
Concern about climate change	2.124368	2.417749**	1
Concern about view impact	-4.354802	-4.326954***	0
Log of offer amount	1.800294	2.782895***	1.326606257
McFadden R <sup>2</sup>	0.492090		

\*\* Significant at the 0.05 level

\*\*\* Significant at the 0.01 level