Willingness to pay for green power in an unreliable electricity sector: Part 1. The case of the Lebanese residential sector

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Abstract

A willingness to pay (WTP) analysis for renewable-based electricity is undertaken for the Lebanese residential sector. A survey of 600 samples was conducted based on a stratified random sampling method, in which energy use and expenditures, socioeconomic, and demographic characteristics were collected. Four scenarios for WTP for green power were designed to best reflect the possibilities of integrating renewable energy sources in Lebanon's 'unreliable' electricity sector; (1) local system covering partial electricity needs, (2) local system covering entire electricity needs, (3) utility-provided green power covering partial electricity needs, and (4) utility-provided green power covering entire electricity needs. The results based on a Tobit model highlight the importance of renewable energy options that displace completely the diesel generator sets, i.e. options 2 and 4. Other parameters such as ownership of the home, age, perception of trust in government institutions, and awareness of renewable systems were also found significant in influencing WTP for RE.

Keywords: green power; willingness-to-pay; renewable energy; Lebanon.

Nomenclature

CAS	Central Administration of Statistics
CV	Contingent valuation
PV	Photovoltaic
LCEC	Lebanese Center for Energy Conservation
MEW	Ministry of Energy and Water
MOE	Ministry of Environment
OLS	Ordinary least squares
RE	Renewable energy
UK	United Kingdom
UNDP	United Nations Development Program
USA	United States of America
USD	United States Dollar
WTP	Willingness to Pay
IIN	**Independently and identically normally distributed**
ML	**Maximum Likelihood**

1. Introduction

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The Lebanese government has set itself a target of achieving 12% of its energy mix from renewable energy sources by 2020, a pledge set by the Lebanese Council of Ministers in 2009 and reaffirmed in the 2009 Copenhagen Climate Change Summit and in the Ministry of Energy and Water's (MEW) Policy Paper of 2010 [1]. A United Nations Development Program project in Lebanon, CEDRO,[1] has already undertaken several resource assessments, such as the wind atlas and the national bioenergy strategy, to identify the potential renewable energy sources to be considered in meeting Lebanon's objective. Appraising customers' willingness to pay (WTP) for renewable energy can better inform policy-makers on the nature and extent of policies and programs required to support the development of renewable energy sources. Contingent valuation (CV) studies have been frequently used to estimate the percentage of customers wanting to join renewable energy (RE) programs and elicit the willingness to pay (WTP) for RE or RE attributes either through a premium or an absolute payment. Results from CV studies shed light on the willingness to support various renewable energy targets or goals, and can be used to assess the significance of various economic, social, demographic, and attitudinal attributes in determining WTP.

In response to the severe blackouts that can reach 13 hours per day in some cities [2], consumers rely heavily on off-grid distributed (backup) diesel generators during blackout periods [3]. Consequently, eliciting the willingness to pay of Lebanese citizens for renewable energy power has to take account of, within the survey questionnaire, the existing unreliability (and thus complexity) of the Lebanese electricity sector. The approach adopted to address this issue is to offer four distinct cases in the questionnaire: (1) a local RE system that satisfies partial electricity needs and hence would simply reduce the use of a diesel generator, (2) a local RE system that satisfies the entire electricity needs and hence can completely displace the diesel genset, (3) utility-provided green power that satisfies partial electricity needs and hence would simply reduce the use of the genset, and (4) utility-provided green power that satisfies the entire electricity needs and hence can completely displace the diesel unit.

The remainder of the paper is structured as follows. Section 2 presents an overview of Lebanon's electricity sector and its renewable energy prospects. In section 3, a review of the related literature is provided. This is followed in section 4 with a detailed description of the data and the Tobit methodology employed, while in section 5 we illustrate and interpret our findings. Finally, in section 6, we offer some concluding remarks on the results and some policy implications.

2. Lebanon's electricity sector and renewable energy prospects

For many years the Lebanese power sector has been notoriously characterized by a demand-supply deficit and significant technical and non-technical network losses. These problems have led to daily blackouts averaging 6 hours for the entire country and reaching 13 hours per day in certain regions [2], which consumers offset by the use of diesel back-up self-generation [4]. According to the MEW, a vital goal of the outlined strategy for the power sector [4] is to provide 24 hour reliable electricity by 2015. This objective will be subjected to several years of delay due

[1] CEDRO is a cedar tree in Spanish, and the project was named CEDRO given combination of Spanish funding (from 2007-2014) and the fact that cedar trees are considered national emblems for Lebanon. From 2014 – 2016, CEDRO is operated via a grant from the European Union (www.cedro-undp.org).

to political and financial reasons. According to NationMaster,[2] Lebanon ranks third among 92 countries in the average number of electric power outage hours per year.

The MEW policy paper [4] reiterates the Government of Lebanon's pledge to source 12% of its electricity supply from renewable energy sources by 2020. It specifies preliminary targets for onshore wind power, hydropower, and waste-to-energy, with indirect emphasis on distributed and microgeneration through the enabling of the 'net metering' program. Figure 1 shows the current and expected evolution of the power sector capacity from 2015 to 2020, based on the MEW Policy Paper [4] and the Lebanese Center for Energy Conservation's[3] (LCEC) expectations for the sector [5]. The power output projection from the mix in Figure 1 is expected to fulfill the 12% target of renewable electricity supply by 2020. For more information on Lebanon's electricity sector the reader can refer to [3-6].

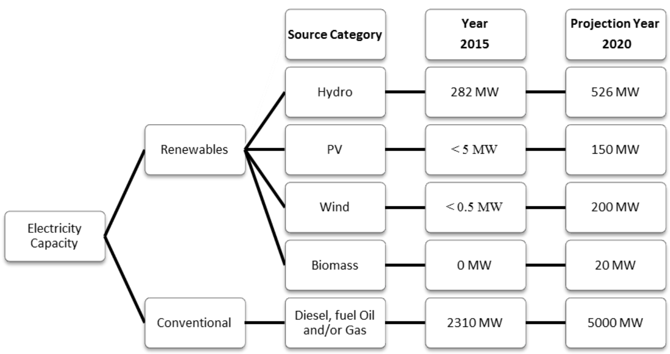

Figure 1. Lebanon's electricity mix: 2015 versus 2020

Given that renewable energy systems are commonly characterized by the variability of their power output, their development, whether at the local or utility level, has to take account of their impact on the reliability of individual facilities and the network at large. Replacing or complementing diesel backup generation, along with electricity from the national grid, with renewable energy sources, requires intelligent and often more complex designs. For example, in the context of the UNDP-CEDRO Project, the photovoltaic (PV) systems (and microwind and hybrid microwind-PV systems) designed and implemented have a 'dual-mode architecture' where systems are categorized both as stand-alone systems in times when utility power is absent and grid-connected systems when utility power is present. Figure 2 shows an example of this configuration. For small systems typical for the residential sector, integrating renewable energy with battery storage offers a possible solution for complete or partial displacement of the diesel back-up generators, depending on the magnitude and yearly characteristics of the load coupled with the RE system's sizing and resource availability. Battery storage can be recharged from the

[2] NationMaster provides a compilation of data on individual countries as well as groups of countries (www.nationmaster.com).

[3] The Lebanese Center for Energy Conservation (LCEC) advises the Ministry of Energy and Water on matters related to energy efficiency and renewable energy; www.lcecp.org.lb.

national grid as well as from the RE system and can be designed to offer autonomy for several hours or up to a few days. This system is more expensive than a normal grid-tied system due to the need for a battery bank, charge controller, and a dual-mode inverter.

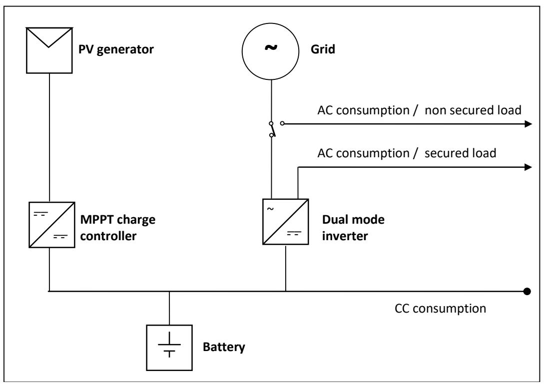

Figure 2. Block diagrams of the PV hybrid facilities [7]

Within this setting, it makes a big difference both from a technical as well as financial perspective if the proposed green power source enables the household to eliminate its need for the backup generator or not.

3. Literature review

Voluntary green power markets are making immense efforts to increase their sales, especially that so far these programs have had a limited impact [8]. Tampier [8] estimates the cost of gaining new customers at $100-300. To know where to direct their efforts, green power providers must know what the important determinants of green power demand are. Several studies have tried to address this question by surveying potential and/or existing green power customers.

An examination of the willingness to pay for green power literature reveals that the most widely used stated preference methods is the contingent valuation method.[4] WTP studies can either estimate the influence of various independent variables on the dichotomous decision to pay (or not to pay) for renewable electricity [for example, see 11-14], and/or estimate the percentage premiums or absolute amounts that individuals are willing to pay [e.g. 16]. This study falls in the latter category.

The decision to participate or not in a green power program has been investigated by multiple researchers. Clark *et al.* [17] investigated the motivations for enrolling or not enrolling in Detroit Edison's Solar Currents Program using a logistic model on data from a survey of participants and a sample of non-participants. In addition to psychological factors, the authors found that higher

[4] CV is a commonly used technique for goods that are not physically traded; i.e. for which markets do not exist [9]. See Menegaki [10] for an in-depth review of valuation methods including stated preference methods.

income and a smaller family are significant determinants of the decision to participate. Besides environmental benefits, consumers believe that participating in green power programs will reduce the cost of solar energy in the future and will reduce dependence on imported oil as well. A survey conducted in the UK, MORI opinion poll, found that only 21% are willing to pay more. But, it did not investigate the relationship between WTP and demographic variables [18]. In contrast, in Sweden 75% of the respondents to a survey indicated they would seriously consider buying green electricity and 40% would consider even paying more for green electricity [19], yet only 1% did actually purchase green electricity in spite of the low price premiums [20]. Hansla *et al.* [21] found an even larger share of respondents (80%) who are willing to participate in a green power program.

Numerous studies have examined the willingness of consumers to pay a premium for electricity from renewable energy sources using a variety of determinants that frequently include: income, age, gender, education, household size (or number of children), house ownership status, RE or environmental awareness, and altruistic attitudes. Farhar and Houston [22] conducted a national US willingness to pay survey and found that WTP is a function of income, social group, gender, age, and education. Similarly, Zarnikau's [14] survey results in the U.S. reveal that age, education, and income affect willingness to pay. Bigerna and Polinori [23] and Abdullah and Jeanty [24][5] reached similar findings as well with respect to income, age, and education for Italy and Kenya, respectively. Sardianou and Genoudi [25] found 'age' and 'education' to be statistically significant factors in Greece influencing the adoption of renewable energy, in contrast to Diaz-Rainey and Ashton [26] who found these variables to be statistically insignificant in the U.K. Batley *et al.* [12] also indicated that willingness to pay extra for renewable energy is sensitive to income.

In addition to the commonly used explanatory variables, some researchers have examined other determinants of WTP. Batley *et al.* [12] found that 'energy efficiency' of an individual is positively related to the willingness to pay extra for renewable energy in the U.K. Also, several researchers found that willingness to pay is a function of the type of renewable source in question [27-29], with Gracia *et al.* [29] reporting that respondents were sensitive as to whether renewable energy was produced in their region or not.

A closely related strand of literature examines the WTP for impacts on certain attributes of RE sources, such as the effects on pollution, wildlife, landscape, employment, etc. These studies include Roe *et al.* [30] for the U.S., Bergmann *et al*. [31] for Scotland, and Longo *et al.* [32] for England.

The premium respondents are willing to pay exhibits considerable divergence between studies. In the UK, a mean willingness to pay 16.6% extra for electricity generated from renewables was found in a random sample, and 18.45% in an energy aware sample [12]. Interestingly, there is no significant difference in the proportion of people willing to pay more between the two samples. Borchers *et al.* [27] found that in the U.S. consumers are willing to pay premiums between 8% and 16% of their monthly electric bill, with the range depending on the source of electricity. Also for the U.S., Roe *et al.* [30] found that respondents are willing to pay at least \$3.22/year for a 1% increase in RE. In Japan, consumers expressed a WTP 24,000 yens (equivalent to 205 USD)

[5] Note that this study estimates the WTP for grid electricity or PV electricity for non-electrified houses.

additional per year [15]. Bollino [11] found a mean WTP ranging between 14.64 and 56.34 euros per year in Italy, while Gracia *et al.* [29] found a yearly WTP of 14.88 euros (2.6%) for wind, 26.88 (4.6%) for solar, and -18.12 (-3.1%) for biomass in Spain. Similarly to the previous two European studies, Zografakis *et al.* [33] found that customers in Crete are willing to pay on average an extra 17.88 euros per year. Goett *et al.* [28] report that customers exhibit non-linear behavior as the percentage of renewables increase; i.e., to double the percentage of renewable energy they are willing to pay less than double the premium. They thus conclude that "the concept of the social good is more important to consumers than the actual amount of good that is produced."

Clearly, findings for willingness to pay for renewable or 'green' electricity vary among studies, as do, albeit to a lesser extent, the identified statistically significant explanatory variables that influence WTP. This is expected given the different countries, regions, and time periods, as well the diverse methods and questionnaire designs (including the provision of information) used [16]. For example, willingness to participate in green electricity programs are found to vary between 21% to as high as 80%, with the reported median monthly WTP ranging from 1 USD to 17 USD [16,18]. A meta-analysis on approximately thirty studies on WTP for RE published after the year 2000 was undertaken by Soon and Ahmad [34]. Soon and Ahmad [34] compiled and reviewed the various studies and revealed that there are considerable variations in the magnitude, sign, and significance of WTP estimates with respect to how much householders are actually WTP for RE. Studies are conducted in different years and countries, focusing on different RE sources, measuring WTP in different currencies and temporal units, and using different elicitation formats to derive WTP [34]. Soon and Ahmad [34] found that WTP for RE ranged from a negative 0.37 USD to 52.38 USD per month, where two-thirds of studies reported an average positive WTP below 10 USD, with a smaller proportion of the studies obtaining average WTP estimates between 10 USD – 20 USD [34].

As noted above, Lebanon ranks third among 92 countries in the average number of electric power outage hours per year. Of the 25 highest ranked countries on the NationMaster list, none have carried out a WTP study for green power. We are not aware of any other WTP for green power study in a country plagued by electric outages. Zografakis *et al.* [33] examined the WTP in Crete and conclude that customers who suffer from electricity shortages report a higher WTP for green power.

4. Data and Methodology

4.1 Data Analysis

A face-to-face survey[6] of 600 residents, aged 18 and above, was conducted by Statistics Lebanon[7], in the second half of 2013, using a stratified random sampling method based on geographical and gender (i.e., female/male) characteristics to ensure national representation (as when compared to values published by the Central Administration of Statistics - CAS). [8] The objective of the study as well as some background on the energy sector constitute the

[6] Face-to-face surveys tend to have higher response rates than mail surveys [9,30]. The questionnaire template is available from the authors upon request.
[7] Statistics Lebanon; http://www.statisticslebanonltd.com/
[8] CAS; http://www.cas.gov.lb/

introduction of the questionnaire. The first part of the questionnaire contains a variety of questions including the WTP questions, while the second set of questions are purely demographic in nature. Table 1 gives a descriptive analysis of the different types of variables (continuous, categorical, ordinal, and interval), showing their respective mean, standard error of the mean, median, standard deviation and the minimum and maximum values.

Four scenarios for WTP for green power were designed to best reflect the possibilities of integrating renewable energy sources; (1) local system covering partial electricity needs, (2) local system covering entire electricity needs, (3) utility-provided green power covering partial electricity needs, and (4) utility-provided green power covering entire electricity needs;

1- WTP-L_1: WTP for RE procured locally (i.e. installed on the roof with battery storage capability) that partially satisfies the household's electricity load requirements, and hence reduces the energy costs. However, the household will not be able to do away with the diesel generator especially if it is highly dependent on electric heating in the winter and/or air conditioning in the summer.
2- WTP-L_2: WTP for RE procured locally (i.e. installed on the roof with battery storage capability) that completely satisfies the household's electricity load requirements thus eliminating the household's need for a diesel generator. This setting will result in a substantial reduction of the utility bills.
3- WTP-U_1: WTP for RE procured from the national grid. Due to the ongoing blackouts, the household must thus keep renting/operating their diesel generators.
4- WTP-U_2: WTP for RE procured from the national grid. Assuming the utility provides electricity on a 24-hour basis the household can eliminate the need for the backup diesel generator.

The monthly median willingness to pay for renewable energy is approximately $20 when diesel-generation is not completely displaced (WTP-L_1 and WTP-U_1), and $50 when diesel-generation can be completely eliminated (WTP-L_2 and WTP-U_2). Given the savings achievable in the cases when the household can do away with the diesel generator it is reasonable that the WTPs are higher and statistically different than WTP-L_1 and WTP-U_1. The median WTP for renewable energy is similar for the decentralized renewable energy systems (or 'locally' procured) and those procured by renewable energy through the national grid. Surprisingly, this shows no strong preference to 'locally' sourced renewable energy as one would have expected given the current state of electricity.

Table 1. Descriptive statistics of the variables

Variable	Mean	Std. Error of Mean	Median	Std. Deviation	Min	Max	Description
Opinion of electricity sector Q1	1.59	.036	1.00	.889	1	5	1: very poor - 5: very good
Daily Blackouts (hours) Q3	4.01	.048	4.00	1.177	0	5	Hours of blackouts/day
Backup monthly fee Q7	91.62	2.786	80.00	67.671	30	850	USD/month
Utility monthly payment Q8	47.83	1.246	50.00	30.521	20	190	USD/month
RE awareness Q9	2.61	.052	2.00	1.272	1	5	1: Non - 5: Excellent
AC dependence Q19	2.69	.064	3.00	1.566	1	5	1: Never - 5: Very much
Electric heating dependence	2.28	.057	2.00	1.386	1	5	1: Never - 5: Very much

Q21							
Government trust Q29	3.11	.053	3.00	1.291	1	5	1: Not at all - 5: Very much
WTP-L1	29.48	1.166	20.00	28.568	0	120	USD/month
WTP-L2	54.12	1.654	50.00	40.525	0	300	USD/month
WTP-U1	24.79	1.172	20.00	28.703	0	120	USD/month
WTP-U2	59.50	2.076	50.00	50.863	0	400	USD/month
Gender D1	1.5	0.02	1.5	.5	-	-	1: female; 2: male
# of members in household D2	4.38	.068	4.00	1.663	1	10	Householders
Marital status D3	1.34	0.019	1	.475	-	-	1: Married; 2: Not married
Number of Children D4	1.52	.066	1.00	1.616	0	7	Number of children
Age D5	39.40	.577	38.00	14.131	18	80	Years
Education D6	2.82	0.04	3.00	.981	1	4	1: Non and elementary school 2: High school or technical school diploma 3: University/college first degree 4: University higher degree (MSc/PhD)
Employment D9	0.74	0.18	1.00	.441	-	-	1: Yes; 2: No
Income D12	1467.91	34.067	1250.00	828.889	500	5001	USD/month

As depicted in Table 1, the survey's questions sought to gather information on energy use and expenditures, socioeconomic, and demographic characteristics. Other questions targeted 'behavioral' actions or attitudes towards green initiatives and projects. These were the involvement in an environmental or a renewable energy club and/or institution (98.8% answered no involvement in such organizations), or any work related or other relationship with a firm that provides RE services (98% answered no). Only 28% of respondents claim to have above average knowledge about RES and only 20 out of the 600 respondents have a RE system in their houses (in 19 cases it's a solar hot water system). One third of the participants (32%) do not trust that the government can manage the development of renewables. Approximately 47% of respondents indicated that power outages last more than 9 hours per day. Given the recurrent power outages, it is no surprise that 61% of the respondents think that the status of the electricity sector in Lebanon is "very poor". Around half of the respondents do not have an air-conditioning system or have one but rarely use it, and almost 59% do not use electric heating or rarely use it.

Commented [L1]: For consistency purposes

The sample is equally split between males and females, and the majority (66%) are married. As can be seen from Table 1 the mean age is 39.4, and only 1.3% have no education whatsoever. 74% of the respondents are in the workforce. Household income mean is $1,468 per month. In terms of home ownership, approximately 64.5% indicated they own their homes, while 35.5% indicated they are renting. Approximately 64.8% of the homes are apartments in buildings, 34.5% are independent houses, and 0.7% is characterized as villas.

Table 2 provides the respective percentages of the sampled respondents who gave zero bids. Clearly, a larger number of respondents were found not willing to pay a premium for renewable energy if they have to keep paying the standby generator fee. This is a clear signal that a critical attribute of any green power program in Lebanon is that it displaces the diesel gensets.

Table 2. Percentage of zero responses for each case

WTP category	Percentage answering zero
WTP-L_1	28.9%

WTP-L_2	11.5%
WTP-U_1	34.9%
WTP-U_2	13.5%

One important finding regarding energy expenditures is shown in Figure 3. A significant amount of income is earmarked to secure the electricity and hot water (given that approximately 81% of water is heated through an electric boiler in Lebanon [35]) needs of a household. The Lebanese consumers pay, on average, approximately 10.4% of their income on electricity including both the utility bill and the backup generator bill (taking the median values as indicators). This value can be considered as conservative, because heating costs are not considered. Under the UK definition, "a fuel poor household is defined as one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth" [36]. Approximately 50% of the Lebanese citizens pay more than 10% of their income on energy for electricity in Lebanon and therefore approximately half the Lebanese can be considered, on average, fuel poor.

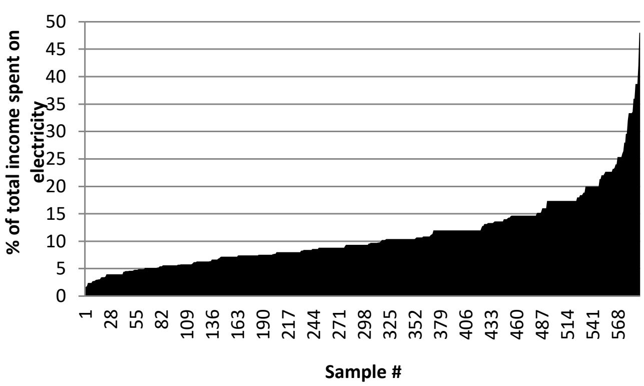

Figure 3. Ratio of electricity expenditures over income

4.2 Methodology

In order to estimate the WTP for renewable energy and the influence of various attitudinal, psychological and socio-economic factors, studies have employed a wide variety of discrete choice models, such as probit, ordered probit, binomial logit, multinomial, nested logit, mixed logit, double-hurdle, and tobit or censored regression models [16].

In our survey data the dependent variable WTP is censored, i.e. a significant fraction of the observations in a certain range are reported as a single value, zero. In such cases, the tobit model [37] is typically employed since conventional regression methods such as the ordinary least squares (OLS) will produce biased as well as inconsistent coefficient estimates. Tobit models also known as censored regression models combine the probit and truncated models into one, imposing the assumption that the decision to participate and the level of participation are determined by the same process. In other words, the explanatory variables' effect on the extensive and intensive margins of contribution is the same.

It is true that in a Tobit models explanatory variables are not allowed to influence the decision of whether or not to contribute in a different way than the decision of how much to contribute [16], but this restriction can be easily tested using a likelihood ratio test [38];

$$\lambda = -2[\ln L_T - (\ln L_p + \ln L_{TR})]$$

where L_T denotes the likelihood for the Tobit model, L_P the likelihood for the probit model, and L_{TR} the likelihood for the truncated regression model.

Tobit models have been commonly used in regressions of voluntary contributions with micro-data [39]. Examples include assessing the WTP in Sweden to avoid power outages [40] and the WTP for the use of the Pemigewasset Wilderness Area in New Hampshire [41].

For ease of exposition, we will consider option WTP-L_1 in explaining the methodology. The other three regressions are treated in a similar way. In the first regression (case WTP-L_1) we have n_1=426 observations with positive y's and n_2=173 observations with y=0, for a total of 599 observations. Let y* be a random variable, also known as a latent or index variable, related to y (the stated WTP variable) as follows:

$$y_i = y^*_i = x_i^{'}\beta + u_i \quad \text{if } y^* > 0 \quad \text{i=1,2,…}$$

$$y_i = 0 \quad \text{if } y^* \le 0$$

where x_i denotes a vector of explanatory variables and u_i is $IIN(0, \sigma^2)$.

Empirically, the model used is the following:

$$WTP_i^* = c + b_1Q_1 + b_2Q_3 + b_3Q_7 + b_4Q_8 + b_5Q_9 + b_6Q_{10} + b_7Q_{19} + b_8Q_{21} + b_9Q_{29} + b_{10}d_1$$
$$+ b_{11}d_2 + b_{12}d_3 + b_{13}d_4 + b_{14}d_5 + b_{15}d_6 + b_{16}d_7 + b_{17}d_8 + b_{18}d_9 + b_{19}d_{10} + b_{20}d_{11} + b_{21}d_{12} + u_i$$

WTP represents the stated willingness-to-pay in USD and the other variables are as defined in Table 1.

Correlations among explanatory variables are all found to be less than 0.8, the commonly used threshold for assessing multicollinearity. Also, the Variance Inflation Factors (VIFs) are all well below the limit of 10. Hence, there is no reason to be concerned about multicollinearity.

To estimate the coefficients of the regression above and the variances, we will use the Maximum Likelihood (ML) estimator because it is known to be more efficient than the Heckman 2-step estimator [42,43].

The estimated *b's* represent the marginal effect of each of the regressors on y^*. However, we are interested in the effects on y, the observed variable, which can be calculated when the dependent variable is left censored from below by multiplying the estimated coefficient with the probability of being uncensored $\Pr(y^* > 0)$. This calculation does not assume that u_i is normally distributed. For more details on the Tobit model, see [38,44].

To get consistent estimates errors should be homoscedastic. In order to avoid any heteroskedasticity complications, we have computed the coefficient covariance matrix using the Huber/White robust covariances that are robust to misspecification of the variance function.

5. Results and Discussion

Tobit regressions for the four WTP measures yield some interesting results. Table 3 shows the results for WTP-L_1 and WTP-L_2 and Table 4 shows the results for WTP-U_1 and WTP-U_2. Along with the estimated coefficients (coef.) of the explanatory variables, the tables include the standard errors (S.E.), z statistics (z-Stat), and p-values (Prob.) of each coefficient.

From Table 3 we can see that eight independent variables significantly impact WTP for RE in both cases, WTP-L_1 and WTP-L_2. Regressors Q7 and Q8 show that the higher the current monthly payments to the Lebanese national utility and to the diesel backup generator, the more is the WTP of respondents. The magnitude of the coefficients is larger for WTP-L_2, indicating a larger impact on WTP in the scenario where the diesel generator is displaced. Knowledge on renewable energy (Q9) is also significant for both cases, entailing that policies that raise consumer awareness in this sector can potentially have a positive impact on WTP for RE. This finding is in line with the conclusions of Zarnikau [14] and Zografakis *et al.* [33] that more knowledge of RE results in higher WTP. Furthermore, the perception of the government's management of RE specific funds (Q29) is important for WTP, where the more the government is viewed as trustworthy, the more the respondents, on average, are WTP.
Among the demographic variables, only two are statistically significant; D5 and D11. The negative sign on the coefficient of (D5) indicates that the younger the respondent, the more, on average, is his/her WTP. This finding is in line with the results of Ek [45], Zarnikau [14], and Wiser [46]. Ownership or rental of property (D11) is an important variable as well, where as expected, those who own the property they are residing in are, on average, willing to pay more. This finding was also confirmed by Wiser [46]. Understanding the modular nature of RE systems and the flexibility in relocating the system may improve WTP for consumers who are renting their premises.

Table 3. ML - Censored Normal (TOBIT) WTP L_1 and WTP L_2

		WTP-L_1				WTP-L_2			
Var.	Description of variable	Coef.	S.E.	z-Stat.	Prob.	Coef.	S.E.	z-Stat.	Prob.
c	Constant	6.552	47.721	0.137	0.891	65.606	55.154	1.190	0.234
Q1	Opinion of electricity sector	3.120	1.788	1.745	0.081	0.319	1.965	0.162	0.871
Q3	Daily blackout hours	1.654	1.391	1.189	0.234	2.180	1.386	1.573	0.116
Q7	Monthly payment to backup generator	0.047	0.024	1.960	0.050	0.177	0.029	6.122	0.000
Q8	Utility monthly payment	2.074	1.086	1.909	0.056	2.510	1.067	2.352	0.019
Q9	RE awareness	4.009	1.378	2.909	0.004	3.527	1.439	2.450	0.014
Q10	Own solar water heater	-1.619	10.875	-0.149	0.882	-17.489	12.267	-1.426	0.154

Q19	AC Dependence	-1.275	0.933	-1.367	0.172	2.241	0.931	2.408	0.016
Q21	Electric heating dependence	2.158	0.990	2.180	0.029	2.932	1.015	2.889	0.004
Q29	Government trust	5.494	1.343	4.091	0.000	5.649	1.315	4.296	0.000
D1	Gender	0.042	3.281	0.013	0.990	2.368	3.460	0.684	0.494
D2	Members of household	-0.553	1.132	-0.488	0.626	-1.839	1.166	-1.576	0.115
D3	Marital status	-4.410	4.776	-0.923	0.356	-4.279	5.261	-0.813	0.416
D4	No. of children	0.835	1.528	0.546	0.585	0.736	1.661	0.443	0.658
D5	Age	-0.402	0.132	-3.034	0.002	-0.259	0.136	-1.898	0.058
D6	Education	-2.873	2.215	-1.297	0.195	1.057	2.452	0.431	0.666
D7	Member of environmental NGO	-0.004	16.702	0.000	1.000	-2.799	20.980	-0.133	0.894
D8	Member of any RE institution/NGO	-4.995	12.820	-0.390	0.697	-22.265	22.758	-0.978	0.328
D9	Employment	-1.007	1.226	-0.822	0.411	-0.179	1.333	-0.134	0.893
D10	Type of housing	0.001	1.545	0.001	0.999	2.150	1.720	1.250	0.211
D11	Ownership status	5.882	2.997	1.963	0.050	7.133	3.266	2.184	0.029
D12	Income	-0.109	0.178	-0.612	0.540	-0.048	0.154	-0.313	0.754

Table 4. ML - Censored Normal (TOBIT) WTP U_1 and WTP U_2

		WTP U_1				WTP U_2			
Var.	Description of variable	Coef.	S.E.	z-Stat.	Prob.	Coef.	S.E.	z-Stat.	Prob.
c	Constant	-19.532	56.574	-0.345	0.730	-27.768	62.287	-0.446	0.656
Q1	Opinion of electricity sector	0.125	2.100	0.060	0.953	1.063	2.365	0.449	0.653
Q3	Daily blackouts hours	-1.333	1.573	-0.848	0.397	0.876	1.876	0.467	0.640
Q7	Monthly payment to backup generator	-0.024	0.036	-0.671	0.502	0.301	0.036	8.382	0.000
Q8	Utility monthly payment	2.998	1.216	2.465	0.014	4.780	2.263	2.112	0.035
Q9	RE awareness	1.525	1.496	1.019	0.308	1.579	1.747	0.903	0.366
Q10	Own solar water heater	22.891	11.464	1.997	0.046	-3.188	13.925	-0.229	0.819
Q19	AC Dependence	-0.684	1.011	-0.676	0.499	2.439	1.075	2.268	0.023
Q21	Electric heating Dependence	2.785	1.061	2.624	0.009	4.538	1.159	3.915	0.000
Q29	Government trust	8.631	1.460	5.913	0.000	10.941	1.650	6.630	0.000
D1	Gender	-1.831	3.636	-0.504	0.615	0.908	4.293	0.211	0.833
D2	Members of household	-0.749	1.222	-0.613	0.540	-2.197	1.350	-1.627	0.104
D3	Marital status	2.742	5.249	0.522	0.602	-1.577	5.941	-0.265	0.791
D4	No. of children	1.705	1.714	0.995	0.320	3.182	1.842	1.727	0.084
D5	Age	-0.264	0.143	-1.846	0.065	-0.210	0.172	-1.224	0.221
D6	Education	-3.149	2.372	-1.327	0.184	-1.761	3.024	-0.582	0.560
D7	Member of environmental NGO	-7.505	20.475	-0.367	0.714	23.671	17.117	1.383	0.167
D8	Member of any RE institution/NGO	-8.301	14.313	-0.580	0.562	-17.457	19.927	-0.876	0.381
D9	Employment	-1.878	1.276	-1.472	0.141	-1.708	1.610	-1.061	0.289
D10	Type of housing	-1.403	1.679	-0.836	0.403	-0.100	2.189	-0.046	0.964
D11	Ownership status	4.696	3.376	1.391	0.164	1.546	3.645	0.424	0.671
D12	Income	-0.069	0.180	-0.381	0.704	-0.370	0.234	-1.585	0.113

Results for WTP for green power from the national grid, shown in Table 4, show less common significant variables between each other as compared to the two 'local' cases in Table 3. Similarly to the previous two cases, the monthly payments to the utility and to the backup generator are positive and significant for WTP-U_2. However, for WTP-U_1 the monthly generator fee does not seem to influence the WTP. This wasn't the case in the locally installed RE systems. An explanation may have to do with the respondent's feeling of control in the locally sourced RE and being able to manage both the diesel generator and the RE system, while this is not the case when green power is sourced from the utility. Trust in the government is also of importance for WTP in both cases, in that the more positive the respondents' views of the government is the higher the amount they are willing to contribute to green power. Also similarly to the previous set of results, age is again negative and significant highlighting the importance the younger households in supporting utility-delivered RE power.

Variables Q19 and Q21 seek to understand the relationship between low (high) dependence on electric cooling and heating and the respondents' WTP. It is assumed that consumers who are highly dependent on electric cooling and/or heating, and especially in the cases in which green power can satisfy these loads' requirements, will be willing to pay more. In other words, we expect these two variables to have larger magnitudes and be statistically significant in WTP-L_2 and WTP-U_2 relative to WTP-L_1 and WTP-U_1. The results in tables 3 and 4 are in line with our expectations. Interestingly, D11 which was significant for the first two cases is not significant anymore. This is a reasonable result in that home ownership is important when a home RE system is considered, but not when green power is provided by the utility. In that case, it doesn't matter whether the consumer owns or rents the premises.

A few variables are significant in only one of the regressions. WTP-L_1 is sensitive to the impression respondents have of the electricity sector; a favorable opinion impacts WTP positively. It is usually expected that consumers who own a RE system or have implemented some energy saving practices will be willing to pay on average more for green power compared to others. However, the results show only one case (WTP-U_1) for which the coefficient of owning a solar water heater (Q10) is positive and significant. This could be due to the fact that very few respondents (3.3%) claimed they own a RE system. Income is another variable that has been typically found to be positively related to WTP [12,14,22-24,33], yet it is found to be insignificant in all four cases of this study.

Both Zografakis *et al.* [33] and Longo *et al.* [32] find that the more frequent the electricity outages, the more the respondent is WTP. However, in this study, there does not seem to be a relationship between length of outages and WTP (Q3 is not significant in any of the cases) probably because these outages are covered by standby generators and the costs of operating these generators per month (Q7). Hence, Lebanese consumers are already paying the additional generator fee in order to avoid the negative welfare effects of power outages.

6. Concluding Remarks

The UNDP-CEDRO project commissioned a national survey that undertook the sampling of 600 residential units across the country to elicit their willingness to pay for renewable energy sources. Based on a stratified random sampling method, energy use and expenditures, socioeconomic, and demographic characteristics were collected. A big challenge was to design the survey to reflect the unreliability of the electricity sector and take account of its repercussions on consumers' willingness to pay for green power. Consequently, four scenarios for WTP for green power were devised to best reflect the possibilities of integrating renewable energy sources; (1) local RE system covering partial electricity needs, (2) local RE system covering entire electricity needs, (3) utility provided green power covering partial electricity needs, and (4) utility provided green power covering entire electricity needs.

Tobit regressions for the four WTP measures yielded interesting results .The overarching finding is the critical impact of the unreliability of the electricity sector, and consequently the existence of backup diesel generators, on the willingness to pay for renewable energy. Across all scenarios, higher monthly utility bills result in higher WTP amounts. Similarly, the more consumers pay for diesel generators the higher is their willingness to pay for renewable energy, particularly when the latter can displace the need for gensets completely (see Table 1). Designing green power programs that can ultimately lead to displacing the diesel generators have a better chance of success and attracting more funding.This paper's WTP estimates for green electricity, especially when this leads to displacing diesel gensets, are considerably higher than estimates from the literature. Bigerna and Polinori [23] indicated that values for WTP for RE range from 0.74 – 28.9 euros per month in Europe and 0.85 – 22.5 euros per month in the USA. In Lebanon, when RE is integrated without displacing the genset, the median WTP for RE power was found to be approximately 20 USD, within the European and US ranges. Yet a considerably higher value of 50 USD per month was indicated if the complete displacement of the genset is enabled via the RE power.

The variables on 'familiarity with renewable energy systems' and 'age' were also dominant, indicating the need to invest more in awareness raising on renewable energy systems, targeted in particular to the relatively younger generation. Information campaigns targeted at filling existing information gaps and misleading perceptions should help involve many of the passive consumers in the development of RE. Based on the results, campaigns can also focus on coastal areas that depend heavily on air-conditioning, as well as electrically-heated houses (as opposed to using diesel for heating).

Renting or owning a home plays a role as well for the 'locally' procured RE system only, as expected, where ownership means, on average, more WTP for RE. Introducing tailored incentives and/or policies for the renting (and/or leasing) community would help in involving this sector, as would campaigns to show the flexibility in relocating RE systems. Possible policy measures involve enforcing energy performance labeling schemes on houses, coupled with both the eventual regulation that sets the minimum standards for energy performance, as done in the UK for example [47], and varying tax rates on properties pegged to their respective energy performance [48]. These policies should encourage landlords to upgrade their properties in terms of energy performance, inclusive of renewable energy, through financial instruments such as grants and soft loans.

Perception on 'trust in government' is the final variable showing significance across all scenarios. This is a strong message to the Lebanese government to improve its management of the sector if it is serious about achieving its 12% by 2020 RE target.

Renewable energy offers a possibility for Lebanese citizens to rise above the fuel poverty line caused by their expenditures on electricity from diesel gensets and from the national grid (see Figure 3), particularly because the levelised costs of PV systems are less than that of diesel gensets [49]. The perception held of the electricity sector is mostly 'very poor' or 'poor', and therefore if the benefits of renewable energy can be further highlighted and marketed, RE can offer a pathway towards an improved energy system as a whole.

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