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Towards a cleaner environment: Determinants of willingness to pay for clean air and renewable energy in Poland

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ABSTRACT

Objective: The article aims to compare the willingness to pay for energy from renewable sources with the willingness to pay for clean air in Poland and to establish factors that influence these phenomena. These topics are usually addressed in separate studies, making a credible comparison difficult.

Research Design & Methods: We survey a representative group of single-family residents and apply advanced machine learning techniques based on Bayesian model selection (averaging) to construct a credible list of factors that determine willingness to pay for clean energy.

Findings: We find that people are willing to pay more for clean air than for energy from renewable sources. Both aspects of willingness to pay are affected by the size of the electricity bills, the importance of the environment and the knowledge about renewable energy supplies. Willingness to pay for energy from renewable sources is also influenced by educational level and awareness of the need to increase the share of renewable energy in the domestic energy mix. Furthermore, we find that young people are more willing to pay for energy from renewable sources, whereas older people are more likely to pay for clean air.

Implications & Recommendations: Arguably, a higher willingness to pay requires, first and foremost, greater environmental awareness and the promotion of its benefits among the population at large. Since willingness to pay studies are based on respondents' declarations, their actual willingness to bear the costs of energy transition may be lower. A variety of initiatives should be taken to foster closer bonds between people and their environment to make them feel more responsible for the shared objective.

Contribution & Value Added: The study bridges a significant gap by examining the willingness to pay for renewable energy and clean air in the same sample of respondents. We focus on single-family home residents. Using quantitative methods, we identify factors that are common to willingness to pay for clean air and renewable energy sources, as well as those that are specific to each type.

Article type:	research article
Keywords:	willingness to pay; clean air; air pollution; renewable energy sources; Bayesian model selection
JEL codes:	D10, Q53, Q49

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INTRODUCTION

Air quality in Poland is among the worst in Europe, particularly in the southern part of the country, where even lax quality standards are routinely exceeded during the winter season (Blazy *et al.*, 2021; EEA, 2024). Although the share of renewable energy sources (RES) in the country's gross energy consumption improved over the last two decades, it remains relatively low compared to the rest of the EU (Eurostat, 2025). As a result, attempts have been made to assess the willingness of Polish citizens to bear at least some of the costs of the necessary energy transition by assessing their willingness to pay (WTP).

Studies dealing with WTP for clean air come mainly from China (see, *e.g.*, Freeman *et al.*, 2019; Ito & Zhang 2020), while scholars have studied WTP for clean, renewable energy sources (RES) for some time in Europe (see, *e.g.*, Borchers *et al.*, 2007; Sundt & Rehdanz, 2015; Hojnik *et al.*, 2021). In Poland, Kowalska-Pyzalska (2019) and Mamica (2021) have conducted similar studies on RES. To our knowledge, this study is the first attempt to compare WTP for clean air with WTP for RES based on the opinions of the same representative group and to focus on residents of single-family homes. We argue that having the two WTPs measured based on the same method and the same sample provides a better, more credible insight into their differences. Clean air and green energy are somewhat similar topics. Hence, if WTPs for them are compared separately, the differences found may be attributed, at least partially, to, *e.g.*, differences in research methodology or sample characteristics.

The questionnaire survey was conducted from July to August 2021 among a representative sample of 1007 people who live in single-family homes in Poland using the computer-assisted telephone interviewing (CATI) method. We chose this group because a large portion of such dwellings still rely on coal-derived energy. Therefore, the decisions taken by their owners may have a significant impact on the overall air quality and energy transition of the country.[1]

The article is structured as follows. Section 2 explains the rationale behind the energy transition in Poland and describes selected studies that evaluate the WTP of people for renewable energy and clean air. Section 3 describes the data acquisition and Bayesian modelling techniques used in the study. Section 4 presents the results and a discussion. Section 5 concludes.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The European Union aims to achieve climate neutrality by 2050 (European Commission, 2019a) through a series of policy recommendations for national strategies (Kud *et al*., 2021). To make environmentally friendly energy sources (RES hereafter) an effective tool to achieve the stated goals, an appropriate strategy must be adopted, considering locally specific factors, social contexts, and barriers to renewable energy development (Jeleński *et al*., 2021).

In a 2017 analysis of all EU countries, Poland recorded the smallest decrease (about 1%) in CO2 emissions (Brodny & Tutak, 2021), which results directly from its coal-dominated energy mix (Karpinska & Śmiech, 2021). In general, Poland accounted for 7.7% of EU emissions (greenhouse gases and air pollutants) in 2017 (Brodny & Tutak, 2021). In 2021, coal-fired power generation accounted for 72.4% of total power produced in Poland (Forum Energii, 2022). The proportion of coal in the energy mix is steadily decreasing (Tokarski *et al.*, 2024).

The resistance to the switch from coal is mainly due to the strong position of the coal mining industry and the government that supports it. Close ties between coal companies and the government serve to safeguard the interests of the coal lobby. The state owns a large stake in most coal companies and unions play a considerable role in political decision-making (Brauers & Oei, 2020). Noteworthy, coal is used not only for energy production but also for heating. Air in Poland is among the most polluted in Europe, particularly in the South (Blazy *et al.*, 2021). In 2018, the daily limit allowed for PM10 was exceeded in 39 of 46 zones (Adamkiewicz *et al.*, 2021). Usually, the average annual concentration of PM2.5 should not exceed 5 µg/m3 (EEA, 2023). In 2023, the average concentration of PM2.5 in Poland was 2.8 times higher than the WHO annual air quality guideline (IQAir, 2024).

Recently, there has been an increasing trend towards more reliance on environmentally friendly or renewable energy sources, especially in the residential sector (Cardella *et al.*, 2022). To address low emissions and increase the share of renewable energy sources in its total energy supply, Poland launched its Clean Air programme in 2018, which aims to replace 3 million old solid fuel boilers with a 22.4 billion EUR state budget subsidy available over ten years (Blazy *et al.*, 2021). Since the cost of renewable energy is often higher than that generated from burning fossil fuels, a system of subsidies

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[1] W define an owner of a single-family home as someone who owns the building, lives there (alone or with family members) and is responsible, or co-responsible, for paying household bills. Next, we define a single-family home as a free-standing residential building occupied by only one family. The interviewers questioned either the homeowners, or their relatives if they were also responsible for paying bills.

for the former is required (Shen *et al.*, 2020). Therefore, WTP for renewable energy and clean air should be seen as a composite indicator of public support for energy transition. This approach assesses the price that people are willing to pay for a given commodity using survey methods (Bigerna & Polinori, 2014). The issue of WTP for clean energy has been studied for some time (Borchers *et al.*, 2007; Hojnik *et al.*, 2021; Sundt & Rehdanz, 2015). Respondents are usually asked how much they would be willing to spend 'extra' each month if the energy used to power their homes came from renewable sources rather than non-renewable sources (Navrud & Bråten, 2007; Soon & Ahmad, 2015). The WTP plays an important role in the implementation of ambitious renewable energy development policies (Dogan & Muhammad, 2019). The few studies that deal with WTP for clean air come mostly from China (Freeman *et al.*, 2019; Ito & Zhang, 2020), although some work in this field was done decades ago (Harrison & Rubinfeld, 1978). The WTP for clean air applies to both pollutants produced by motor vehicles and by coal-fired boilers (Katz & Sterner, 1990; Nishitateno & Burke, 2021).

For quite some time now, there has been a widespread consensus that we should see virtually every positive change in entitlement as advantageous. The most accurate way to assess the monetary contribution to the well-being that results from such adjustments is to evaluate the largest amounts that individuals are prepared to pay, known as WTP (Nguyen *et al.*, 2021). The WTP is a unique metric capable of accounting for external factors, and quantifying outcomes in monetary terms. Consequently, it facilitates straightforward comparisons of costs and benefits, enabling a clear assessment of net benefits (Gafni, 2001). The contingent valuation method (CVM) and the discrete choice experiments (DCE) can both serve to quantify how each component affects WTP (Alberini *et al.*, 2018). Direct and indirect surveys are two popular strategies to collect relevant data to estimate WTP. Unlike revealed preferences, which reflect actual behaviour, data obtained from surveys are often known as stated preferences. In direct surveys, respondents are asked how much they would be willing to pay for a particular product. Conversely, in indirect surveys, products are evaluated using a rating or ranking system, which makes it easier to estimate a preference framework and thus determine WTP (Breidert *et al.*, 2006). The stated preference approach has some limitations for estimating WTP, namely: 1. respondents may deliberately mark certain answers to influence policy; 2. they may not be motivated to give considered or meaningful answers; 3. the answers given may not necessarily reflect the actual future contributions, and 4. the way the questions are phrased may affect the answers (Hudson & Ritchie, 2001). However, despite its flaws, WTP makes it possible to identify the factors that affect the declared amounts of extra payments. Therefore, we have compiled the following three hypotheses for this research:

H1: Most people in Poland are willing to pay extra for clean air and renewable energy.

H2: Most people in Poland declare a greater willingness to pay extra for actions aimed at improving air quality compared to having electricity generated from RES.

H3: H3. Similar determinants affect the willingness to pay for clean air and the willingness to pay for renewable energy.

Based on a review of existing studies, Kowalska-Pyzalska (2019) argues that the following factors have a positive impact on WTP for RES: familiarity with RES, attitudes toward the environment and RES, household income, social norms, home ownership, education level, knowledge of technical aspects of energy systems and risk-taking. On the other hand, age (older individuals tend to declare smaller extra payments), the focus on comfort and happiness, resistance to risk and loss, and the perception that switching energy suppliers is difficult, may all have a negative effect on WTP. Finally, household size, gender, energy price, total energy bills paid (sometimes the higher the price, the lower the declared WTP), and the source of green energy yield ambiguous results. A survey of Dutch residents showed that WTP for sustainable energy is associated with 'understanding and worry' (Pleeging *et al.*, 2021).

The authors have decided to investigate the WTP for air quality improvement and RES to obtain a broader and more coherent perspective on energy transformation, allowing insights that would be unattainable if these analyses were independent.

RESEARCH METHODOLOGY

In July-August 2021, the Office of Social Research 'Observer' surveyed 1007 adults living in single-family homes in Poland using the CATI method. Before the actual survey, they conducted a pre-test on a group of 20 respondents. The interviewers were trained to clarify any misunderstandings and ensure that the respondents provided accurate responses. The survey comprised 44 questions, but for this study, we chose 22 of them as potential explanatory factors. We removed several corrupted and incomplete responses from the data set. Moreover, according to studies conducted so far, households are reluctant to respond to income-related questions (Sokołowski *et al.*, 2023), which the pre-test confirmed.

The survey included the following questions about the WTP for clean air and RES:

1. How much would you be willing to pay extra each month to improve air quality in your neighbourhood?
2. How much would you be willing to pay extra each month for energy if it came from renewable sources?

For the sake of clarity, we label the willingness to pay for clean air as WTP1, while the willingness to pay for renewable energy sources (RES) as WTP2. We do not expect the respondents to decide whether they are ready to pay for one or the other. The questions are open-ended. The number of verified responses for question 1 is 803, and 818 for question 2. This is due to missing or incorrect responses. Furthermore, the study aims to identify the factors that influence people's willingness to pay more (or less) rather than the factors that influence the willingness to pay at all. That is, while previous studies focused on the latter (cf., *e.g.*, Kowalska-Pyzalska, 2019), we wish to study the factors that affect the dynamics of WTP. That is why only nonzero responses are considered to identify the factors using Bayesian model selection methods.

In total, for the regression analysis, we have identified 621 complete responses for willingness to pay more for better air quality (WTP1>0) and 673 for energy from RES (WTP2>0). These values are lower than for questions 1 and 2 alone because some of these responses were incomplete with respect to the potential determinants. The proportion of people who were unwilling to pay for clean air (WTP1=0) and clean energy (WTP2=0) was not that substantial. It equalled 182 (22.7%) and 145 (17.7%), respectively, with 123 respondents giving negative answers to both questions. Based on the literature, we have compiled the list of potential variables for WTP1 and WTP2. Table 1 presents the variables, which were largely developed based on the literature (Dogan & Muhammad, 2019; Hojnik *et al.*, 2021; Kowalska-Pyzalska, 2019; Liobikienė & Dagiliūtė, 2021; Zorić & Hrovatin, 2012).

It is more than likely that only a subset of these variables is relevant to determining the variation of WTP1 and WTP2. Therefore, we treat them as potential determinants of WTP variation. To establish the actual determinants of WTP1 and WTP2, we apply Bayesian model selection, BMS hereafter (Zeugner & Feldkircher, 2015). BMS is a probability-based model selection technique known from statistics and machine learning, which has made its way into numerous fields including survey data analysis (see, *e.g.*, Aliverti & Russo, 2022; Little, 2022). Noteworthy, the way the research question in this study is phrased affects the selection of the inference method. If we were to examine the factors that affect the decision only whether to pay (or not) we would then use logistic or tobit regression, and then we would include the zero-value observations for WTPs (cf., *e.g.*, Kowalska-Pyzalska, 2019). However, since (i) we focus on the factors that affect WTP dynamics and (ii) the number of zero-value observations is relatively modest, we opt for BMS.

The BMS procedure involves sampling from a model space of all possible 2^k regression models (where k is the maximum number of regressors) and detecting configurations with the highest explanatory power. In practice, the algorithm almost never runs over all 2^k models as it is designed to terminate once a sufficient number of the most probable models is found. The explanatory power of each model in this procedure is evaluated using posterior model probability, which is a standard Bayesian practice. The most prevalent application of BMS is for covariate selection (Steel, 2020) and our application is no different. We investigate the model space to estimate the Posterior Inclusion Probability (PIP), which determines how likely it is for a given determinant (*i.e.*, the potential factor) to be included in the optimal model and thus how relevant it is. The lower the PIP, the less likely a given predictor is to be included in the optimal model, and thus the less relevant it is in explaining WTP. In general, there is no rule as to what the cut-off value for PIP should be, and this is usually determined empirically. We return to this aspect in the results section. Another important piece of information is the direction of influence of a given determinant. In BMS, this is known as the conditional posterior sign (CPS), which reflects the probability that the parameter of a particular determinant has a positive or negative sign, showing the direction of its effect. Consequently, for values of CPS equal or close to one, this impact is regarded as definitely positive, for values equal or close to zero, this impact is negative, whereas values around 0.5 are considered inconclusive.

Table 1. Potential explanatory variables for WTP1 (clean air) and WTP2 (RES)

Variable	Code	Variable scale	Mean	SD	Min	Max
General						
Age	G1	Ordinal (1-6)	2.96	1.30	below 25	65 and above
Gender	G2	Nominal (1, 2)	1.39	0.49	1 (F)	2 (M)
Education	G3	Ordinal (1-5)	4.33	0.76	1 (primary)	5 (tertiary)
Employment – private	G4.1	Nominal (0, 1)	0.45	0.50	0 (no)	1 (yes)
Employment – public	G4.2	Nominal (0, 1)	0.21	0.41	0 (no)	1 (yes)
Self-employed	G4.3	Nominal (0, 1)	0.09	0.28	0 (no)	1 (yes)
Unemployed	G4.4	Nominal (0, 1)	0.05	0.23	0 (no)	1 (yes)
Homeowner	G5	Nominal (0, 1)	0.93	0.26	0 (no)	1 (yes)
Property characteristics						
House thermal insulation	P1	Ordinal (1-5)	3.59	1.18	1 (uninsulated)	5 (very good)
House age	P2	Ordinal (1-6)	3.03	1.55	1 (before 1980)	6 (after 2020)
Heating source	P3	Nominal (0, 1)	0.56	0.50	0 (renewables)	1 (fossil fuels)
Installed photovoltaic panels	P4	Nominal (0, 1)	0.08	0.27	0 (no)	1 (yes)
Household size	P5	Ratio (integer)	3.56	1.22	1	10
Financial aspects						
Average heating bill	F1	Ratio	2274	2255.1	0	15000
Average electricity bill	F2	Ratio	301	309	5	3000
Average monthly expenses per resident	F3	Ordinal (1-4)	2.78	0.96	1 (below 500)	4 (over 1200)
Energy conservation for financial reasons	F4	Ordinal (1-5)	4.07	0.94	1 (definitely no)	5 (definitely yes)
Declared awareness of environmental actions						
Familiarity with RES	D1	Ordinal (1-5)	3.60	0.86	1 (very low)	5 (very high)
Attitude to increasing the share of RES in Poland's energy mix	D2	Ordinal (1-5)	4.13	0.89	1 (very low)	5 (very high)
Importance of environmental protection	D3	Ordinal (1-5)	4.23	0.84	1 (very low)	5 (very high)
Energy conservation for environmental reasons	D4	Ordinal (1-5)	3.89	0.99	1 (very low)	5 (very high)
Willingness to obtain information on activities that promote environmental protection	D5	Ordinal (1-3)	1.46	0.78	1 (low)	3 (high)

Note: We group the potential determinants listed above by category: general (G), property characteristics (P), financial aspects (F), and declared awareness of environmental actions (D); SD is the standard deviation.
Source: own study.

We rely on BMS since the existing WTP literature is largely inconclusive about the main factors that affect both WTP1 and WTP2. By stating so, we do not wish to imply that the theory is sparse. Quite the contrary. Many publications provide lists of potentially critical determinants of WTP, but their contents rarely overlap. Based on the literature review, we have compiled a shortlist of 22 of such determinants. Naturally, it makes little sense to combine all of them into a single regression model. Traditional model-building and specification-search procedures may also fail due to potential weaknesses of standard statistical tests (*e.g.*, due to the high dimensionality of the model and the fact that asymptotic properties may not hold in finite samples). Furthermore, considering the scarcity of the joint literature on WTP1 and WTP2, we opt not to devise a model using largely ad hoc procedures and apply BMS to see what the data can tell us.

RESULTS AND DISCUSSION

Approximately 82.3% of the respondents are willing to pay extra for renewable energy sources, while 77.4% are willing to contribute financially to clean air. Those willing to pay more for clean air (WTP1) declare PLN221.33 (USD 53.98) per month on average, which is approximately PLN120 (USD29.30) more than they are willing to pay for renewable energy (WTP2; PLN98.65 on average, or approximately USD24.06 per month). The median for WTP1 is PLN100 (USD24.39), which is PLN50 more than WTP2. Therefore, clean air and renewable energy seem important to them, although they are willing to pay substantially more for clean air than for renewable energy. The trend intensifies in the tails of the distributions of both variables, *i.e.*, the difference between means is higher than that in medians, which also indicated the asymmetry of these distributions. Indeed, the skewness of the distribution for WTP1 is 2.2 and for WTP2 – 2.0. Moreover, both the WTP1 and WTP2 distributions are characterised by a very high concentration of values around the modal. Kurtosis is 5.44 and 4.06, respectively, which shows that although the range of both variables is quite large (1−1600, and 1−500, respectively), a relatively large number of responses groups around the central tendency (*i.e.*, a larger proportion than would result from an approximation by a normal distribution; see Figure 1 for the histograms for WTP1 and WTP2, respectively). Hence, both distributions are far from the 'normal' curve. It may also be argued that Figure 1 shows several outliers. However, because of the high kurtosis (*i.e.*, the concentration of the distribution around their modal), the distributions may simply be heavy-tailed (*e.g.*, Laplace-like distribution), which is quite common.

We find that the majority of the respondents have opted for WTP1 and WTP2 and that the declared values are rather large given the income of households in Poland at the time (*i.e*., median annual disposable household income in 2021 was 19.1 thousand USD in PPP; see OECD, 2023). Therefore, we confirm hypothesis H1. Since we find the values for WTP1 to be substantially higher than for WTP2, we also confirm hypothesis H2. Improving air quality in Poland tends to be perceived in terms of switching energy carriers or the substitution of hard coal in domestic boilers with less polluting but more expensive fuels. As a result, the payments to improve air quality currently take the form of purchasing more expensive energy carriers. In this instance, each user makes their own decision, which reduces the risk of purposefully misreporting the actual WTP.

Table 2. Statistics for WTP1 (clean air) and WTP2 (RES) in PLN

Variables	Average	Median	Mode	SD	Kurtosis	Skewness	Min	Max	Count
WTP1	221.33	100	100	269.16	5.44	2.2	1	1600	621
WTP2	98.65	50	50	108.74	4.06	2.03	1	500	673

Source: own study.

We specify relevant determinants in BMS based on the 0.2 cut-off level for PIP. This is for two reasons. First, given the above-mentioned literature, we have found that most regression models for similar analyses consist of at least five explanatory variables. This is somewhat reflected in the PIP≥0.2 criterion. We assume that *a posteriori* the probability of a given variable being part of the model should be about 1/5, which is the inverse of the expected number of explanatory variables in the model. Second, empirical results have shown that PIP values drop substantially after about 0.2 (*e.g.*, to about 0.1, which means that the next predictor is about twice less likely). Furthermore, before BMS, it is advisable to check for possible multicollinearity between the potential explanatory variables. This is because highly correlated variables could affect the regression results. Fortunately, we find that the highest absolute value for the correlation coefficient does not exceed 0.6 (we provide correlation tables in the Appendix). This reassures us that BMS results are not distorted by the potential multicollinearity.

The results of BMS show interesting correspondences and some differences between the potential determinants of WTP1 and WTP2. In the case of the WTP1 model, the posterior inclusion probability (PIP) is at least around 0.2 (1/5) for four potential explanatory variables, all of which have a positive impact on WTP1 (the exact values of each variable are shown in Table 3). People are willing to pay more for clean air if: 1) they pay more for heating anyway; 2) they declare that the environment is more important to them; 3) they are senior citizens, and if 4) they declare a greater familiarity with renewable energy sources. This is slightly different in the case of WTP2, in the case of which we identify six determinants with PIPs in the 20% range (Table 4 shows the exact values for each variable).[2] According to our findings, the following factors positively affect WTP2: 1) the size of energy bills; 2) declared strong commitment to environmental protection; 3) familiarity with RES, and 4) age (younger people tend to exhibit a higher WTP2). On the contrary, factors such as 5) educational level and 6) attitude toward expanding the share of RES, have a negative impact on WTP2. Table 5 compares the impact of potential determinants with a PIP of at least 20% in the two models (for WTP1 and WTP2). The common determinants common of both WTP1 and WTP2 are: 1) declared concern for the environment and 2) familiarity with renewable energy sources. Furthermore, heating and energy bills can be viewed to some extent as a common determinant, since changes in the former affect WTP1, while changes in the latter affect WTP2. The age of the respondents also has an impact, but interestingly, the causations are reversed: older respondents tend to be willing to pay more for clean air, while younger ones tend to pay more for RES. Other characteristics described above seem to be specific to the type of WTP. Overall, we find hypothesis H3 to be confirmed to some degree. That is, there are indeed similar determinants for WTP1 and WTP2, although some factors are specific to only one of the two.

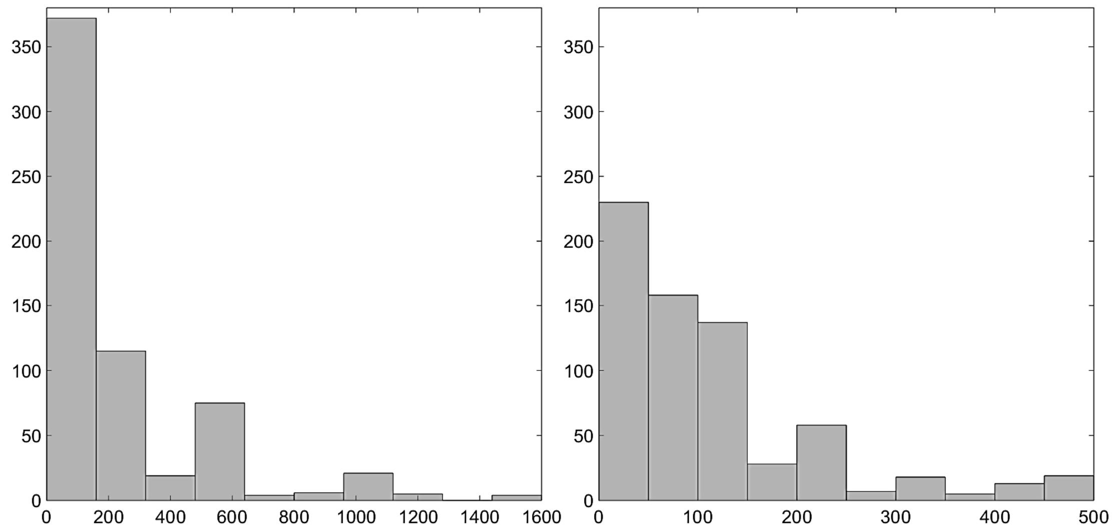

Figure 1. Histograms for declared WTP1 (clean air; left) and WTP2 (RES; right)
Note: The x-axis represents the amounts to be paid within a specific band (in PLN); the y-axis represents the number of people.
Source: own elaboration.

To sum up, the study has indicated that people in Poland are largely willing to pay extra for clean energy and that WTP1 (clean air) is greater than WTP2 (RES). This provides support for hypotheses H1 and H2 formulated in Section 2. Our findings are consistent with other studies that report increasing social understanding of the importance of air quality in Poland (Król & Gomola, 2022). According to the European Commission, about 45% of Poles in 2019 were aware that air quality deteriorates (European Commission, 2019b). The literature suggests that Poles are aware that low emissions are generated by households burning coal (Ligus, 2017). In addition to acknowledging local air pollution issues, they understand the necessity of energy transition, with around 74% favouring a gradual shift awa

[2] For WTP2, 'familiarity with RES' has a PIP of just under 20%, very close to the adopted cut-off criterion. That is why we have decided to include it in the analysis. This variable is also present in other studies.

Table 3. BMS results for WTP1 (clean air)

Variable name	PIP	Post. mean	Post. SD	Cond. post. sign
Average heating bill	0.7196	0.0848	0.0632	1
Importance of environmental protection	0.4689	0.0486	0.0590	1
Age	0.3746	0.0359	0.0529	1
Familiarity with RES	0.2343	0.0198	0.0412	1
Average electricity bill	0.1000	0.0059	0.0221	1
Willingness to obtain information on activities that promote environmental protection	0.0884	0.0049	0.0203	1
Employment – public sector	0.0832	-0.0043	0.0185	0
House thermal insulation	0.0813	0.0041	0.0182	1
Average monthly expenses per resident	0.0735	0.0034	0.0165	1
Employment – private sector	0.0717	0.0033	0.0163	1
Gender	0.0604	-0.0024	0.0138	0
Household size	0.0562	-0.0019	0.0127	0
Energy conservation for financial reasons	0.0554	0.0020	0.0130	1
Education	0.0548	0.0019	0.0122	1
Self-employed	0.0500	-0.0013	0.0108	0
Energy conservation for environmental reasons	0.0461	0.0008	0.0111	0.6525
Attitude to increasing the share of RES in Poland’s energy mix	0.0441	0.0001	0.0099	0.4964
Homeowner	0.0438	0.0010	0.0097	1
Installed photovoltaic panels	0.0428	0.0008	0.0091	1
Unemployed	0.0422	-0.0008	0.0091	0.0020
House age	0.0419	0.0008	0.0093	0.9720
Heating source	0.0396	0.0001	0.0080	0.6363
(Intercept)	1	0.2550	NA	NA

Source: own study.

Table 4. BMS results for WTP2 (RES)

Variable name	PIP	Post. mean	Post. SD	Cond. post. sign
Average electricity bill	1	0.4213	0.0353	1
Importance of environmental protection	0.5593	0.0578	0.0596	1
Age	0.4304	-0.0370	0.0484	0
Attitude to increasing the share of RES in Poland’s energy mix	0.2729	-0.0236	0.0441	0
Education	0.2427	-0.0176	0.0357	0
Familiarity with RES	0.1937	0.0139	0.0329	1
House age	0.1037	0.0056	0.0203	1
Average heating bill	0.0945	-0.0048	0.0187	0
Willingness to obtain information on activities that promote environmental protection	0.0793	-0.0037	0.0167	0
Household size	0.0717	0.0031	0.0148	1
Energy conservation for financial reasons	0.0519	-0.0015	0.0108	0.0046
Energy conservation for environmental reasons	0.0489	0.0005	0.0112	0.6360
House thermal insulation	0.0486	-0.0011	0.0096	0.0271
Homeowner	0.0462	-0.0011	0.0091	0
Unemployed	0.0442	-0.0009	0.0086	0
Employment – public sector	0.0436	-0.0009	0.0085	0.0002
Heating source	0.0420	0.0008	0.0082	0.9982
Self-employed	0.0403	0.0005	0.0075	0.9997
Employment – private sector	0.0380	-0.0003	0.0072	0.1629
Installed photovoltaic panels	0.0375	-0.0002	0.0068	0.1061
Gender	0.0374	-0.0004	0.0073	0.0858
Average monthly expenses per resident	0.0362	-0.0001	0.0068	0.3469
(Intercept)	1	0.4365	NA	NA

Source: own study.

Table 5. Comparison of significant determinants for WTP1 (clean air) and WTP2 (RES)

Variable name	WTP1	WTP2
Heating bills	Yes (1)	No (0)
Electricity bills	No (1)	Yes (1)
Importance of environmental protection	Yes (1)	Yes (1)
Familiarity with RES	Yes (1)	Yes (1)
Age	Yes (1)	Yes (0)
Education	No (1)	Yes (0)
Attitude to increasing the share of RES in Poland's energy mix	No	Yes (0)

Notes*:* The Table shows those variables in the model for which the posterior inclusion probability (PIP) is at least 20% for WTP1 and WTP2 in Poland; 'Yes' – PIP of at least 20%; 'No' – PIP below 20%, (1) represents a predominantly positive relationship between the factor and WTP (CPS close to or equal to 1); (0) represents a negative relationship (CPS close to or equal to 0). Source: own study.

from a coal-based economy in 2021, compared to 61% in 2015 (Herudziński & Swacha, 2022). This indicates a growing social acceptance of changes in the energy sector. Over 60% of young Poles declare that in the future they will be active energy prosumers, which shows a strong interest in renewable energy sources (Gryz & Kaczmarczyk, 2021). The above-mentioned results from previous studies on environmental awareness and attitudes are consistent with a relatively high WTP1 and WTP2 found in this study (*i.e.*, relative to average or median household income in Poland at the time). We may attribute differences in the declared amounts to the greater immediate impact of air quality on individual respondents, particularly their health. Finally, all consumers easily understand the term 'clean air,' while 'renewable energy sources' may raise interpretive issues.

Using BMS, we have also established a set of determinants common to WTP1 and WTP2 (hypothesis H3). We have confirmed that WTPs for clean air and RES were higher for those who declare a better understanding of the environment and see its condition as important. Climate change awareness has been reported to have a positive impact on WTP for RES (Zografakis *et al.*, 2010). Interestingly, the analysis has shown that senior citizens are willing to pay more for clean air, whereas younger people are willing to pay more for energy from renewable sources. The fact that we have focused the regression analysis on people who are willing to pay at all (WTP>0) may account for the high positive relationship between the bills paid and the WTP.

Given these findings, we recommend to promote awareness of current environmental issues through marketing initiatives. It also appears necessary to assist nongovernmental organisations such as the Polish Smog Alert. Various initiatives should be taken to foster closer bonds between people and their environment to make them feel more responsible for the shared goal. This could be achieved through programmes, in which households receive guidance on energy-saving strategies in the form of nudges (*e.g.*, visual cues). Effective measures can also involve well-designed buildings thermo-modernisation programmes, with a particular emphasis on increasing the energy efficiency of single-family homes. Promoting the use of smart meters, which allow real-time energy consumption monitoring, could further enhance energy efficiency efforts.

Since the regression analysis did not account for those who declared 'no' (*i.e.*, zero) for both WTP1 and WTP2, these recommendations apply to people who are willing to pay. To devise appropriate recommendations for those unwilling to pay more for clean air or RES, it is necessary first to determine whether their decisions are motivated by a lack of knowledge, indifference to the environment, or financial concerns. For example, in Poland in 2017, exposure to hidden energy poverty was 23.7% and it was linked to a certain extent to income poverty (Karpinska & Śmiech, 2020). This figure nearly matches the 22.7% and 17.7% of respondents in our survey who reported zero for WTP1 and WTP2, respectively, and may imply that energy poverty is the reason why some respondents declared their unwillingness to pay at all. It would be unreasonable to expect people who are facing energy poverty to be willing to spend extra money on renewable energy (Mamica *et al.*, 2021).

Undoubtedly, one of the limitations of the study reflects the limitations of survey-based research methodologies in that respondents may manipulate data by indicating their aspirational behaviours, which often would not align with the actual experience. Consequently, these findings may not indicate the amounts that households can actually pay, nor do they provide any reliable guidance in this regard. With the caveat that these findings only represent the expressed preferences, the key conclusion is that such payment declarations reveal both the need for change and the readiness of single-family households to fund it, at least to some extent. Conversely, the higher reported willingness to pay for clean air shows that Poles are more concerned with the immediate, tangible, and local aspects of energy transformation. Another potential limitation comes from the fact that to study potential determinants of the WTP variation, the BMS procedure excludes respondents who declare zero willingness to pay. In doing so, it overlooks the perspectives of those unwilling or unable to pay, which may be driven by factors like the above-mentioned energy poverty. In theory, the entire dataset could be analysed by developing a BMS procedure for tobit-class models. However, such procedures are not yet available.

CONCLUSIONS

The respondents are generally willing to pay more for the sake of the environment, and in particular to spend more on clean air than on renewable energy. Furthermore, the values declared in both cases are relatively large given the median household income in Poland at the time of the survey. The notion that low emissions are harmful to health may partially explain why clean air is linked to a higher WTP. Many of the initial 22 determinants have relatively low posterior inclusion probabilities (PIP). Nonetheless, we may draw certain conclusions from the analysis. First, factors such as the size of energy bills, the importance of the environment to the respondents, and their familiarity with RES influence both WTP1 (clean air) and WTP2 (RES). The positive relationship between the payment of higher energy bills and WTP1 and WTP2 can probably be explained in terms of the financial situation and composition of the survey group. That is, higher energy bills may indicate wealthier households, and wealthier households can afford a higher WTP when measured in currency values. The study supports the notion that there is an impact on awareness about the importance of environmental protection on WTP for clean air and RES.

Finally, we would argue that increasing the WTP requires first and foremost raising environmental awareness and promoting its benefits among the general population. Since the WTP studies are based on the respondents’ declarations, their actual willingness to bear the costs of energy transition may be lower. The analysis was carried out before Russia invaded Ukraine. On the one hand, this may have driven WTP even lower due to the considerable increases in the prices of energy, food, and other commodities since 2021. On the other hand, if higher RES is associated with a decreased dependency on Russian oil and gas this may have driven WTP in Poland higher, at least in terms of WTP2. The net effect is difficult to ascertain.

The study closes a research gap by examining the willingness to pay for clean air and renewable energy in the same sample of respondents. Future research should use empirical methods to assess why some groups are unwilling to pay more for ‘environmental initiatives’ and whether this is associated with energy poverty. The government should provide aid in the thermo-modernisation of buildings and increase investments in diverse, clean, renewable energy (solar, wind, biomass, *etc*.), even if it generates transitional costs. To address energy poverty, policymakers should focus on minimalizing the burden of increasing energy costs for the least well-off. Since environmental awareness and knowledge about RES positively influence WTP, educational campaigns that raise public awareness about RES and environmental protection are also crucial. These campaigns should target different groups based on their preferences (*e.g.*, younger for RES vs. older for clean air).

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Appendix A: Correlation coefficients between potential determinants of WTP

Table A1. Spearman's rank correlation coefficients between variables in ordinal or ratio scale

Variable	Code	G1	G3	P5	D3	D1	D2	F4	D4	F3	F2	F1	P2	P1
Age	G1	1												
Education	G3	-0.04	1											
Household size	P5	-0.20	-0.06	1										
Importance of env. protection	D3	0.10	-0.02	0.04	1									
Familiarity with RES	D1	-0.01	0.00	0.11	0.37	1								
Attitude to increasing the share of RES in PL energy mix	D2	0.07	0.04	0.03	0.40	0.25	1							
Energy conservation for financial reasons	F4	0.09	0.02	0.01	0.23	0.16	0.40	1						
Energy conservation for environmental reasons	D4	0.05	0.00	0.03	0.48	0.30	0.60	0.47	1					
Avg. monthly exp. per resid.	F3	0.11	0.12	-0.05	0.08	0.09	0.11	0.07	0.12	1				
Average electricity bill	F2	-0.12	-0.01	0.23	0.05	0.05	-0.03	-0.06	0.00	-0.03	1			
Average heating bill	F1	0.17	0.10	0.00	0.05	0.02	0.16	0.13	0.12	0.10	0.12	1		
House age	P2	-0.13	0.23	0.05	0.04	0.12	-0.02	-0.03	-0.01	0.13	0.07	-0.07	1	
House thermal insul. status	P1	-0.02	0.10	-0.03	0.22	0.22	0.12	0.08	0.15	0.18	-0.05	0.04	0.33	1

Note: Spearman's rank correlation coefficient is used because most variables are in ordinal scale (*e.g.*, Likert's scale). For Pearson correlation coefficients the results remain virtually unchanged. Grayscale identifies higher correlation values in absolute terms.
Source: own elaboration.

Table A2. Kendall's τ coefficients between dichotomous (nominal scale) variables

Variable	Code	G2	G5	D5	P4	G4.1	G4.2	G4.3	G4.4	P3
Gender	G2	1								
Homeowner	G5	0.01	1							
Willingness to obtain inf. on activities that promote environmental protection	D5	-0.05	0.15	1						
Installed photovoltaic panels	P4	-0.01	0.04	0.07	1					
Employment – private sector	G4.1	-0.09	0.05	0.10	0.02	1				
Employment – public sector	G4.2	0.08	0.08	0.03	0.02	-0.45	1			
Self-employed	G4.3	-0.08	0.05	-0.06	0.00	-0.26	-0.15	1		
Unemployed	G4.4	0.12	-0.12	-0.05	-0.02	-0.21	-0.13	-0.07	1	
Heating source	P3	0.04	-0.02	0.02	-0.03	-0.07	0.01	-0.05	0.04	1

Note: Grayscale identifies higher correlation values in absolute terms.
Source: own elaboration.

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The contribution share of authors is equal and amounted to 33.(3)% for each of them.
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Use of Artificial Intelligence

The authors declare that AI was not used in any way in the generation of the paper.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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