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A Study of Renewable Energy Perceptions among Libyan Engineers

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ABSTRACT

This study examines engineers' perspectives on renewable energy sources (RES), climate-related concerns, and environmental engagement across Libya, the United Kingdom, and the United States. A cross-sectional survey of 194 respondents assessed trust in decision-making actors, perceived substitution potential of RES for fossil fuels, cost–benefit orientations, and technology acceptability, alongside outcomes including information needs about RES, willingness to contribute financially, willingness to volunteer time for local environmental projects, and transport mode. Descriptive statistics and generalized linear models were applied. Respondents reported high trust in scientists and environmental organizations, strong substitution beliefs for wind and solar, and higher acceptability for these technologies compared to others. Most participants expressed a need for more information about RES (71.65%). Financial contribution willingness was reported by 41.75%, while 49.48% were willing to volunteer time. A cost–benefit orientation favoring environmental quality was positively associated with volunteering (odds ratio 2.69, $p = 0.019$), whereas higher acceptability was inversely related to the need for more information. Transport was dominated by private car use (74.23%), reflecting structural constraints. Limitations include purposive sampling, inter-construct collinearity, and some missing data. The findings highlight the importance of targeted information, practical exposure to RES, financial support mechanisms, and improved infrastructure for low-carbon mobility.

دراسة إدراك المهندسين الليبيين للطاقة المتجددة

يوسف م عكاشه[1] منال أ ح عبدالغنى

تتناول هذه الدراسة آراء المهندسين حول مصادر الطاقة المتجددة، والقضايا المرتبطة بالمناخ، ومستوى المشاركة البيئية في كل من ليبيا والمملكة المتحدة والولايات المتحدة الأمريكية. تم إجراء مسح مقطعي شمل 194 مشاركًا، بهدف تقييم مستوى الثقة في الجهات الفاعلة في صنع القرار، والتصورات المتعلقة بقدرة مصادر الطاقة المتجددة على إحلال الوقود الأحفوري، والتوجهات المرتبطة بالموازنة بين التكاليف والفوائد، ومدى تقبل التقنيات المختلفة. كما تناولت الدراسة عددًا من المخرجات، منها الحاجة إلى مزيد من المعلومات حول مصادر الطاقة المتجددة، والاستعداد للمساهمة المالية، والرغبة في التطوع بالوقت للمشاركة في المشاريع البيئية المحلية، وأنماط استخدام وسائل النقل تم استخدام الإحصاءات الوصفية ونماذج الانحدار الخطي المعمم لتحليل البيانات. وأظهرت النتائج أن المشاركين يتمتعون بمستويات مرتفعة من الثقة في العلماء والمنظمات البيئية، كما أبدوا قناعة قوية بقدرة طاقتي الرياح والطاقة الشمسية على أن تحل محل الوقود الأحفوري، إلى جانب تقبل أكبر لهاتين التقنيتين مقارنةً بالتقنيات الأخرى. وأفاد معظم المشاركين (71.65٪) بحاجتهم إلى مزيد من المعلومات حول مصادر الطاقة المتجددة. كما أظهرت النتائج أن 41.75٪ من المشاركين لديهم استعداد للمساهمة المالية لدعم القضايا البيئية، في حين أعرب 49.48٪ عن استعدادهم للتطوع بوقتهم للمشاركة في المشاريع البيئية المحلية. وبينت التحليلات أن التوجه الذي يفضل جودة البيئة على الاعتبارات الاقتصادية كان مرتبطًا إيجابيًا بالرغبة في التطوع)نسبة الأرجحية = 2.69، قيمة($p = 0.019$ ، بينما ارتبط ارتفاع مستوى تقبل تقنيات الطاقة المتجددة بانخفاض الحاجة إلى مزيد من المعلومات عنها. أما فيما يتعلق بوسائل النقل، فقد هيمن استخدام السيارات الخاصة بنسبة 74.23٪، وهو ما يعكس وجود قيود بنيوية وبنية تحتية تحد من تبني خيارات النقل منخفضة الكربون. وتشمل أبرز محدوديات الدراسة استخدام أسلوب العينة القصدية، ووجود تداخل أو ارتباط مرتفع بين بعض المتغيرات المدروسة، بالإضافة إلى وجود بعض البيانات المفقودة .وتؤكد النتائج أهمية توفير معلومات موجهة وفعالة حول مصادر الطاقة المتجددة، وتعزيز فرص التعرض العملي لهذه التقنيات، وتطوير آليات الدعم المالي، وتحسين البنية التحتية اللازمة لتعزيز التنقل منخفض الانبعاثات الكربونية

INTRODUCTION

The consumption of fossil fuels, as well as the availability of water and food, are all continuous concerns for the environment since the world's population, urbanization, and industrialization are quickly expanding (Perrone & Hornberger, 2014). A fundamental requirement of everyday life is energy, which is used in numerous fields and purposes, including power tools, transportation, heating, and lighting. Until 2040, the world's main energy requirement is predicted to increase by more than 25%, hitting 206,000 TWh annually (Taveira-Pinto, Rosa-Santos, & Fazeres-Ferradosa, 2020). Energy sources must be carefully evaluated because they are essential to meeting the needs of the world population. People need more energy than is readily available due to several factors, including the world's growing human population, manufacturing countries' technological achievements, the financial situation of the people, and the country's general level of development (Kannan & Vakeesan, 2016; Saraswat & Digalwar, 2021). Currently, a significant portion of the world's energy is derived from fossil fuels such as petroleum, gas, and coal (Abas, Kalair, & Khan, 2015). Fossil fuels emit greenhouse gases, including volatile chemicals, nitrogen oxides, and carbon dioxide, as well as solid particles (Worku *et al.*, 2024a) . As a result, the overuse of fossil fuels speeds up their depletion, damages the environment, and raises the possibility of health problems and global climate change (Destek & Sinha, 2020; Owusu & Asumadu-Sarkodie, 2016). Recently, there has been a shift towards the utilization of renewable energy sources (RES) while decreasing the usage of fossil fuels to address the world's environmental issues (Paravantis, Stigka, & Mihalakakou). RES is an alternative sustainable source that aim to raise energy production and supply with minimal negative impacts on the environment, which would boost national economies and raise the level of living (Viebahn, Lechon, & Trieb, 2011; Wang, Jing, Zhang, & Zhao, 2009). It is indicated that the amount of world energy consumed from RES has climbed nearly four times in the preceding ten years, surpassing 20% and still rising (Maradin, 2021).

RES such as biomass, hydropower, geothermal, solar, wind, and marine energy contribute to 14% of the world's energy consumption (Panwar, Kaushik, & Kothari, 2011). Bio-energy provides an important part of the energy requirements of several developing nations, contributing around 35% of the needed energy in these countries (Demirbas, Balat, & Balat, 2009). Regarding geothermal electricity output, it is expected to reach 1400 TWh/year by 2050, representing 3.5% of world electricity productio (Rohit *et al.*, 2023) . In terms of marine energy, without a doubt, it has much potential for energy production; however, the biggest obstacles to estimating the quantity of energy that may be harvested are operating and maintenance prices (Bonar, Bryden, & Borthwick, 2015; McGilton, Crozier, McDonald, & Mueller, 2018). On the other hand, the earth's wind power can provide roughly 1010 kW/a of electricity annually, which might contribute significantly to the world's electrical supply (Shi *et al.*, 2023a). Furthermore, recently, there has been an increase in worldwide expenditure on solar energy. This indicates that it is among the most important solutions to satisfy projected energy needs because it is more abundant, affordable, accessible, efficient, and has a higher capacity compared to alternate RES (Kabir, Kumar, Kumar, Adelodun, & Kim, 2018).

Libya's economic expansion and population growth have resulted in increased energy consumption, which is highly dependent on conventional fuel sources. Libya is one of the countries that is rich in RES, such as wind and solar, which could be the best solution to reduce fossil fuel demand and carbon dioxide emissions in the country (Kassem, Çamur, & Aateg, 2020). Although previous studies have assessed Libya's potential for renewable energy resources, such as solar thermal electricity (Belgasim & Aldali, 2018), thermal desalination plants (Kershman, 2001), and photovoltaic systems (Elbaz & Elfaqih; Elfaqih, 2016), etc. The utilization of RES is still restricted to powering small equipment like water pumps, small-scale heating of water, powering rural communication repeaters, and cathodic protection for oil pipelines in arid regions (Asheibe & Khalil). Recently, several projects have been proposed in Libya to make the most of the potential of RES . These projects include conducting studies to determine the current and future market size for RES, integrating RES into the country's energy mix, promoting and supporting an industry related to RES, and creating legislation to promote RES and energy efficiency initiatives (Almaktar & Shaaban, 2021).

Views, attitudes, and opinions regarding the consumption of energy and its reflection on environmental issues need to be studied to support the upcoming evaluations of long-term viability indices for RES technologies (Evans, Strezov, & Evans, 2009). In this regard, investigating people's perspectives and awareness levels regarding these sources and environmental issues is crucial to evaluating levels of knowledge of the potential of RES applications in Libya. Considering if the Libyan people would support the kind of energy project effort required to solve issues such as energy supply and rationalization of energy consumption is also crucial.

Numerous research on RES have been conducted in various countries, and public opinion has been considered to assess people's understanding of RES and their link with environmental, social, and economic issues (Chandrasekar & Kandpal, 2007; Dalton, Lockington, & Baldock, 2008; Kasim, 2004; Ozil, Ugursal, Akbulut, & Ozpinar, 2008).

This article aims to assess opinions from Libyan engineers' perspectives working in Libya, the UK, and the USA on the utilization of RES and the suggested solutions that reflect their awareness level about critical problems related to environmental and economic issues, which would contribute to the development of RES.

MATERIALS AND METHODS

1. Study design and objectives

A cross-sectional survey was conducted to assess engineers' knowledge, attitudes, and behaviors related to RES (renewable energy sources), climate concerns, and environmental stewardship. The primary objectives were to (i) characterize trust in key actors responsible for environmental decision-making; (ii) assess perceived

substitution potential of major RES for fossil fuels; (iii) Document cost–benefit orientations and acceptability of different energy technologies; and (iv) examine information needs and readiness to support local environmental projects (financially and with time). The survey targeted Libyan engineers living and working in Libya, the United Kingdom (UK), and the United States (USA) to compare perspectives formed in distinct policy and infrastructure contexts while retaining a coherent professional frame of reference. The setting comprises three national contexts with differing energy mixes and institutional arrangements for RES, yet a common professional culture of engineering. Eligible participants were adult engineers (or closely related fields) of Libyan origin residing in one of the three countries. These respondents are particularly relevant for RES discourse, given their technical training, exposure to practical energy challenges, and potential roles as adopters and advisors in RES projectsGive an explanation of how you gathered the data. Include any measures taken. All of your research instruments should have information about their validity and reliability. Give a description of any materials used in the study. Last but not least, list the steps in the order they were taken in the procedure. Always include specifics about any measures taken to prevent bias and threats to the study's validity.
Describe your data analysis process. Include a description of any power analysis you carried out and the statistical tests you used. Crawford and Loprinzi (2019) describe their statistical analyses in the aforementioned paper.

2. Instrument development and content

The questionnaire comprised 36 structured items organized into six thematic blocks, each anchored to RES policy and practice:

1. General awareness and climate understanding (concern about climate change; recognition that fossil-based power elevates climate risk; awareness of climate-related consequences).
2. Trust in actors responsible for environmental decisions (scientists, environmental groups, government, business/industry, and ordinary people).
3. Perceived substitution potential of RES (agreement that wind, solar, and wood fuel can replace fossil fuels).
4. Cost–benefit and affordability (priority assigned to environmental quality; perceived local environmental benefits of RES; household affordability constraints).
5. Acceptability of energy sources (support or opposition for solar, wind, hydro, biomass, waste incineration, nuclear, fossil plants).
6. Behaviors and engagement (home energy conservation practices; main transport mode; willingness to make a financial contribution to local environmental projects; willingness to volunteer time; information need regarding RES).

Items employed conventional five-point response formats (e.g., strongly disagree → strongly agree; oppose → support). The instrument was prepared in English and Arabic to maximize comprehension and inclusivity, reflecting the bilingual reality of the target population and ensuring the RES terminology remained semantically aligned across languages. The bilingual survey underwent forward translation and independent review to ensure technical equivalence of RES terminology (e.g., distinguishing "support/oppose" for technology acceptability from "agree/disagree" on attitudinal claims). Cognitive checks with a small group of engineers assessed clarity, jargon, and response burden. Minor refinements improved wording uniformity and ensured answer options matched local usage across the three settings.

Variable definitions and operationalization Attitudinal batteries were aggregated into indices by averaging item scores (1–5):

- Trust index (five actors), capturing confidence in institutional and social actors' environmental decision-making.
- Substitution index (three items), capturing agreement that specific RES can substitute for fossil fuels.
- Cost–benefit index (three items), capturing commitment to environmental quality, perceived local benefits of RES, and perceived household-level affordability.
- Acceptability index (seven sources), capturing support/oppose judgments for major energy technologies including leading RES.

A higher-order Climate-understanding composite combined (i) concern about climate change, (ii) recognition that fossil-based electricity heightens climate risk, and (iii) the breadth of consequences selected; components were standardized before averaging to yield a centered composite. Behavioral and demographic controls included sex, age group (≤39 vs ≥40), and a home-conservation count indicating the number of energy-saving actions reported.

3. Data handling, reliability and validity

Data were screened for out-of-range values, inconsistent labels, and duplicates. Harmonization ensured consistent coding of yes/no and Likert-type responses, with "don't know/unsure" set to missing for modeling. Battery indices were computed as respondent-level means across non-missing items (requiring at least one valid item per battery), a common practice that preserves information while avoiding leastwise loss. All transformations were documented and applied uniformly across respondents and items to ensure reproducibility and interpretability in the RES context. Internal consistency was assessed with Cronbach's alpha for each battery. The Acceptability index exhibited conventional "good" reliability. Elevated alphas in some other batteries flagged item redundancy and construct overlap—expected given their conceptual proximity in the RES domain. Content validity followed from systematic coverage of the principal RES constructs (trust, substitution feasibility, cost–benefit/affordability, and technology-specific acceptability). Construct validity was supported by coherent patterns across indices (e.g., higher perceived substitution tends to align with higher acceptability), consistent with the RES literature.

4. Statistical analysis plan

A. Descriptive statistics. We reported counts, percentages, and means (SDs) for demographics, batteries, and outcomes to characterize the sample and the RES attitude landscape across the three settings.

B. Modeling of associations. We estimated adjusted associations between attitudinal indices and outcomes, controlling demographic and conservation behaviour:

- Binary outcomes (information need; volunteering) via logistic regression with maximum likelihood estimation; model fit summarized by discrimination and calibration metrics (Shi *et al*., 2023b; Taveira-Pinto *et al*., 2020)
- Ordinal outcome (financial contribution) via proportional-odds (ordered logit) where assumptions and stability permitted; where not, an alternative nominal approach was considered (Viebahn *et al*., 2011; Wang *et al*., 2009).
- Nominal outcome (transport mode) via multinomial logistic regression with overall accuracy and confusion matrix summaries (Viebahn *et al*., 2011).
- Acceptability as an outcome via OLS when an ordered specification was not feasible, reported with attention to coefficient stability and collinearity (Worku *et al*., 2024b).

To avoid unnecessary mathematics in this Methods section, we refer readers to the cited sources for model details while maintaining standard practice throughout. Analyses treated the indices as linear terms (given their ordinal 1–5 scaling and common usage in RES attitude research), a choice that favors interpretability and comparability.

For each fitted model, list wise deletion was applied to observations missing any variables required by that specification (outcome or predictors). Battery indices permit partial item nonresponse (mean of available items), reducing loss of information while preserving scale meaning. No imputation was performed, consistent with the descriptive/associational aims and the professional focus on engineers' RES perspectives. We note that item nonresponse (e.g., volunteering) reduces effective sample size and precision for those models.

For logistic and ordinal models, linearity in the log-odds was assumed for continuous predictors (indices). Ordered models were considered when category ordering was meaningful and estimable.

otherwise, multinomial models were preferred. We summarized discrimination and calibration for binary models, and accuracy for nominal models, to assess adequacy without mathematical derivations. Because the RES attitudinal constructs are conceptually proximate, we explicitly assessed multicollinearity; elevated collinearity was anticipated and handled through conservative interpretation (e.g., emphasizing the pattern rather than the uniqueness of any single index when entered jointly).

5. Ethical considerations and reporting

Participation was voluntary, anonymous, and low risk. No personal identifiers were collected. Analyses were conducted in aggregate, and reporting adheres to good-practice principles for survey research in the RES field, including clarity of constructs, transparency about index formation, explicit treatment of missingness, and cautious interpretation under multicollinearity.

RESULTS AND DISCUSSIO

Sample profile and measurement overview

A total of 194 responses were analyzed. Among respondents with valid entries, 76.6% were male and 23.4% female, with two missing gender entries. The age distribution was balanced: 52.5% were ≤39 years, 47.5% were ≥40 years, and 17 entries were missing age. A simple indicator of home energy-conservation behavior (count of reported actions) was concentrated at one positive action for the vast majority, suggesting widespread adoption of at least a single low-effort practice.

Five attitudinal constructs organized the analysis: a climate-understanding composite (centered by construction) and four 1–5 indices—trust, substitution, cost–benefit, and acceptability. Descriptive statistics for these constructions appear in Table 1. The trust and acceptability indices sit above the mid-point (means 3.81 and 3.74, respectively), indicating generally positive orientations toward expert actors and toward renewable options. The substitution index (mean 3.56) reflects moderate agreement that renewables can replace fossil fuels, while cost–benefit perceptions (mean 3.44) reveal value alignment with environmental quality tempered by affordability concerns. As expected, the climate-understanding composite centers near zero given its standardized construction.

Table 1 also offers a first diagnostic of measurement quality: while the acceptability index exhibited conventional internal consistency (documented elsewhere), some other batteries displayed redundancy and strong inter-correlation, which later manifests as multicollinearity in multivariable models. In practice, this means that when multiple indices enter the same specification, coefficients should be interpreted conservatively with attention to pattern rather than the uniqueness of any single regressor.

Table (1): Summary of key indices

Index	n	Mean	SD	Min	Median	Max
Climate understanding (composite)	193	0.004	0.93	−0.77	0.324	0.324
Trust (1–5)	189	3.81	0.613	3.00	3.80	5.00
Substitution (1–5)	187	3.56	0.495	2.00	3.33	4.00
Cost–benefit (1–5)	173	3.44	0.569	2.00	3.33	4.00
Acceptability (1–5)	193	3.74	0.737	1.00	3.57	5.00

Interpretive note. As seen in Table 1, central tendencies indicate broadly favorable attitudes toward renewable energy options and their stewards, alongside a realistic awareness of household cost constraints. The centered climate-understanding composite provides the baseline for adjusted analyses that follow.

Trust in environmental decision-makers

Respondents expressed highest trust in scientists and environmental organizations to make sound environmental decisions, with comparatively lower trust in business/industry, government, and ordinary people. The gradient reported in Table 2 is consistent with technical professional norms, where methodological rigor and evidence carry premium weight.

Table 2: Mean trust by actor (1–5)

Actor	Mean	n
Scientists	4.24	164
Environmental groups	4.10	168
Businesses & industry	3.61	85
Government	3.45	120
Ordinary people	3.35	127

These differences are not merely cosmetics. As later results show, attitudinal profiles often travel as bundles: high trust in experts tends to be accompanied by higher acceptability of renewable technologies and somewhat stronger substitution beliefs. Nonetheless, once multiple, conceptually adjacent indices enter a joint model, high overlap can blunt the apparent uniqueness of trust—an empirical sign of shared variance rather than a lack of substantive importance. In practical terms, the profile in Table 2 implies that messaging anchored in scientific authority and environmental.

Technology appraisals: substitution potential and cost–benefit orientation

Substitution potential

On the question of whether renewables can replace fossil fuels, respondents rated wind (mean 3.89) and solar (mean 3.83) most favorably, while wood fuel (mean 2.46) drew more skepticism (see Table 3). These results map closely to modern deployment realities where wind and solar dominate new capacity additions, and where household-scale wood fuel must contend with air quality concerns, logistics, and poor fit with dense urban living. The Table 3 ranking signals that perceived feasibility and maturity drive substitution beliefs. In subsequent modeling of acceptability as an outcome (Section 3.6), the substitution index is the clearest upstream correlation: believing renewables can carry the load predicts broader technology acceptance.

Cost–benefit and affordability

Participants reported that renewables improve the local environment (mean 3.97) and that they prioritize environmental quality even at added cost (mean 3.70). Simultaneously, many agreed that renewables are too expensive for their homes (mean 3.59), as shown in Table 4. The juxtaposition in Table 4 captures a familiar tension: values and willingness are high, but affordability is decisive. This tension resurfaces in civic engagement, particularly in financial contribution—and contextualizes why volunteering time may outpace monetary support (Section 3.5). Policy translation is straightforward: couple information with financial facilitation (e.g., incentives, favorable financing, or cost sharing) to convert positive attitudes into household adoption.

Table (3): Perceived substitution potential (agreement; 1–5)

Resource	Mean	n
Wind	3.89	174
Solar	3.83	172
Wood fuel	2.46	113

Table (4): Cost–benefit items (agreement; 1–5)

Statement (abridged)	Mean	n
Renewables help improve the local environment	3.97	155
I give priority to environmental quality even if it costs me more	3.70	114
Renewable energy is too expensive for my home	3.59	117

Acceptability of energy sources

Solar and wind were the most acceptable options overall, followed by hydropower; biomass and waste incineration occupied the middle ground; nuclear and fossil fuel plants were least acceptable. Detailed scores appear in Table 5. The pattern in Table 5 suggests a visibility–externality logic: visible, modular, low-emission technologies (solar/wind) are easiest to accept; technologies perceived to carry local externalities (incineration/biomass) or systemic risks (nuclear) face skepticism. These acceptability baselines matter operationally: the acceptability index is inversely related to information need (Section 3.5), implying that familiarity (and likely direct exposure) mitigates perceived knowledge gaps.

Table (5): Acceptability of energy sources (1–5)

Source	Mean	n
Solar panels	4.73	190
Wind energy	4.65	189
Hydro	3.98	170
Biomass plants	3.36	174
Waste incineration	3.20	173
Nuclear power	2.82	174
Fossil fuel plant	2.75	168

Information needs and civic engagement Information need

A large majority expressed a desire for more information about renewable energy, with 71.65%responding "Yes" (see Table 6). This is a crucial lever for outreach: the indicated demand can be met via channels that respondents already trust (Section 3.2) and through formats that highlight concrete performance and cost trajectories. To probe correlates of information need, a multivariable logistic model related the binary outcome to the five attitudinal indices plus demographics and conservation behavior. As summarized in Table 7, the acceptability index was negatively associated with needing more information (OR≈0.60, p≈0.070), while male respondents showed a borderline higher likelihood (OR≈2.07, p≈0.108). Model diagnostics were acceptable: AUC≈0.691, Brier≈0.191, and Hosmer–Lemeshow χ^2≈4.19 (df=8), indicating reasonable discrimination and calibration for a social-attitude model. High VIFs for the indices (observed elsewhere) caution against attributing excessive uniqueness to any single index when modeled jointly.

Table (6): Need for more information

Response	Count	Percent
Yes	139	71.65
No	52	26.80
Missing	3	1.55

Table (7): Correlates of needing more information (logistic model)

Predictor	OR (95% CI)	p-value
Acceptability index	0.60 (—)	0.070
Cost–benefit index	1.66 (—)	0.124
Substitution index	1.68 (—)	0.199
Trust index	0.82 (—)	0.521
Climate understanding	0.55 (—)	0.159
Conservation count	1.63 (—)	0.687
Age ≥40	0.89 (—)	0.773
Male	2.07 (—)	0.108

Model diagnostics: AUC = 0.691; Brier score = 0.191; Hosmer–Lemeshow χ^2 = 4.19 (df = 8).

Notes: Confidence intervals are omitted here for brevity; variance inflation among attitudinal indices was high.

The inverse association between acceptability and information need (Table 7) implies that positive personal stance and exposure reduce perceived knowledge gaps. Practically, outreach should emphasize hands-on, visible experiences—demonstrations, site visits, or interactive dashboards—that convert abstract attitudes into grounded familiarity.

Financial contribution willingness

Two in five respondents indicated readiness to contribute financially to local environmental projects (see Table 8). This is a meaningful baseline given the affordability concerns flagged earlier (Table 4).

Table (8): Financial contribution willingness

Response	Count	Percent
No	110	56.70
Yes	81	41.75
Missing	3	1.55

An ordered model was considered; where proportional-odds assumptions or stability could not be adequately supported, a pragmatic nominal contrast (No vs Yes) was used to summarize patterns. Estimates were suggestive rather than definitive under joint adjustment—an unsurprising outcome given overlapping attitudinal construct. The descriptive signal nevertheless indicates substantial willingness to back environmental projects financially, especially where cost-sharing mechanisms lower individual burden. To translate willingness into action, program design should prioritize transparent pricing, staged contributions, and co-benefits (local air quality, neighborhood amenities), addressing the cost narrative in Table 4 directly.

Volunteering willingness

Nearly half of respondents reported willingness to volunteer time (see Table 9). This form of civic engagement is particularly salient where household budgets or uncertainty constrain financial giving.

Table (9): Volunteering willingness

Response	Count	Percent
Yes	96	49.48
No	41	21.13
Missing	57	29.38

A multivariable logistic model examined correlations of volunteering (Table 10). A strong proenvironmental cost–benefit orientation was associated with higher odds of volunteering (OR≈2.69, p≈0.019), while age ≥40 was associated with lower odds (OR≈0.37, p≈0.041). Model performance was solid for an attitudinal context: AUC≈0.723, Brier≈0.181, Hosmer–Lemeshow χ^2≈3.26 (df=8). Other indices were not statistically precise jointly, consistent with high correlation across batteries. The volunteering model (Table 10) illuminates a values-to-action pathway: respondents who place environmental quality and local benefits at the center are far more likely to contribute time. The negative association with older age likely reflects opportunity costs and time constraints. Programmatically, this argues for modular, time-bounded opportunities and clear impact communication to harness value-driven engagement.

Table (10): Correlates of volunteering (logistic model)

Predictor	OR (95% CI)	p-value
Cost–benefit index	2.69 (—)	0.019
Age ≥40	0.37 (—)	0.041
Trust index	1.63 (—)	0.211
Substitution index	1.22 (—)	0.676
Acceptability index	1.14 (—)	0.721
Climate understanding	1.01 (—)	0.978
Conservation count	1.55 (—)	0.742
Male	0.26 (—)	0.106

Mobility patterns and integrative modeling of acceptability

Transport mode

Travel to work/study was dominated by private car use (74.23%), with lower shares for bus (11.34%), walking (6.19%), train (4.12%), bicycle (2.06%), and car sharing (1.03%) (see Table 11). A multinomial specification was explored but provided unstable estimates with very low accuracy due to severe class imbalance (car dominance) and small cell sizes in minor modes. As such, Table 11 is best interpreted descriptively. The practical implication is clear: infrastructure and urban form are exerting strong structural constraints on low-carbon commuting choices. Policy translation here is not about persuasion alone; it is about supply-side feasibility.

Table (11): Main transport mode

Mode	Count	Percent
Car	144	74.23
Bus	22	11.34
Walk	12	6.19
Train	8	4.12
Bicycle	4	2.06
Car share	2	1.03

Acceptability as an outcome

To examine how attitudes cohere around technology approval, acceptability was modeled as an outcome. Where an ordered specification was infeasible, a linear model provided an interpretable summary (see Table 12). The substitution index showed the clearest positive association with acceptability ($\beta \approx +0.219$, $p \approx 0.071$), while other indices and controls were not precise jointly— again consistent with shared variance among attitudinal constructs. Diagnostics indicated high VIFs across indices, reinforcing caution in ascribing uniqueness when they are entered together. The Table 12 result is theoretically coherent: believing that renewables can substitute for fossil fuels appears to anchor broader acceptance. This does not render trust or climate understanding unimportant; rather, it shows that when closely related constructions are pooled, the unique variance that remains for each is small. For design and communication, the lesson is to centre feasibility narratives—credible pathways, system integration, and cost trajectories—because these most strongly lift acceptability.

Table (12): Acceptability as an outcome (linear specification)

Predictor	Coef (β)	p-value
Substitution index	+0.219	0.071
Cost–benefit index	+0.129	0.182
Trust index	−0.050	0.576
Climate understanding	+0.180	0.112
Conservation count	+0.188	0.584
Age ≥40	−0.153	0.171
Male	+0.005	0.969
Intercept	+2.591	0.001

Model diagnostics: Goodness-of-fit indices not emphasized; multicollinearity among indices was high (VIFs notably elevated).

Notes: Linear summary used when ordered estimation was not feasible.

Synthesis: from attitudes to action

Across sections, a coherent narrative emerges. Trust is highest in scientific and environmental institutions (Table 2); solar/wind dominate both substitution and acceptability judgments (Tables 3 and 5); respondents value local environmental benefits and prioritize environmental quality, while acknowledging household cost barriers (Table 4). A clear information appetite exists (Table 6), and value orientation drives volunteering (Table 10), with financial contributions meaningful but constrained (Table 8). Private car use remains dominant (Table 11), underlining that behavior change is gated not only by attitudes but also by infrastructure and context. For policy and practice, three vectors are salient:

1. Familiarity and acceptance. Exposure and hands-on familiarity reduce information need (Table 7) and lift acceptability (Table 12). Emphasize demonstration, live cases, and transparent performance.
2. Affordability and participation. Cost narratives constrain household adoption (Table 4) and, to a lesser degree, financial contribution (Table 8). Incentives, accessible financing, and community cost sharing can bridge intent–action gaps.
3. Civic energy and time. Value-driven respondents volunteer (Table 10). Design modular, time-bounded roles with visible local impact to convert attitudes into action.

CONCLUSION

The evidence portrays a technically trained cohort with clear, consistent support for RES and a practical grasp of the constraints that shape adoption. Trust is concentrated in scientists and environmental organizations, reflecting an orientation toward evidence and expert judgment in environmental decision-making. Technology appraisals favor wind and solar in both perceived substitution potential and acceptability, with hydropower positioned positively and biomass and waste incineration viewed more cautiously. Nuclear and fossil-fuel plants register the lowest support. These preferences are not superficial; they are consistent with the technologies perceived feasibility, maturity, and local externalities.

A majority of respondents seek additional information on RES, even as overall acceptability is high. The inverse association between acceptability and the desire for more information indicates that familiarity and exposure help close perceived knowledge gaps. This argues for outreach that moves beyond abstract messages and presents RES through visible, practical experiences: demonstrations, site tours, pilots in workplaces and universities, and consistently maintained public dashboards that show costs, yields, and reliability over time. Such measures convert general support into informed confidence.

Cost remains a central thread running through attitudes and behaviors. Participants affirm the environmental benefits of RES and express willingness to prioritize environmental quality, but household-level affordability is a persistent hurdle. This tension helps explain the observed pattern in civic engagement: volunteering time is more prevalent than making a financial contribution. Programs that aim to mobilize resources should therefore offer graduated pathways for both time and money. On the financial side, staggered contributions, community cost sharing, and transparent life-cycle costings can lower perceived barriers. On the time side, modular opportunities with clear local impact can channel pro-environmental values into consistent participation.

The transport profile underscores that individual behavior is constrained by infrastructure. With private cars dominating commutes, lower-carbon mobility will depend on supply-side feasibility as much as on persuasion. Planning and investment that expand reliable public transport, improve first/last-mile connectivity, and make active modes safer and more convenient are prerequisites for meaningful change in this domain. Communication alone cannot overcome structural limitations.

Methodologically, overlapping attitudinal constructs are a feature of the topic rather than a flaw in the study. Trust, substitution beliefs, cost–benefit orientations, and acceptability are interwoven. When these indices are modeled together, unique contributions can appear muted because they share variance. This calls for careful interpretation and for future measurement work, which reduces redundancy without stripping constructs of their substantive richness. Larger, more balanced samples would also help to improve stability, especially for outcomes with notable item nonresponse.

Taken together, the results outline a practical path for policy and practice. First, build familiarity through credible, visible experiences with RES. Second, pair information with financial facilitation to close the affordability gap for households. Third, design civic programs that value both time and money, recognizing that many engineers will contribute to one or the other depending on constraints. Fourth, address infrastructure directly where daily behavior change depends on system-level provision. These steps align with respondents’ values and capacities and offer a realistic route from supportive attitudes to sustained action on RES.

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