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Solar Power Adoption and Perceived Energy Security in Bangladesh through Perceived Financial Sustainability

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ABSTRACT

The impact of household solar power is that it can add to the reliable electricity services provided that, as long as additional operation is not uneconomical, it continues to operate. This paper focuses on exploring the relationships between solar power adoption, perceived policy support, perceived financial sustainability and perceived energy security in Bangladesh. The analysis is based on the reported partial least squares structural equation modelling results of 470 households using solar electricity. Four reflective constructs comprise twenty indicators. Measurement assessment shows that there is satisfactory internal consistency, convergent, and discriminant validity. The perceived financial sustainability and perceived energy security have a positive relationship with solar power adoption. Perceived support of the policy also has positive relations with both outcomes. The highest direct coefficient of the predictors of perceived energy security belongs to financial sustainability. The exact indirect coefficients are 0.118 which is the adoption of solar power and 0.071 which is the perceived policy support which has the bootstrap confidence intervals not equal to zero. The two directions indicate complementary statistical mediation. The model accounts 21.4% variation in financial sustainability and 31.6 % in energy security. The predictive assessment yields positive predictive relevance values of all endogenous indicators, but the gains are small over linear model benchmarks. The results endorse focusing on the persistence of affordability and home solar implementation and institutional helping. The cross-sectional perceptions cannot build causal impacts and gains of national energy security. The provenance of fieldwork has not been well documented in order to be independently verified.

INTRODUCTION

The household energy security relies on the continuity of electricity supply in relation to the essential activity and the ability of the household to maintain the devices that supply it. Setting up a solar power system defines the potential of producing electricity (Wimmer, 2023). The household good is conditional upon subsequent use, operating conditions, and the capacity to cover ongoing costs. This difference leads to the focus on the correlation between the level of adoption and financial needs of further functioning. A system can play an important role in the day-to-day operations and still exposes the users to the cost of uncertainty in terms of maintenance or replacement costs. Interpretation of household experience must thus be based on an evaluation that links everyday usage with perceived long-term affordability (Scott-George *et al.*, 2021).

Here solar power uptake is discussed in terms of the level of the real application among households that already have access to solar power. It has not been determined as a desire to buy a system or desire to embrace a technology. This difference is important as current users consider solar electricity based on their experiences (Sunny *et al.*, 2023). Their decisions may indicate the frequency of electricity usage, the extent to which the electricity supplements daily life and the extent to which it has become an integral part of household consumption. A study of the level of adoption thus deals with circumstances in which an existing technology can still be useful, as opposed to the determinants of an initial purchase decision (Miskat *et al.*, 2023).

The notion of perceived energy security is at the household level. It includes availability of electricity, daily reliability, sufficiency to meet much needed requirements, persistence during outages, and reliability in future supplies. These dimensions describe an experienced and anticipated service outcome. They do not quantify national generation adequacy, electricity imports, reserve margin, and financial status of electricity utilities. This boundary has to be maintained since domestic perceptions cannot build a shift in energy security nationally (Das *et al.*, 2021). They are however able to show how their users perceive the usefulness of their electricity setups to everyday life and expectations in the future.

Financial sustainability offers a viable linkage between habitual solar consumption and realm of energy security. Continuing costs and possible maintenance and replacement of components should be taken into consideration by households (Payel *et al.*, 2023). When the obligations seem to be bearable, the trust on the sustainability of the electricity service can be enhanced. On the other hand, the feeling of insecurity may be eroded by uncertainty about the future costs despite the current adequate electricity supply. Financial sustainability is then viewed as a judgement at the household regarding the viability of further consumption. It does not

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determine profitability, a positive net present value or a specific repayment period as is the case with an audited investment appraisal (Shakeel & Rajala, 2020).

This relationship has an institutional aspect to it based on perceived policy support. This is based on the expectation-forming of the further use of solar by households when considering the following public efforts, government commitment, and the policy environment (Murshed *et al.*, 2022). These impressions may affect the future perceived cost and perpetuation of service. Perceived support does not, however, mean proved receipt of a subsidy or membership in a certain programme. A respondent would be able to perceive the policy environment positively without getting a direct help. This model then makes a distinction between general measurements of institutional support, and the descriptive question of actual public assistance.

The research question is: Is perceived financial sustainability statistically significant as the part of the relationship between solar power adoption and perceived energy security? There is also a related question that investigates whether the perceived policy support is related to energy security through the same mediating relationship. Direct routes are maintained as well as the indirect routes. This specification acknowledges that solar utilisation and institutional trust might still be linked to electricity security by using other means besides affordability (Murshed *et al.*, 2022). The idea is to evaluate an internally consistent pattern of household correlations without presuming that one mediator overkills applicable accounts.

The paper adds a combined understanding of the use of technology, organizational apprehensions and household financial anticipations. It adds an analytical contribution, and not a claim that any particular construct is a newly-discovered finding. The model separates actual use/intention, perceived affordability/financial performance and household security/national outcomes. It also entails measurement assessment, structural estimates as well as a predictive comparison (Ahmed *et al.*, 2022). This combination allows individual consideration of construct quality, explanatory relationships and predictive performance. These differences are especially significant when statistically significant coefficients may be otherwise understood to be indicative of significant practical impact.

The analysis is based on the provided results of the analysis of 470 households and retains the reported measurement and structural statistics. The research plan defining the target questionnaire and the eligibility criteria is associated with the research plan, and does not include a full fieldwork record (Pimonenko *et al.*, 2022). The analysis, therefore, fails to designate undocumented period of collection, the method of sampling, and ethics authorization. Its conclusions address the already reported analytical sample and are subject to confirming the underlying survey records. This reporting limit does not allow the statistically determined findings to be extrapolated to the degree to which the available materials can support them.

Conceptual foundation and hypothesis development

Household solar use and continuing affordability

The conceptual background considers the household solar electricity as an ongoing service provision that is facilitated by technical equipment and financial ability (Roy *et al.*, 2023). The construct of adoption entails the routine internalization in household activities. The perceived capability to sustain that arrangement in the long-term is captured in the financial sustainability construct. These constructs have a positive correlation since frequent use could render the contribution of the system more apparent and predictable (Amin *et al.*, 2023). A family that uses solar power in its daily routines might find it easier to consider the value of its sustained use and be able to fit in the associated costs to its budget.

This argument does not mean that increased utilization is likely to cause a decrease in spending. The increased usage may have extra equipment requirements, higher storage needs, or quicker wear out (Knez *et al.*, 2022). The postulated positive association thus relates to the evaluation of financial manageability among the respondents over the range of experiences in households that are being observed. It enables the practical benefits to coexist with costs (Fyza & Sarkar, 2020). The question of interest to be addressed empirically is whether the households that report higher levels of solar integration also report higher levels of confidence in the ability to meet the financial needs to sustain further operation, controlling perceived policy support (Kumar & Rathore, 2023).

Hypothesis H1: is that there is a positive correlation between the adoption of solar power and the perceived financial sustainability among households that use solar power in Bangladesh. This hypothesis specifies an association between existing use and a financial perception (Safi *et al.*, 2023). It does not assert that acquiring a bigger system will automatically enhance affordability. Nor does it determine the direction in which change is going to be made over time. A family with more financial means can possibly implement its system to a greater extent, and reverse ordering is a viable option that needs longitudinal data to test (Islam *et al.*, 2023).

Policy support and perceived financial sustainability

Perceived policy support deals with the perceived good environment of the household solar electricity. Its indicators deal with supportive policies, meaningful public initiatives, institutional commitment and continued use and adequacy of support (Shammin & Haque, 2022). These tests can provide an indication of the soundness of the investment climate in the household. Favorable institutional environment can be viewed as enhancing the chances of assistance, information or service arrangements being available (Salah Uddin, 2023). These expectations can be associated with an enhanced

perceived ability to cover future costs.

The two are conceptual and need not be considered as evidence regarding a specific policy instrument. The questionnaire does not determine the worth of financial support obtained or conditions of a public financing programme (Liza & Islam, 2020). It evaluates how the respondent thinks there is support. Monetary sustainability can consequently be connected to the perception of policy by reassurance, information or anticipated opportunity instead of being documented transfer of money (Krupnov *et al.*, 2022). This difference allows the latent relationship to be viewed but does not attribute it to an unmeasured subsidy or regulatory action.

Hypothesis H2: Perceived policy support is positively related to perceived financial sustainability among solar-using households in Bangladesh. The specification identifies the institutional perceptions and adoption level as an explanatory variable (Talut *et al.*, 2022). The two predictors can be related as the solar electricity experience can be combined with various perceptions of the policy environment around. Their association does not have a distinct directional hypothesis. The structural coefficients reflect the relationship of each structure with financial sustainability given the other predictor in that equation (Munjer *et al.*, 2023).

Direct relationships with household energy security

The solar electricity that is periodically incorporated into the domestic use can lead to the perceived availability and sufficiency. Its usefulness is subject to the condition that the users consider it as helping to sustain necessary activities and service continuity (Paul *et al.*, 2022). A direct connection with perceived energy security is thus possible even after the issue of financial sustainability is taken into account. This line picks up the correlation between existing use and household electricity confidence that is not statistically mediated by the given financial mediator (Wimmer, 2023). It does not decouple the contribution of solar generation with all the other sources of electricity that can be used in the household (Scott-George *et al.*, 2021).

H3: solar power adoption is positively related to perceived energy security by solar-using households in Bangladesh. The result is the electricity supply to the household in general (Sunny *et al.*, 2023). In the case of households that have grid access and are also solar generators, the security perceptions could be based on joint setups. The proposed hypothesis must, then, be understood as the correlation of the use of sun to the apparent safety of the domestic electricity as opposed to an actual enhancement of the dependability of the solar device in isolation (Miskat *et al.*, 2023).

Security perceptions may also be directly related to policy support. Trust in institutions may impact anticipations of service provision, and the sustainability of support systems, and the overall acceptability of further solar utilization (Das *et al.*, 2021). These expectations can be applicable even in cases where the respondents rate their own financial status independently. This possibility can be represented in the model by use of a direct path. Nevertheless, none of the particular institutional mechanisms is individually gauged, and as a result, the coefficient does not allow clarifying whether information, a sense of security, technical support, or some other characteristic explains the identified relationship (Payel *et al.*, 2023).

H4: It hypothesizes that perceived policy support has a positive relationship with perceived energy security in the households where solar is used in Bangladesh. The given proposal acknowledges an institutional component of household confidence as it still maintains the difference between the perceived support and the effectiveness of the policies (Shakeel & Rajala, 2020). Service problems can be combined with a favourable evaluation of government commitment and technically reliable equipment can be combined with an unfavourable evaluation of government commitment. The assumption is about the mean statistical association among the sample of analysis as opposed to making blanket statements about specific households (Murshed *et al.*, 2022).

Financial sustainability and statistical mediation

The capacity of households to fund the running of their systems is one of the ways that they may assess future security of electricity. Maintenance, repair, and replacement of components come into play when determining whether a service can be continued or not beyond its current state (Ahmed *et al.*, 2022). A family that finds these requirements manageable could articulate increased optimism in bearing the necessary electricity requirements. Both present reliability measurements and future continuity expectations can be linked to financial sustainability (Sultana, 2023). The correlation is particularly relevant since the security construct incorporates assurance that the key needs will remain fulfilled.

H5: to investigate the relationships that exist between perceived financial sustainability and perceived energy security in relation to solar-using households in Bangladesh is the following hypothesis: This trajectory attributes the explanatory role of the financial construct to solar adoption and policy support (Pimonenko *et al.*, 2022). The model does not identify security with affordability. Technical and environmental factors may not be fully under control by household finances, and this can also affect the reliability of electricity (Roy *et al.*, 2023). Rather, the hypothesis is that higher perceived financial manageability is linked to higher perceived security in cases where other identified predictors are taken into consideration simultaneously.

Since there are two indirect pathways that result when the above relations are combined. Greater utilization of the sun could be associated with increased financial confidence, which is, in turn, related to increased energy security (Amin *et al.*, 2023). In a similar vein a favorable policy climate can be associated with financial perceived

manageability and consequently with security.

H6: Perceived financial sustainability mediates the positive association between adoption of solar power and perceived energy security.

H7: There is a mediating role by perceived financial sustainability between perceived policy support and perceived energy security.

The interpretation of mediation is a statistical breakdown of any relationships in the given model. Indirectly, the fact that the positive coefficient is present does not mean that adoption or policy perceptions had to be experienced prior to financial confidence. Nor does it find that financial confidence was the antecedent of security perceptions (Knez *et al.*, 2022). These variables can be related in a single observation through the cross-sectional structure. Temporal and causal explanations are put forward as guesses to be pursued later on. Direct and indirect coefficients are thus considered jointly and the mediation terms are applied in this limitation during the interpretation (Fyza & Sarkar, 2020).

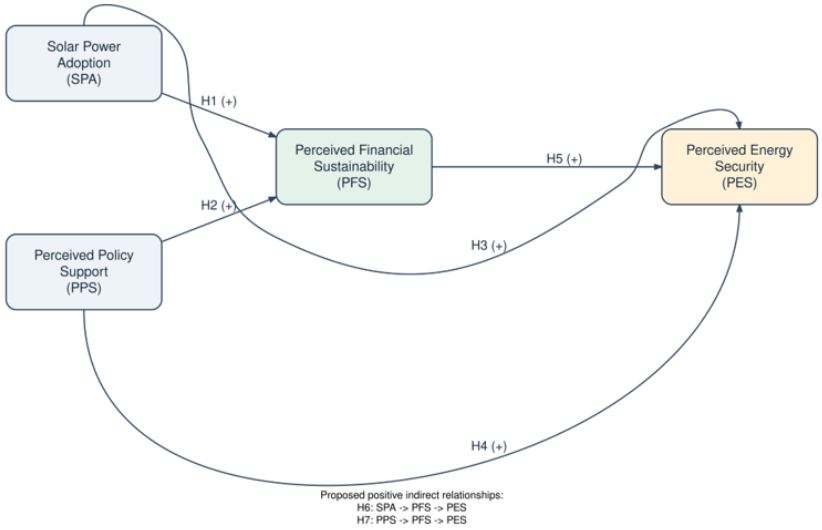


Figure 1: Conceptual framework

The diagram presents the hypothesised direct paths. H6 and H7 concern the two indirect paths through PFS. The exogenous constructs may correlate.

MATERIALS AND METHODS

Research design and analytical evidence

The proposed study adopts a quantitative framework of the household model that employs partial least squares structural equation modelling. The analytical evidence is in the form of a workbook of results that represents thirteen tables and two provided diagrams, which are interpreted against the research plan that was used with it. An analytical sample of 470 is mentioned in the workbook. It includes descriptive summaries, measurements, structural estimating, bootstrap, and predictive comparisons (Sahithi, 2021). The materials analyzed in this manuscript do not include respondent-level records and the estimation script.

The targeted decision-making unit is the household, which is one knowledgeable adult. The survey will only include the respondent who is at least eighteen years old with the present household being in Bangladesh. The qualified households will be required to be currently on solar electricity and must have used their current system at least six months. The respondents should also be conversant with the use of solar in the household and costs incurred. These conditions are specified in the research plan (Adaikkalam Zabihi *et al.*, 2025). The workbook does not contain a separate screening log that would permit independent verification of each eligibility decision.

All the eight administrative divisions and rural, peri-urban and urban residences are the part of the analytical sample. The distribution is a description of geographic coverage in the reported data. It does not figure out a nationally representative sample. There is no description of a sampling frame, household selection probability, recruitment channels, dates of survey, response rate, and non-responses in the materials. None is claimed to have employed a probability sampling procedure. The inference about population is still weak and the numerics used are treated as correlations between the analytical sample and not as the parameter which is used to describe the whole group of solar-using households in Bangladesh.

Instrument and construct measurement

The questionnaire will include household characteristics, solar system characteristics, and twenty statements that connote four constructs. There are five indicators to each construct (Mellenbergh *et al.*, 2003). The options of agreement are one-strongly disagree to five-strongly agree. Another unable-to-assess response is given and it is supposed to be coded as missing. In regards to solar application and electricity supply the instrument requests the respondents to think about the past six months. The financial sustainability covers both the current costs and

anticipated future needs, whereas the policy support indicates the up-to-date cognizance of the external environment.

Measurements of solar power adoption encompass routine utilization, inclusion in the day-to-day operations, widespread utilization, electricity contribution to daily household demand and known dependency. The measures of perceived policy support are favourable government policies, meaningful support initiatives by the government, institutional commitment, favourable environment to support sustained use, and sufficiency of support. Perceived financial sustainability measures carrying on affordable, maintenance, replacement, budget compatibility, and long-term viability (Andiappan & Wan, 2020). The availability, reliability, essential adequacy, continuity during disruptions, and future confidence are the perceived energy security measures. Conceptual segregation is ensured in these definitions between behaviour, institutional perceptions, financial expectations, and service outcomes.

Each of the four constructs is indicated in the provided model as reflective. The indicators are considered expressions of respective latent concepts. The statements are new in the study and are not being presented as having been previously validated. The plan suggests that it should be checked by the experts, a Bangla translation check and a pilot survey preceding main data collection (Mimansha Patel & Nitin Patel, 2019). The results in terms of the completion of those activities is not provided in the provided results. Handing over of internal statistical performance is thus evaluated independently of content validity and the linguistic appropriateness of the tool.

Measurement and structural assessment

Construct descriptives will be based on unweighted means of the five respective items. Their sample size is reported to be 470 per construct. Measurement assessment takes into account outer loadings, squared loadings, Cronbach alpha, rho A, composite reliability and average variance extracted. The heterotrait-monotrait ratios and their two-sided percentile bootstrap intervals are used to test discriminant validity. The evaluation preserves each of the twenty items. Acceptable numerical diagnostics are regarded as evidence of internal measurement performance, but it is acknowledged that the diagnostics is not able to substitute substantive evaluation of the wording and scope of the measures.

The policy support and adoption of solar is given as a predictor of financial sustainability in the structural model. Energy security is projected by these two constructs and financial sustainability. The factors of inner variance inflation measure predictor collinearity in each equation (Chen, 2023). The reported explanatory power is in the form of R squared and adjusted R squared. The effect sizes contrast included and excluded predictor models based on fixed full-model construct scores. This computation determines the incremental value of each predictor, given the reported score specification; it is not said to be a fully re-estimation of all models of reduced measurement.

The workbook reports over 5,000 valid bootstrap estimates of direct, indirect, total and discriminant validity. The directional hypotheses are tested in a positive direction against two-sided percentile intervals which have a zero-point left out. Bootstrap standard errors are shown as normal approximations of probability values reported. The applicable component paths are multiplied by specific indirect coefficients within the respective bootstrap resamples. Total coefficients are a combination of direct and indirect components that maintain their covariance. The process prevents the consideration of the uncertainty in different paths as independent in assessing how they relate to each other.

Predictive assessment and reporting boundaries

Predictive assessment employs k-fold procedure as outlined in the workbook as PLSpredict-style analysis. Forecasts rely on the information about the earliest antecedent and are compared with training-fold mean forecasts and the linear model forecasts. Q squared predict is used to test improvement against the mean benchmark. Root mean squared error gives the main comparison with the linear model and mean absolute error is secondary (Sahithi, 2021). The held-out prediction records are 4,700 each endogenous indicator. They are replicated forecasts on the basis of the 470-observation sample, as opposed to 4,700 households recruited separately. Precise report on the fold is not stated.

The proposed participant information statement outlines voluntary participation, right to refuse questions or discontinue participation, collective analysis, and direct personal identifiers avoidance. These are a list of the characteristics of the intended instrument. The provided materials do not define the means of consent documentation, the existence of an institutional ethics review. No approval, exemption, funding declaration, or carried out consent procedure is fabricated (Mellenbergh *et al.*, 2003). Similarly, a missing-data audit is not available, thus making it impossible to confirm the treatment of the unable-to-assess responses in the course of estimation. Such documentation boundaries are applicable to submitting and reproducibility.

RESULTS AND DISCUSSION

Respondent and household characteristics

Table 1 explains the sample of 470 households which is

Table 1: Respondent and Household Characteristics

Characteristic	Category	n	%
Age group	18-24 years	69	14.68
	25-34 years	125	26.60

	35-44 years	152	32.34
	45-54 years	60	12.77
	55 years or older	64	13.62
Gender	Male	163	34.68
	Female	157	33.40
	Another identity	73	15.53
	Prefer not to disclose	77	16.38
Education	No formal schooling	55	11.70
	Primary	70	14.89
	Secondary	83	17.66
	Higher secondary	69	14.68
	Diploma or equivalent	66	14.04
	Bachelor's degree	53	11.28
	Master's degree or above	74	15.74
Occupation	Government employment	51	10.85
	Private-sector employment	66	14.04
	Business or self-employment	49	10.43
	Agriculture, fishing or livestock	56	11.91
	Skilled trade or daily wage	59	12.55
	Homemaking	55	11.70
	Student	42	8.94
	Retired	44	9.36
	Currently unemployed	48	10.21
	Other	0	0.00
Monthly household income	Below BDT 20,000	61	12.98
	BDT 20,000-39,999	109	23.19
	BDT 40,000-59,999	59	12.55
	BDT 60,000-79,999	51	10.85
	BDT 80,000-99,999	66	14.04
	BDT 100,000 or above	67	14.26
	Prefer not to disclose	57	12.13
Household size	1-2 members	88	18.72
	3-4 members	133	28.30
	5-6 members	162	34.47
	7 or more members	87	18.51
Division	Barishal	62	13.19
	Chattogram	52	11.06
	Dhaka	58	12.34
	Khulna	53	11.28
	Mymensingh	52	11.06
	Rajshahi	69	14.68
	Rangpur	62	13.19
	Sylhet	62	13.19
District	Barishal	36	7.66
	Bogura	38	8.09
	Chattogram	26	5.53
	Cumilla	26	5.53

	Dhaka	35	7.45
	Dinajpur	29	6.17
	Gazipur	23	4.89
	Habiganj	32	6.81
	Jamalpur	25	5.32
	Jashore	31	6.60
	Khulna	22	4.68
	Mymensingh	27	5.74
	Patuakhali	26	5.53
	Rajshahi	31	6.60
	Rangpur	33	7.02
	Sylhet	30	6.38
Residence	Rural	229	48.72
	Peri-urban	121	25.74
	Urban	120	25.53
Electricity decision-making role	Main decision-maker	79	16.81
	Joint decision-maker	199	42.34
	Provides information or advice	105	22.34
	Familiar but not involved in decisions	87	18.51

Note: Percentages use N = 470, including nondisclosure categories. All reported categories are retained.

analytically described. The largest age category is 35–44 years, representing 32.34%, followed by 25–34 years at 26.60%. The percentage of male respondents are 34.68%, female respondents are 33.40%, another identity 15.53% and nondisclosure 16.38%. These types are held in the form of reports. Its distribution cannot be perceived as a demographic estimate of Bangladesh. It determines the structure of this data set and suggests that recruitment and coding records will be beneficial in determining the connection between the sample and the target population. The level of education goes beyond lack of formal education up to a postgraduate. The largest individual group is the secondary education of 17.66%, but the distribution is even among the seven groups of education. There is also an unequal distribution of household income. The most common category is BDT 20,000–39,999 per month, representing 23.19%. There is 12.13 % income nondisclosure. These results suggest that the sample has varying reported resource positions albeit no structural estimates included household income as a control variable nor did it test whether the relationships varied among income groups.

The percentage of rural households and peri-urban and urban households are 48.72% and 25.74%, respectively. The greatest size of 34.47% is composed of households with five or six members. The respondents who are joint electricity decision-makers are 42.34%, which is compared to 16.81% who are the main decision-maker. Learned respondents thus need not be the sole decision-maker in the household. The descriptive profile has been used to interpret the questionnaire as a household experience tool and has not tested any variation in the questionnaire based on residence, household size, and decision role.

Solar system characteristics

Table 2 illustrates that the sample has a number of solar

Table 2: Household Solar Power System Characteristics

Characteristic	**Category**	**n**	**%**
Solar system type	Standalone solar home system	131	27.87
	Grid-connected rooftop	120	25.53
	Hybrid system	104	22.13
	Shared or community system	115	24.47
	Other	0	0.00
	Not sure	0	0.00
Duration of solar use	6-11 months	127	27.02
	1 to less than 3 years	125	26.60
	3 to less than 5 years	110	23.40
	5 years or longer	108	22.98

Grid access	No	187	39.79
	Yes	283	60.21
Battery storage	No	178	37.87
	Yes	292	62.13
	Not sure	0	0.00
Primary financing source	Household savings	79	16.81
	Bank loan	66	14.04
	Microfinance loan	77	16.38
	Supplier instalments	61	12.98
	Grant, subsidy or donation	72	15.32
	Shared or community financing	54	11.49
	Subscription or service payment	61	12.98
	Other	0	0.00
	Not sure	0	0.00
Solar electricity share	Less than 25%	130	27.66
	25-49%	129	27.45
	50-74%	113	24.04
	75-100%	98	20.85
	Not sure	0	0.00
Installed capacity	Below 500 W	65	13.83
	500 W to less than 1 kW	123	26.17
	1 to less than 3 kW	66	14.04
	3 to less than 5 kW	44	9.36
	5 kW or above	57	12.13
	Shared system; capacity unknown	115	24.47
	Not sure	0	0.00
Public assistance	No	219	46.60
	Yes	124	26.38
	Not sure	127	27.02
Solar electricity uses: multiple response	Lighting	470	100.00
	Fans	377	80.21
	Mobile charging and communication	424	90.21
	Television or computers	290	61.70
	Refrigeration	149	31.70
	Water pumping	92	19.57
	Cooking or other appliances	182	38.72
	Home-based business	93	19.79
	Other uses	27	5.74

Note: N = 470. Solar electricity uses allow multiple responses; those percentages can sum above 100%.

supply arrangements. There are standalone solar home systems 27.87% and grid-connected rooftop systems 25.53% and hybrid systems 22.13% and shared systems or community systems 24.47%. The grid access is reported at 60.21% and there is a 62.13% report on battery storage. These attributes will suggest that household energy security can imply various variations of solar production, storage, and alternative sources of electricity. The pooled structural model fails to differentiate their respective technical contributions, and does not assume that all households operate under the same operating conditions. The use duration falls in four categories with 27.02% taking six to eleven months and 22.98% taking at least five years. The most common reported range of capacity is 500 watts to less than one kilowatt at 26.17%. Another 24.47% note sharing systems whose household capacity is unknown. The sample shows that solar electricity provides household consumption less than half of the 55.11% population. Therefore, considerable normal solar consumption can be in line with sustained dependencies

on alternative electricity sources, which strengthens the difference between the levels of adoption and full energy self-sufficiency.

The financing arrangements are savings, loans, instalments to suppliers, grants, joint financing and service payments. The household savings constitute 16.81%, the microfinance loans constitute 16.38% and the grants, subsidies or donations constitute 15.32%. The percentage of those who receive public assistance is 26.38%, denied is 46.60%, and uncertain at 27.02%. Every household report lighting, 90.21% reach communication and 80.21% fans. The number of home-based business use is reported at 19.79%. The percentage of multiple-response use will not have to add up to one hundred since a household can utilize solar electricity in various activities.

Table 3: Descriptive Statistics of Study Constructs

Construct	N	Mean	SD	Min	Max	Skewness	Excess kurtosis
SPA	470	3.176	0.982	1	5	-0.180	-0.716
PPS	470	3.222	0.981	1	5	-0.142	-0.754
PFS	470	3.194	0.995	1	5	-0.216	-0.816
PES	470	3.138	0.994	1	5	-0.011	-0.798

Note: Descriptives use unweighted five-item means. Kurtosis is excess kurtosis.

Construct distributions and indicator reliability

Table 3 presents construct means that are near the midpoint of five-point scale. The most important in policy support is 3.222, financial sustainability is 3.194, solar adoption is 3.176 and the energy security is 3.138. The standard deviations vary between 0.981 and 0.995 which represents a significant variation about these means. The slight divergences between the means cannot be assumed to be statistically determined ranking positions due to the absence of a comparison test. More specifically, the findings cannot be used to state that households are equally reflective of strong financial confidence or high-energy security.

Construct scores reported have the full range of one to five. Skew values are slightly negative across constructs with excess kurtosis being negative across. These distributions are regular with large variance between the response, instead of the narrow range of responses that a most preferred category suggests. They do not impose normality or unilaterally justify the modelling technique. Descriptive values also apply to unweighted item means, and the structural analysis to estimated construct scores. These two types of summaries are used analytically differently, and cannot be considered numerically equivalent

Table 4: Indicator Reliability and Outer Loadings

Construct	Indicator	Loading	Indicator reliability
SPA	SPA1	0.822	0.676
SPA	SPA2	0.840	0.705
SPA	SPA3	0.781	0.610
SPA	SPA4	0.828	0.686
SPA	SPA5	0.818	0.670
PPS	PPS1	0.807	0.651
PPS	PPS2	0.823	0.678
PPS	PPS3	0.772	0.596
PPS	PPS4	0.843	0.710
PPS	PPS5	0.802	0.644
PFS	PFS1	0.818	0.669
PFS	PFS2	0.841	0.708
PFS	PFS3	0.785	0.616
PFS	PFS4	0.825	0.681
PFS	PFS5	0.802	0.644
PES	PES1	0.828	0.686
PES	PES2	0.855	0.731
PES	PES3	0.803	0.645
PES	PES4	0.825	0.681
PES	PES5	0.795	0.632

Note: Indicator reliability is the squared outer loading. All twenty indicators were retained.

Table 4 indicates external loadings and indicator's reliability of all the twenty statements. Loadings range from 0.772 for PPS3 to 0.855 for PES2. All the loadings are over 0.708 reference value of the workbook. The loadings on squares are between about 0.596 and 0.731 which portend that every retained indicator has a significant proportion of its variance with the corresponding construct representation. The findings have not given any numerical ground to drop an item just to enhance the reported loading threshold, and all the five indicators are found within each construct.

The loading pattern is fairly stable in the four blocks of measurements. Solar adoption loadings range from 0.781 to 0.840, policy support from 0.772 to 0.843, financial sustainability from 0.785 to 0.841, and energy security from 0.795 to 0.855. These ranges assist in maintaining internal coherence and at the same time maintain the various substantive aspects of each concept. Strong loadings, however, do not give certainty that respondents understood all statements as intended. This difference applies to the future replacement costs and social policy support, which might demand knowledge beyond direct household experience.

Reliability and discriminant validity

Table 5 shows that the four constructs have a satisfactory internal consistency. Cronbach's alpha ranges from 0.869 to 0.880, rho A from 0.872 to 0.883, and composite reliability from 0.905 to 0.912. The variance of average extracted is between 0.656 and 0.675. These values reinforce the internal reliability and convergent validity of the reflective measurement specification of the reported measurement. The fact that the measures of reliability are close to each other also indicates that the positive evaluation is not based on the report of one chosen coefficient. It is an evaluation of the available sample as opposed to external validation. Further evidence that the constructs are empirically different can be found in Table 6. Solar adoption and policy support (0.251), financial sustainability and energy security (0.540) are the values of HTMT. All ratios are lower in comparison to the two reference comparisons that are given in the workbook. Their upper 95% bootstrap values are less than one, and the upper value is 0.620. The highest degree of pairwise similarity is then found between the financial mediator and security outcome, with the measurement diagnostics reported to not suggest that they reduce to an unmeasurable construct.

This distinction is important since the expectations of financial confidence and financial security might otherwise be taken as other manifestations of a broad positive assessment. Findings justify the modelling of them distinctly. However, HTMT does not rule out the potential of shared respondent effects, shared wording effects, or an overall positive response tendency. Its contribution is more limited: it assesses a relative relationship between indicators that are attributed to various constructs. Evidence of discriminant validity should thus support and not substitute substantive attention to the overlap between future financial confidence and future electricity confidence.

Collinearity and explanatory power

In Table 7, the inflation factors of inner variance are low.

Table 5: Internal Consistency Reliability and Convergent Validity

Construct	Alpha	rho A	Composite reliability	AVE
SPA	0.877	0.881	0.910	0.669
PPS	0.869	0.872	0.905	0.656
PFS	0.873	0.873	0.908	0.664
PES	0.880	0.883	0.912	0.675

Note: AVE = average variance extracted. All constructs have five indicators.

Table 6: Discriminant Validity Using HTMT

Construct pair	HTMT	95% percentile CI	Valid resamples
SPA – PPS	0.251	[0.149, 0.350]	5000
SPA – PFS	0.466	[0.376, 0.547]	5000
SPA – PES	0.436	[0.346, 0.520]	5000
PPS – PFS	0.340	[0.243, 0.431]	5000
PPS – PES	0.417	[0.320, 0.508]	5000
PFS – PES	0.540	[0.451, 0.620]	5000

Note: Two-sided 95% percentile intervals; all HTMT estimates are below 0.85 and all upper limits are below one.

Table 7: Structural Model Collinearity Assessment

Outcome	Predictor	VIF
PFS	SPA	1.052
PFS	PPS	1.052

PES	SPA	1.219
PES	PPS	1.112
PES	PFS	1.273

Note: Inner VIF calculated within each equation using PLS construct scores.

The values of both predictors of financial sustainability are 1.052. Solar adoption has a value of 1.219; policy support has 1.112 and financial sustainability is 1.273 in the energy security equation. These diagnostics suggest that there are no severe predictor collinearity issues evident in the reported construct-score regressions. It is possible to interpret the coefficients without evidence that the estimation of coefficients is influenced by near-linear dependence between included predictors. This outcome fails to consider omitted variables, endogeneity, and common method effects.

Table 8 indicates that 21.43% of the variance in perceived financial sustainability can be explained by solar adoption and policy support. Its adjusted value is 21.09%. The three predictors of perceived energy security have a value of 31.61% predicting 31.17 % adjusted. The number of predictors is adjusted to yield trivial decreases. The model thus represents significant variation in both results and the majority of the variation remains unexplained. The values are explained sample statistics and are not percentages of households that receive the benefits of solar power or are estimates of the national improvement in energy security.

Table 8: Explanatory Power of the Structural Model

Outcome	R^2	Adjusted R^2	Predictors	N
PFS	0.214	0.211	2	470
PES	0.316	0.312	3	470

Note: Statistics calculated from regressions on PLS construct scores; N = 470.

Table 9 shows that the largest incremental predictor of financial sustainability is solar adoption with the f squared of 0.159. Policy support provides 0.058 to that equation. Incremental value of financial sustainability is the highest 0.121 which is succeeded by policy support 0.068 and solar adoption 0.049. With reference categories provided in the workbook, the solar adoption relationship with financial sustainability is only medium; the others are small. Interpretations of statistical significance must thus be carried along with such more modest measures of incremental explanatory contribution.

Table 9: Effect Sizes of Structural Relationships

Path	R^2 included	R^2 excluded	f^2	Magnitude
SPA → PFS	0.214	0.089	0.159	Medium
PPS → PFS	0.214	0.169	0.058	Small
SPA → PES	0.316	0.282	0.049	Small
PPS → PES	0.316	0.270	0.068	Small
PFS → PES	0.316	0.233	0.121	Small

Note: Effect sizes use fixed full-model scores. Reference cutoffs are 0.02, 0.15, and 0.35.

Direct relationships and hypothesis tests

Under the mentioned positive-interval decision rule, Table 10 supports all the five direct hypotheses. There is a positive relationship between solar adoption and financial sustainability with a standardised coefficient of 0.363 and a 95-percent interval of 0.282 to 0.440. Financial sustainability also has a positive relationship with policy support with the coefficient of 0.218 with an interval range of 0.137 to 0.298. These results support H1 and H2. The coefficient of adoption is relatively higher

Table 10: Direct Relationships and Hypothesis Testing

H	Path	β	SE	t	95% CI	p approx.
H1	SPA → PFS	0.363	0.041	8.893	[0.282, 0.440]	<0.001
H2	PPS → PFS	0.218	0.041	5.314	[0.137, 0.298]	<0.001
H3	SPA → PES	0.203	0.043	4.752	[0.121, 0.284]	<0.001
H4	PPS → PES	0.227	0.042	5.369	[0.144, 0.311]	<0.001
H5	PFS → PES	0.324	0.045	7.187	[0.233, 0.409]	<0.001

Note: All hypotheses supported. N = 470; 5,000 valid bootstrap estimates. CI = 95% percentile interval; p values are two-sided normal approximations.

in number, however, the analysis lacks a formal test to compare the two paths.

The direct coefficient of solar adoption is 0.203 with a range of between 0.121 and 0.284. The coefficient of policy support is 0.227 with a range of 0.144-0.311. Both intervals are all above zero, which helped to validate H3 and H4.

The above estimates show there are positive conditional relationships when financial sustainability is added. The fact they persisted is also pertinent to the interpretation of mediation since neither of the two explanatory constructs can be fully characterized by the described indirect route in terms of relationship to energy security. Perceived energy security has a direct coefficient of 0.324 with financial sustainability with an interval of 0.233 to 0.409 that supports H5. It is the largest direct coefficient in the energy security equation. This ranking is similar to that of the effect-size results, which also point to financial sustainability as the highest incremental predictor in that equation. No pairwise bootstrap contrast can be obtained, however, to show statistically that its coefficient is greater than the others. The approximate probability values of all the five are less than 0.001 and the percentile ranges offer the most general inferential foundation.

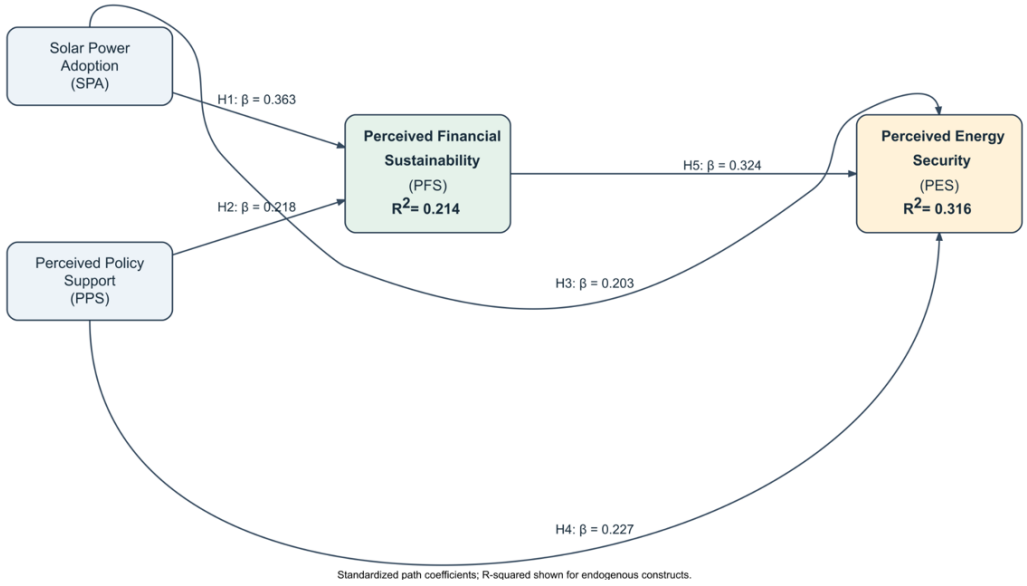


Figure 2: Structural model with standardised coefficients and explained variance

Specific indirect and total relationships

According to Table 11, there is a positive indirect effect of solar adoption and financial sustainability on energy security. The coefficient is 0.118, with a 95% interval from 0.077 to 0.164. The policy support indirect coefficient is equal to 0.071; the interval is between 0.040 and 0.106. Both intervals do not contain zero, which is in favour of H6 and H7. These estimates show the financial mediator explains a statistically significant portion of the relationship of each explanatory construct to energy security in the given model.

Table 11: Specific Indirect Relationships and Mediation Testing

H	Indirect path	β	SE	95% CI	Mediation
H6	SPA → PFS → PES	0.118	0.022	[0.077, 0.164]	Complementary
H7	PPS → PFS → PES	0.071	0.017	[0.040, 0.106]	Complementary

Note: H6 and H7 supported; approximate $p < 0.001$ for both. Each indirect estimate uses 5,000 valid bootstrap products. Both direct paths also remain positive

The two mediation patterns are complementary as both the direct and indirect coefficients are positive and their intervals are non-zero. The results do not substantiate the definition of financial sustainability as the only channel linking each of the predictors with energy security. They also fail to determine the unquantified processes that are the other direct relationships. The indirect coefficients are dependent on the assumed model order, and measured variables. Their explanation is still associative break down and the favorable findings cannot be used to determine a chronological order of adoption or institutional buttress with financial solvency to next level of security.

According to Table 12, solar adoption and energy security

Table 12: Total Relationships with Perceived Energy Security

Path	Direct β	Indirect β	Total β	95% CI
SPA → PES	0.203	0.118	0.320	[0.244, 0.397]
PPS → PES	0.227	0.071	0.297	[0.215, 0.381]

Note: Total β = direct β + indirect β. Both approximate p values are below 0.001; 5,000 valid bootstrap totals.

have a total coefficient of 0.320, a 95% interval of 0.244 to 0.397. The policy support total coefficient is 0.297, with a range of 0.215 to 0.381. Both overall relationships are positive. A division of the indirect point estimates by the totals yield around 36.74 % in the case of solar adoption and 23.79 % in the case policy support. These derived ratios are only a description of the point-estimate decomposition. There is no reported confidence interval and cannot be used as causal percentage and population shares.

Predictive assessment

In Table 13, the Q squared predict values of all ten endogenous indicators are reported to be positive.

Table 13: Out-of-Sample Predictive Assessment

Item	Q^2 predict	PLS RMSE	LM RMSE	PLS MAE	LM MAE	Δ RMSE	Δ MAE
PFS1	0.120	1.174	1.189	0.979	0.996	-0.015	-0.017
PFS2	0.129	1.144	1.155	0.947	0.950	-0.011	-0.003
PFS3	0.147	1.124	1.134	0.931	0.936	-0.011	-0.005
PFS4	0.124	1.117	1.128	0.915	0.930	-0.011	-0.014
PFS5	0.152	1.132	1.142	0.944	0.948	-0.010	-0.004
PES1	0.171	1.133	1.151	0.939	0.952	-0.019	-0.013
PES2	0.172	1.143	1.145	0.952	0.947	-0.003	0.005
PES3	0.140	1.103	1.113	0.892	0.903	-0.010	-0.011
PES4	0.147	1.093	1.102	0.895	0.905	-0.008	-0.010
PES5	0.128	1.104	1.112	0.915	0.916	-0.008	-0.001

Note: ⊿ = PLS error minus LM error. Negative differences favour PLS. Each item has 4,700 repeated held-out predictions from 470 observations. RMSE is the primary comparison.

Financial sustainability has values of 0.120 to 0.152 and energy security with values of 0.128 to 0.172. The procedure thus gives predictive information of all evaluated indicators as compared to training-fold mean predictions. The ten PLS root mean squared errors are also less than the linear model errors. This upward trend justifies a positive comparison within the given predictive process, whereas the magnitude of the changes defines its practical understanding.

The amounts of the RMSE improvements are modest (around 0.003 to 0.019 response-scale units). The absolute PLS RMSE values lie between 1.093 and 1.174. Mean absolute error also gives PLS as the best choice of nine indicators, though the linear model slightly works better with PES2. The findings, therefore, do not conclude high predictive payoffs, but in line with this, consistent but small payoffs. Validation of two or more held-out on a separate sample is also different. The forecasted results enhance the analysis without eliminating its external validity constraints.

Discussion

Financial sustainability within household solar experience

The findings position the financial sustainability between the already in place solar use and the perceived security of electricity as well as maintaining a direct relationship between the two. This trend is in line with a domestic assessment where sustained affordability constitutes one component of the worth assessed towards solar electricity (Miskat *et al.*, 2023). The advantages of routine use might be practical, but the ability to continue to realize those advantages will be subject to the part of the issue of whether the expenses that have to be incurred in future will be manageable. The positive indirect value implies that a test that solely examines the intensity of adoption would miss a statistically significant financial aspect of the given relationship.

The adoption coefficient is also informative by the fact that it is relatively higher in the financial sustainability equation. It shows that it is reported that it has been integrated into household electricity use and this is closely linked with financial manageability in the model. The first way to interpret it is that frequent use brings the benefits to a level that they can be seen by households so that ongoing expenditures can be deemed valuable and viable (Wimmer, 2023). The other reason is that families which are not financially strapped are able to operate their systems on a greater scale. These two interpretations can be cross-sectionally associated. The results hence encourage exploration of the relationship in the long run instead of creating a direction of influence.

The answer to the various questions is provided in the descriptive and structural results. The average financial sustainability is slightly above the scale mid-point but the relationship of average financial sustainability to energy

security is positive. A positive coefficient does not imply that there is a consistent financial confidence (Scott-George *et al.*, 2021). This implies that those households that have relatively higher financial sustainability perceptions are more likely to report relatively higher security perceptions, given the predictors included. This difference does not allow an optimistic structural outcome to mask the difference in household experience. It also has an explanation of reasons why support can be important even with favourable estimated relationships.

The best direct coefficient in the security equation is financial sustainability, though its incremental effect size is still in the small range in the workbook. The substantive interpretation must thus be in proportions. Relevant is financial confidence, but it cannot explain most of the differences in security perceptions (Sunny *et al.*, 2023). The unexplained variation may be due to the technical performance, household demand, or the availability of storage, quality of service, and other factors. These are only a realistic extension of the framework and not quantified explanations that have been established by the current findings.

Institutional perceptions and direct relationships

A positive relationship exists between policy support and the financial sustainability as well as energy security. Complementary mediation pattern denotes that the financial pathway is only partly responsible to the reported relationship. Institutional confidence can thus be linked to household security by expectations not necessarily limited to immediate affordability (Miskat *et al.*, 2023). The instrument however, gauges overall perception of support and not individual policy mechanisms. The results fail to pinpoint the type of public action that has created the association or whether the way the respondents perceive it is indicative of the kind of assistance the respondents are receiving.

The distribution of public assistance is an added value. It is only 26.38% who report receiving assistance and 27.02% are unsure. But the policy support construct can be measured on the entire analytical sample. This confirms the difference between programme receipt and general policy perception. When responding to policy questions, a household can rely on the information that is available to the community, observable policy efforts, or the institutional expectations at large (Das *et al.*, 2021). The uncertainty category also implies that future studies need to differentiate between the knowledge of support, eligibility, experience of application, and receipt. These differences would render institutional interpretation more accurate.

The continuity of a proximate adoption relationship toward energy security is in line with the realism of solar electricity to vital operations. Lighting use is reported by all households and common applications are communication and fans. These description trends define that the technology is used on repetitive domestic tasks. They fail to show that the positive coefficient is said to be because of a particular usage. However, they assist in understanding why security perceptions can be associated with daily incorporation of another financial mediator (Payel *et al.*, 2023). The role of the system in the daily services does not physically relate to its affordability.

The summative coefficients of adoption and policy support are very close numerically with the overlapping intervals. They lack enough evidence to be classified as statistically different sources of energy security. An interpretation of the policy that favors one based on a marginally larger point estimate would be over the analysis (Shakeel & Rajala, 2020). The more justifiable conclusion is that both behavioural and institutional perceptions have positive relationships with the outcome. Their different directions justify the inclusion of both dimensions as the financial mediator will have a different contribution to each point-estimate decomposition.

Measurement and predictive interpretation

The outcomes of the measurement indicate that it is reasonable to interpret the four constructs as distinct, mutually consistent dimensions. Stable loadings, positive reliability coefficients and low HTMT values, alleviate the fear that the structural results could be due to solely poor differentiation of measurement blocks. It is an indispensable basis of interpretation (Sultana, 2023). It does not determine that the refinements of the statements newly formulated exhaust all ideas, and perform precisely the same work on various languages and peoples. Specifically, ability of respondents to make estimates of the costs of future components might differ in terms of experience, technical expertise, and access to suppliers.

Predictive assessment brings a helpful qualification to the explanatory results. The positive relevance of predictions and steadily decreasing RMSE values indicate that there is extra information in the specified model that is not reported. These small differences of errors indicate that this advantage is not so impressive. Explanatory coherence should not thus be synonymous with accurate prediction in case of an individual household (Roy *et al.*, 2023). A model is able to find significant average relations and still is not enough to make operational decisions relying on the fact that it correctly predicts the household in which the future will be characterized by the insecurity of electricity and/or economic hardship.

The most important value of the framework is that it helps to understand the relations and limits of measurements. It focuses on the focus on continuation, financial anticipation, institutional perception, and household service confidence as related but different levels. Its current evidence is not as well-informed to assess intervention impacts or predict future outcomes. This balance helps to maintain the relevance of the results without hyperinflating its scope (Amin *et al.*, 2023). The framework can be reinforced later on with data identifying these perceptions with recorded spending, system performance, and observations of the same households occurring repeatedly.

Practical implications

The results affirm the need to consider continuing affordability in evaluations of household solar programmes. The number of installations and initial purchase prices will tell little about whether a household is able to sustain its system. The monitoring of the programmes might thus incorporate cost of maintenance anticipated, replacement readiness and awareness of the household on recurring duties (Fyza & Sarkar, 2020). These would fit in the assessment with the financial aspect of the model. They would also differentiate a system which still is in place and one which still provides a low cost and reliable service throughout its life of operation.

The financing providers and suppliers might enhance transparency in the information about continuing costs. A family must be in a position to know what aspects of their house must be maintained, what parts need to be replaced and what services are included in the purchase package. Transparency would assist the households to make sound financial judgments as opposed to depending on uncertainties. The study does not estimate the effect of such information on affordability or security. It determines an area of relevance in programme planning and consequent evaluation by a measured intervention.

The messages of broad support could also be differentiated by the public institutions as compared to the information that households can act on. The fact that the uncertain category of the public assistance is large means that awareness of the programmes and program receipt should be classified differently (Safi *et al.*, 2023). The communication may be directive, detailing eligibility, application criteria, limits of assistance, and service obligations in a language that is easy to understand. Verified awareness and access measures should be used to determine the progress. The positive overall view of policy support is inadequate indication that aid goes to the households that have the highest level of need or that the support provided to them will solve their financial difficulties.

Household and system diversity may need to be addressed in support arrangements. Individual, grid-linked households and members of joint systems have varied operating and payment policies. Replacement requirements may also arise with battery ownership that are not comparable to systems that do not store data. The collective outcomes are not used to determine which group is in need of the greatest help. They rationalize gathering data that enables programmes to evaluate these differences. Targeting ought to be based on evidence of real burdens and conditions of service instead of an opinion that all solar users have the same financial risks.

The household indicators of energy security monitoring should include both financial and service questions and household level. The avenue of critical business operations, business continuity in times of disturbance, and reliability over the future availability are factors that satisfy results that are recognisable to the user (Islam *et al.*, 2023). Combining these perceptions with operational records would enable easier evaluation of the presence of financial support linked with lasting service improvements. According to the current model, affordability is an area that is worthy of consideration, yet realistic assessment should consider technical reliability. A not working equipment, and financial reassurance would not be an adequate household energy security result.

Limitations and future research

The major design constraint is the cross-sectional design. Categories that are perceived simultaneously cannot create a temporal precedence or preclude reverse relationships. Households that are financially confident can afford to use solar electricity more widely, and households with access to reliable electricity may be more favourable regarding their finances and policy support. Future longitudinal studies are to quantify these constructs at each follow-up, with intervening measures of equipment, expenditure, and assistance (Krupnov *et al.*, 2022). This would give a better foundation to analyze the order that the mediation framework implies.

Verification is also restricted by the documentation available. The materials provide no establishment of recruitment procedures, fieldwork dates, response rates, exclusions, and completed ethics arrangements. The workbook is a summary of results, without offering respondent-level records, or executable estimation code. These gaps are not allowing independent audit of cleaning decisions and model reproduction. They must be settled prior to the representation of the manuscript in the form of a completed documented empirical submission. The statistical consistency of the reported tables does not replace the evidences concerning the manner of obtaining the observations.

Each of the main constructs is a respondent-reported construct. The tendency to give common responses and even to share expectations can lead to their associations. The fact that there is low collinearity and good discriminant validity does not demonstrate that there is no common method bias. It is recommended that future research integrates household perceptions with household maintenance expenditure, history of repair, downtimes of systems, and history of generation where possible (Talut *et al.*, 2022). Isolating the information sources would assist in separating the confidence and the performance observed. Documenting uncertainty would also indicate clearly whether positive responses are informed judgments or lack of awareness of future operating requirements.

Only current solar users with a planned at least six months experience will be included in the sample. Those households which stopped using it, were unable to adopt it, or simply did not have a proper system are out of that defined scope. The exclusion can restrict the knowledge of financial vulnerability and failure of services. Future studies ought to consider both discontinued and non-discontinued users in terms of suitable comparative samples. It also needs to test measurement comparability prior to comparing coefficients across types of systems, residential, income groups, or various solar experience levels.

Additional analytical advancement must maintain parsimony but must also deal with certain influences omitted. Possible candidates include household income, access to the grid, battery storage, system age and service arrangements since the questionnaire already acknowledges their applicability at the descriptive level (Munjer *et al.*, 2023). They ought to be included by a well-defined conceptual reason other than by a quest to acquire greater explanatory power. Also required is the independent predictive validation. These minor advancements compared to the linear benchmark are worth testing on new samples that can be designed with completely reported fold structure, preprocessing guidelines, and processes that avoid information leakage between training and testing observations.

Last but not least, the results ought to inform the choice of results to be subsequently assessed. An intervention aimed at enhancing maintenance affordability must capture the results on whether the anticipated expenses are relieved and whether a continuity of services increases thereafter. The practical contribution to the intervention would remain ambiguous with just approval of the intervention. Following the perceptions and perceived service conditions would allow to determine the accord or the disagreement between the household confidence and the operational performance, which would further support the interpretation of the financial pathway suggested in the current study.

CONCLUSION

A study conducted on 470 households reports positive relationships between solar power adoption, perceived policy support, perceived financial sustainability, and perceived energy security. Under the given rule of the bootstrap interval, all the five direct hypotheses and the two specific indirect hypotheses are supported. Adoption and policy support have a complementary statistical route to financial sustainability and the direct relationships between financial sustainability and security are positive. The model describes 21.4% of the variance of financial sustainability and 31.6% of energy security variance.

The results justify viewing the solar electricity in the home in terms of sustained usage and affordability and institutional perceptions. Financial sustainability is an issue of concern since assurance about the future financial commitments is linked to assurance about sustaining the necessary electricity services. Nevertheless, the evidence relates to domestic perceptions and lacks by establishing national energy security benefits, audited financial feasibility or causal policy impacts. There are consistent but small predictive improvements. The empirical foundation needs to be reinforced with full fieldwork documentations and independent validations in order to be able to extrapolate the findings beyond the analytical sample on which the study was conducted.

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