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Determinants of investments in energy storage by electricity prosumers in Poland

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Abstract

The latest data from the Polish Energy Market Agency shows that at the end of 2025, the number of electricity prosumers in Poland is about 1.6 million, and the total capacity of RES micro-installations exceeded 13 GW. The dynamic growth of prosumption, primarily based on photovoltaics, is associated with significant daytime energy overproduction not matched to usage patterns. Energy storage facilities help solve this problem by enabling surplus electricity to be stored and used during periods when the photovoltaic installation does not generate enough power. The use of storage facilities optimises energy production, enabling increased self-consumption.

This article aims to identify the key determinants influencing prosumers' investment decisions regarding the installation of individual electricity storage facilities. This paper relies on CAWI-collected data from a purposive sample of 534 active electricity prosumers in Poland. CHAID decision trees were the primary method of data analysis.

The article indicates that many factors, both market- and individual-level, influence prosumers' investment decisions in energy storage, and that storage costs may remain a significant constraint on its use, even if not directly mentioned.

This article is the result of the first author's research internship at Maria Curie-Skłodowska University in Lublin.

Keywords: prosumer, photovoltaics, energy storage, self-consumption

INTRODUCTION

The latest data from the Polish Energy Market Agency shows that at the end of 2025, the number of electricity prosumers in Poland is about 1.6 million, and the total capacity of RES micro-installations exceeded 13 GW. The dynamic growth of prosumption, primarily based on photovoltaics, is associated with significant daytime energy overproduction not matched to usage patterns. Energy storage facilities help solve this problem by enabling surplus electricity to be stored and used during periods when the photovoltaic installation does not generate enough power, particularly after sunset or on very cloudy, rainy days. The use of storage facilities optimises energy production, enabling increased self-consumption.

This article aims to identify the key determinants influencing prosumers' investment decisions regarding the installation of individual electricity storage facilities. This paper relies on CAWI-collected data from a purposive sample of 534 active electricity prosumers in Poland. CHAID decision trees were the primary method of data analysis.

STUDY BACKGROUND

Prosumption and prosumer in the energy market

The term 'prosumer' is derived from the two words 'PROducer' and 'conSUMER'. Alvin Toffler coined the term in his 1980 book "The Third Wave" (Toffler, 2022). According to Toffler 'prosumer' is a hybrid entity capable of engaging in production and consumption - merging of the roles of classical producer and consumer (Ertz et al., 2025).

In the energy market context, his term is more legally defined and refers to entities (individuals or businesses) that generate electricity exclusively for their own use from renewable energy sources. In accordance with Article 2(14) of the RED II Directive, a renewable energy prosumer is an end-user operating within the confines of their own premises or, where permitted by a Member State, within other premises, who generates renewable electricity for their own consumption and who may store or sell the electricity they have generated themselves, provided that, in the case of a renewable energy prosumer who is not a household, these activities do not constitute their main commercial or professional activity (Inês et al., 2020). The RED II Directive imposes an obligation on EU Member States to introduce legislation granting consumers the right to obtain renewable energy prosumer status. In particular, Member States are obliged to ensure that prosumers, either independently or through aggregators, have the right, amongst other things, to:

- generate energy, including for their own use, and store it, as well as sell any surplus;
- install and operate energy storage systems connected to generation installations for their own use;
- receive remuneration, including from support schemes, reflecting the market value of the energy generated and fed into the grid.

Under Polish legislation, in accordance with Article 2(27a) of the Act on Renewable Energy Sources, a renewable energy prosumer means an end user generating electricity exclusively from renewable energy sources for their own use in a micro-installation, provided that, in the case of an end user who is not a household electricity consumer, this does not constitute the main economic activity as defined in accordance with the provisions issued pursuant to Article 40(2) of the Act of 29 June 1995 on Public Statistics. A prosumer is a consumer who has their own energy source, intended primarily to meet their own energy needs (reducing demand from the grid), but who, in the event of a surplus, may also supply and sell energy to the grid (on their own initiative or at the operator's request).

Prosumption challenges in the Polish energy market

The rapid growth of prosumer installations (up to the level of the total capacity of RES micro-installations, more than 13 GW of installed power in 2025, with the number of electricity prosumers in Poland at about 1.6 million) poses an increasing challenge to the Polish energy system in technical, investment, and organisational terms. This challenge is forcing distribution network operators to take action; they must ensure that new prosumer installations can be connected to the grid whilst simultaneously facing rising costs for grid expansion, modernisation, and maintenance, alongside a decrease in demand for grid energy from this group of consumers. The large-scale deployment of distributed generation, particularly photovoltaics, causes local overloads, increased voltage in low-voltage networks, and greater variability in energy flows. Due to the characteristics of PV electricity generation and the patterns of electricity consumption in prosumer households, self-consumption is very low, ranging from 15% to 25%. The remaining energy is fed into the DSO grid and drawn from the DSO grid at 70% or 80% during peak demand hours. This causes significant voltage fluctuations and surges, resulting in the systems being shut down by safety mechanisms. Consequently, energy that could have been generated is lost. Energy storage systems are a key tool for both prosumers and distribution system operators to address these issues. From the perspective of distribution system operators, consumer energy storage systems can contribute to: mitigating the negative effects on the grid of connecting a significant number of prosumer installations; eliminating restrictions on the power and energy generated by prosumer installations; reducing investment costs in the modernisation of the low-voltage grid; limiting voltage fluctuations in the low-voltage grid; reducing active power losses in the grids; the possibility of limiting grid overloads.

For prosumers, the most significant benefit of owning and using energy storage systems is the more efficient use of the electricity generated by reducing grid consumption during peak hours and increasing self-consumption. Other benefits include:

- the ability to use the energy storage system as an emergency power source,
- the ability to become virtually entirely independent of grid energy supplies in the case of off-grid installations,
- avoiding the risk of unplanned disconnections from the grid due to grid overload,
- avoiding the need to go through the process of claiming compensation for grid failures,
- care for the natural environment.

Electricity storage forms the foundation of modern distributed energy systems. An energy storage system is an advanced device that stores surplus electricity generated by photovoltaic installations. Prosumer energy storage systems are small energy storage units designed to store energy from domestic photovoltaic installations. Their capacity usually ranges from a few to several dozen kilowatt-hours. In Poland, the most popular storage unit is the 10 kWh model. The reason for this is that this type of storage unit is ideally suited to a 5–7 kW photovoltaic system, which is most commonly found in detached houses.

Electricity storage as a possible solution to ineffectiveness

The prosumer energy storage market in Poland is growing rapidly. The two main factors driving the development of prosumer energy storage systems are: the introduction of net billing and schemes supporting energy storage. The net billing system has a huge impact on the development of energy storage. This billing model focuses on the value of energy. Prosumers sell surplus energy to the grid. Sales are made at the wholesale price, which is generally lower. They then purchase the energy they need at the retail price. The retail price includes distribution charges and other mark-ups. Net billing requires payment for the total amount of electricity drawn from the grid. This is a fundamental change compared to discounts. On 1 July 2024, a key change to the net-billing system was introduced: settlement based on the hourly Market Energy Price (RCE). In the net-billing system, the energy purchase price is determined according to an hourly rate. This means that the value of the energy sold changes dynamically. RCE prices at midday are often negative or very low. This is when photovoltaic energy production is at its highest. Evening RCE prices are significantly higher. At this time, however, household demand rises. This price difference makes energy storage essential. You sell the energy stored during the day in the evening at a higher rate. You can also use it for your own needs. Monitoring hourly RCE prices is key to profitability. The Net-Billing settlement system with the RCE attribute requires active management of the energy produced. The second, equally important system – though one that affects prosumers differently – is the subsidy scheme, particularly under the government's 'My Electricity' programme. Energy storage systems were first included in the My Electricity IV programme, introduced in 2022. The subsidy covered the purchase and installation of electricity storage systems with a capacity of at least 2 kWh. The maximum expenditure available was set at PLN 7,500 per project. The subsequent My Electricity V programme maintained the method of subsidising the purchase of energy storage systems. The My Electricity VI programme increased the subsidy for electricity storage systems with a minimum capacity of 2 kWh, working in conjunction with a PV installation with a minimum capacity of 2 kW, to PLN 16,000. Under this programme, to obtain funding for a micro-photovoltaic installation registered for connection from 1 August 2024, investment in an electricity storage system or a heat storage system is required. The next programme being prepared for 2026 also provides for funding for the purchase of energy storage systems.

The following factors also have a positive impact on the development of prosumer energy storage systems:

- rising electricity prices,
- falling energy storage prices; the average cost of 1 kWh of energy in a battery has fallen by over 90% over the last few years (in 2024 alone, a drop of around 20% was recorded),
- the higher efficiency of new equipment.

To maximise the benefits of photovoltaic installations and reduce household electricity bills, households equipped with photovoltaic systems often install energy storage systems. The main motivation for this is to increase the flexibility of accessing and using stored energy in line with their needs.

In 2022, when no subsidies were available for purchasing energy storage systems, the number of such systems was estimated at around 2,000. In subsequent years, the number of storage systems increased significantly. According to data from the Energy Market Agency, by the end of 2023, the number of prosumer storage systems stood at 10,197. By the end of 2024, this number had risen to 46,976, meaning that 36,779 prosumers had installed energy storage systems during the year. The number of prosumers active in 2024 stood at exactly 1,520,275, meaning that just over 3% of Polish prosumers had energy storage systems.

A prosumer who owns an energy storage system becomes a flexumer. The term 'flexumer', like 'prosumer', is a combination of the English words' prosumer' and 'flexibility', which mean, respectively, prosumer and flexibility. A flexumer, therefore, is a person who generates electricity from a micro-photovoltaic installation whilst simultaneously consuming it. The difference lies in the fact that a flexumer uses energy storage in its installation and can thus offer flexible services to the energy system.

Energy storage systems, like most such devices, are not permanent. Even when used under favourable conditions, they lose their properties over time. Capacity is the main factor that degrades, although efficiency also decreases. The National Renewable Energy Laboratory (NREL) estimates that, on average, an energy storage system loses about 20% of its battery capacity after 10 years of use. Generally speaking, publications predict that the lifespan of properly operated energy storage systems is approximately 15 years, which corresponds to the 10-year warranty most manufacturers offer.

Inefficiency example

Saturation of individual PV installations (for individual dwelling areas, even close to 95% of households) leads on the local level to temporary energy overproduction, when energy supply at day peak is too high compared to local usage, resulting in curtailment due to overvoltage, as in most locations, energy return beyond the local grid is technically not provided.

From the individual PV owner's perspective, repeated curtailments are not only annoying but also reduce energy bill savings and significantly delay the return on the PV investment. To illustrate the scale of the problem, a real-life example is presented.

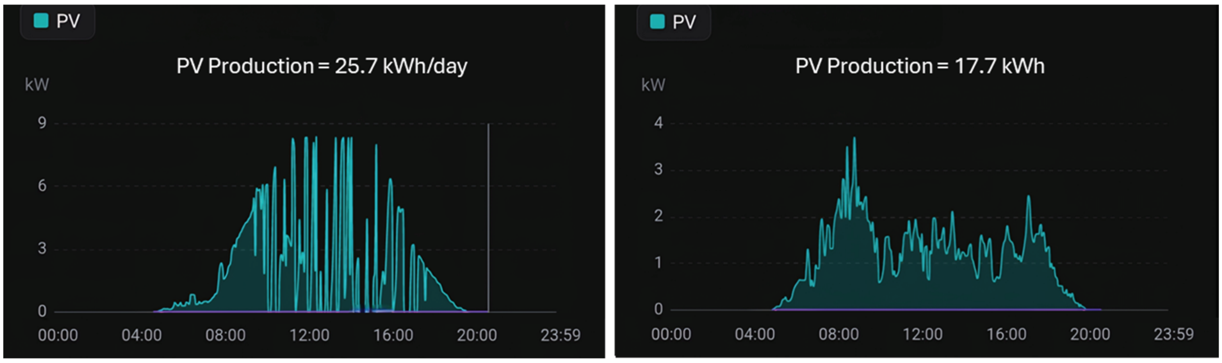
Figure 1 presents the production pattern for typical sunny and cloudy days (springtime) for an 8.8kW peak microinstallation. An average production on a sunny day is in the range of 25 to 40 kWh due to curtailments caused by temporary overvoltage. Without it, this installation can produce 50-55 kWh of energy per day on a sunny spring day. So the lack of the possibility to increase autoconsumption or store energy results in about a 40-50% loss of production. Including the effect of weather conditions, the cumulated inefficiency, measured as a decrease in total monthly production from spring to autumn, is about 21% over the 3 years (between 2022 and 2025), with a nearly linear decline of approximately -7% per year.

On an individual level, the owner has two possibilities to deal with this:

- to increase autoconsumption, mostly by the usage of smart household appliances, that can be programmed to operate at production peak time,
- to purchase an energy storage system and retrofit it to use stored energy at night, increasing overall auto-consumption.

Figure 1: Examples of electricity production patterns in typical sunny and cloudy day in environment prone to curtailment of PV installations due to overvoltage in the local distribution network

a) sunny day example b) cloudy day example



Source: Own research.

Both situations are not ideal – for the first one, there is not full flexibility in energy usage, taking into account owner usage patterns, and in some situations even concurrent loading of two PHEV vehicles is not enough to bring the voltage back to a normal level. For the second, although energy storage has many advantages – it can still be costly and hard to integrate with existing PV equipment. Regardless, this way still seems more reasonable than waiting for grid improvement by the operator.

At the aggregate level, the lack of large-scale investment in energy storage creates irreversible energy losses that could not be produced despite technical possibilities, leading to overuse of natural resources and environmental impacts.

As actions at the individual level will probably be more effective, an exploratory survey study of possible factors influencing decisions to purchase energy storage has been conducted.

METHODS

The paper uses an exploratory approach, analysing survey data on factors explaining energy storage investments within the broader topic of individual experiences with the use and ownership of home photovoltaic installations. A purpose-type sample of 534 Polish adult owners of PV installations was collected through CAWI.

The main research question is:

> RQ: What factors are explaining the interest in expanding existing PV installations with an energy storage facility?

The dependent variable to explain was the consideration of purchasing an energy storage system. In the original survey, the measure was a 5-point scale with categories ranging from 'Definitely yes' to 'Definitely no'. For further analysis, including classification trees, answers were categorised as 'Yes' (answers: 'Definitely yes', 'Probably yes') and 'No' (answers: 'Do not know', 'Probably not', 'Definitely not'), creating a dichotomy. This consideration was explored in the context of some sociodemographic variables and a set of declarations related to the current use of the owned PV installation, including savings on electricity bills, auto-consumption level, intention to add another PV-connected investment, and others.

The main analysis method is a CHAID-type classification tree with 10-fold cross-validation. CHAID (Chi-squared Automatic Interaction Detection) is a decision tree method that uses chi-square tests of independence to select splits and build tree structure (Kass, 1980). The core idea of this algorithm is to evaluate each predictor at each splitting node by testing its association with the dependent (target) variable using chi-square statistics (or also F-tests for continuous targets) (Maimon & Rokach, 2014, p. 79). The predictor with the strongest statistically significant association is chosen to split the node.

The main advantage of the CHAID approach for exploration is its high interpretability of results and its good fit for survey or marketing research data at categorical or binary levels. Also, built-in significance testing is an advantage, although the method is sensitive to sample size, as large sample sizes inflate the chi-square statistic (Loh, 2011).

SAMPLE

A purpose-type sample of individual PV installation owners/users' data collected through CAWI has been used for this paper. Effective sample size is 534 persons, differing in gender, age, type of place of residence and completed level of education (Table 1).

Table 1: Sample structure

Variable	Categories	N	%
Gender	Female	280	52,4%
	Male	254	47,6%
Age group	18-29 yo	82	15,4%
	30-39 yo	133	24,9%
	40-49 yo	126	23,6%
	50-59 yo	100	18,7%
	60+ yo	93	17,4%
Place of residence	rural area	213	39,9%
	town <10k inhab.	37	6,9%
	town 10-30k inhab.	47	8,8%
	town 30-50k inhab.	30	5,6%
	city 50-100k inhab.	64	12,0%
	city >100k inhab.	143	26,8%
Education level completed	primary school	5	0,9%
	vocational school	23	4,3%
	high school	181	33,9%
	university (1st stage)	82	15,4%
	university (2nd stage)	217	40,6%
	Ph.D.	26	4,9%
PV user status	Yes	534	100,0%
	No	0	0,0%

Source: Own research

RESULTS

As the main approach for the research part of this paper, the authors employed a CHAID-type classification tree to explore the factors influencing the consideration of purchasing energy storage as an addition to an individual's owned PV installation.

Initial tree is using four sociodemographic variables to explain the mentioned considerstion to purchase the energy storage: respondent gender (nominal: male vs. female), age (in 5 groups and as exact age in years), type of residence place (ordinal: rural vs. 5 categories of urban areas) and completed level of education (on 6 levels, ordinal: from primary level to Ph.D.).

Such an approach to predicting the purchase of energy storage is generally ineffective – only one significant variable, in terms of chi-square value, was gender, with no other variables included in the model (Figure 2), and such classification does not differ from classification purely by chance. Less than 58% of those not interested in such a purchase are properly classified, and about 54% from those who declared interest in such an investment (Table 2).

Figure 2: Initial CHAID tree – sociodemographic variables

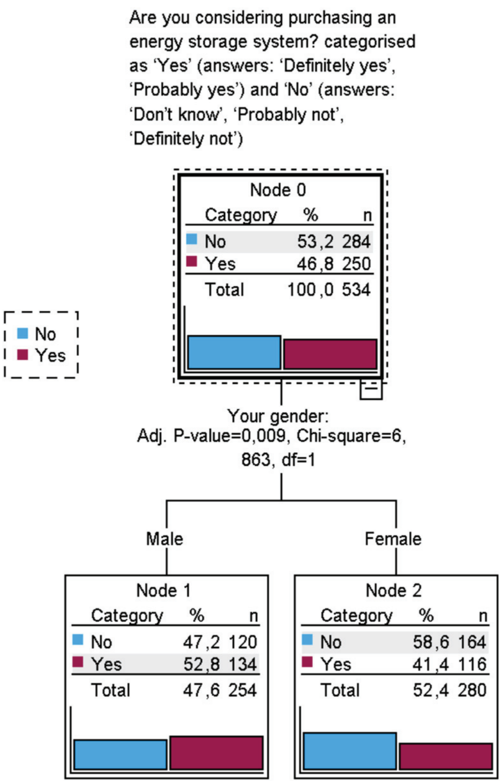


Table 2: Classification results

Observed	Predicted		
	No	Yes	Percent Correct
No	164	120	57,7%
Yes	116	134	53,6%
Overall Percentage	52,4%	47,6%	55,8%

Notes:
Growing Method: CHAID
Dependent Variable: Are you considering purchasing an energy storage system? categorised as 'Yes' (answers: 'Definitely yes', 'Probably yes') and 'No' (answers: 'Don't know', 'Probably not', 'Definitely not')

Source: Own research.

Taking into account suggestions from correlations between variables and preliminary interviews during questionnaire construction, a broader set of possible predictors has been selected to capture opinion and experience factors. For the final CHAID tree, 6 of 16 'candidates' are included in the model (Table 3).

Table 3: Variables selected and included in final CHAID tree

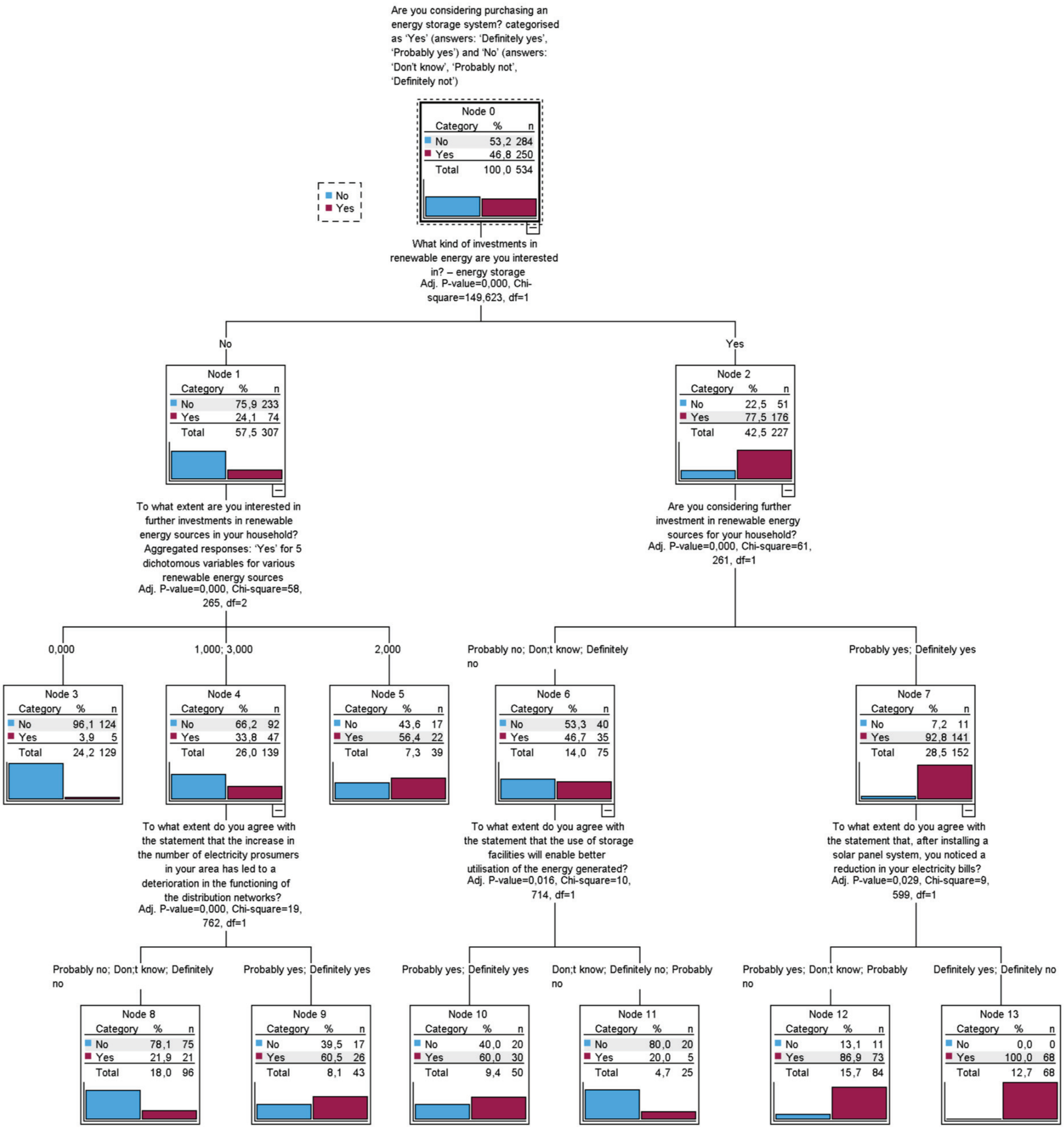
Variable (question wording)	Answer categories	Level of measurement	Included in the tree
Do you think that the current costs of installing storage facilities are too high?	5-point: defintely not/not/ no opinion/yes/definitely yes	Ordinal	No
Do you agree that you are satisfied with the investment you have made?	5 point canonical Likert: Strongly disagree/Disagree/ Neither agree nor disagree/ Agree/Strongly agree	Ordinal	No
Do you know what percentage of the energy produced in your micro-installation you use for your own consumption?	No / Yes	Binary	No
Nested: If 'yes' – what percentage (%)	Formally open-ended	Numeric	No
Common start: To what extent do you agree with the statement that:	n/a	n/a	n/a
...after installing a solar panel system, you noticed a reduction in your electricity bills?	5 point canonical Likert: Strongly disagree/Disagree/ Neither agree nor disagree/ Agree/Strongly agree	Ordinal	Yes
...the use of storage facilities will enable better utilisation of the energy generated			Yes
…new possibilities for systemic or legal solutions regarding the use of surplus energy generated by prosumers should be introduced			No
...the increase in the number of electricity prosumers in your area has led to a deterioration in the functioning of the distribution networks			Yes
...the overall condition of the distribution networks is good			No
…a higher quality of energy networks would result in a greater number of prosumer installations			No
Have you ever experienced curtailment of production from your micro-PV-installation?	Yes/No opinion/No	Ordinal	No
How old are you exactly? (write your age)	Formally open-ended	Numeric	No
In which year did you install your micro-installation? (write year)	Formally open-ended	Numeric	No
Are you considering further investment in renewable energy sources for your household?	5-point: defintely not/not/ no opinion/yes/deinitely yes	Ordinal	Yes
What kind of investments in renewable energy are you interested in? energy storage	Yes/No	Binary	Yes
To what extent are you interested in further investments in renewable energy sources in your household? 'Yes'/' No' for following choices: energy storage, electric vehicle, increasing the capacity of your existing installation, use of another renewable energy source, other	Aggregated responses: 'Yes' for 5 dichotomous variables for various renewable energy sources, coded as a sum of 1 for each positive answer	Ordinal aggregated from 5 binary ones	Yes

Source: Own research.

The final CHAID tree performs much better (Figure 3, Table 4) than the simple approach, so declarations and opinions are performing better than the sociodemographic background of PV installation owners.

This tree correctly classifies about 82% of cases, which is positive – more cases are correctly classified as group considering purchasing energy storage (87,6%) versus group not considering doing so (77,1%).

Figure 3. Final CHAID tree – opinion and further considerations variables



Notes: Growing Method: CHAID

Dependent Variable: Are you considering purchasing an energy storage system? categorised as 'Yes' (answers: 'Definitely yes', 'Probably yes') and 'No' (answers: 'Don't know', 'Probably not', 'Definitely not')

Source: Own research.

Table 4. Classification results – for final CHAID tree

Observed	Predicted

	No	Yes	Percent Correct
No	219	65	77,1%
Yes	31	219	87,6%
Overall Percentage	46,8%	53,2%	82,0%

Notes:
Growing Method: CHAID
Dependent Variable: As for Figure 3.

Source: Own research.

Comparing the initial approach to the final one, the accuracy of predicting the declared purchase of energy storage, measured by the two-sample proportion test, is significantly higher in each prediction category and in the overall result. However, the effect size is no greater than medium, with the highest effect size for the difference in predicting positive response (Table 5).

Table 5. Results of the two-sample proportion test for comparing prediction accuracy across models

	Proportion [%]		Z-test		Effect size	
Comparison	Initial model	Final model	Z-value	p-value	h-value	Interpretation
No purchase	57,7%	77.1%	4.83	<0.001	0.42	small
Purchase	53,6%	87.6%	8.25	<0.001	0.78	medium/large
Overall	55,8%	82.0%	9.19	<0.001	0.58	medium

Source: Own research.

So there is a significant small difference between the two models in not considering purchase classification results (58% vs 77%), $Z = 4.83$, $p < .001$. The observed effect size, h, is small: $h = 0.42$. This indicates that the magnitude of the difference between the proportions is small.

For considering purchase, the two-sample proportion test indicated a significant medium difference in the percentages correctly predicted by both models (54% vs 88%), $Z = 8.25$, $p < .001$. The observed effect size $h = 0.78$ is medium, close to high (with a 0.8 threshold). This indicates that the observed difference between the proportions has the highest magnitude.

Overall: Results of the two-sample proportion test indicated a significant difference between the two models in overall classification accuracy (56% vs 82%), $Z = 9.19$, $p < .001$. The observed effect size is medium ($h = 0.58$). This indicates that the difference between the proportions is medium in magnitude.

DISCUSSION AND LIMITATIONS

In the presented paper, a large background of prosumer decision-making connected with purchasing energy storage systems has been presented. Public documents and discussion focus on economic factors of energy storage adoption: savings, costs and subsidies, with billing system change being most often mentioned.

Although at the exploratory level through survey research, those factors are not visible in the analysis. In general, awareness of savings levels and the possible inefficiency of PV installations is rather low, and there are also many obstacles at the level of consumer attitudes. The final CHAID decision tree predicts prosumer considerations for purchasing energy storage at a reasonably good level, although it does not provide precise suggestions for real adoption factors.

This study has several limitations, despite a reasonably large sample size and a controlled design. Firstly, the questionnaire focused more on experiences than on attitudes and motivations. Secondly, no formal adoption model is employed. So, further research focused on modelling the propensity to purchase an energy storage system is needed.

SUMMARY

The rapid growth of photovoltaics in Poland was largely the result of state co-financing of investments through government subsidies. The same is true for energy storage systems. Subsidies can accelerate the development of renewable energy, but they should not be the sole reason for investment. The development of prosumer energy storage systems should be part of a conscious energy strategy for prosumers, rather than merely a reaction to emerging government subsidies. Changes to the billing system have proven highly effective in encouraging prosumers to increase self-consumption and improve energy management.

The further development of the prosumer energy storage market should be driven by increased user awareness, combined with economic considerations. Further research on the formal study of prosumers' attitudes and preferences is needed.

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