Gábor Vona

International comparative analysis of prosumers in selected fields of energy use and further customer preferences in environmental issues

Gábor Vona, PhD Student, Department of Sustainability Management and Environmental Economics, Institute of Sustainable Development; Corvinus University of Budapest
Email: gabor.vona@uni-corvinus.hu

By providing insights into the energy choices and attitudes of retail customers, this article widens the knowledge about consumer behaviour related to photovoltaic (PV) systems. The calculations rely on the dataset of a survey conducted in Italy, Norway, Serbia, Ukraine, and the United Kingdom between 2016 and 2019 by ENABLE.EU team. (1) The analysis revealed the areas where both prosumers and traditional customers with PV plans in the near future demonstrate significant advancements. These common characteristics are the type of building, use of energy-efficient bulbs, disposal of smart meters, less energy consumption, acceptance of the inconvenience arising from eco-friendly measures, educational level, and household income. Further differentiating attributes leading to PV plans are family size, employment status, age, gender, and commitment to environmental issues. In addition, prevailing phenomena were identified between Western and Eastern countries. (2) Prior to PV installations, formal information channels (one-sided p-value: 6.01%) are preferred when obtaining information about such systems. Both in the circle of prosumers and those with PV plans in the near future, technological, environmental, and remaining (e.g. financial) reasons are the most motivating drivers ranked in ascending order. (3) Ultimately, the study examined the nexus amongst having future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity.

Keywords: environmentally conscious consumer behaviour, sustainable consumption, prosumers with a photovoltaic system

On the 25th of September 2015, the General Assembly of the United Nations adopted in New York 17 Sustainable Development Goals (SDGs) to be achieved by 2030. By redefining the embeddedness of the economy into nature and society, the SDGs offer a comprehensive framework. Combatting climate change (13th) necessitates, amongst others, the accomplishment of many SDGs, such as ending poverty (1st), providing access to affordable and clean energy (7th), fostering innovation and sustainable industrialisation (9th), creating sustainable and resilient cities and communities (11th), and spreading sustainable consumption and production patterns (12th) *(United Nations, 2015, pp. 1, 14).* Decarbonisation targets lessening or removing greenhouse gases responsible for anthropogenic (i.e. originating in human activity) climate change and concomitant corollaries, e.g. sea level rise and increase in mean temperature. Instead of tackling them, preventive mitigation should be given priority. In this manner, the augmentation in global average temperature in the 21st century can be limited not only to the jointly accepted 2°C but to 1.5°C relative to pre-industrial levels in accordance with the Paris Agreement. It is a legally binding international treaty in force after its ratification in 2016 *(United Nations, 2023)*. Focus points are the energy and mobility turn whose estimated potential is an 80 to 90% reduction in carbon dioxide emissions *(Bild der Wissenschaft, 2019, p. 9).* For the current decade, the European Union envisages cutting back greenhouse gas emissions by at least 40% by 2030 compared to 1990. The European Green Deal designates 2050 as the target year for achieving complete carbon neutrality *(European Commission, 2021).*

As a consequence of aggravating global perils, countries should be urgently impelled to realise steeper slopes in the reduction of greenhouse gases, which enable them to remain within the ecological threshold. First, the main ongoing instruments are composed of increasing energy savings and efficiency. Second, preserving and extending the prominent role of carbon-neutral energy, thereby augmenting the share of renewable energy, and utilising the waning reserve of fossil resources in a more eco-friendly manner can be highlighted regarding power supply. Third, modernising district heating systems, enhancing storage capacity, developing new supply routes, attracting investments into energy-sensitive sectors, constructing cross-border capacities, integrating the grid network at the international level, and further regional cooperation are also parts of this concept *(Hübner, 2019, pp. 185–207).*

Building more on non-depletable sources (e.g. solar, wind, and geothermal) and establishing the base of the hydrogen economy (mobility, power generation, storage technology, and feedstock) can result in a more decentralised power supply meeting the criteria of affordability, sustainability, and uninterrupted availability *(World Economic Forum, 2023).* Following the principle of biomimicry in the context of decentralisation, retail prosumers can play a role similar to mitochondria in cellular local energy production. Etymologically, a prosumer unifies the energy producer and the consumer into one single individual. Prosumers are 'small-scale end users who, in addition to using electricity from the grid, generate power for their own use and export back into the electricity system' *(Inderberg et al., 2018, p. 258).* Their penetration contributes not only to environmental sustainability and decarbonisation but also to energy democracy and energy justice *(Wittmayer et al., 2022, pp. 1–2)*. Regarding the energy mix of primary energy consumption in 2021, the share of fossil fuels was globally close to 82.28%: oil amounted to 30.95%, natural gas to 24.42%, and coal to 26.90%. The proportion of nuclear energy is 4.25% and the remaining 13.47% belongs to renewables. Paragons (such as Norway and Sweden) already have a carbon-neutral share (nuclear energy, hydroelectricity, solar, wind, biofuels, geothermal, biomass, and other carbon-neutral sources) surmounting 70%. Despite the almost exponential expansion of solar energy since its introduction in the 1980s, its potential still offers abundant benefits by creating more prosumers (both residential and corporate) and moderating the vulnerability of the energy supply *(BP, 2022)*. In addition to carbon dioxide, the energy industry is responsible for a considerable share of the emissions of air pollutants such as acidifying gases (nitrogen oxides and sulphur oxides) *(HCSO, 2023)*.

This research aims at revealing relationships contributing to economic conjuncture, societal prosperity, and environmental health by evaluating the current position and attitudes of retail prosumers and their counterparts with or without PV plans in the near future. The household survey conducted by ENABLE.EU team provided comprehensive international data in the fields of home, mobility, prosumers, heating and cooling, electricity, governance, and socio-economic characteristics. To address the research questions (RQs), asymptotic independent samples z-tests, chi-square tests of independence, and logistic regression were applied. First, indicators of environmental awareness and social and economic attributes were investigated to determine whether they can be qualified as differentiators in the context between prosumers and traditional customers and between traditional customers with PV plans in the near future and those without such intentions. Ultimately, this scrutiny was expanded from the level of individuals to that of nations. (RQ1) Second, conclusions were drawn with regard to the role of information channels and the type of triggering reasons prior to the installation of PV systems or resulting in PV plans. (RQ2) Third, the nature of interrelationships amongst disposing of future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity was disclosed. (RQ3) Furnishing stakeholders with valuable findings may improve the environmental awareness of individuals (through targeted communication about energy savings, energy efficiency, renewables, and recent progress). Furthermore, generating appropriate market incentives related to installation, emphasising decisive reasons (e.g. financial benefits during use spanning more decades), opting for the most efficient information channels, and eliminating hindrances can support the spread of cleaner technologies and, as a consequence, bolster the transition towards carbon neutrality and advance its date.

1. Literature review

By relying on all databases offered by the Web of Science, the term 'prosumers' as the sole keyword was used to ensure as many hits as possible without any restrictions. The simplified systematic review encompassed 618 open-access articles about prosumers in the field of renewable energy production irrespective of the publication year. The bibliographic analysis based on the title, the name of the journal, and the abstract resulted in 25 papers that could be considered related to the decision-making process prior to becoming a prosumer or disposing of PV plans in the near future. Most articles address promoting prosuming. Categorising the remaining hits was out of the scope of the review.

Zdonek et al. (2022, pp. 19–20) assessed a program initiated by the Polish government targeting the popularisation of PV microinstallations with the purpose of future expansion. Motivators, barriers, concerns perceived by beneficiaries, experiences gained during the initial period with regard to the stability of the electricity network, operational risks and expectations related to the future disposal after the useful lifetime of PV panels were surveyed. *Guzman–Henao (2022, pp. 11–12)* applied the game theory to point to improvement emerging from the interaction between prosumers and consumers at the residential level in Colombia. Both eliminating the income tax coupled with sold electricity surpluses and selling surplus amongst consumers would have a salutary effect. *Xia-Bauer et al. (2022, p. 14)* initiated new prosumer-oriented business models in Germany, namely, peer-to-peer electricity trading and the aggregation of small-size prosumers. The authors collected drivers and barriers related to both business model innovations and ascribed a particular role to utilities when upscaling the participation of prosumers. *Kettner et al. (2022, p. 629)* made recommendations for a more equitable future electricity system in Austria characterised by more inclusion through superseding current legal barriers, relying on renewable energy communities and targeted support in the function of the household's income. *Inderberg et al. (2018, pp. 267–268)* identified national prosumer pathways by contrasting Germany, Norway, and the United Kingdom. The respective developmental trajectories are shaped by both country-specific factors and overlapping dimensions. *Karjalainen–Ahvenniemi (2019, p. 51)* highlighted the importance of trustworthy information and professional advice by scrutinising the adoption of residential PV systems in Finland. *Kotilainen–Saari (2018, pp. 17–18)* evaluated policies as influencers in shaping customers' attitudes. The researchers recommend discernment with respect to the target group (non-adopters of PV systems or prosumers) and the nature (economic or non-economic, by underlining the impacts of the latter) of policies. By investigating the domestication process of

PV technology in Norway and the United Kingdom, *Standal et al. (2020, p. 8)* suggested considering gender and social aspects and practical knowledge when designing policies. *Zimmermannová et al. (2018, pp. 14–15)* examined the impact of subsidies on financial indicators (such as NPV and IRR) of retail photovoltaic projects in the Czech Republic. Subsidies lessen the initial investment costs; hence, they make the payback period shorter and the project more lucrative. Many further authors analysed the profitability of PV-related investments (installation and optionally electrical energy storage) *(Gissey et al., 2021; Niekurzak–Kubińska-Jabcoń, 2021; Szelag-Sikora et al., 2021)*. Both *Olczak et al. (2021, p. 13)* and – to a smaller extent – *Niekurzak–Kubińska-Jabcoń (2021, p. 10)* estimated avoidable greenhouse gas emissions by increasing PV capacities. The profile of PV end users was explored in Poland by *Ropuszynska-Surma–Weglarz (2018)* and in Denmark with chronological distinction by *Hansen et al. (2022)*. Inventorying enablers (and optionally disablers) contributing to the diffusion of prosumer PV systems is one of the most favourite research fields *(Palm, 2018; Panos–Margelou, 2020; Rataj et al., 2021; Rausch–Suchanek, 2021; Mularczyk et al., 2022; Schwanitz et al., 2022; Wicki et al., 2022)*. Finally, a few studies have expounded the advantages of becoming collective prosumers in energy communities compared to their private counterparts *(Petrichenko et al., 2022; Ritzel et al., 2022; Wittmayer et al., 2022)*.

The dissimilarities amongst the types of customers, the antecedents of PV microinstallations, and the level of environmental awareness of individuals with PV plans are possible research gaps. Based on the literature review and the available data, three RQs were formulated. This study aims at disclosing the following:

- First, which variables do qualify as differentiators when comparing (i) prosumers with traditional customers, (ii) those disposing of PV plans in the near future with those without such intentions, and (iii) countries with each other? (RQ1)
- Second, which conclusions can be drawn with regard to the role of information channels and that of installation reasons when making decisions about PV systems? (RQ2)
- Third, what kind of interrelationships can be identified amongst disposing of future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity? (RQ3)

2. Methodology

2.1 Method

Quantitative analyses were carried out.

RQ1: Asymptotic independent samples z-tests were performed to test the equality of means. Logistic regression was employed for binary classification.

RQ2: Answering this question necessitates asymptotic independent samples z-tests.

RQ3: Chi-square tests of independence and asymptotic independent samples z-tests were executed. In addition, measures of association were calculated.

Logistic regression, the tests of independence, and the measures of association were made in the statistical software IBM SPSS Statistics Version 27. The asymptotic independent samples z-tests were carried out in Microsoft Excel.

2.2 Data collection

Between 2016 and 2019, the ENABLE.EU team undertook a project with the purpose of disclosing the drivers of individual energy choices and behaviours with the participation of 11,265 retail customers from eleven countries, of which five are relevant for this study with regard to the section on prosumers (Italy – 1,025 persons, Norway – 1,221, Serbia – 1,000, Ukraine – 1,011, and the United Kingdom – 1,015). The team compiled a questionnaire for conducting a household survey so that influencing social and cultural factors could be revealed. The survey comprises seven sections: home/building characteristics and household possessions, mobility, prosumers, heating and cooling, electricity, governance, and social and economic characteristics. The dataset contains 473, predominantly nominal and ordinal scale variables *(ENABLE.EU team, 2019)*. Table 1 recapitulates the sections split by country.

RQ1: The sections on home/building characteristics and household possessions, mobility, prosumers, governance, and social and economic characteristics bear importance for addressing this question.

RQ2: The findings rest solely on the section on prosumers.

RQ3: The sections on prosumers and electricity enable us to disclose the interrelatedness between each selected pair of variables.

Table 1

Dataset: available combinations of sections and countries (extract)

Country (abbreviation)	Home	Mobility	Prosum-ers	Heating and cooling	Elec-tricity	Govern-ance	Socio-economic
Italy (IT)	x	x	x	---	---	---	x
Norway (NO)	x	x	x	---	---	x	x
Serbia (RS)	x	---	x	---	x	x	x
Ukraine (UA)	x	---	x	x	---	x	x
United Kingdom (UK)	x	---	x	---	x	x	x
Number of countries	5	2	5	1	2	4	5

2.3 Data analysis

Prior to applying the mentioned techniques, data transformation was performed as detailed in Table A1 (see online Annex).

Both Kolmogorov–Smirnov and Shapiro–Wilk tests were applied to test for normal distribution. Apart from single exceptions, the null hypothesis of normal distribution can be declined. For this reason, the results of independent samples z-, t- or Welch tests are not valid. Asymptotic independent samples z-tests proved to be viable alternatives for testing the equality of means as a normal distribution is not a prerequisite. These tests require merely finite standard deviations and large (sub)samples, which are both ensured. In this study, a (sub)sample size of approximately 100 was accepted. A series of null hypotheses ($H_0: \bar{y} - \bar{x} = 0$) with the one-sided alternative hypotheses ($H_1: \bar{y} - \bar{x} > 0$) was carried out by dint of the formula of the asymptotic independent samples z-test. On the one hand, $\bar{y}$ denotes the higher value in question, and $\bar{x}$ refers to the corresponding lower value; on the other hand, $\delta_0 = 0$. Under the square root stand variances (s^2) and sample sizes (n) *(Hunyadi et al., 2000, pp. 468–469)*.

$$Z = \frac{\bar{y} - \bar{x} - \delta_0}{\sqrt{\frac{s_Y^2}{n_Y} + \frac{s_X^2}{n_X}}} \rightarrow N(0,1) \quad (1)$$

The null hypothesis of independent variables can be tested by means of the test of independence. This chi-square test requires that each expected count (n_{ij}^*) is at least 5. By denoting the number of rows with r and that of columns with c, the test statistic can be calculated as detailed below:

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(n_{ij} - n_{ij}^*\right)^2}{n_{ij}^*} \quad (2)$$

The null hypothesis can be declined if the test statistic exceeds the right-tailed value of $\chi^2_{1-\alpha}(\nu)$, where α is the significance level and ν is the number of degrees of freedom determined as ν=(r–1)·(c–1) *(Hunyadi et al., 2000, pp. 460–462)*. In addition, both symmetric and directional measures of association were calculated *(Kovács, 2014, pp. 35–40)*.

Both logistic regression and discriminant analysis are appropriate tools for classifying cases. Specifically, logistic regression was given priority due to the lower number of its prerequisites and the dichotomous nature of the dependent variable (y) with Bernoulli distribution. One of the requirements is the rule of thumb between the sample size (n) and the number of variables (p): n>10p. In addition, regressors should be linearly independent to avoid multicollinearity between them. The logit transformation of the probability (i.e. the natural logarithm of the odds ratio) is a linear function of the explanatory variables ($\underline{x}$) as shown below:

$$logit\ p(\underline{x}) = ln\left[\frac{p(\underline{x})}{1-p(\underline{x})}\right] = ln(odds) = \underline{\beta}' \cdot \underline{x} \quad (3)$$

Based on (3), the multiple logistic regression model can be expressed as follows:

$$p(\underline{x}) = \frac{\exp\left(\underline{\beta}' \cdot \underline{x}\right)}{1+\exp\left(\underline{\beta}' \cdot \underline{x}\right)} \quad (4)$$

The regression parameters ($\underline{\beta}$) are estimated with the maximum likelihood technique *(Kovács, 2014, pp. 87, 93–95, 126–147*; *Szüle, 2016, pp. 49–58)*.

3. Findings

RQ1: The analysis rests on three levels as detailed below.

1st level: Comparing prosumers with traditional customers (i.e. those currently not disposing of any PV systems) along each aspect where available data are appropriate for a more profound investigation.

2nd level: Traditional customers are differentiated according to whether they have PV installation plans in the near future. Regarding the split along PV plans in the near future, the difference between the subtotals and the total number is caused by the 'Do not know' answers.

3rd level: Traditional customers are split by country so that national specificities can be made visible.

Type of building (H1):

1st and 2nd levels: The differences are significant. According to the mean, both prosumers and traditional customers with PV plans in the near future live in houses attached to building(s), e.g. an individual rooftop solution is possible. The type of residence in the case of those without plans shifts towards apartments, which restricts the leeway for installation.

3rd level: Based on the share of single-family houses, the international overview aligns the countries in the next descending order: 1. UK, 2. RS, NO, 3. UA, 4. IT.

Floor area (H3):

1st level: At a significance level of 5%, the hypothesis that prosumers live in dwellings with a greater floor area can be rejected.

2nd level: The floor area is not an explanatory variable of having PV plans in the near future.

3rd level: The countries demonstrate significant dissimilarities. The home of Norwegians is the most spacious, followed by IT, RS, UK, and UA.

Proportion of energy-efficient bulbs inside homes (H12B):

1st level: Prosumers reached a significantly higher proportion of energy-efficient bulbs inside homes (midway between 50% and 100%) than those without installed PV systems (slightly above 50%).

2nd level: Similarly, traditional customers with PV plans in the near future made more considerable advancements in the transition towards energy-efficient bulbs than their counterparts.

3rd level: Within-group analysis elucidated that the United Kingdom takes the lead by attaining the level of prosumers before Italy and Norway (no significant difference between them at a significance level of 5%). Ukraine is the closest to the group average. By estimating the proportion for one-fourth, Serbia lags behind.

Having an electricity smart meter (H13A):

1st level: The share of citizens equipped with electricity smart meters is higher in the case of prosumers: 2 out of 5 respondents compared to the proportion 1:5 perceived in the circle of non-adopters of PV systems.

2nd level: Those with PV plans in the near future made advancements in the field of installing electricity smart meters compared to their counterparts.

3rd level: In Norway, more than half disposes of electricity smart meters (salient share of hydroelectricity) *(BP, 2022)*. In the United Kingdom, the ratio of users to total individuals is approximately 1:4. In the remaining countries (IT, UA, and RS), the penetration is rather rudimentary.

Having gas and heating smart meters (H13B and H13C):

The number of definite responses is inferior to the previous question. The use of natural gas in Norway is negligible.

1st and 2nd levels: A higher share of both prosumers and traditional customers with PV plans in the near future benefits from metering than that of the respective less conscious group.

3rd level: Similar phenomena prevail as identified concerning electricity smart meters. Heating smart meters (1. IT, UK, 2. UA, 3. RS) are less common than gas smart meters (1. UK, 2. IT, 3. RS, UA).

Agreeing with negative statements about environmental issues (AGR_NEG_STAT):

1st level: No significant difference can be captured at a significance level of 10% between prosumers and their counterparts not disposing of PV systems when assessing how they can identify themselves with environmental issues.

2nd level: Dividing the latter group into two parts along installation plans in the near future reveals a significant difference. Those with plans occupy a more favourable position with the presumed explanation that not refusing to act manifests itself in conceiving such plans.

3rd level: The comparison between countries led to significant differences for each case. By demonstrating the lowest average and thus the most moderate resistance against participation in environmental actions, Norway ranks number one. It is followed by UK, UA, RS, and IT.

Less energy consumption due to mobility and household appliances (LESS_ENERGY_CONS):

1st level: Prosumers have significantly less energy consumption thanks to environmentally friendly alternatives than citizens without any PV systems.

2nd level: Disposing of installation plans in the near future results in significantly less energy consumption compared to the lack of such intentions.

3rd level: Country-specific dissimilarities prevail: the former members of the Western Bloc (NO, UK) significantly outpace the less developed states (UA, RS).

Agreeing with the inconvenience arising from environmentally friendly measures (AGR_INCONV_EFM):

1st and 2nd levels: Both prosumers and traditional customers with PV plans in the near future show a greater propensity for limitations in city centres for cars causing air pollution or paying higher prices for renewable energy than those without installation plans.

3rd level: Aligning countries according to how their citizens accept the inconvenience connected to environmentally friendly measures results in the order starting with the United Kingdom and Norway. The respondents from Serbia and Ukraine proved to be less supportive proponents of environmentally friendly measures if they bear disadvantages.

Table 2 recapitulates the main test results.

Table 2

Asymptotic independent samples z-tests (extract)

Variable	Mean and p-value of z-test	A) Prosumers	B) Traditional customers	Ba1) With plans in near future	Ba2) Without plans in near future
H1	Mean	1.990	2.408	2.076	2.478
	Sign.	0.000		0.000	
H3	Mean	3.365	3.151	3.121	3.165
	Sign.	0.054		0.239	
H12B	Mean	1.968	2.702	2.271	2.834
	Sign.	0.000		0.000	
H13A	Mean	1.581	1.790	1.717	1.815
	Sign.	0.000		0.000	
H13B	Mean	1.739	1.893	1.815	1.926
	Sign.	0.010		0.000	
H13C	Mean	1.723	1.959	1.922	1.971
	Sign.	0.000		0.000	
AGR_NEG_STAT	Mean	11.525	11.133	10.580	11.249
	Sign.	0.128		0.000	
LESS_ENERGY_CONS	Mean	1.429	0.851	1.113	0.791
	Sign.	0.000		0.000	
AGR_INCONV_EFM	Mean	8.891	9.588	8.895	9.755
	Sign.	0.005		0.000	

Variable	Mean and p-value of z-test	Bb1) Italy	Bb2) Norway	Bb3) Serbia	Bb4) Ukraine	Bb5) United Kingdom
H1	Mean	2.855	2.307	2.249	2.518	2.125
H3	Mean	3.640	3.872	3.025	2.385	2.683
H12B	Mean	2.227	2.308	4.036	2.898	1.986
H13A	Mean	1.882	1.456	1.981	1.952	1.726
H13B	Mean	1.897	..	1.982	1.987	1.771
H13C	Mean	1.918	..	2.000	1.981	1.930
AGR_NEG_STAT	Mean	11.829	10.092	11.645	11.174	10.930
LESS_ENERGY_CONS	Mean	..	1.158	0.554	0.615	1.021
AGR_INCONV_EFM	Mean	..	9.388	9.702	10.213	9.045

Monthly expenditures on electricity (H8A):

The amounts remained in the original currency and were not indexed because of inflation in spite of the circumstance that the survey was conducted between 2016 and 2019.

1st level: This investigation is hindered by low national subsample sizes.

2nd and 3rd levels: By accepting the limitations due to small subsamples (see Table 3), the null hypothesis of equal monthly expenditures on electricity cannot be declined at a significance level of 5%.

Table 3

Average monthly bill for electricity expressed in national currency

Country (currency)	Type	Mean	Std. dev.	Number of cases	z-test	p-value
Italy (EUR)	PV plans	122.94	80.91	32	1.278	0.101
	No plans	104.39	63.46	654		
Norway (NOK)	PV plans	2,167.45	6,257.45	89	1.522	0.064
	No plans	1,149.83	2,636.55	974		
Serbia (RSD)	PV plans	3,888.52	1,458.09	61	0.424	0.336
	No plans	3,805.82	1,735.57	919		
Ukraine (UAH)	PV plans	344.63	449.05	56	1.405	0.080
	No plans	259.13	286.33	826		
United Kingdom (GBP)	PV plans	84.95	158.61	252	1.227	0.110
	No plans	69.71	110.45	224		

Total distance per week expressed in kilometres (TOT_DIST_PER_WEEK):

1st level: Data are not available.

2nd level: The intention to install PV systems in the near future does not significantly influence the total distance travelled per week.

3rd level: Italians travel weekly a total distance of 119.5 kilometres, Norwegians, living in a larger country (IT: 302.1, NO: 323.8 thousand km^2), are significantly more mobile with an additional increment of 42.2 kilometres per week on average *(HCSO, 2022, Table 9.1)*.

Environmentally friendly mobility (ENV_FR_MOB):

1st level: Data are not available.

2nd level: Having PV plans in the near future does not differentiate non-adopters of PV systems with respect to their attitudes in this aspect of mobility.

3rd level: Interestingly, Italian customers ascribe more importance to air quality impact and CO_2 emissions impact when making mobility decisions.

Score of supporting government actions affecting the transportation system (SCORE_TRANS_SYS):

1st level: Data are not available.

2nd level: Disposing of PV plans in the near future does not have any impact on the score.

3rd level: Based on the international comparison, Italians support more intensively related government actions.

Severity of traffic problems (SEV_TRAF_PROB):

1st level: Data are not available.

2nd level: Having PV plans in the near future does not affect the estimation of the severity of traffic problems.

3rd level: Presumably, the Norwegian mentality, attitudes (e.g. being more tolerant) and favourable circumstances (a country with lower population density [16.6 vs. 197.4 person/km^2] and more forests in absolute value [12.180 vs. 9.566 million ha] coupled with fewer passenger cars per thousand inhabitants [544 vs. 670 pieces]) imply that traffic problems such as traffic congestion and noise, the excessive presence of vehicles, local air quality, and global warming are perceived as less severe *(HCSO, 2022, Tables 9.1, 9.26, 9.27)*.

Table 4 contrasts the mobility indicators listed above.

Table 4

Asymptotic independent samples z-tests (extract)

Variable	Mean and p-value of z-test	A) Prosumers	B) Traditional customers	Ba1) With plans in near future	Ba2) Without plans in near future	Bb1) Italy	Bb2) Norway
TOT_DIST_PER_WEEK	Mean	..	146.133	274.245	137.761	119.467	161.703
	Sign.			0.115		0.004	
ENV_FR_MOB	Mean	..	6.680	6.664	6.628	7.539	5.964
	Sign.			0.441		0.000	
SCORE_TRANS_SYS	Mean	..	23.052	23.154	22.972	23.279	22.860
	Sign.			0.342		0.020	
SEV_TRAF_PROB	Mean	..	15.670	14.975	15.589	19.406	12.540
	Sign.			0.105		0.000	

Total number of persons living in the household for at least 6 months of the year (S1):

1st level: There is no significant difference in the size of households between prosumers and non-adopters of PV systems.

2nd level: Contrarily, disposing of PV plans in the near future is a differentiator: those with installation intention have more family members (+0.4 on average).

3rd level: The size of the households is the largest in Serbia and then in Ukraine. As a consequence of demographic tendencies, Western countries (1. UK, NO, 2. IT) have smaller households.

Highest level of completed studies (S2):

1st level: Prosumers attained a higher level of completed studies than non-adopters of PV systems and are the closest to the value 4, i.e. the first stage of tertiary education (bachelor or master).

2nd level: Analogous to this phenomenon, traditional customers with PV plans in the near future are better educated than those without such intentions.

3rd level: The descending order of countries (1. NO, 2. UK, 3. UA, 4. RS, 5. IT) sheds light on significant differences in the share of participants in the education system, primarily in tertiary education. The low average position of both Serbia and Italy corresponds to secondary and post-secondary non-tertiary education. These findings are in accordance with the number of students per ten thousand inhabitants *(HCSO, 2022, Table 9.8)*.

Most typical current employment status (S3):

1st level: The null hypothesis of identical most typical current employment status between prosumers and non-adopters of PV systems cannot be declined, but surprisingly, the mean of the employment status of prosumers is the narrowest to the economically not active categories.

2nd level: In contrast, those with PV plans in the near future are more active than individuals without such intentions.

3rd level: The traditional customers of Serbia demonstrate the most active category, followed by shared rankings: 1. NO, UA, 2. UK, IT.

Year of birth (S4):

1st level: Prosumers were born earlier: at a significance level of 10%, the difference in the average year of birth amounting to 2.6 years can be considered significant.

2nd level: Contrary to the previous direction, traditional customers with installation plans in the near future are 5.2 years younger than those without such intentions.

3rd level: This investigation does not bear relevance.

Gender (S5):

1st level: As 1 denotes male and 2 female customers in the questionnaire, the null hypothesis of equal gender distribution cannot be rejected when differentiating clients along installed PV systems.

2nd level: More men can be found amongst the traditional customers with installation plans in the near future than in the circle of those not intending to establish any PV systems.

3rd level: This investigation does not bear relevance.

Type of area of residence (S6):

1st and 2nd levels: Irrespective of being a prosumer or disposing of plans in the near future as a traditional customer, the type of area of residence cannot be considered as a differentiator. The means can be placed between living outside the centre of a city with more than 0,5 million inhabitants (value of 2) and residing in a town or a city with less than 0,5 million inhabitants (value of 3).

3rd level: Norway and the United Kingdom are the most urbanised countries with an outstanding share of urban population: 83.3% and 84.2% respectively. As value 4 stands for villages, the Serbian mean shifts towards rural settlements, which is confirmed by the fact that 56.7% of the total population lives in cities (UA: 69.8%, IT: 71.3%) *(World Bank, 2023a)*.

Subjective evaluation of current household income (S8):

1st level: In accordance with the financial requirements of PV systems, prosumers evaluate their present income – in spite of subjectivity – more advantageously than non-adopters of PV systems. Even if the value of 2 denotes coping with financing the current standard of living, this fact does not hamper the installation.

2nd level: The same statement relates to the interrelationship between traditional customers with installation plans and those without such intentions.

3rd level: In the case of the international comparison (1. NO, 2. IT, 3. UK, 4. RS, 5. UA) of non-adopters of PV systems, the accruals in the mean hint at emerging difficulties when financing the current standard of living. The indicator of GDP per capita basically underpins the previous order of the countries: 1. NO, 2. UK, 3. IT, 4. RS, 5. UA *(World Bank, 2023b)*.

Table 5 provides an overview of socio-economic characteristics.

Table 5

Asymptotic independent samples z-tests (extract)

Vari-able	Mean and Sign. of z-test	A) Prosu-mers	B) Tradi-tional custo-mers	Ba1) With plans in near future	Ba2) Without plans in near future	Bb1) Italy	Bb2) Norway	Bb3) Serbia	Bb4) Ukraine	Bb5) United Kingdom
S1	Mean	2.907	2.723	3.064	2.706	2.425	2.575	3.168	2.822	2.650
	Sign.	0.187		0.000						
S2	Mean	3.696	3.296	3.500	3.263	3.016	3.613	3.070	3.297	3.433
	Sign.	0.000		0.000						
S3	Mean	2.826	2.597	2.351	2.592	2.753	2.552	2.352	2.601	2.746
	Sign.	0.108		0.001						
S4	Mean	1966.7	1969.3	1973.6	1968.4					
	Sign.	0.077		0.000						
S5	Mean	1.505	1.548	1.470	1.558					
	Sign.	0.203		0.000						
S6	Mean	2.638	2.757	2.782	2.770	2.851	2.424	3.132	2.763	2.681
	Sign.	0.166		0.410						
S8	Mean	1.957	2.288	2.192	2.314	2.095	1.821	2.382	3.034	2.175
	Sign.	0.000		0.001						

RQ2: At a significance level of 10%, prosumers prioritised formal information channels when obtaining information about PV systems. Installation with the purpose of affordable own energy and other (non-environmental and non-technological) reasons dominates, followed by environmental reasons. Technological reasons were the least frequently enumerated. Table 6 highlights the main results. The distribution of the variable P1 confirms the outstanding role of financial reasons: 64 of 97 respondents sell surplus PV electricity via the public electricity grid. Although the share of sellers deviates from country to country, the low sample sizes do not render it possible to test assumed dissimilarities.

Table 6

Asymptotic independent samples z-tests, 97 prosumers

Variable	Mean	Std. dev.	Number of cases	z-test	p-value
FORM_INF_PV_SYS (y_1)	0.74	0.57	80	(H_1: $y_1 > y_2$) 1.55	0.060
INFORM_INF_PV_SYS (y_2)	0.59	0.65	80		
FIN_OTH_REASON (y_3)	1.04	0.63	84	(H_1: $y_3 > y_4$) 5.47	0.000
ENV_REASON (y_4)	0.51	0.61	84	(H_1: $y_4 > y_5$) 3.38	0.000
TECH_REASON (y_5)	0.23	0.47	84		

Analogous to the previous findings, the descending order of importance of installation reasons begins with affordable own energy and other (non-environmental and non-technological) motives, with a distinct difference were evaluated environmental benefits in the circle of traditional customers with PV plans in the near future. Technological reasons as less relevant influencers close the comparison as outlined in Table 7.

Table 7

Asymptotic independent samples z-tests, 579 traditional customers with PV plans in the near future

Variable	Mean	Std. dev.	Number of cases	z-test	p-value
AGR_FIN_OTH_REASON (y_1)	8.47	1.86	559	(H_1: y_1>y_2) 12.41	0.000
AGR_ENV_REASON (y_2)	7.09	1.81	537	(H_1: y_2>y_3) 4.19	0.000
AGR_TECH_REASON (y_3)	6.57	2.22	550		

RQ3: To test the assumption that routines for own energy conservation actions influence the opinion about why others do not participate in saving electricity, cross-tabulation analysis was carried out by relying on two ordinal variables. The first variable, i.e. the number of routines for own energy conservation actions (ROUT_ENER_CONS_ACT) encompasses checking rooms before leaving the home, switching lights off before leaving rooms, and unplugging electronic appliances after use. Hence, it ranges from 0 to 3. The higher the value is, the more environmentally conscious the customer is. These routines were considered equivalent when summing them. The second variable, the score given to estimate the factors detaining other people from saving electricity (DET_OTH_SAV_ELEC) attempts to quantify the perception of individuals regarding how they judge mainstream practices. To create an ordinal variable, the interrogated factors were assumed to be weighted identically and classified into three categories: 4–9, 10–15, and 16–20 points. The lower the score is, the better the judgement corresponds to reality as the members of the European Union achieved advancements in energy efficiency, moving towards a higher share of renewable energy, and reducing greenhouse gas emissions *(European Commission, 2021)*. Tables 8 and 9 recapitulate the observed cases via cross-tabulation. The expected count is at least 5 for each cell in both tables.

Table 8

Contingency table of Serbia

	Count	DET_OTH_SAV_ELEC (grouped)			Total
		4–9	10–15	16–20	
ROUT_ENER_CONS_ACT	0	13	117	85	215
	1	17	109	58	184
	2	43	151	81	275
	3	43	171	112	326
	Total	116	548	336	1,000

Table 9

Contingency table of the United Kingdom

	Count	DET_OTH_SAV_ELEC (grouped)			Total
		4–9	10–15	16–20	
ROUT_ENER_CONS_ACT	0	13	63	26	102
	1	19	196	80	295
	2	14	206	122	342
	3	5	155	116	276
	Total	51	620	344	1,015

In the case of assigning customers to 3 categories regarding the variable DET_OTH_SAV_ELEC, the country-specific cross-tabulation analyses confirm the dependence of the variables at the country level. The results of the chi-square tests are shown in Table 10.

Table 10

Tests of independence

Country	Test statistic	p-value
Serbia	16.121	0.013
United Kingdom	33.897	Less than 0.001

The null hypothesis of independence can be rejected at the commonly used significance levels in both cases. The strength of the association between the two ordinal variables was characterised by both symmetric and directional measures. The latter investigation rests on the assumption that the nature of the interrelationship between the two variables is one-sided: the number of own routines may impact how the behaviour of others is perceived. For this reason, the directional measure was computed by choosing the score (DET_OTH_SAV_ELEC) as the dependent variable.

At the significance level of 5%, the Serbian indicators describe a zero association between the score given to estimate the factors detaining others from saving electricity and the number of routines for own energy conservation actions. This special situation corresponds to the case where the variables are not independent but the correlation between them is close to zero.

If the significance level is set to 10%, both symmetric and directional measures underpin a non-zero association for each country. The rationale behind a negative association is that, on the one hand, the more environmentally conscious the customer is, the more routines for own energy conservation actions can be observed. On the other hand, increasing consciousness would imply better and up-to-date information about recent progress, which would result in lower scores given to estimating the circumstances under which others refuse to save electricity. Correspondingly, Serbia demonstrates a weak negative association. Interestingly, a stronger contradictory positive association can be captured in the United Kingdom. Table 11 details the selected indicators of association.

Table 11

Ordinal by ordinal measures

Measures	Serbia		United Kingdom	
	Value, %	p-value	Value, %	p-value
Kendall's tau-b	–5.29	0.056	+14.31	0.000
Kendall's tau-c	–5.16	0.056	+12.98	0.000
Gamma	–8.14	0.056	+23.51	0.000
Spearman correlation	–5.94	0.061	+15.80	0.000
Somers' d symmetric	–5.25	0.056	+14.10	0.000
Somers' d directional	–4.66	0.056	+12.06	0.000

The survey encompassed the section on prosumers in addition to electricity in both Serbia and Albion. This enables us to explore the interrelationships between the next triad of variables: (i) planned PV installation in the near future, (ii) the number of routines for own energy conservation actions, and (iii) the opinion about why other people omit to save electricity. By ascribing more environmental awareness to customers pondering installing a PV system at their homes, three hypotheses were formulated.

Hypothesis (1): Customers with PV installation plans demonstrate a stronger negative association between the number of routines for own energy conservation actions and the score given to estimate the factors detaining others from saving electricity than their counterparts without such intentions.

Result: Country-specific scrutiny is not ensured as the requirement of at least 5 expected counts is not met. Even the merged sample of traditional customers with PV plans produces 1 cell with an expected count of less than 5 (exact value: 2.54).

Dividing customers of the merged sample into two groups based on whether they are planning a PV installation in the near future elucidates that none of the null hypotheses of independence can be rejected. None of the subsamples confirms the presumed negative association between the number of routines for own energy conservation actions and the score given to others' passive behaviour concerning saving electricity.

Hypothesis (2): Customers with PV installation plans have more routines for own energy conservation actions than their counterparts without PV installation intention.

Result: At a significance level of 5%, both the test of independence and the symmetric measures suggest independence for Serbia and a weak negative association for the United Kingdom.

Hypothesis (3): Customers with PV installation plans are more able to evaluate the factors detaining other people from saving electricity with fewer scores; thus, their opinion is closer to reality.

Result: At a significance level of 5%, Serbia can be characterised by independence and Albion by a weak negative association.

Tables 12 and 13 indicate the results of the chi-square tests and concomitant indicators.

Table 12

Tests of independence

Denomination	Hypothesis (1)		Hypothesis (2)		Hypothesis (3)	
	PV plans	No plans	Serbia	UK	Serbia	UK
Number of records	394	1,244	985	653	985	653
Test statistic	7.994	9.197	0.747	18.389	2.864	8.149
Degrees of freedom	6	6	3	3	2	2
p-value	0.239	0.163	0.862	0.000	0.239	0.017

Table 13

Ordinal by ordinal measures, United Kingdom

Symmetric measures	Hypothesis (2)		Hypothesis (3)	
	Value	p-value	Value	p-value
Kendall's tau-b	–0.142	0.000	–0.109	0.004
Kendall's tau-c	–0.171	0.000	–0.110	0.004
Gamma	–0.235	0.000	–0.214	0.004
Spearman correlation	–0.154	0.000	–0.112	0.004
Somers' d symmetric	–0.140	0.000	–0.109	0.004

4. Discussion

RQ1: As an alternative approach, logistic regression was applied by opting for the forward stepwise method based on conditional statistics. Prior to the runs, the presence of multicollinearity was controlled based on two statistics coupled with linear regression: tolerance and its reciprocal, i.e. the variance inflation factor. Entering 13 predictors (H1, H3, H12B, H13A, AGR_NEG_STAT, AGR_INCONV_EFM, S1, S2, S3, age in 2019 /calculated as calendar year difference: 2019-S4/, S5, S6, S8) into the model resulted in diagnosing collinearity in the cases of H1 and H3. The absolute value of the Pearson correlation exceeds 0.2 in the interaction of H1 with S6 and H3; in addition, the same applies to the relation between H3 and S1, S6, and S8. For this reason, both the type of building and the floor area were removed from the model. Concerning adopters of PV systems, the total correct classification rate is approximately 97.7%; however, the partial correct classification rate related to prosumers remains below 3%. As a consequence, this model cannot be considered apt for predicting prosumers. Regarding having PV plans in the near future in the circle of traditional customers, a similar undesirable outcome occurred. Despite the salient partial correct classification rate (i.e. specificity) related to not having PV plans, the slight true positive rate (i.e. sensitivity) denotes that this model cannot be used for prediction.

Table 14

Beta coefficients and significance levels of Wald tests

Variables	Prosumers		Traditional customers					
	Run 1		Run 2		Run 3		Run 4	
	beta	p-value	beta	p-value	beta	p-value	beta	p-value
S1 [household size]	0.2108	0.012	0.0814	0.034	0.1156	0.001	0.1063	0.002
S2 [education]	0.8504	0.000	0.2163	0.029	0.3178	0.000	0.2938	0.000
age_2019	0.0327	0.001	–0.0157	0.000	–0.0107	0.002	–0.0114	0.001
S5 [gender]	–	–	–0.3621	0.003	–0.4226	0.000	–0.4217	0.000
S6 [area of residence]	–	–	0.1185	0.014	0.1154	0.010	0.1096	0.013
H12B [energy efficient bulbs]	–0.3494	0.008	–0.3406	0.000	–0.2422	0.000	–0.2428	0.000
AGR_NEG_STAT	0.1178	0.029	–	–	–0.0751	0.001	–0.0784	0.000
AGR_INCONV_EFM	–	–	–0.1419	0.000	–	–	–	–
H13A [electricity smart meter]	–1.0825	0.000	–0.3599	0.010	–0.4117	0.001	–0.4223	0.000
Constant	–7.8094	0.000	1.2783	0.045	–0.2197	0.705	–	–
Number of cases	3,206		2,707		3,119		3,119	
Maximum correct classification rate, %	97.70		83.50		85.80		85.80	
Cut value or its range	0.26–0.32		0.45		0.4		0.47–0.48	

Table 14 summarises the regression parameters and significance levels of the logistic regression in a comparative way. Both runs 3 and 4 contain the restriction of excluding AGR_INCONV_EFM for the sake of a larger sample size, whereas run 4 tests the impact of eliminating the constant compared to run 3. The results partly confirm the significance of the explanatory variables arising from the asymptotic independent samples z-tests.

Likewise, *Ropuszynska-Surma–Weglarz (2018, pp. 18–19)* concluded – without indicating any correct classification rates – from their logit models that there are significant relationships between becoming a prosumer and many attributes as listed below (the findings of the present study are added in parentheses):

a) gender (partly confirmed in the sense that more men can be found amongst the traditional customers with PV plans than in the group without such intentions),
b) age (entirely confirmed: at a significance level of 10%, prosumers are older than non-adopters of PV systems, and traditional customers with installation plans in the near future are younger than their counterparts not having any plans),
c) total number of persons living in the household (partly confirmed: those with PV plans have on average 0.4 more family members than those without such plans),
d) type of building (entirely confirmed: significant difference in favour of prosumers and those with PV plans),
e) floor area (at a significance level of 5%, no significant difference exists),
f) type of education (entirely confirmed: significant difference in favour of prosumers and those with PV plans),
g) knowing energy tariff (incomparable with the respective questions E1 and E2 of the survey in the section on electricity),
h) sorting rubbish (it is not investigated in the survey),
i) washing or ironing at particular times (it is not investigated in the survey),
j) switching off electronic equipment just after using them (missing values in the cells E6A3 and E6A4 as part of ROUT_ENER_CONS_ACT do not enable any underpinned comparison),
k) using LEDs (entirely confirmed: prosumers reached a higher proportion of energy-efficient bulbs inside homes than non-adopters of PV systems, and the same applies to the context between traditional customers with PV plans and without plans),
l) installing energy-saving household appliances (entirely confirmed: significant difference in favour of prosumers and those with PV plans, this statement refers to both LESS_ENERGY_CONS and its part, i.e. G1A3).

Nonetheless, the co-authors stated that the variables below proved to be irrelevant when deciding about a PV installation:

a) monthly average net income (refuted: significant difference in favour of prosumers and those with PV plans),
b) monthly expenditures on electricity (confirmed: at a significance level of 5%, no significant difference exists)
c) changing the provider (refuted based on G1A4: the probability of switching in the case of prosumers: 18/97=18.56%, those with PV plans: 70/579=12.09%, those without such intentions: 34/3868=0.88%),
d) having a smart meter (refuted if it is interpreted as disposing of electricity smart meter: significant difference in favour of prosumers and those with PV plans).

The proposal of *Standal et al. (2020, p. 8)* to involve various gender aspects when designing new policies can be confirmed merely for the preparatory phase. The share of men is higher in the circle of customers taking an affirmative stance on PV plans in the near future than in the group without such intentions.

Rataj et al. (2021, p. 13) discerned an oppositional prosumer's profile. They described the typical target persons of retail PV systems as individuals prior to retirement, being members of households with low income and residing in rural municipalities that are situated in regions affected by unemployment. Additionally, opting for the installation is propelled by subsidies and the price level of energy bills; however, it depends neither on local insolation nor on environmental pollution.

Rausch–Suchanek (2021, pp. 7–8), Wicki et al. (2022, p. 13), and *Kettner et al. (2022, p. 629)* shed light on the empirical fact that the income of households is one of the major determinants of the penetration of residential PV installations. In addition, the characteristics of the dwelling qualified as influencers in the case of the last trio of researchers.

In accordance with the articles above, *Hansen et al. (2022, p. 9)* underlined the role of economic resources and technical competences of households (the latter by virtue of technically educated men) perceived on the example of early adopters in the course of the diffusion of photovoltaics. *Schwanitz et al. (2022, pp. 22–23)* mentioned both low saving rates and restrained engagement of households as barriers and educational background as one of the enablers.

RQ2: Compared to environmental and technological reasons, the present study found the preponderance of other (e.g. financial) motivators. Furthermore, formal information channels (one-sided p-value: 6.01%) are preferred when collecting information about PV systems. Without distinguishing between formal and informal information channels in detail, *Karjalainen–Ahvenniemi (2019, p. 51)* alluded to the importance of trustworthy information stemming from both prosumers and experts. In view of the recommendations of *Kotilainen–Saari (2018, p. 18),* consumers can be actuated by both economic and non-economic policies in turning them into prosumers by ascribing more potential to non-economic policies. *Palm (2018, pp. 7–8)* split Swedish prosumers into two parts. The first wave of residential PV installations (2008–2009) was driven mainly by environmental reasons. The situation changed during the second wave (2014–2016) when economic reasons predominated. In addition to environmental and economic motives, *Mularczyk et al. (2022, pp. 8–10)* identified the ease of use of technology as influencer, while social dimensions did not impact the decision about PV investment. Analogous to the present research, *Zdonek et al. (2022, pp. 7–8)* concluded that ecological factors fell behind economic ones (e.g. minimising the electricity costs). Likewise, *Hansen et al. (2022, p. 9)* accentuated financial gains and independence from suppliers when investigating the background of early adopters' decisions. *Schwanitz et al. (2022, p. 23)* pointed out that the deficiency of or the dominated status of post-material values (incl. environmental ones) and limited governmental support work as impediments.

RQ3: Asymptotic independent samples z-tests enable us to validate the findings.

Hypothesis (2): The United Kingdom confirms that those considering installing a PV system at their home in the near future have significantly more routines for own energy conservation actions than their counterparts without such intentions. Although the Serbian subsample consisting of customers with PV installation plans cannot be considered as a large sample (only 61 individuals), the practices of Serbian customers suggest no significant differences in the number of routines.

Hypothesis (3): Albion refutes the hypothesis that those considering installing a PV system at their home in the near future are aware of recent advancements in the fields of the expansion of energy efficiency, residual use of renewable energy, and abatement of greenhouse gas emissions. British customers with PV plans overestimate others' passive attitudes, i.e. the lack of inclination to save electricity more than those without such intentions. In the case of Serbia, the difference is not significant.

The results are presented in Table 15.

Table 15

Asymptotic independent samples z-tests

Country	Type	Mean [(2) routines, (3) scores]	Std. dev.	Number of cases	z-test	p-value
Hypothesis (2)						
Serbia	PV plans	1.59	1.15	61	0.83	0.204
	No plans	1.72	1.14	924		
United Kingdom	PV plans	1.92	0.92	333	4.11	0.000
	No plans	1.62	1.00	320		
Hypothesis (3)						
Serbia	PV plans	13.54	3.70	61	0.80	0.212
	No plans	13.93	3.59	924		
United Kingdom	PV plans	14.48	2.96	333	3.02	0.001
	No plans	13.73	3.35	320		

Pothitou et al. (2016, p. 1226) pointed to a positive relationship between propensity for pro-environmental behaviour and actions to reduce energy use. Knowledge about greenhouse gas emissions and energy savings is a major determinant of the number of activities related to reducing energy consumption. This is in line with Hypothesis (2): having PV plans in the near future entails more routines. However, seeking for any preceding research to buttress the findings of Hypotheses (1) and (3) proved to be a vain attempt.

5. Conclusion, limitations, and further research

RQ1: The analysis revealed conclusions in the context between prosumers and traditional customers, as well as between traditional customers with PV plans in the near future and those without such intentions. The respective more conscious group is better educated and has a more stable financial background. Its members achieved a higher proportion of energy-efficient bulbs inside their homes, which are on average single-family houses attached to building(s). These dwellings are more likely to be equipped with smart meters. They consume less energy thanks to environmentally friendly alternatives and agree more strongly with the inconvenience arising from eco-friendly measures. In addition, traditional customers with PV plans have a larger family, demonstrate a higher share of men and more commitment to environmental issues, and are younger and economically more active than their counterparts without plans. This study identified phenomena with distinctive dissimilarities between Western and Eastern states in the aspects of size and current income of the household, use of energy efficient bulbs and smart meters, less energy consumption due to mobility and household appliances, and accepting the inconvenience coupled with environmentally friendly measures. Furthermore, the comparison between Norway and Italy pointed to significant country-specificities regarding the weekly total travelled distance, opting for environmentally friendly mobility, supporting government actions affecting the transportation system, and estimating the severity of traffic problems.

RQ2: Prosumers prioritise formal information channels (one-sided p-value: 6.01%) when acquiring information about PV systems. Both in the circle of prosumers and those with PV plans in the near future, technological reasons are the least motivating drivers of installation, followed by environmental and finally by other (e.g. financial) motives.

RQ3: (i) Serbia demonstrates a weak negative (one-sided p-value: 6%), whereas the United Kingdom demonstrates a stronger contradictory positive association between the number of routines for own energy conservation actions and the evaluation of factors detaining other people from saving electricity. These two variables proved to be independent when distinguishing traditional customers along having PV plans in the near future on the merged dataset of the two states. (ii) British individuals with PV plans have more routines for energy savings and overestimate others' passive attitudes more than citizens without such intentions. In Serbia, the dissimilarities are not significant.

Limitations and future research:

The results have some limitations. The first is engendered by the missing values represented by the 'Do not know' or 'Did not answer/No answer/Refuse to answer' or 'Not applicable' records in the dataset. Second, deviations from the predefined set of values could be observed sporadically. Records were excluded pairwise to mitigate these problems. Third, Table 1 foreshadowed a limitation with respect to the sections. Selecting the countries appropriate for analysing the attitudes of prosumers designated and restricted the framework of related scrutiny. In a few cases, the prerequisites of the applied methods could not be entirely met, e.g. owing to the small size of the subsample.

Future research may unveil the interrelatedness between dimensions of consumer behaviour related to the section on mobility.

Bolstering the spread of photovoltaics may strengthen the resilience and competitiveness of the economy in tandem with a thriving society (e.g. improving well-being through higher healthy life expectancy, reducing inequalities, unfolding knowledge-based society) and restoring the integrity of ecosystems by tackling both climate change and air pollution. By applying a more human- and nature-centred approach when accomplishing the SDGs, countries have the opportunity to evolve into climate champions by reducing environmental load, dedicating substantial roles to individuals, setting up a fruitful national innovation bedrock and establishing new science-based industries as general catalysts, undergoing a transformation process associated with sustainable production and consumption patterns, plus decent economic growth. Post-war history proved that a rapid catch-up to the most developed countries and taking the lead afterwards is realisable by allocating and utilising resources purposefully and relying on the innovation regime as propelling mainspring hauling the whole institutional setting. Prosumerism is an illustrative example of how new flagships can be introduced by recognising the potential of alternative energy sources, integrating the industry of green technologies into the innovation regime, and harvesting an abundance of gains *(Hübner, 2019, p. 207)*.

Acknowledgements

The author is grateful for the valuable remarks and impulses provided by Gábor Harangozó (Corvinus University of Budapest).

References

Bild der Wissenschaft (2019): Vol. September.

Gissey, G. – Zakeri, B. – Dodds, P. – Subkhankulova, D. (2021): Evaluating consumer investments in distributed energy technologies. *Energy Policy.*Vol. 149. pp. 1–12. https://doi.org/10.1016/j.enpol.2020.112008

Guzman, L. – Henao, A. (2022): Are the current incentives sufficient to drive the use of solar PV in the Colombian residential sector? - An analysis from the perspective of the game theory. *Energy Strategy Reviews.* Vol. 40. pp. 1–16. https://doi.org/10.1016/j.esr.2022.100816

Hansen, A. – Jacobsen, M. – Gram-Hanssen, K. (2022): Characterizing the Danish energy prosumer: Who buys solar PV systems and why do they buy them? *Ecological Economics.* Vol. 193. pp. 1–10. https://doi.org/10.1016/j.ecolecon.2021.107333

HCSO (Hungarian Central Statistical Office) (2022): *Statistical Yearbook of Hungary, 2021*. Budapest.

Hübner, K. (ed.) (2019): *National Pathways to Low Carbon Emission Economies*. Abingdon and New York. Routledge. https://doi.org/10.4324/9780429458118

Hunyadi, L. – Mundruczó, G. – Vita, L. (2000): *Statisztika*. Budapest. Aula.

Inderberg, T. H. – Tews, K. – Turner, B. (2018): Is there a Prosumer Pathway? Exploring household solar energy development in Germany, Norway, and the United Kingdom. *Energy Research & Social Science*. Vol. 42. pp. 258–269. https://doi.org/10.1016/j.erss.2018.04.006

Karjalainen, S. – Ahvenniemi, H. (2019): Pleasure is the profit – The adoption of solar PV systems by households in Finland. *Renewable Energy*. Vol. 133. pp. 44–52. https://doi.org/10.1016/j.renene.2018.10.011

Kettner, C. – Kratena, K. – Sommer, M. (2022): The socio-economic impact of renewable electricity generation with prosumer activity. *Elektrotechnik und Informationstechnik*. Vol. 139. pp. 624–631. https://doi.org/10.1007/s00502-022-01072-7

Kotilainen, K. – Saari, U. (2018): Policy Influence on Consumers' Evolution into Prosumers - Empirical Findings from an Exploratory Survey in Europe. *Sustainability*. Vol. 10. No. 1. pp. 1–22. https://doi.org/10.3390/su10010186

Kovács, E. (2014): *Többváltozós adatelemzés*. Typotex. https://edit.elte.hu/xmlui/bitstream/10831/31150/1/14_KOVACS_E_Tobbvalt_adatelemzes.pdf

Mularczyk, A. – Zdonek, I. – Turek, M. – Tokarski, S. (2022): Intentions to Use Prosumer Photovoltaic Technology in Poland. *Energies*. Vol. 15. No. 17. pp. 1–15. https://doi.org/10.3390/en15176300

Niekurzak, M. – Kubińska-Jabcoń, E. (2021): Analysis of the Return on Investment in Solar Collectors on the Example of a Household: The Case of Poland. *Frontiers in Energy Research*. Vol. 9. pp. 1–12. https://doi.org/10.3389/fenrg.2021.660140

Olczak, P. – Zelazna, A. – Matuszewska, D. – Olek, M. (2021): The My Electricity Program as One of the Ways to Reduce CO_2 Emissions in Poland. *Energies*. Vol. 14. No. 22. pp. 1–17. https://doi.org/10.3390/en14227679

Palm, J. (2018): Household installation of solar panels – Motives and barriers in a 10-year perspective. *Energy Policy*. Vol. 113. pp. 1–8. https://doi.org/10.1016/j.enpol.2017.10.047

Panos, E. – Margelou, S. (2020): Long-Term Solar Photovoltaics Penetration in Single- and Two-Family Houses in Switzerland. *Energies*. Vol. 12. No. 13. pp. 1–9. https://doi.org/10.3390/en12132460

Petrichenko, L. – Sauhats, A. – Diahovchenko, I. – Segeda, I. (2022): Economic Viability of Energy Communities versus Distributed Prosumers. *Sustainability*. Vol. 14. No. 8. pp. 1–24. https://doi.org/10.3390/su14084634

Pothitou, M. – Hanna, R. – Chalvatzis, K. (2016): Environmental knowledge, pro-environmental behaviour and energy savings in households: An empirical study. *Applied Energy*. Vol. 184. pp. 1217–1229. https://doi.org/10.1016/j.apenergy.2016.06.017

Rataj, M. – Berniak-Woźny, J. – Plebańska, M. (2021): Poland as the EU Leader in Terms of Photovoltaic Market Growth Dynamics - Behind the Scenes. *Energies*. Vol. 14. No. 21. pp. 1–19. https://doi.org/10.3390/en14216987

Rausch, P. – Suchanek, M. (2021): Socioeconomic Factors Influencing the Prosumer's Investment Decision on Solar Power. *Energies*. Vol. 14. No. 21. pp. 1–10. https://doi.org/10.3390/en14217154

Ritzel, C. – Mann, S. – van Zyl-Bulitta, V. (2022): Prosuming Alone or Together: A Bisectoral Approach to Conceptualizing the Commons Prosumer. *International Journal of the Commons*. Vol. 16. No. 1. pp. 295–309. http://doi.org/10.5334/ijc.1185

Ropuszynska-Surma, E. – Weglarz, M. (2018): Profiling End User of Renewable Energy Sources among Residential Consumers in Poland. *Sustainability*. Vol. 10. No. 12. pp. 1–21. https://doi.org/10.3390/su10124452

Schwanitz, V. – Rudek, T. – Hubert, W. – Wierling, A. (2022): The Development of Citizen-Installed Renewable Energy Capacities in Former Eastern Bloc Countries - The Case of Poland. *Energies*. Vol. 15. No. 7. pp. 1–29. https://doi.org/10.3390/en15072597

Standal, K. – Talevi, M. – Westskog, H. (2020): Engaging men and women in energy production in Norway and the United Kingdom: The significance of social practices and gender relations. *Energy Research & Social Science*. Vol. 60. pp. 1–9. https://doi.org/10.1016/j.erss.2019.101338

Szelag-Sikora, A. – Sikora, J. – Niemiec, M. – Grodek-Szostak, Z. – Suder, M. – Kubon, M. – Borkowski, T. – Malik, G. (2021): Solar Power: Stellar Profit or Astronomic Cost? A Case Study of Photovoltaic Installations under Poland's National Prosumer Policy in 2016–2020. *Energies*. Vol. 14. No. 14. pp. 1–17. https://doi.org/10.3390/en14144233

Szüle, B. (2016): *Introduction to data analysis.* Budapest. Corvinus University of Budapest. Faculty of Economics. http://unipub.lib.uni-corvinus.hu/2317/1/Introduction_to_data_analysis.pdf
Wicki, L. – Pietrzykowski, R. – Kusz, D. (2022): Factors Determining the Development of Prosumer Photovoltaic Installations in Poland. *Energies*. Vol. 15. No. 16. pp. 1–19. https://doi.org/10.3390/en15165897
Wittmayer, J. – Campos, I. – Avelino, F. – Brown, D. – Doracic, B. – Fraaije, M. – Gährs, S. – Hinsch, A. – Assalini, S. – Becker, T. – Marín-González, E. – Holstenkamp, L. – Bedoic, R. – Duic, N. – Oxenaar, S. – Puksec, T. (2022): Thinking, doing, organising: Prefiguring just and sustainable energy systems via collective prosumer ecosystems in Europe. *Energy Research & Social Science*. Vol. 86. pp. 1–13. https://doi.org/10.1016/j.erss.2021.102425
Xia-Bauer, C. – Vondung, F. – Thomas, S. – Moser, R. (2022): Business Model Innovations for Renewable Energy Prosumer Development in Germany. *Sustainability*. Vol. 14. No. 13. pp. 1–17. https://doi.org/10.3390/su14137545
Zdonek, I. – Tokarski, S. – Mularczyk, A. – Turek, M. (2022): Evaluation of the Program Subsidizing Prosumer Photovoltaic Sources in Poland. *Energies*. Vol. 15. No. 3. pp. 1–23. https://doi.org/10.3390/en15030846
Zimmermannová, J. – Pawliczek, A. – Čermák, P. (2018): Public Support of Solar Electricity and its Impact on Households - Prosumers. *Organizacija*. Vol. 51. No. 1. pp. 4–19. https://doi.org/10.2478/orga-2018-0001

Internet references

BP (2022): *Statistical Review of World Energy*. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/xlsx/energy-economics/statistical-review/bp-stats-review-2022-all-data.xlsx
ENABLE.EU team (2019): *Households survey questionnaire.* http://www.enable-eu.com/wp-content/uploads/2019/10/enable_eu_dataset_households.zip
European Commission (2021): *Progress made in cutting emissions*. https://climate.ec.europa.eu/eu-action/climate-strategies-targets/progress-made-cutting-emissions_en
HCSO (2023): *15.1.1.18. Emissions of air pollutants and greenhouse gases*. https://www.ksh.hu/stadat_files/kor/en/kor0017.html
United Nations (2015): *A/RES/70/1 Transforming our world: the 2030 Agenda for Sustainable Development.* https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf
United Nations (2023): *The Paris Agreement*. https://www.un.org/en/climatechange/paris-agreement
World Bank (2023a): *Urban population (% of total population).* https://api.worldbank.org/v2/en/indicator/SP.URB.TOTL.IN.ZS?downloadformat=excel
World Bank (2023b): *GDP per capita (current US$).* https://api.worldbank.org/v2/en/indicator/NY.GDP.PCAP.CD?downloadformat=excel
World Economic Forum (2023): *Why the response to the energy crisis must embrace an accelerated and balanced transition.* https://www.weforum.org/agenda/2023/01/davos23-response-to-energy-crisis-must-embrace-accelerated-balanced-transition/