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Survey on residential rooftop solar power systems in Hungary

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Abstract.

Hungary has seen rapid growth in residential rooftop photovoltaic (PV) systems, with installations reaching 2.65 GW – over 35% of the country's total PV capacity in 2023. However, detailed data on system characteristics and prosumer behaviour remain unknown. This study presents preliminary results from a 2025 survey assessing residential PV sizing, orientation, and electricity consumption. Results indicate that most PV systems were sized for an annual net-zero energy balance under the net billing scheme, with a median generation-to-demand ratio (GTDR) of 1.06. About 40% of systems have multiple orientations, with a shift toward west-facing panels to enhance self-consumption. PV owners consume nearly three times the national household average, with high adoption of heat pumps (83%) and electric vehicles (25%). These findings support policy recommendations for the transition from net billing to net metering and provide data for grid integration planning and national-scale PV modelling.

Key words. Photovoltaic, survey, load matching, rooftop solar

1. Introduction

In recent years, photovoltaic (PV) power systems have continued to spread across Europe. Hungary is among the European frontrunners, having more than 20% of its electricity generation from PV in 2023 [1]. The exponential growth in installed PV capacity over the years has led to a revision of national targets, now aiming for double the originally planned capacity – 12 GW by 2030. Residential PV systems play a key role in this expansion, contributing 2.65 GW, more than 35% of the currently installed 7.55 GW capacity [2]. Despite their growing presence, knowledge about these systems remains limited.
While assumptions can be made for the photovoltaic system sizes, especially in the case of net metering tariff schemes, when most probably, systems are sized to fulfil the electricity demand of the buildings on an annual level, creating Net Zero Energy Buildings (NZEBs), there is a lack of justification data on how systems sized. As PV system size compared to the consumption of the building is a key factor in load matching indicator (LMI) calculation, this leads to the lack of knowledge of on the load matching of these buildings as well.
The lack of comprehensive data and appropriate legislation has led to the emergence of blocked districts, where further PV connections, with grid feedback are restricted now [3]. These restricted areas are one of the most pressing issues in the Hungarian energy sector. Resolving this challenge requires well-informed policies and action plans, which can be supported by collecting simple yet essential data on residential PV systems.

This paper presents the findings of a survey conducted to gain a better understanding of Hungarian residential PV systems. The key focus areas and preliminary results are outlined, providing insights into various aspects of these systems. Once the survey reaches a representative sample size, the results will help answer multiple questions, including (but not limited to) system orientation and sizing, primary sources of electricity consumption, the level of household electrification, housing typologies, and self-consumption rates of residential PV systems. Based on these findings, recommendations for policy actions and potential improvements can be formulated in the future [4].

2. Survey Design and Methodology

A. Main objectives

The paper draws on the data of a survey carried out at the beginning of 2025. While the actual size of the national residential systems is publicly available, other key factors influencing direct on-site utilization of PV systems are missing. The main objectives of the survey are:

- justifying that national residential PV systems were sized to generate as much electricity over the year as they consume, as a result of the net billing scheme,
- revealing the orientations of residential PV systems,
- quantifying electricity consumption and
- detection of typical consumer appliances of PV owners.

B. Design of the survey

The survey was designed to be interpretable and understandable for both non-professionals and any levels of experts. Wide range of questions are supported with graphical illustrations (like example bills, example tilt angles etc.) and descriptions for each question. The question types were chosen to facilitate easier completion while still obtaining the required precision of data for each question. Where applicable, branching was used to ease filling and ensure data clarity.

1) Numeric input questions:

Numeric input questions were used at the places where the users most often know exact values. This included the sizing of the systems (module and inverter capacity), electricity consumption data (from existing bills, grid extracted energy and surplus fed back to grid), PV yield data (supported by materials where owners can find such information), and usage data of large consumers, such as electric water heater, heat pump and electric vehicle (if metered on a separate meter).

2) Multiple choice questions

Multiple-choice questions were used in two main cases. Firstly, where numerical inputs were expected to cause false data, or were considered too challenging to the open public. For example, in the case of tilt and azimuth angles, where instead, a single-answer, a multiple-choice approach was used. In this case, PV systems were categorized into ranges by their orientation. While data is categorical in this case, the approach could be sufficient, for example, for load-matching indicator calculations [5].
Multiple answer multiple-choice questions (with user-provided extensions of categories) were used mainly for searching patterns about household appliances and their usage.

C. Sampling and data collection

The survey is administrated via Google Forms. As there are no publicly available database on contact information of residential rooftop solar owners, one of the most challenging parts of the survey is to find appropriate channels to prosumers. Therefore, multiple platforms for advertising the questionnaire were used, including social media, leaflets, workplace forums (especially with some related fields) and articles.
Verification of representativeness will be based on three key pillars: the number of fill-ins, the nominal size of the systems and the spread of the number of systems across regions of the country. For all these, basic statistical data are publicly available for validation.

3. Results and discussion

A. Sizing of PV systems

The sizing of the photovoltaic systems is the most crucial question from the perspective of self-consumption (and load matching). As net billing systems favoured PV system sizing where the annual generation equals the annual demand of the consumers, previous assumptions of our studies used an annual generation-to-demand ratio (GTDR) of 1, with a +/- 10% margin.
Survey results brought similar results. The median value of GTDR appears to be 1.06, while lower and upper quartiles cover the range of 0.99-1.25. Mean value is 1.14. Results suggest that systems are tendentially a bit oversized compared to the NZEB sizing, which seems to be reasonable from the perspective of the billing system. In this manner, under different weather conditions (e.g. a year unfavourable for PV yield), systems could still cover demand and result in a bill without payment obligations.

B. Orientation of PV systems

Orientation of the residential PV systems is an unknown parameter in Hungary. Hence, in case of need, Hungarian stock can either be simulated with uniform distribution with some restrictions (like excluding northern orientations) or the implementation with other regions' probability density functions for the orientation [6]. Survey results can suggest a more reliable approach compared to both.
Being roof-mounted systems and aiming a GTDR a bit above 1 as seen, systems can face multiple orientations to provide the sufficient roof surface area. Survey results suggest that approximately 40% of the systems have multiple orientations. A question also covered the share by the specific main and sub-orientations. Thus, results of the orientations can be displayed capacity-based.
From the perspective of azimuth angles (categorized into orientation by 45° steps in the range of -180 to 180°) preliminary results show that azimuths of the systems are slightly shifted to a western orientation (Fig. 1). This could ensure a better on-site utilization of the PV systems as suggested in our previous paper.

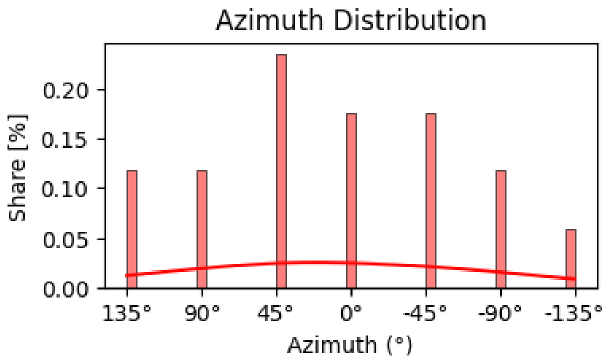

Fig. 1. Distribution of azimuth angles of Hungarian residential PV systems

From the perspective of the distribution of the tilt angles, ranges of tilts have been grouped to 15-30-45-60°. Preliminary results suggest that compared to the optimal 30-35° tilt angle (from the perspective of yield for a unit of system in the region), systems exhibit the shift of the distribution rather towards the higher values (Fig. 2).

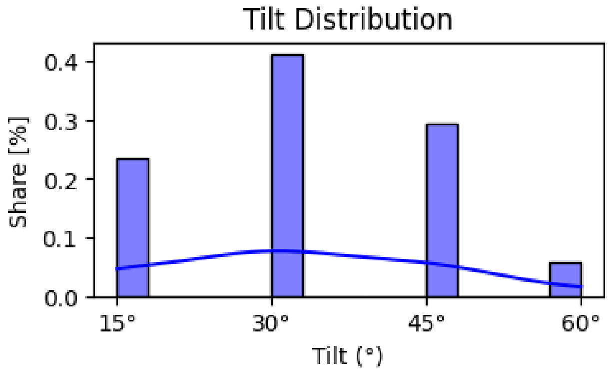

Fig. 2. Distribution of tilt angles of Hungarian residential PV systems

This could be in relation with the characteristics of building typology, as flat-roofed constructions are not common in Hungary buildings are usually built with roofs of higher slopes [7].
While decomposition to specific tilt and azimuth shares are useful for searching for probability density functions describing the stock, the combination of the specific tilt-azimuth pairings can suggest a better visual representation of the specific answers for the systems in the query as presented in Fig. 3.
An interesting note at this stage of fills is that while 30° systems exhibit a shift a bit towards western orientations, 45° systems rather face a bit towards the east. The change in numbers across the fills could be interesting later.

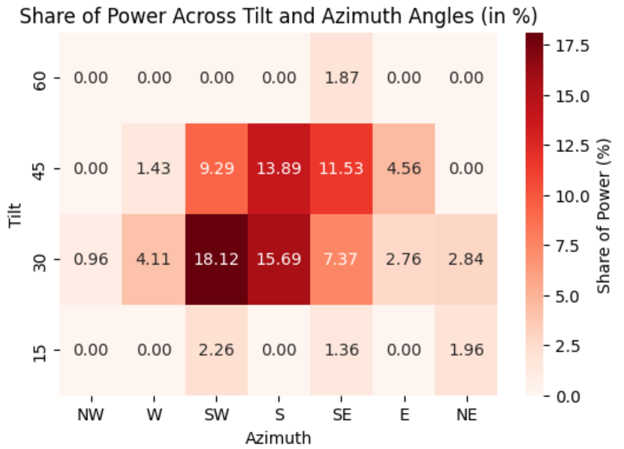

Fig. 3. Share of capacity per tilt and azimuth combinations

In general, results show that systems are most probably oriented to suggest the highest yield per unit of capacity – that is reasonable under net billing system. However, in case of the introduction of the net metering scheme, lower tilt angles and azimuth towards western orientations are more favourable. The trends of the orientations are controversial from the perspective of load matching. While tilts differ to reduce LMIs, azimuth on the other hand seems to be more appealing.

C. Electricity consumption of prosumers

Electricity consumption is an unknown factor for the national prosumers. While energy streams injected to the grid and retrieved from the grid can suggest that the energy consumption of these prosumers is higher than the national average, quantification of it is challenging as on-site utilized share is "behind-the-meter" and can be calculated by only the prosumer, having access to both the data of PV generation and grid consumption.
With the results of the survey, overall consumption of these prosumers can be better estimated. At this stage, it shows a mean value of around 7,100 kWh/year, with a median of 6,240 kWh/year. The distribution of the yearly consumption is presented in Fig.4. Results suggest that PV owners have almost three times high energy consumption as the average of residential households [8].

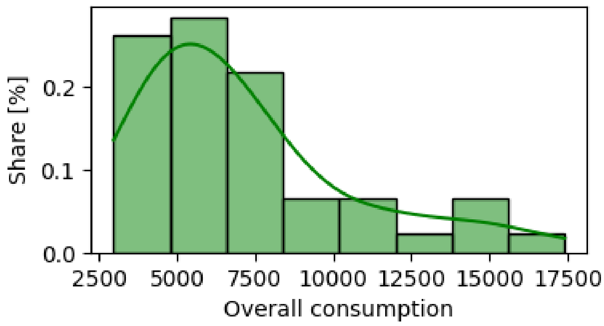

Fig.4. Histogram of prosumers overall consumption
This finding is enforced by the answers for asking whether the owners do anything to exploit their PVs better. 40% of the fills have responded that they "Tend to use more electrical appliances".

D. Typical consumer appliances

A major difference to the national average consumption underlies in this. When asking about heating and cooling appliances, 83% of the fillers responded that they own some kind of heat pumps (predominantly air-to-air heat pumps), which is more than 3 times of the national average [9]. From the perspective of function, these appliances are not only used to cooling purposes, but majority are used for heating as well, which yields higher energy consumption, yet can also end in lower simultaneities with PV production during wintertime.

Another key difference is that a relatively high share of the fillers, 25% own an electric car, and 70% charge their cars at home (with approximately half of the share from 1 phase, the other half from 3 phase).

4. Conclusion

The spread of distributed energy sources, including rooftop solar is a key issue of energy transition. Despite their significant installed capacity, there is a lack of knowledge of these systems in Hungary. This paper presented preliminary results of a survey focusing on residential rooftop solar systems characteristics. Focus questions included the sizing and orientation of these systems as well as the households' consumptions and main consuming appliances.
Findings reinforced that systems are predominantly sized to generate as much electricity over a year long period as the households' consumptions, with a bit of oversizing. From the perspective of orientation, higher tilt angles and systems oriented bit towards west are found to be more frequent in the national stock.
Overall electricity consumption of consumers owning these PV systems is almost 3 times the average consumption. Prosumers admittedly use more electricity.
Results of the survey can support policy measures on the path from shifting from net billing to net metering by extending knowledge on the consumer habits and self-consumption of residential PV system owners. Orientation and sizing of the systems could support national-scale

simulations for better planning of domestic PV systems in their integration into the grid.

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