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The winter package of the EU: possibilities for Ukraine's households

Abstract: This article studies the implications of the Fourth Energy Package and relevant EU Directives for households and explores their potential benefits in Ukraine. Understanding the effects of energy policies on the residential sector is crucial for promoting sustainability amidst global energy and climate challenges. Methods of descriptive legal studies and investment analysis are used to examine the primary EU legislation on renewable energy communities and citizens' groups, focusing on their applicability to homes and renewable energy cooperatives. The analysis of Ukraine's experiences with the adoption of green power and incentives have revealed challenges for small solar home installations operating without the feed-in tariff. Introducing net-billing makes projects unfeasible without such a tariff, and even selling electricity through aggregators on the intraday market does not help. Consequently, the payback period for small installations with batteries becomes unreasonably long (exceeding twenty-five years), while larger facilities have shorter payback terms

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(fifteen to seventeen years). These findings highlight the need for careful consideration of household green-power policies. Implementing the Fourth Energy Package in Ukraine requires measures to address the financial feasibility of small solar installations, particularly those lacking feed-in tariff support. Expanding legislative provisions to include consumers of green power, especially those in multi-apartment buildings, can enhance their participation in the electricity producers' market. Moreover, raising household electricity prices may be necessary to support sustainable energy practices. Overall, this study underscores the importance of evidence-based policymaking for successful power transitions in homes and the broader energy sector.

Keywords: Ukraine, prosumer, renewable energy communities, renewable energy policy, household

Abbreviations and nomenclature

ACAB	–	the Associations of Co-owners of Apartment Buildings
CMU	–	the Cabinet of Ministers of Ukraine
EC	–	the European Commission
EnCom	–	the Energy Community
EU	–	the European Union
EUR	–	euro (the single European currency, used in nineteen member states)
FIT	–	feed-in tariff [EUR/kWh]
LCOE	–	levelized cost of electricity [EUR/kWh]
NGO	–	non-governmental organization
NREAP	–	the National Renewable Energy Action Plan
NRC	–	Ukraine's National Recovery Plan
PV	–	photovoltaics
REC	–	renewable energy community
RES	–	renewable energy sources
SAEE	–	the State Agency of Energy Efficiency and Energy Saving of Ukraine
UAH	–	Ukrainian hryvnia
UNDP	–	the United Nations Development Program
USD	–	United States dollar

Introduction

The full-scale invasion of Ukraine by the Russian Federation to, which began on Feb 24^{th}, 2022, and the subsequent shelling of energy infrastructure demonstrated the vulnerability of Ukraine's centralized energy system to military attacks. Since the war is still in progress, the precise losses are unknown. However, the preliminary assessments as of late February 2023 (i.e. in one year of the full-scale war) indicate that the direct losses to the domestic energy industry reached 8.1 billion USD (KSE 2023). Electricity generation and transmission have significantly suffered from Russian aggression. A preliminary estimation of the total damages for these subsectors is almost 6.5 billion USD, including 2 billion USD of direct losses to electricity transmitting infrastructure, 4.14 billion USD to electricity generation, and 0.354 billion USD to electricity distribution (KSE 2023). The war has an impact not only Ukraine but many other countries globally (through disrupted food supply chains etc.) (Pryshliak et al. 2023).

One of the reasonable solutions to the problem is to decentralize electricity output and supply by all possible means. Given the rapid maturing of renewable energy technologies and the range of economic, social and environmental benefits from their implementation (Sowa 2020; Kalinina et al. 2021; Antoniuk et al. 2022; Prokopenko et al. 2023; Koval et al. 2023), it is reasonable to develop distributed energy systems based on them. Industrial-scale wind and solar power plants undoubtedly have their right to exist, allowing the economy of scale and favoring employment; however, they also become a target in light of the military risks of a hostile neighboring country.

The Russian-Ukrainian war has affected the EU in terms of reducing its dependence on imported energy resources, including those from the Russian Federation. The EU aims to become the first carbon-neutral continent by 2050, and this target may be revised to reach carbon neutrality even earlier. Considering the negative consequences of the COVID-19 pandemic on the European economy, the use of modern, low-carbon advanced technologies is one of the ways to accelerate economic growth in the EU. For this, alongside the existing energy and climate legislation, a REPowerEU plan (EC 2022) was adopted, which was aimed at increasing energy use from RES. It is not only about the use of wind and solar energy but also about increasing the production of so-called green hydrogen.

This paper aims to investigate the novelties which arose for households from the provisions of the Fourth Energy Package and the respective EU Directives as well as to consider what possibilities the transposition of the package could bring to Ukrainian households. These possibilities are projected to fully align with the need to decentralize the energy system, reduce its vulnerability to military risks, and strive for climate-friendly technologies. In this paper, the households were considered primarily through their ability to generate electricity, to store it (to a lesser extent) but not in view of their demand response measures.

1. Research method

The paper considers the primary legislation of the EU in the realm of RECs and other forms of citizens' groups which could be related to both households and renewable energy cooperatives using the method of descriptive legal studies. In addition, the authors study the experience of households in Ukraine with the energy output from RES, together with the existing incentives to do so. The research uses a payback period for solar installations to substantiate implementing investment projects on RES in the residential sector. This indicator denominates the number of years required to recover the original cash investment (Kiran 2022) and is calculated using the formula:

$$PP = \frac{I}{ACF} \qquad (1)$$

where:

PP – payback period [years],
I – cost of investment [EUR],
ACF – average annual cash flow [EUR/year] (Kiran 2022).

The shorter the payback period, the more feasible the investment is. Several assumptions are applied to calculate the payback period of home solar PV installations. Specifically, a household is assumed to produce electricity, partially consume it, and sell the excess to the grid. The average annual capacity factor for rooftop solar PV in Ukraine is 14.1% (Trypolska and Rosner 2022). The investment cost for a PV installation varies from 662 to 944 EUR/kW. The smaller installations are more expensive, including solar panels, the grid inverter, a system of fastenings to install panels on a roof, and installation and commissioning works (Utem 2023). The investment cost for a battery of 5-kW capacity is 2,300 EUR (Utem 2023), if the household considers its installation. The capital expenditures for solar PV installations in Ukraine are slightly lower than those indicated in the studies for other countries. For instance, for the USA, these figures vary from 3,160 USD/kW for residential PV to 1,060 USD/kW for utility-scale PV installations, including the installation cost (NREL 2022). Investment costs for the grid-connected solar photovoltaic system are pretty high in Singapore, where their average value reaches 2,000 USD/kW (Kuang et al. 2022); approximately the same expense is applicable for the entire PV installation in Great Britain, where they may reach 2000 EUR/kW for small units (3.5 kW) (JustWe 2023). The average capital cost for PV systems in Latvia's residential sector is 1,495 EUR/kW (Sotnyk et al. 2022); in Croatia, they are about 1,178 EUR/kW (Bošnjaković et al. 2021). Close to investment costs in Ukraine is the installation of solar panels in Algeria – 796 USD/kW (Dekkiche et al. 2023). Solar module costs differ from 240 USD/kW in China to 260 USD/kW in India and 330 USD/kW in Europe (IEA 2022). In addition, the cost of energy and labor fluctuates. The numbers vary significantly, as high investment costs for polysilicon and wafer manufacturing make solar PV generation outside of China less feasible (IEA 2022). The cost of solar batteries in the selected counties is approximately the same as in Ukraine, namely, 478 EUR/kW in Germany and 466 EUR/kW in China (Enfsolar 2023). In Australia, the cost of PV batteries can reach 1,400 USD/kWh (SC 2023). The average monthly electricity consumption per Ukrainian home with heating other than electricity was 168 kWh (or 954 kWh with electric heating) in 2020, which is almost twice as low as the EU average (304 kWh) (NERC 2021). The household is assumed to have a heating system based on any source except electricity (as it affects the average electricity consumption pattern).

2. Material

2.1. The fourth Energy Package of the EU

The Fourth Energy Package, or the so-called "Winter Package: Clean Energy for All Europeans" (2019) (EC 2019a), includes several proposals aimed at introducing changes to the legislation on the energy market, climate legislation, as well as proposals for new measures. It provides for the set of directives to integrate climate goals into the new market design. In particular, the Renewable Energy Directive 2009/28 (RED) (which was replaced by the RED II Directive (2018/2001/EU)), the Energy Efficiency Directive 2018/2002/EU (EED), the Governance Regulation 2018/1999 and the Directive 2019/994/EU on common rules for the internal electricity market were adopted. The new directives came into force for EU countries in December 2018 to be fully transposed into the legislation of member states by 2021. The directives set a target share of 32% from RES and an increase in energy efficiency of 32.5% by 2030. According to the EC, implementing the Fourth Energy Package provisions will contribute to 900,000 new jobs in the EU, mainly in small and medium-sized enterprises. Despite the continuous advancements in the EU legislation, some items of the European energy and climate legislation are mandatory for Ukraine, which became an EU accession candidate country in June 2022. The EU Fourth Energy Package envisages several essential principles that must eventually be embodied into Ukrainian legislation and set up the development trends in the energy and climate sphere. The package operates several principles and concepts, in particular:

- citizens become co-owners of the energy transition, i.e. they may own the energy assets;
- electricity consumers may willingly mobilize their private capital to commence the investments (Krug et al. 2022);
- consumers may participate in the electricity market directly not only as consumers but also as producers (this way, 'producer' means a natural or legal person who generates electricity (EC 2019b));
- the package recognizes the decentralization trends and establishes small-generation protection requirements. It also identifies new market players, such as RECs, active con-

sumers, aggregators, citizens energy communities, independent aggregators, and self-consumers.

In the pan-European legislation, an "active customer" means a "final customer, or a group of jointly acting final customers, who consumes or stores electricity generated within its premises located within confined boundaries or, where permitted by a Member State, within other premises, or who sells self-generated electricity or participates in flexibility or energy efficiency schemes, provided that those activities do not constitute its primary commercial or professional activity" (EC 2019b).

Renewable energy self-consumer is "a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its consumption, and who may store or sell self-generated renewable electricity, provided that, for a non-household renewables self-consumer, those activities do not constitute its primary commercial or professional activity" (EC 2019b). At least two active customers form the so-called jointly acting self-consumers of renewable energy. Renewable energy self-consumers may own renewable energy generating facilities or may hire an entity possessing such facilities.

A citizen energy community means "a legal entity that: (a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises; (b) has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and (c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders" (EC 2019b).

A renewable energy community is "a legal entity which is based on voluntary participation, is autonomous and is controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity; the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities" (EC 2018).

The prosumer consumes the self-produced electricity and supplies the leftovers to the grid. With the growing number of self-consumers, the necessity to arrange and systematize the activity of collective groups of self-consumers emerged, for which independent aggregators are used. An "independent aggregator" refers to "a market participant engaged in aggregation who is not affiliated to the customer's supplier; aggregation' means a function performed by a natural or legal person who combines multiple customer loads or generated electricity for sale, purchase or auction in any electricity market."

Overall, the given definitions aim to distinguish and arrange the activity of various types of prosumers, including those living in multi-apartment buildings, but not limited to. To understand the differences better, multiple types of organized groups of prosumers are described in greater detail in Table 1.

There is no official definition of small generation in EU Directives. However, there is a provision that, if necessary, member states can apply non-auction methods of supporting the small

Table 1. Different types of prosumers in the Fourth Energy Package

Tabela 1. Różne typy prosumentów w IV Pakiecie Energetycznym

	RECs	Renewable self-consumers (including jointly acting)
Geographical scope	Proximity of RES installations	Limited to the same building
Membership	Open	Limited to the same building
Legal form	Requires a legal entity	Does not require a legal entity, but requires a contract with a local electricity supply company
Purpose	Environmental, social and/or economic benefits (to a smaller extent)	
Activities	Generation, storage, selling, sharing, aggregation or other energy services, distribution	

Source: Clean Energy Package – Legal Framework for Renewables Self-Consumption Workshop on renewables self-consumption Energy Community event, 02 June 2021 (EnCom 2021).

generation, including the FIT or a feed-in premium. RED II encourages the maximization of producers' involvement in competitive markets for the electricity sale. Incentives should take the form of additional payments for electricity sold on the market.

Administrative/consent procedures for small installations should be simpler than those that are required for large procedures. The duration of obtaining permits for facilities with a capacity of up to 150 kW should not exceed one year. RED II requires simplifying grid connection procedures for small installations with a 10–50 kW capacity and welcomes simple notification procedures for installations with a capacity of up to 10 kW. Undoubtedly, the operation of RECs presents technical challenges to the grid, which are beyond the scope of this paper.

There are numerous reasons for empowering citizens through energy communities. In particular, RECs:

- are a tool to increase public acceptance of new projects;
- may mobilize private capital and enable the energy transition;
- could be a tool to increase flexibility in the market (EnCom 2021).

Energy communities are expected to play a crucial role in the power markets, which is proved by Di Silvestre et al. (2021) in their review of the Italian electricity market. In 2019, Germany, Denmark, and the Netherlands had a combined total of nearly 3,000 REC initiatives. These countries have a successful history of RES redeployment: in 2012, nearly half (46%) of installed RES capacities in Germany belonged to prosumers (Kuchmacz and Milka 2019). This became possible due to the availability of support schemes, such as FITs, coupled with investment grants (Di Silvestre et al. 2021). Fina and Auer (2020) stated that RECs might ensure significant annual savings because of the electricity exchange within the borders of RECs and fewer electricity transmission losses. Some countries implemented the respective legislation enabling the existence of RECs well ahead of the pan-European legislation. For instance, France adopted such legislation in 2016, Austria did so in 2017, and Spain did in 2019. However, this form of organization has not gained its full momentum due to a wide array of impediments and risks described by Vernay and Sebi (2020). Krug et al. (2022) stated that countries transposed the provisions of the respective directives in their legislation quite "literally." As they lack enabling schemes, the development of REC remains fragile but rapid. Energy communities require the implementation of a wide array of contemporary technologies; along with energy-generating equipment, they may use the Internet of Things, neural network, blockchain technology, etc.

2.2. The experience of Ukraine

Ukraine switched to a bilateral electricity market in 2019, which anticipated a new subdivision of markets (day-ahead market, intraday market, the market of auxiliary services, balancing market, etc.). Producers of electricity from renewables, having a higher LCOE in 2019 compared to those of the existing nuclear and fossil-fuel-based facilities in Ukraine, had to sell all the electricity produced by the industrial-scale facilities to the off-taker (the Guaranteed Buyer). Coal and nuclear enterprises in Ukraine are financed directly from the state budget (Zhyber and Solopenko 2020), whereas effective mechanisms for financing electricity generation from renewables were not found. This resulted in significant debts being amassed toward green energy producers (Trypolska and Riabchyn 2022). In turn, the households were obliged to sell their electricity to the universal service providers, who had a better payment discipline. In 2020, the residential sector accounted for 30.9% of electricity consumption in Ukraine (Moiseyev 2023). In 2022–2023, this figure dropped due to the destruction of Ukraine's industry throughout the war, primarily because of the damage to metallurgy, which accounts for 23% of the total electricity consumption in Ukraine. By contrast, this sector accounted for 41.7% of electricity consumption in pre-war times. Thus, the share of other consumers would grow (Moiseyev 2023).

Before the Russian-Ukrainian war, Ukraine's share of renewable energy in the power balance has increased significantly. In 2020, the percentage of RES in the total energy consumption (including large hydropower) reached 9.2% (SAEE 2021). More recent data (for 2021 and 2022) have been collected but are publicly unavailable due to martial law (State Statistic Service of Ukraine indicates that "Data for 2021 will be released after the end of timing for submission of statistical and financial reporting set by Ukraine's law *On the protection of interests of entities that submit reporting and other documents during the period of martial law or state of war*"). Due to the unprecedented deployment of large-scale solar power plants, the share of RES in power generation reached 13.9%, which exceeded the obligation imposed by the 2020 NREAP. The share in heating and cooling amounted to 9.3% and the share in transportation reached 2.5%. The large-scale installations and, to a lesser extent, the household solar facilities were primarily responsible for the growth of the installed capacities on RES.

Speaking of the perception of renewable energy in general, the Ukrainian households surveyed in the study mostly imagine solar PV installations (EcoAction 2022). Ukraine applies the FIT for solar PVs, wind power plants, and a combination thereof. The FIT is valid until the end of 2029.

Before the war, Ukraine had around forty-five thousand solar PV facilities (compared to six million households). Thus, there is a potential for growth of both solar and wind installations (Fig. 1). Since introducing the FITs for households, small wind power plants have not gained popularity in Ukraine: as of 2023, there are only eight small wind and combined wind and solar facilities.

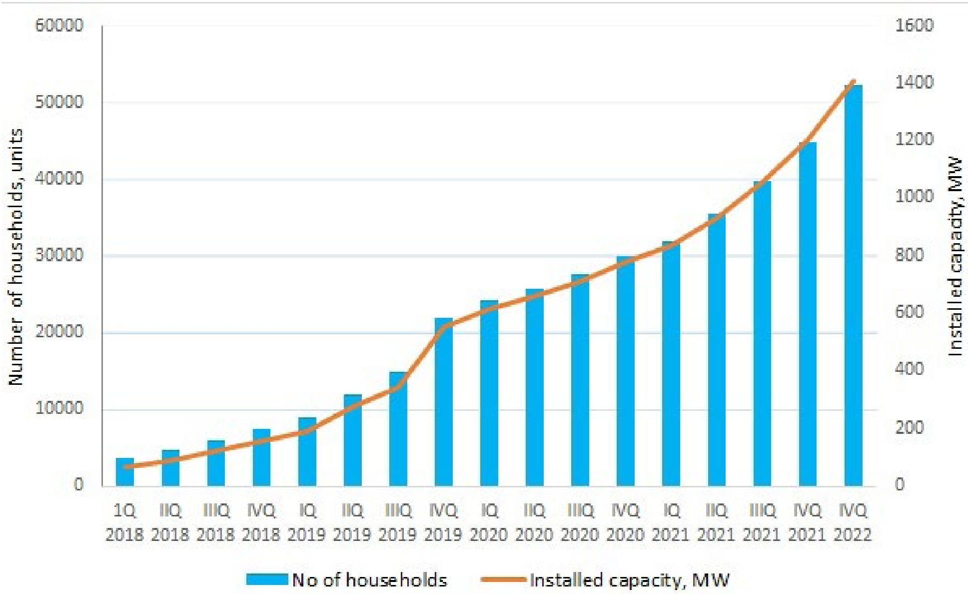

Fig. 1. The number of household solar power installations in Ukraine, units and their installed capacities [MW] (SAEE 2023)

Rys. 1. Liczba przydomowych instalacji fotowoltaicznych na Ukrainie, jednostki i ich moc zainstalowana [MW]

By the end of 2022, the cumulative installed capacity of solar power plants in Ukrainian households reached 1.411 GW or roughly 1% of the solar PV adoption rate. This is significantly smaller than the adoption rates in other countries: 11% in Germany, 23% in Italy, 16% in the Netherlands, and 4% in the United Kingdom in 2021 (Dillon 2022). During the first year of the full-scale war, the installed home capacities added 206 MW (SAEE 2023). However, in 2022, 8% of solar PV installations were destroyed and 13% were temporarily occupied by the aggressor (KSE 2023).

The government expects the growth of the installed capacities of households and other prosumers. This is anticipated by the 2050 Energy Strategy of Ukraine, as well as by the Ukraine's National Recovery Plan (NRC 2022), presented in Lugano, Switzerland in July 2022. The latter suggests a 5–10 GW increase in RES installed capacities by 2030 in order to support the EU's zero-carbon energy transition, estimated to cost around 15 billion EUR.

To understand the projected role of the households, the data on the available and forecasted installed capacities, as anticipated by the draft of the 2030 NREAP, was used (Fig. 2). This document had to embody the provisions of the RED II and its transposition into the legislation of Ukraine.

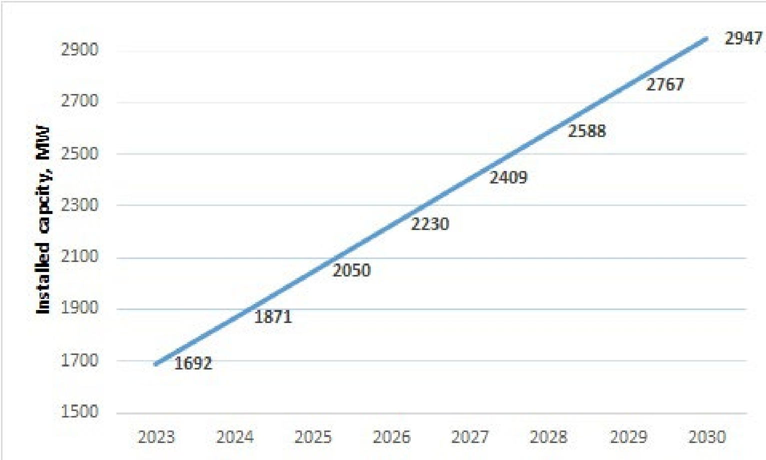

Fig. 2. The projected installed capacities of solar installations in Ukraine in households and energy cooperatives [MW] (NREAP 2030)

Rys. 2. Prognozowana moc zainstalowana instalacji fotowoltaicznych na Ukrainie w gospodarstwach domowych i spółdzielniach energetycznych [MW]

The feasibility of reaching the targets set by the draft of the 2030 NREAP raises concerns because the government is trying to change the existing support scheme for RES. Before the war, a FIT was the primary impetus for homes to install solar PVs. This is 0.163 EUR/kWh until 2025 (i.e. if the entity will have been granted a FIT before 2025) and will be 0.146 EUR/kWh after 2025 (i.e. if the entity is given a FIT in the period 2025–2029). In any case, the entity will receive payments against the FIT only until the end of 2029, even if there is insufficient time for an installation to pay back. Residential solar PV projects were considered primarily a business model (Trypolska and Rosner 2022) due to extremely low electricity tariffs for households (0.066 EUR/kWh since June 2023) (CMU 2023) and the inability to make any RES project feasible. Due to the war and heavy cross-subsidization, the off-taker continuously struggles to pay for the electricity sold against the FIT. In the first months of the war, there were periods when households were not paid at all for the green electricity provided to the grid. However, the war exposed the problem of the security of energy supply, when due to permanent shelling, energy distributing facilities had no chance to maintain the equipment. Additionally, the incomes of households dropped significantly, with an unprecedented 35% unemployment rate in 2022. The latter is projected to reach 23% in 2023, along with a 60% unemployment rate among internally displaced persons (NBU 2022, 2023). Even those who were employed claimed to have suffered a decrease in wages. A very high inflation rate has also aggravated the declining welfare: even though the average nominal salary grew by 5.9% in 2022, the real average wage decreased by 11.8% (NBU 2023). Additionally, due to the war, millions of internally displaced people have been observed. Most of them rent apartments or houses, which is a limiting factor for purchasing solar installations by tenants, as people make such an investment mostly once in a lifetime (Jager 2006). Under these conditions, investment in solar PV facilities would hardly be a high priority.

With the outbreak of war and the apparent vulnerability of energy generation, transmission, and distribution, the EU announced its intention to donate 5,700 PV panels to Ukraine within a project called "Ray of Hope" through the EU Civil Protection Mechanism. The PV panels will be installed primarily in hospitals, fire departments, and schools (i.e. objects of critical infrastructure). The installed capacity of one object will not exceed 2 MW (EU4Ukraine 2023). The panels will be produced by the Enel company (Spain) and, to a certain extent, will contribute to the boost of the economy of Spain. However, it is difficult to underestimate their significance for Ukraine. Additionally, Ukraine will face new types of consumers of RES energy (public sector), with which the country has relatively little experience.

3. Results

In an attempt to smoothly move away from the FIT system, the government adopted a law aimed at, among other things, the transition towards the net billing system (SCU 2023). According to the law, the net billing system would be related to the electricity price of the day -ahead market, which was 0.069 EUR/kWh in April 2023, 0.07 EUR/kWh in May 2023, and 0.071 EUR kWh in June 2023 (Oree 2023a). Additionally, the law obliges households to purchase batteries good enough to store electricity for at least four hours of consumption.

Below, the payback period for different solar PV home installations was calculated (for 12.5, 30, and 50 kW of capacity) with and without the batteries, at different FIT rates (depending on the year when it was granted – before 2025 or after 2025) and with net billing, using Formula 1. The results of calculations of solar installations of households are shown in Table 2. In this table, own consumption was calculated as a multiplication of the number of months in a year and the data of the average monthly consumption of electricity by households in Ukraine, which is provided by the National Commission for Energy and Utilities of Ukraine.

Table 2 leads us to several conclusions:

- small solar household installations (12.5 kW) that are willing to operate against the FIT will not have enough time to pay their investments back;
- the introduction of net billing for households makes solar PV projects unfeasible;
- the (overregulated) market electricity price for households is too low to make renewable energy projects feasible and bankable without the FIT. This fact impedes households to look for alternatives in electricity supply other than from the centralized grid, which is confirmed by UNDP (2020a).

At the time of writing this article, there was martial law in Ukraine, which prohibits the growth of utility prices during the war. However, given the significant destruction of energy-generation and transmission infrastructure in Ukraine, the government increased the electricity prices for homes (to obtain funds to restore the energy infrastructure). This is necessary because the current electricity price for households is four times smaller than the self-cost of electricity

Table 2. The payback period for solar PV installations of households under different support schemes in Ukraine

Tabela 2. Okres zwrotu instalacji fotowoltaicznych gospodarstw domowych w ramach różnych programów wsparcia na Ukrainie

	12.5 kW			30 kW			50 kW		
Support scheme	FIT granted in 2023–2024	FIT granted in 2025–2029	Net billing	FIT granted in 2023–2024	FIT granted in 2025–2029	Net billing	FIT granted in 2023–2024	FIT granted in 2025–2029	Net billing
Investments [EUR]	11,800			19,874			33,123		
Electricity output [kWh/year]	13,200			33,300			61,758		
Own consumption [kWh/year]	2,016			2,400			3,024		
FIT rate [EUR/kWh]	0.163	0.146	–	0.163	0.146	–	0.163	0.146	–
Electricity price [EUR/kWh]	0.066			0.066			0.066		
Payback period [years]	6.5	7.2	16	3.9	4.4	9.6	3.5	3.9	8.5

output in Ukraine. The government subsidizes the difference between the electricity self-cost and its price for the population. The average annual subsidies reached 140 billion UAH (3.45 billion EUR) (Topalov 2023). The government increased the electricty rate for the households by 60%. In that case, our payback period for solar installations under the net-billing system will remain the same, which means that net-billing will remain unattractive for households.

The necessity to introduce the net billing system was caused by the need to phase out the FIT and the expectation that households would help balance the market, especially during peak hours. To achieve the latter, they must have batteries and inverters while selling electricity to the grid. Given the nature of solar irradiation, households could presumably accumulate energy during the daytime operation of the installation and sell the power surpluses in the evening hours. Indeed, in Ukraine, the highest difference is between the prices of the day-ahead and the intraday markets. The price on the intraday market is somewhat higher, but the market share is only about 6–7% (Oree 2023b). In April 2023, the highest price gap between the day-ahead and intraday market was observed at 6 pm and reached 1.51 EUR/MWh (61.55 UAH/MWh) (Oree 2023b), while the average price in the evening on the intraday market was 78.47 EUR/MWh.

Overall, if households with batteries sell their electricity on the intraday market (obviously, through aggregators), the payback period of their installations would reach 16–29 years, depending on the installed capacity size. This is the case for several reasons, primarily because the electricity prices are meager. Additionally, the aggregators market has yet to be existent. The results of the payback period calculations are shown in Figures 3a–c.

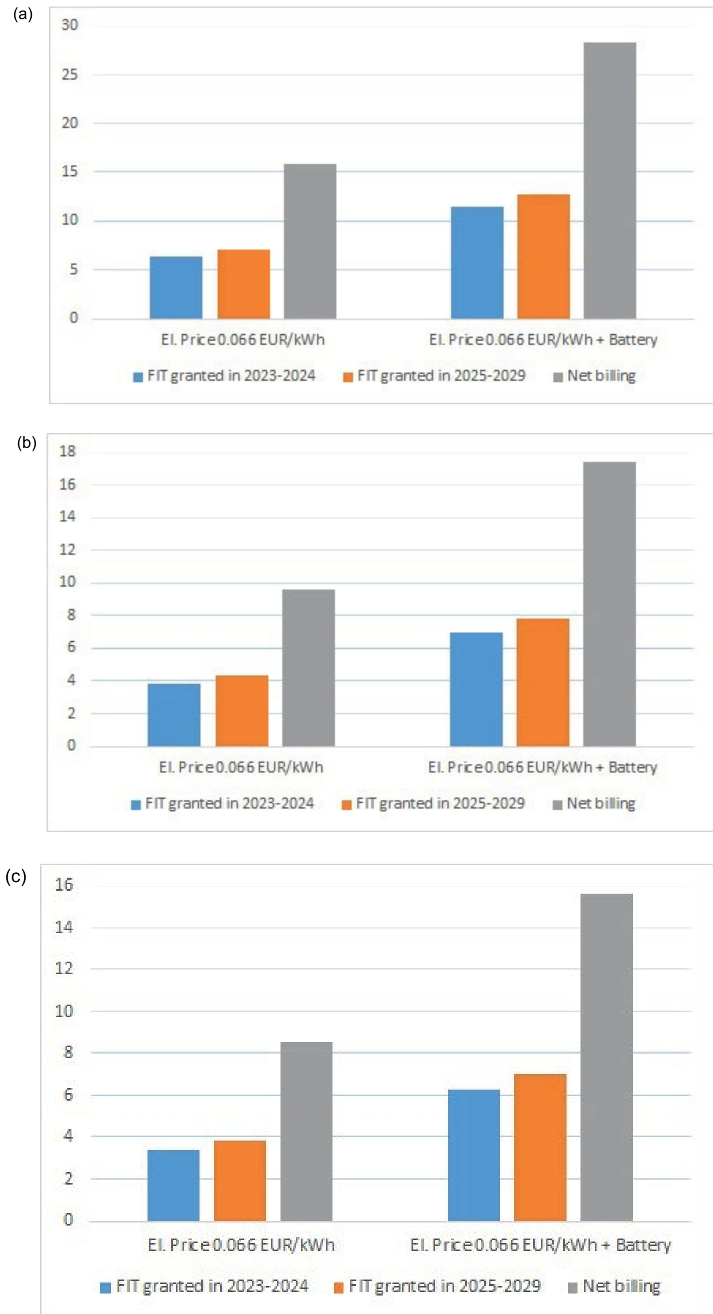

Fig. 3. Payback period for a 12.5-kW (a), 30-kW (b) and 50-kW (c) solar PV power plant under different conditions [years]

Rys. 3. Okres zwrotu elektrowni fotowoltaicznej o mocy 12,5 kW (a), 30 kW (b) i 50 kW (c) w różnych warunkach [lata]

The results of the calculations depicted in Figures 3 a–c indicate that it makes no economic sense to have a small solar PV installation coupled with batteries, as the payback period of such installations will exceed 25 years. This exceeds the battery's lifetime and some components of the PV facility). As a matter of fact, all types of installations become economically unfeasible should the batteries be installed. However, given that Ukraine is at war and will continue to have a hostile neighbor, households need to have "stored" electricity for cases of electricity supply disruption. At the moment, it is rather difficult to monetize the luxury of having 24/7 access to electricity. The fact that solar PV installations are so relatively expensive may cause the stratification of society between those who can afford it and those who cannot. However, these considerations lay beyond the scope of this paper. Nonetheless, it is essential to consider the possibility of investment grants or the undertaking of other support measures to decrease household investment costs. This opportunity should be investigated within the recovery packages aimed at restoring the existing energy infrastructure in Ukraine.

To validate the obtained results, it should be noted that the outputs for Ukraine may differ from those obtained for particular locations or households. The regional location may have an impact upon the average insolation rate, energy consumption, climatic conditions, etc. Moreover, the roof or facade installations of solar panels affects the power generation volume. A particular household may consume an amount of electricity that is different from the country's average (due to behavioral peculiarities, energy-efficiency measures applied, etc.). In addition, the following financial issues may play an essential role:

- High economic instability in Ukraine causes inflation risks influencing the growth of prices of mainly imported solar PV equipment and increasing investment costs.
- An unbalanced taxation policy may reduce the profit from selling green electricity to the grid, making small solar PV installations unfeasible.
- The payback period indicator does not reflect the cost of financial resources involved in green energy projects.

As a consequence of the above factors, high credit and discount rates can make small household solar facilities unprofitable. However, the research findings are in line with case studies observed in other countries. For instance, in Vietnam, the solar PV market contracted significantly after the abolishment of FITs (SPU 2023). In Great Britain, the number of solar PV installations dropped after a 65% reduction in FIT (Vaughan 2016). However, the question remains of whether the intention of having its power supply with the ongoing military risks will supersede the economic rationale of possessing solar PV installations for households in Ukraine.

The cases considered above were those for households installing solar PVs on the roofs of their private houses and other surfaces. However, more than half of the population in Ukraine lives in multi-apartment buildings. The survey conducted in 2019 indicated that 48% of the people in Ukraine live in multi-apartment buildings (3+ floors), 7% live in small multi-apartment buildings (2 floors), and the remainder, 44%, live in private houses (USP 2019). The peculiarity of the real estate market to date is that each apartment has its owner, so 30–500 owners would own the flats in the multi-apartment buildings. One-quarter of the multi-apartment building stock is united in ACABs. Solar PV installations on multi-apartment buildings are rare in Ukraine.

However, with ACAB, it is easier organizationally to solve some matters related to the apartment building.

Given the above, for many owners, agreeing to install a solar PV power plant is challenging. Additionally, there is no current legislation in Ukraine enabling multi-apartment buildings to install RES facilities (e.g. to cover the building's needs in the lighting of common areas, the operation of sockets in common areas, intercoms, etc.).

NGOs are trying to spread the word about the possibilities of using solar energy, even in multiapartment buildings. For example, NGO "EcoAction" described a detailed study about solar PVs for such facilities in 2023 (EcoAction 2023). It commenced as an attempt to narrow the gap between the government's plans for RES development and the need to raise awareness among ordinary people about RES technologies and the possibilities of using green power for distributed energy generation in Ukraine (EcoAction 2022). Overall, the sociological survey indicated that the respondents perceive distributed power generation somewhat better than renewable energy in general: 84% support the idea of distributed energy generation compared to 78% who support the concept of RES spread in Ukraine.

Even though the energy industry experienced one of the highest numbers of amendments to existing regulations (Prokopenko et al. 2021), as of 2023, Ukraine only has the concept of prosumers (called active consumers) and energy cooperatives. By contrast, there are several other forms of new market participants in the EU: RECs and jointly acting renewables self-consumers.

A unique example of the Ukrainian energy cooperative is "Solar Town." There are 300-kW solar PV installed on the rooftop of several public buildings in the town of Slavutych in the Kyiv region (UNDP 2020b). The cooperative sells electricity against the FIT, and 5% of the profit is spent to cover the town's needs. The funds for purchasing the equipment were collected from those residing anywhere in Ukraine (i.e. not necessarily in Slavutych). It was the first experience of an energy cooperative in Ukraine, and its permitting procedures and granting of FIT could have gone faster and smoother. However, in the understanding of the EU directives, Solar Town is not a renewable energy cooperative, as its investors reside in other cities of Ukraine and not where the cooperative operates.

In Ukraine, electricity losses in the transmission and distribution networks are enormous: they reached 19% in 2021 compared to 10.4% in 2020 (Minenergy 2023), which equaled the loss of tens of millions of hryvnias. This was primarily due to the networks being obsolete (Gurkovska 2021). The proximity of electricity production to its consumption, which both households and renewable energy cooperatives can guarantee, ensures far lower electricity losses.

The potential spread of renewable energy cooperatives in Ukraine will obviously be hampered by several impediments, as summarized in Table 3. Nonetheless, their overcoming is absolutely essential, as it would enable, among other things, multi-apartment buildings to benefit from renewable energy technologies.

Table 3. Current impediments to the spread of RECs in Ukraine

Tabela 3. Aktualne przeszkody w rozprzestrzenianiu się REC na Ukrainie

Nature	Description	Possible solution
Legislative	Lack of legislation enabling the operation of RECs in Ukraine	Adoption of respective legislation, similar to that of the EU
Financial (EcoAction 2022)	High upfront cost of equipment	Investment grants; feed-in premiums
Economic	Low electricity prices for households impeding the feasibility of RES projects	Gradual increase in electricity prices for households with the targeted support for low-income households
Informational (EcoAction 2022)	Insufficient spread of information about the distributed energy generation	Wide spread of information about technological solutions, costs, benefits, sequence of orders to gain the permitting procedures etc.
Military	Proximity to the Russian Federation	Solutions are beyond regulatory or market mechanisms
Organizational	Half of the population living in urban multi-apartment buildings	Possibility for more prosperous members to invest in self-generation
Behavioral	Difficulty in reaching an agreement between community members	Information campaigns with successful cases; detailed instructions "how to…"

Conclusions

In 2022–2023, Ukraine's electricity sector has significantly suffered from the military attacks of the Russian Federation and continues to do so. Thus, during the first year of the full-scale war, the total losses of Ukraine's energy industry reached 8.1 billion USD. This mainly concerns the power generation and transmission infrastructure. The preliminary estimate of losses for these sub-sectors is almost 6.5 billion USD.

In such a situation, the decentralization of power generation using contemporary energy technologies becomes absolutely necessary, which coincides with the European energy and climate legislation requirements. Ukraine, which received the historic chance to become an EU-accession candidate country, has to implement the energy acquis, even with a particular institutional lag.

The Fourth Energy Package of the EU establishes several directives enabling different types of small-scale power producers to generate energy, including those from renewables. The package, among other benefits, enables citizens to co-own energy transition and involve private capital. Given the necessity to mobilize all types of capital to satisfy the REPowerEU ambitions, this also becomes an important consideration. The package defines the concepts of the active customer, renewable energy self-consumer, citizen energy community, REC, and independent aggregators through the respective directives. The so-called small generation occupies an essential place in the directives. Its support should be provided through FIT or a feed-in premium. Administrative/consent procedures for small home installations should be simpler than those relating to large installations. Energy communities are expected to play a crucial role in power markets while requiring the introduction of a wide range of modern technologies along with power generation equipment.

Ukraine has essential experience in spreading renewable energy: both large-scale industrial solar PV plants and small household PV installations operate against the FIT. Moreover, the cumulative solar installed capacity of households reached 1,411 MW by the end of 2022. However, the war exposed the problem of energy supply security when power distributing facilities had to make extra efforts to maintain the equipment due to permanent shelling. Additionally, the incomes of households dropped significantly, with an unprecedented 35% unemployment rate in 2022 projected to reach 23% in 2023 and a 60% unemployment rate among internally displaced persons. Because of the war, millions of displaced Ukrainians rent apartments or houses, which is a limiting factor for installing small solar power plants, as people mostly make such investments once in a lifetime. In these conditions, investments in solar PV installations are unlikely to be a priority.

In this regard, Ukraine plans to switch to another model of state support of RES, such as net billing, linked to the electricity price on the day-ahead market. The bill also obliges households to buy batteries to store electricity for at least four hours of consumption, which is very important in blackouts.

The paper's main findings, which constituted its novelty, are as follows. The payback period for small residential solar PV projects was calculated to assess their feasibility under the mentioned new conditions for households. The calculations indicated that small solar home installations willing to operate against the FIT would not have enough time for their investments to pay back. In addition, introducing net-billing for households makes projects unfeasible without the FIT. Even if households sell their electricity through aggregators on the intraday market, the payback period for small installations with batteries becomes very high (twenty-nine years), exceeding the battery's lifetime. However, larger installations have shorter payback terms (fifteen-seventeen years). Overall, such long terms may not be reasonable from an economic point of view. However, Ukraine is a country fighting a war of an unknown duration. Therefore, having a small solar PV installation may be feasible for uninterrupted access to electricity, even self-generated. Eventually, Ukraine will need to cease the cross-subsidization of electricity for households at the expense of business entities and increase the electricity tariffs for homes, making renewable energy projects feasible and bankable.

The conducted analysis of the legislative conditions and experience in Ukraine indicated that people residing in multi-apartment buildings do not have the opportunity to become active participants in the electricity generation market. They can install their solar PVs, but it will only cover a small part of the electricity demand of the common areas of the building (such as intercom systems and lighting).

In the existing legislation, Ukraine lacks the concepts of RECs and jointly acting renewables self-consumers. These shortcomings are to be addressed through the adoption of the respective legislation.

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Pakiet zimowy UE: możliwości dla ukraińskich gospodarstw domowych

Streszczenie

Niniejszy artykuł analizuje konsekwencje Czwartego Pakietu Energetycznego i odpowiednich dyrektyw UE dla gospodarstw domowych oraz bada ich potencjalne korzyści na Ukrainie. Zrozumienie wpływu polityki energetycznej na sektor mieszkaniowy ma kluczowe znaczenie dla promowania zrównoważonego rozwoju w obliczu globalnych wyzwań energetycznych i klimatycznych. Metody opisowych badań prawnych i analizy inwestycji zostały wykorzystane do zbadania pierwotnego prawodawstwa UE dotyczącego odnawialnych źródeł energii dla społeczności i lokalnych grup konsumenckich, koncentrując się na ich zastosowaniu do gospodarstw domowych i spółdzielni energii odnawialnej. Analiza ukraińskich doświadczeń związanych z przyjęciem zielonej energii i ulg ujawniła wyzwania dla małych domowych instalacji słonecznych działających bez taryfy gwarantowanej. Wprowadzenie rozliczeń netto czyni projekty niewykonalnymi bez takiej taryfy, a nawet sprzedaż energii elektrycznej za pośrednictwem agregatorów na rynku dnia bieżącego nie pomaga. W rezultacie okres zwrotu dla małych instalacji z akumulatorami staje się zbyt długi (przekracza dwadzieścia pięć lat), podczas gdy większe instalacje mają krótsze okresy zwrotu (od piętnastu do siedemnastu lat). Wyniki te podkreślają potrzebę starannego rozważenia polityki w zakresie zielonej energii dla gospodarstw domowych. Wdrożenie Czwartego Pakietu Energetycznego na Ukrainie wymaga podjęcia działań mających na celu zapewnienie efektywności finansowej małych instalacji solarnych, w szczególności tych, które nie otrzymują wsparcia w postaci taryf gwarantowanych. Rozszerzenie przepisów prawnych w celu uwzględnienia konsumentów zielonej energii, zwłaszcza tych w budynkach wielorodzinnych, może zwiększyć ich udział w rynku producentów energii elektrycznej. Co więcej, podniesienie cen energii elektrycznej dla gospodarstw domowych może być konieczne do wspierania zrównoważonych praktyk energetycznych. Ogólnie rzecz biorąc, niniejsze badanie podkreśla znaczenie kształtowania polityki opartej na dowodach dla udanej transformacji energetycznej w domach i szerszym sektorze energetycznym.

Słowa kluczowe: Ukraina, prosument, wspólnoty energii odnawialnej, polityka energii odnawialnej, gospodarstwa domowe