EVALUATING THE IMPACT OF SOLAR GENERATION INVESTMENTS ON ENTERPRISES PERFORMANCE IN UKRAINE DURING WARTIME

by

Oleksandr Honcharov

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Thesis Supervisor: _____ Professor Olena Besedina

Approved by _____
Head of the KSE Defense Committee, Professor [Type surname, name]

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Date _____

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LIST OF ABBREVIATIONS

kWh Kilowatt-hour

GWh Gigawatt-hour

RES Renewable Energy Sources

PV Photovoltaic

PVGIS Photovoltaic Geographical Information System

CHAPTER 1. INTRODUCTION

Russian attacks on Ukraine's energy sector have seriously affected its functioning. Many businesses are directly dependent on electricity, and not only its price but also the availability of its supply is important. Damage to power generation capacity causes energy prices to increase and leads to shortages when demand exceeds supply and artificial restrictions occur.

Under these circumstances, it is important to investigate the current impact of the energy sector on the operation of Ukrainian enterprises, as well as to forecast the short- and long-term effects on the operating environment in the future. Ongoing damage to power system components may not be the final one and the price of electricity could rise even more.

The significance and impact of electricity on the operation of businesses varies according to size, type of economic activity, location, and other factors. For example, one of the most vulnerable in these conditions is metallurgical enterprises. Electricity has a significant weight in the production and cost of metallurgical products, much more than in the production of most other enterprises. Metallurgical industry consumed 21% of all electricity in Ukraine in 2021 and electricity is critically important for it[1]. For this and other energy-intensive industries, the issue of price and availability of electricity becomes a question of the feasibility of continuing to operate.

One of the sources of electricity demand coverage in Ukraine is imports from neighboring European Union countries. Poland, Romania, and Slovakia, the main countries contributing to close imbalances in the Ukrainian energy market, have higher electricity prices. But not only in the context of the war but also in the context of Ukraine's future accession to the European Union, it is important to analyze the likely future price increases

in Ukraine to the level of Eastern European prices to conclude the potential for Ukrainian enterprises to be competitive under conditions of electricity prices close to European ones.

External factors alone are not exceptionally decisive. Some enterprises had switched to full or partial energy independence long before the war. Investing in electricity generation has long been an object of keen interest for many companies, while recent losses and risks have only increased the attractiveness of such a strategy. Due to rising prices and frequent blackouts, the issue of electricity self-sufficiency is becoming an important topic of research. Relatively expensive sources of electricity, such as solar panels, deserve to be reconsidered in the new environment.

The study aims to analyze and calculate the impact of the introduction of solar energy systems and its economic impact on companies and the energy system. Solar generation is characterized by much lower capacity relative to traditional sources of electricity. Therefore, it will be primarily considered from the perspective of small and medium-sized enterprises (SMEs). The capacity of solar electric power considered in the study is 100-1500 kWh.

Renewable energy sources, particularly photovoltaic (PV) systems, are not only viewed as a means to diversify and lower costs, but also as a way to decrease emissions and improve the environment. Growing requirements for the origin of electricity in the European Union and environmental concerns could serve as further incentives for the implementation of renewable energy sources.

The research methodology includes calculating and forecasting the output of photovoltaic (PV) systems in kilowatt-hours (kWh) and determining their monetary equivalent. This output will be compared to the cost of electricity from the traditional grid. Additionally, the study will analyze the economic benefits along with any changes in the company's costs and cost structure.

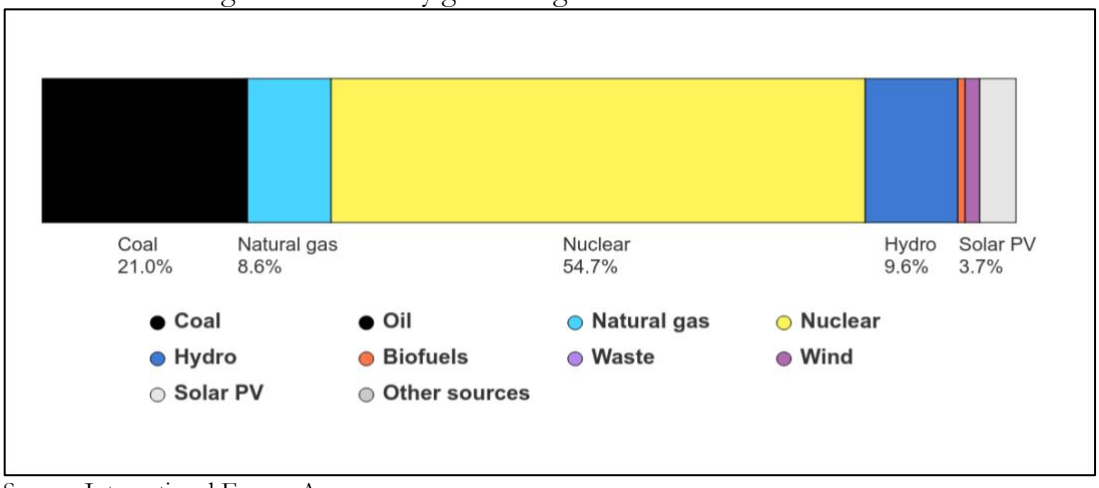
CHAPTER 2. INDUSTRY OVERVIEW AND RELATED STUDIES

2.1. Electricity industry overview

Electricity generation is an important component of the Ukrainian economy, on which the vast majority of Ukrainian enterprises depend. Ukraine's energy sector has generally been characterized as diversified. In contrast to other energy sources (oil, gas, coal, petrol), Ukraine was mainly self-reliant and didn't depend on electricity imports. This was an important part of domestic businesses having access to uninterrupted and cheap electricity, which for many of them was a key aspect of competitiveness.

Electricity can be generated in two main ways: by harnessing the heat from burning fuels or nuclear reactions in the form of steam (thermal power) or by capturing the energy of natural forces such as the sun, wind or moving water. According to the International Energy Agency, the main sources of electricity in Ukraine are nuclear and coal, accounting for 54.7% and 21% of the total. The share of solar generation was only 3.7% (Figure 1).

Figure 1. Electricity generating sources in Ukraine in 2022

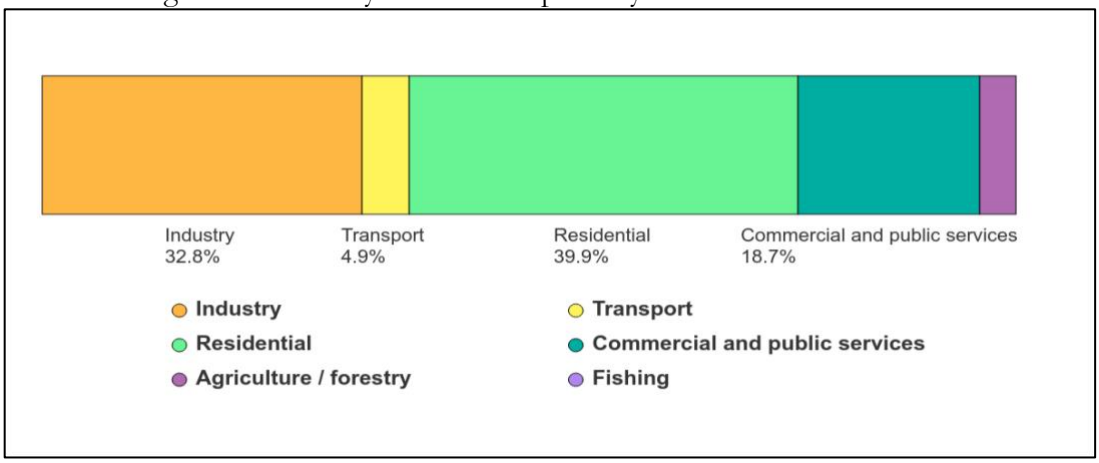


Source: International Energy Agency

The largest electricity consumer in Ukraine is the residential sector, accounting for 40%. The industrial sector accounts for 33%. The agricultural sector, which is core to the Ukrainian economy and ranks first in the structure of exports, consumes only 3% of total electricity (Figure 2).

Major changes and challenges in Ukraine's energy sector occurred with the onset of political events in 2014. The Ukrainian energy industry incurred a loss of power plants and a significant part of coal production essential for operating coal-fired power plants due to the loss of industrial areas in Donbas. Since the start of the full-scale Russian invasion in 2022, the situation worsened significantly. During 2022 Ukraine lost some of its generating capacity, including the Zaporizhzhya nuclear power plant, the largest NPP in Europe. The loss of capacity was compensated for by the loss of consumers and reduced consumption by businesses, but by the end of 2022, the remaining power generation was under direct attacks aimed at its physical destruction. Hydroelectric and thermal power plants suffered the most damage.

Figure 2. Electricity final consumption by sector in Ukraine in 2022



Source: International Energy Agency

After a relatively stable year in 2023, massive attacks on Ukrainian energy facilities continued in 2024. This has brought back power shortages, blackouts and instability. Under these circumstances nuclear power plants and imported electricity are the remaining reliable

sources of energy, but they cannot cover the entire deficit. In such an environment, future blackouts and further price rises are inevitable, so the government, businesses, and household consumers must adapt to these volatile conditions. In September and October 2024, Ukraine resumed commercial electricity exports: in the last days of September, exports reached about 0.8 GWh during certain hours when domestic demand was low[1]. While this amount is relatively small - equivalent to what the South Ukrainian Nuclear Power Plant can generate in just 15 minutes at full capacity.

October saw an increase in export volumes, returning to the levels of 2023. The export of electricity abroad is positive news that indicates the normalization of the situation in the power system. If the electricity shortage in Ukraine resumes, exports can be quickly canceled.

Figure 3. Difference between EU electricity commercial exchanges with Ukraine

Source: ENTSO-E

[1] CES Ukraine

In October, net electricity exports were positive for some time: Ukraine exported more electricity than it imported. In the second decade of October, exports began to decline again, while imports increased. As a result, net exports became negative again.

According to the European Business Association, in November and December 2022, the lack of electricity forced 66% of companies to change their schedules and 40% to reduce production. Many companies began purchasing generators in large quantities. However, generators cannot replace a permanent source of electricity and should only serve as a temporary solution. At the same time, 1 kWh generated costs at least UAH 20, making it more expensive than imported electricity.

On 30 May 2024, the Ukrainian government changed the mechanism that allows companies that import 50% of their electricity to avoid blackouts by raising the required share to 80%[2]. The countervailing effect of the mechanism is the inability to cover the entire demand for imported electricity, which limits the ability of enterprises to utilize it.

According to Eurostat, the cost of electricity in neighboring countries such as Romania, Slovakia, and Hungary is EUR 0.2 per kWh, which is 60-100% higher than in Ukraine - EUR 0.09 per kWh. Therefore, Ukrainian companies that choose to purchase imported electricity should be prepared for significant additional costs. Another problem with importing electricity is that the price of electricity is very volatile. In various time periods, the import price may be 3-4 times higher or even lower than in Ukraine[3]. Long-term contracting could provide a solution to this.

For many large companies, importing electricity has become the only viable solution to fully cover the electricity shortage. In January and February 2023, ArcelorMittal Kryvyi Rih, one of the largest steel producers in Ukraine, imported 42.9 million kWh from Slovakia,

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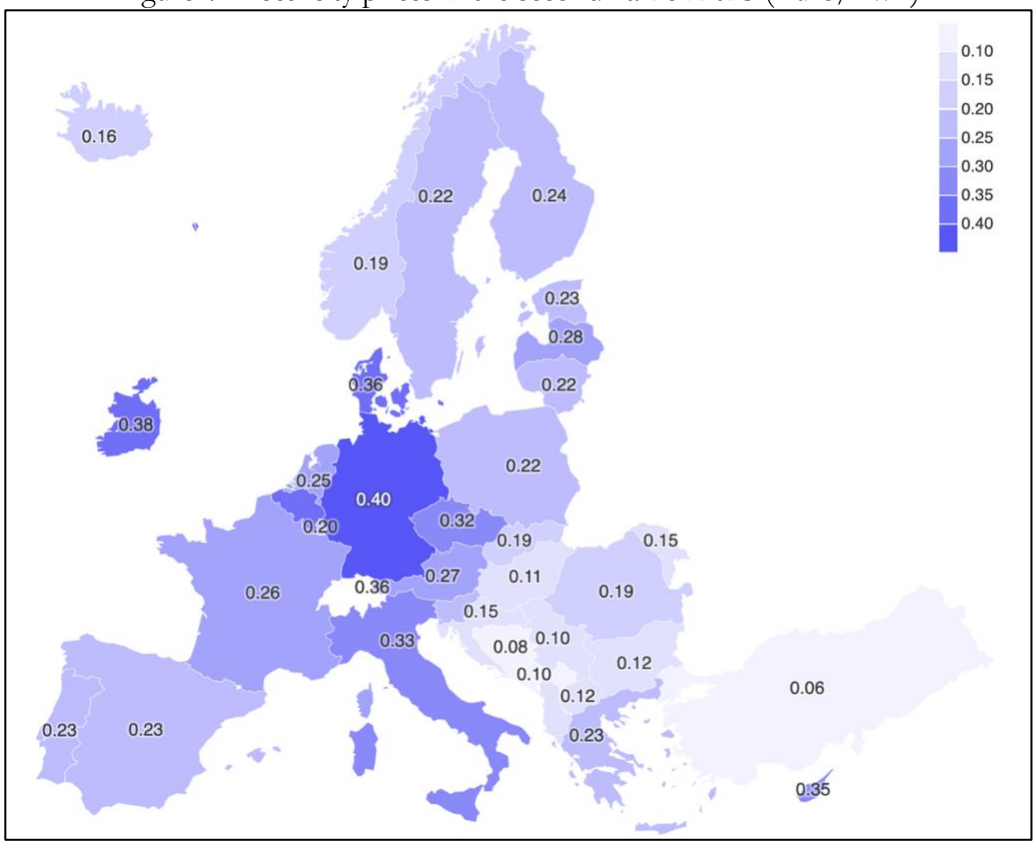
[2] https://biz.ligazakon.net/news/228115_vdteper-pdprimstva-povinn-mportuvati-80-elektroenerg-shchob-uniknuti-vdklyuchen

[3] Quarterly report On European electricity markets (Q3 2021). Eurostat.

costing the company UAH 357 million, according to the company's CEO, Mauro Longobardo[3]. In this case, the average price per 1 kWh was UAH 8.44, which is only slightly higher than the domestic market price.

The technical feasibility of importing is also limited to a certain quantity, which restricts the Ukrainian energy sector's ability to switch to imports[4]. In March 2022, Ukraine established a connection to the ENTSO-E European grid, enabling an import capacity of up to 1.7 GWh of electricity.

Figure 4. Electricity prices in the second half of 2023 (Euro/kWh)



Source: Eurostat

[4] https://www.kmu.gov.ua/en/news/herman-halushchenko-cynkhronizatsiia-z-entso-e-posylyla-i-ukrainu-i-ievropu

Ongoing negotiations aim to raise the import capacity to 2.2 GWh by 2024. However, Ukrainian power generation suffered substantial damage of approximately 9 GWh due to hostile actions in 2024.

Consequently, even with the potential expansion of import capacity from the EU, it is expected to only partially mitigate the overall deficit within Ukraine's electricity system. This is most pronounced during peak load periods when imports are insufficient to cover the shortfall, and the energy market operator resorts to forced disconnections of consumers, primarily industrial ones. Providing imports has become a strategic objective, and work is already underway to expand technical capabilities, allowing more companies to focus on imported power in the future.

In addition to generators and electricity imports, many companies have invested in constructing their own power generation capacity. Some of the most affordable options for small and medium-sized companies are solar power plants. In Ukraine, there is intense competition among companies involved in the installation of such power plants, which are based on imported, primarily Chinese, components.

2.2. Solar panels

Ukraine's solar photovoltaic sector has experienced significant growth and challenges, particularly in the context of recent situation. As of early 2022, Ukraine had achieved a total installed solar PV capacity of 8 GW, marking a substantial increase from 2 GW in 2018. This rapid expansion underscores the sector's potential in contributing to Ukraine's energy diversification.

The recently adopted Ukraine Plan outlines the addition of only 0.7 GW of solar PV capacity by 2027, which is modest compared to the country's technical potential. Techno-economic modeling suggests that by 2027, Ukraine could integrate a total of 9.2 GW of

solar PV, representing a 3.6 GW increase from current levels. By 2030, this capacity could reach 14 GW, requiring an estimated investment of €4.39 billion[5].

However, the ongoing conflict has adversely affected approximately 30% of this capacity by mid-2024. Many installations are located in occupied territories or have uncertain statuses, leading to temporary unavailability. Despite these setbacks, solar PV has played a crucial role in maintaining electricity supply, especially due to its decentralized nature. Both utility-scale and small-scale distributed solar PV systems have enhanced system resilience, providing clean and reliable electricity even as large fossil-fuel plants have been compromised.

Solar energy, in particular photovoltaics (PV), is currently the fastest growing renewable energy source in the EU. Solar energy is cheap, clean and flexible. The cost of solar power decreased by 82% between 2010-2020, making it the most competitive source of electricity in many parts of the EU.

Last year, 56 GW of solar capacity were installed in the EU, around 66% of it on rooftops, empowering consumers and protecting them from high electricity prices and reducing land use. Between 2021 and 2023, annual growth in installed solar capacity was 25%, and this rate is expected to remain steady in the future.

The installations in 2022 and 2023 saved the equivalent of 15 billion cubic meters of Russian gas imports in total, mitigating the risk of disruption of gas supplies to the Union. In addition, the sector provides around 650 000 jobs, 90% of these on the deployment side, and is projected to increase until around 1 000 000 by 2030[6].

Countries such as Germany have implemented reforms to integrate renewable energy more effectively into the national grid. For instance, Germany's recent energy reform requires

[5] https://www.greenpeace.de/publikationen/20240607-greenpeace-report-BE-solar-marshallplan-ukraine-encv.pdf

[6] https://energy.ec.europa.eu/topics/renewable-energy/solar-energy/

most new wind and solar plants with a capacity of at least 25 kilowatts to sell electricity on the open market, aiming to manage electricity surpluses and stabilize the grid[7].

The European Solar Charter highlights that most of Europe's demand for solar modules is met through imports from a single supplier, China (97%). This dependency poses short-term risks to the resilience of the solar value chain and long-term risks to price stability. To align with the development of solar energy, it is essential to ensure access to affordable solar modules from diverse sources while developing a resilient, sustainable, and competitive European solar value chain.

In Ukraine, solar panels are popular with both commercial enterprises and individuals for household needs. Commercial and residential users of solar panels are able to sell surplus electricity produced to the state. It makes PV systems an attractive investment for those who have big areas available for installing solar panels, such as rooftops.

A solar power plant is a facility with a high degree of autonomy, and its launch does not require the hiring of additional employees, as all processes can be controlled by special software. A solar power plant requires minimal operating costs and simple maintenance[8].

One of the main disadvantages of installing solar panels is the geographical location of Ukraine. The distance from the equator, the short daylight hours, and the limitation of solar radiation by weather conditions limit the potential of solar power plants.

The efficiency of solar generation varies from region to region. According to Photovoltaic Geographical Information System (PVGIS) the average annual solar irradiation in Ukraine is 1200-1400 kWh/m^2 (Figure 5). For comparison, in Africa, this indicator reaches 2500

[7] https://www.reuters.com/business/energy/germany-mandate-open-market-sales-new-wind-solar-plants-2024-11-13/

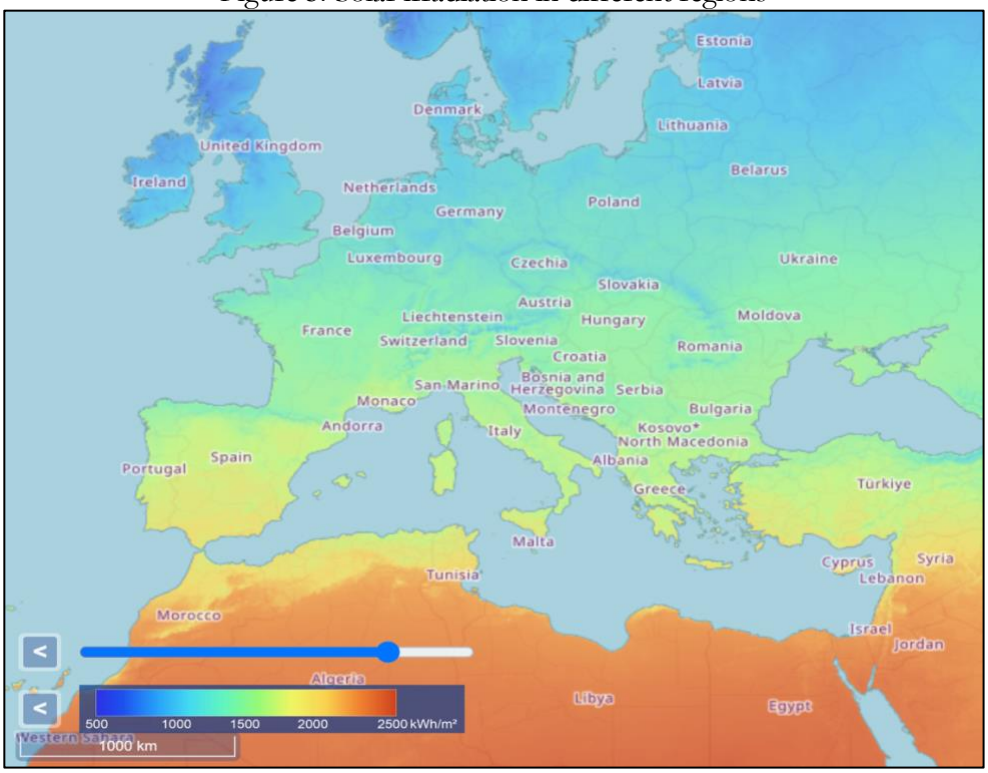
[8] https://rayton.com.ua/en/business/

kWh/m^2 (red color). The potential of solar generation in Ukraine is consequently only 50-60% of the possible global maximum.

In Ukraine, the generation of solar energy strongly depends on the time of year, with the most favorable months for generating electricity being June, July, and August due to the longest daylight hours.

Despite geographical constraints, solar panels are highly attractive for investment in Ukraine. Geographical factors such as location and weather conditions in Ukraine can significantly affect an investment project, reducing its profitability and increasing its payback period. The most attractive areas for such projects in Ukraine are the southern and central regions.

Figure 5. Solar irradiation in different regions



Source: PVGIS

Reducing the carbon footprint is an important factor for companies that export their products to the EU, where the carbon tax (CBAM) will be introduced in 2026[9]. Switching to alternative energy now is an opportunity to compete with other players in the European market on an equal footing in the future.

Considering the different electricity consumption of different enterprises and the technical conditions for installing solar panels, the most attractive investment will be for businesses with a large surface area for solar panels. The transition to solar energy will benefit businesses such as agricultural companies and grain elevators, storage facilities, and industrial manufacturing companies.

One of the largest companies installing PV systems in Ukraine, Rayton, has already completed many projects, including "Kostopilskyi Zavod Sklovyobiv" (1405 kWh), "ACT" (825 kWh), "UmanPyvo" (778 kWh), "Kyivguma" (505 kWh) and many others[10]. The estimated payback period for these types of power plants is 3-5 years. While they may not be sufficient to meet the electricity demands of larger businesses, they can significantly reduce energy costs and serve as a crucial supplementary energy source, which is becoming increasingly important in today's environment. Under mass implementation, they can significantly reduce the burden on the Ukrainian energy system and create a long-term positive impact on company welfare.

According to Yasno, one of the major electricity suppliers in Ukraine, the company also offers solar panel installation projects for businesses and individuals. They have reported that a 100 kWh commercial plant installation project would take approximately 60 days to complete[11]. Yasno also offers direct buyback of surplus electricity produced, simplifying the process and avoiding bureaucracy and the need to cooperate with government bodies.

[9] Carbon Border Adjustment Mechanism, European Commission

[10] https://rayton.com.ua/en/portfolio/

[11] https://yasno.com.ua/solar-stations

Another advantage of investing in solar panels is the availability of the government's program of affordable loans, known as "5-7-9", for micro, small, and medium businesses.

With the rise in electricity prices in Ukraine due to military actions and occasional access issues, installing solar panels presents an alternative cost. It reduces the enterprise's dependence on external factors and allows to continue some energy-independent processes. In situations when an enterprise needs to import electricity or pay for Ukrainian electricity at the import price, solar generation can help reduce the average cost of electricity, depending on its share in the total electricity consumption.

2.3. Related studies

The rapid development of renewable energy sources in the 21st century has attracted significant attention worldwide, particularly in Ukraine. Publications covering renewable energy considered RES as a source of clean energy, a lot of attention was paid to reducing carbon footprint, and the consumption of fossil fuels, such as coal and oil.

Bashynska (2020) presented the status of renewable energy development in Ukraine before 2022 and highlighted the main advantages of investing in renewables in Ukraine in pre-war conditions. The analysis indicated that, due to the budget deficit, the state is currently unable to allocate sufficient funding for a complete transition to a renewable energy sector. Nevertheless, recent developments have rendered investment in Ukrainian renewables highly advantageous. The Ukrainian government is actively promoting private sector investment in the renewable energy industry through the implementation of supportive legislation and attractive economic incentives, including the introduction of a "green tariff". The analysis of the prospects and problems in the electricity generation industry caused by the war significantly supplements and updates earlier studies, while also shifting the focus of attention from state to private initiative.

Jamil et al. (2012) evaluated investments in solar energy in terms of a cheaper analogue to generators and lower emissions. The cost of a photovoltaic (PV) system varies depending

on the local cost of components, which can differ greatly between countries and regions. This variability makes it challenging to compare the life cycle cost of PV systems with other centralized and decentralized electricity generation systems. Solar photovoltaic systems are known for their ease of installation and their ability to produce a high amount of electrical energy compared to other renewable energy sources. Additionally, they offer significant environmental benefits, including reduced emissions by decreasing the load on diesel generator sets and producing no pollution when operating grid interactive solar PV systems.

Bicen et al. (2022) performed technical and economic analyses of solar power generation using the Bursa region, Turkey as an example. The study's results show that solar power plants can be sustainable without a need of incentive mechanisms. As costs decrease and technologies advance, incentive mechanisms may become less necessary in the future. However, it's currently important to provide subsidies for photovoltaic technology, as it is expected to be a significant energy production technology in the future.

Despite the prolonged crisis in the Ukrainian energy sector and the ongoing hostilities, the issue is primarily addressed in analytical reports. Practical methods for addressing economic and power shortage problems are primarily practiced by companies involved in the installation of renewable energy sources and interested in their development. This study aims to enhance previous research in this field by providing new practical insights and considering the current conditions in Ukraine.

CHAPTER 3. METHODOLOGY

The purpose of this study is to analyze the industry of renewable solar energy for companies, calculate the benefit of installing own generating capacity and evaluate the positive impact of diversification of electricity sources on the company's financial results on the example of a particular enterprise.

The hypothesis of this study posits that the implementation of solar panels can have a beneficial economic effect on a company's operations by effectively reducing energy costs. Given the current challenges that the Ukrainian energy sector is facing due to the ongoing conflict, this research seeks to explore not only the financial implications but also the broader advantages of integrating photovoltaic (PV) systems. These advantages may include diversifying electricity sources and fostering greater energy independence for the company, thereby mitigating dependence on external factors and events.

The research methodology consists of calculating and forecasting PV systems' output in kWh and monetary equivalent, comparing this value with the same for electricity from the traditional grid, and analyzing the economic benefits and changes in the company's costs and cost structure.

Solar panels have a unique characteristic: unlike conventional electricity sources and other renewable sources, they cannot operate continuously throughout the day. Their effectiveness depends on various factors such as the season, time of day, and weather conditions. Thus, another assumption is that the effective operating time is not equal to 24 hours per day, and therefore the effective generation capacity is not equal to that specified in the project specifications. To calculate the effective operating time and capacity, one must divide the annual output by the total number of days in the year and by the hourly capacity. This method provides a clear understanding of PV system’s operational efficiency and productivity metrics.

Regardless of the investment amount required, which will vary depending on the scale of the project, the main indicator considered in this analysis will be the difference between the current electricity tariff and the photovoltaic (PV) system tariff per 1 kWh.

$$Price\ difference\ =\ Current\ tariff\ -\ PV\ system\ tariff$$

This indicator shows how much the cost of electricity has changed due to the implementation of own generation capacity. By analyzing the changes in these tariffs and their difference over a certain time period, it will be possible to draw conclusions about the positive or negative changes and trends in this industry. The difference in tariffs is also important for the next step of the assessment. With data on total installed capacity, it is possible to calculate the potential benefit of cost savings on electricity.

The approach to assessing the financial benefits of installing a company's own power generation capacity can be depicted by the following equation:

$$Benefit\ = Capacity * (Tariff\ -\ PV\ syst\ tariff) * Efficiency * Period$$

Efficiency is calculated by dividing the total projected annual output by the number of days in a year (365 or other if efficiency is calculated other than annual) and by the projected capacity of the solar power plant.

$$Efficiency = \frac{Output}{Capacity * Days}$$

Solar panel output and therefore the benefit can be calculated on a monthly or yearly basis (Table 1).

Table 1. Model inputs

Model inputs					
	Capacity	Target price	PV system tariff	Efficiency	Period
Measurement unit	kWh	UAH	UAH	hours or % of capacity	months, years

Advances in solar panel technology and modern information technology allow to extend the methodology and add many technical characteristics that are important for a more accurate assessment of solar panel performance and their effects on enterprise performance. Using the PVGIS Calculator, factors such as the exact location of the site will be added to the model to help more accurately calculate the expected solar radiation, and therefore solar generation, for each month of the year.

This tool offers the capability to project average monthly generation; however, actual results can significantly vary based on weather conditions. The average deviation may range from 5% to 30%. Consequently, three scenarios can be developed: pessimistic, baseline, and optimistic, each based on the solar generation forecast.

This approach allows Current tariff to be treated as a variable that can be replaced by another parameter. Taking into account the existence of inflation, the increase in the price of electricity under war conditions and other factors, this provides an opportunity to evaluate RES investments in the future as well. The price parameter can be the current tariff adjusted for inflation, the level of electricity prices in EU countries (minimum, average, etc.).

The estimation of annual benefits (cost savings) can be used not only to assess the prospects of investment in a project and its payback period. The approach proposed in this study suggests analyzing changes in financial performance in the following framework:

- calculating the material cost difference over a period of time and comparing it with the financial benefit of establishing RES over the relevant period of time;
- comparing the change in the share of material costs among the total costs over a period of time, thus allowing to draw conclusions about the impact of RES investment on the company's cost structure.

CHAPTER 4. DATA

For analysis of renewable energy integration performance by different companies, important indicators will be capacity, current tariff, PV systems tariff, and payback period. The source is the data from Rayton, the biggest Ukrainian company by the number of installed PV systems for business.

Table 2. The outcome of the PV systems installation

Company	Capacity (kWh)	Date	Current tariff (UAH/kWh)	PV system tariff (UAH/kWh)	Payback period (years)
Kostopil glass products factory	1405	08/2023	6.0	1.0	3.5
AST	825	06/2022	5.5	0.7	3.4
Umanpivo	778	08/2022	4.2	0.7	3.8
Radekhiv bio ferm	725	06/2022	5.0	0.7	3.5
"Tribo" factory	544	06/2023	5.5	0.7	3.5
TASCOM	531	2021	3.44	0.69	4.5
Kyivguma	505	06/2023	7.0	0.69	3.0
Berdychiv brewery	355	07/2022	5.0	0.7	3.5
"Gorstal" factory	325	06/2023	-	-	-
The Carpathian mineral waters	287	12/2022	6.5	1.0	3.0
Revega	275	2021	5.0	0.7	3.5
Svit mebliv	246	03/2023	6.5	1.0	3.0
Thermo-Pak	231	10/2023	7.5	0.6	2.0
Radivilyvmoloko	217	09/2023	6.5	1.0	3.0
SE "Zeelandia"	202	09/2023	6.5	0.6	2.0
Karavan TM	170	2021	4.2	0.71	4.1
Lyuboml Hlib	158	09/2022	6.5	1.0	3.0
Steikagro	124	06/2023	6.5	1.0	3.0
Agrosoya	120	04/2023	7.0	1.0	3.0
Uman shopping centre	116	01/2023	6.5	1.0	3.0

Source: Rayton

Capacity displays the number of kWh generated, current tariff – the market value of electricity for the company, and PV (photovoltaic) system tariff – the cost of generated electricity. The payback period is the expected time of the invested costs return.

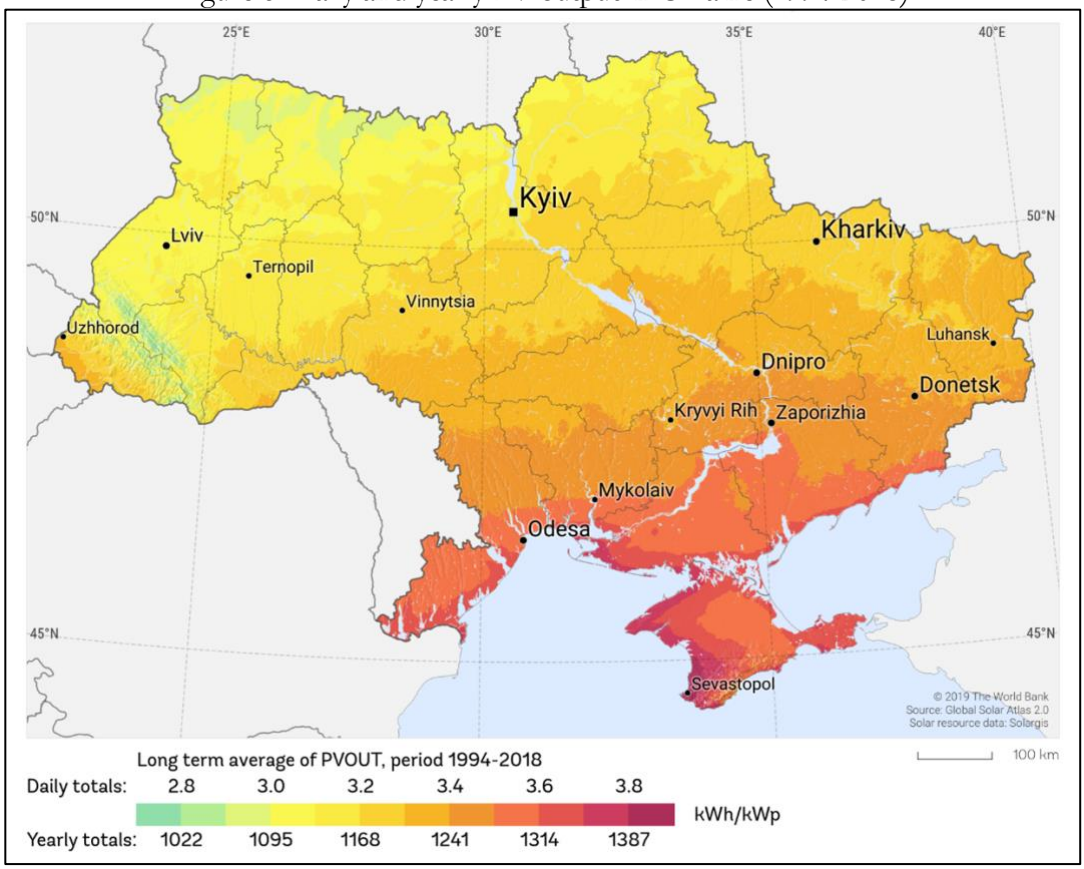
According to the data from Table 2, the current tariff's lowest value was UAH 3.44 in 2021, and the highest – UAH 7.5 in October 2023. Given that these tariffs are close to the average

tariffs for businesses in Ukraine, they have more than doubled in 2 years, however, this rate is not adjusted for inflation and exchange rate.

Detailed data from the World Bank enables analysis of both the regional attractiveness for solar investment and a superficial assessment of the amount of generation in daily and annual terms.

According to this data, the daily maximum generation reaches 3.8-4 kWh/m^2. The most attractive region for the operation of solar power plants is expectedly the most southern regions of Ukraine. At the same time, Crimea and other regions of Ukraine are occupied, which narrows the possibilities for solar power plants in the country.

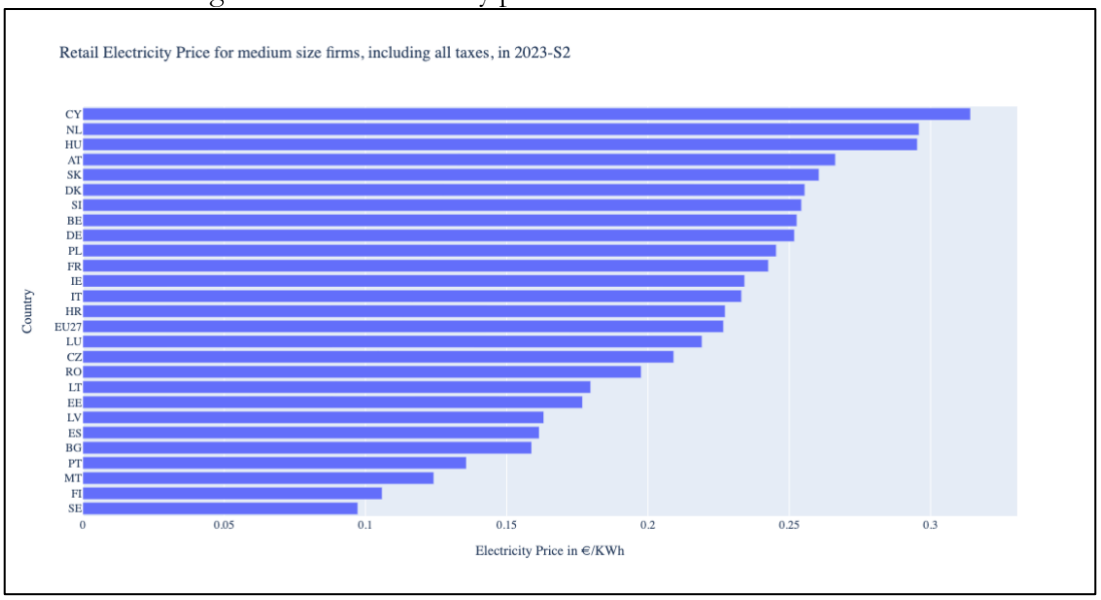
Figure 6. Daily and yearly PV output in Ukraine (1994-2018)



Source: The World Bank

Data on the price of electricity for businesses in different EU countries is important for modeling different scenarios for Ukrainian companies. According to Eurostat, retail electricity prices for SMEs in the European Union in 2023 varied from 0.1 EUR/kWh in Sweden to 0.34 EUR/kWh in Cyprus (Figure 7).

Figure 7. Retail electricity price for SMEs in the EU in 2023



Source: Eurostat

Financial data and indicators are needed in order to assess the impact of renewable energy deployment on a company's operational and financial performance. An example of such data is the financial reports of the Kostopil glass products factory (KZS Glass)[12].

By combining data for multiple years (2021–2023) it will be possible to compare the data of the selected year with other years or periods.

[12] https://www.kzs.glass/our-stockholders/

Table 3. Kostopil glass products factory financial results

	2021	2022	2023
Financial results			
Revenues	865 559	1 626 389	1 792 657
Expenses	(767 311)	(1 288 311)	(1 091 694)
Gross Profit	98 248	338 078	700 963
EBIT	17 504	289 966	624 306
Operating expenses			
Cost of goods sold	553 936	952 451	927 504
Labor expenses	154 555	174 624	206 704
Amortization	123 604	99 745	102 826
Other operating expenses	66 564	162 649	181 590
Total	898 659	1 389 469	1 418 624

Source: KZS Glass financial statements

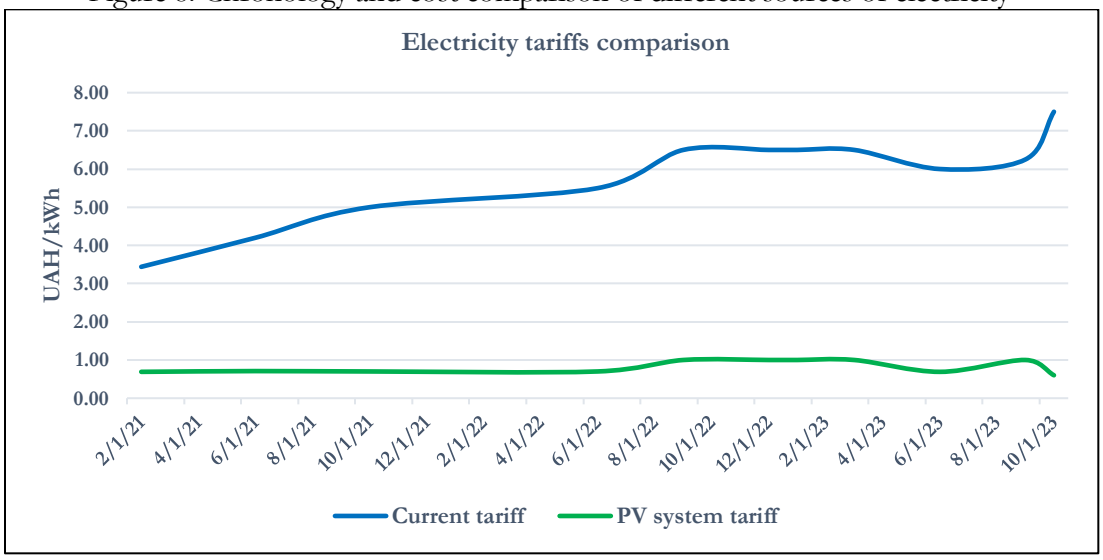
Among the financial data, the cost of materials can also be highlighted, as electricity costs are related to this item in the financial statement.

CHAPTER 5. RESULTS

Based on historical data (Figure 8), the base electricity tariff for companies is characterized by a gradual upward trend. While further growth is quite foreseeable under the current risks in the energy sector, the tariffs obtained through solar panels not only do not increase but even slightly decrease at the end of the observation period.

It might be attributed to a variety of factors, including increased competition and the development of companies specializing in renewable energy systems such as Rayton; increased supply of components such as solar panels; and government support for renewable energy in the form of import fees and VAT exemptions, subsidies for the installation of solar panels and discounted loans.

Figure 8. Chronology and cost comparison of different sources of electricity

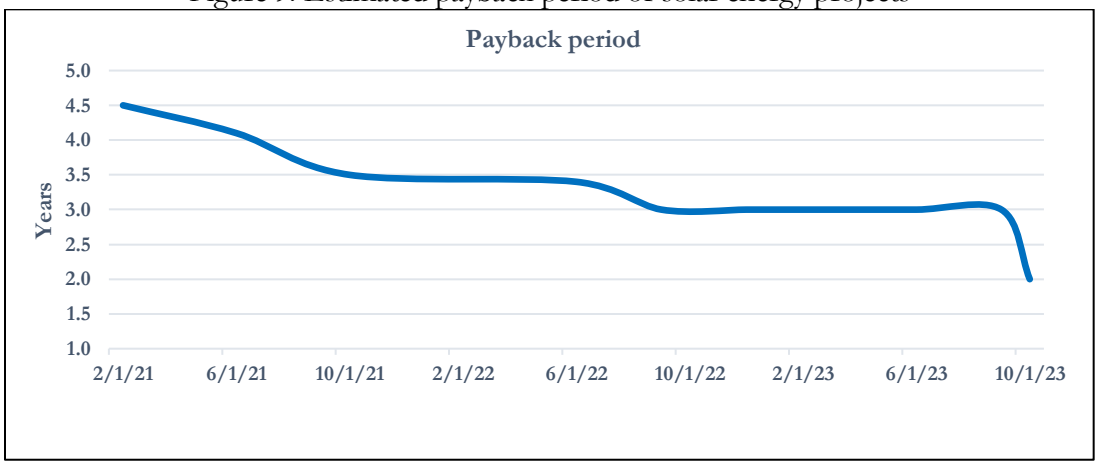


Source: own calculation using data from Rayton

Renewable energy was considered a profitable investment well before the 2022 full-scale invasion and further business environment changes. The profitability of investing in a company's power generation capacity (using solar panels as an example) has become even more favorable after 2022 due to economic and other factors. This was confirmed by the results of the analysis showing the growth of the difference between the base tariff and PV

system tariff in the last 3 years (Figure 8), the decrease of the payback period (Figure 9), and the stable low cost of electricity generation.

Figure 9. Estimated payback period of solar energy projects



Source: own calculation using data from Rayton

Table 4 presents the results of a calculation for a company located in Kostopil, Rivne oblast of Ukraine, with an installed capacity of 1405 kWh.

Table 4. Performance of grid-connected PV: results

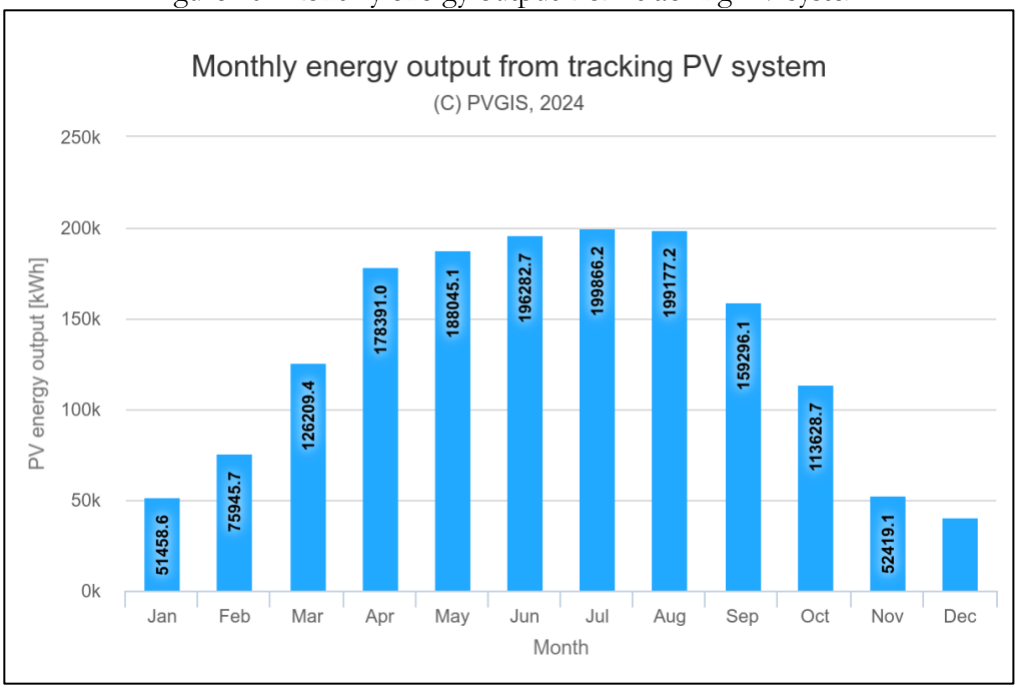
Provided inputs:	**Results:**
Location [Lat/Lon]:	50.883, 26.451
Database used:	PVGIS-SARAH2
PV technology:	CRYSTALLINE SILLICON
PV installed [Wp]:	1405
System loss [%]:	10
Slope angle [°]:	38 (opt)
Azimuth angle [°]:	-2 (opt)
Yearly PV energy production [kWh]:	1581895.72
Yearly in-plane irradiation [kWh/m2]:	1342.08
Year-to-year variability [kWh]:	77453.53
Changes in output due to:	
Angle of incidence [%]:	-2.95
Spectral effects [%]:	1.61
Temperature and low irradiance [%]:	-5.48
Total loss [%]:	-16.11

Source: PVGIS

Using the PVGIS tool, we obtained detailed technical specifications for a specific project in Kostopil, where KZS Glass has installed a solar power plant with a capacity of 1405 kWh. According to the results, the projected annual output of solar panels will be 1 581 895 kWh, which is equal to 131 824 kWh per month on average. The tool offers detailed results based on the month (Figure 10), with electricity output ranging from approximately 45 000 kWh in December to 200 000 kWh in July. Since the analysis is conducted on an annual basis, it is sufficient to consider either an average daily value or an annual value.

Using the example of the enterprise KZS Glass in Kostopil, the total effective operating time (the time similar to the time for which the PV system would operate at full capacity) is 3 hours and 5 minutes. According to this, the duration of 3 hours can be regarded as the standard average in Ukraine.

Figure 10. Monthly energy output from tracking PV system



Source: PVGIS

Table 5. Financial benefits from PV systems installation

Company	Capacity (kWh)	Price differential (UAH)	Annual financial benefits (UAH)
Kostopil glass products factory	1405	5	7 692 375
AST	825	4.8	4 336 200
Umanpivo	778	3.5	2 981 685
Radekhiv bio ferm	725	4.3	3 413 663
"Tribo" factory	544,4	4.8	2 861 366
TASCOM	531	2.75	1 598 974
Kyivguma	505	6.31	3 489 272
Berdychiv brewery	355	4.3	1 671 518
The Carpathian mineral waters	275	5.5	1 957 313
Revega	246	4.3	1 351 340
Svit mebliv	231	5.5	1 656 188
Thermo-Pak	217	6.9	1 858 653
Radivilyvmoloko	202	5.5	1 391 198
SE "Zeelandia"	170	5.9	1 401 929
Karavan TM	158	3.49	771 953
Lyuboml Hlib	124	5.5	1 023 825
Steikagro	120	5.5	951 555
Agrosoya	116	6	814 680
Uman shopping centre	116	5.5	722 700

Source: own estimations

According to the results of the analysis, the annual financial benefit from installation of own generating capacities varies from UAH 722 700 to UAH 7 692 375 depending on the capacity scale.

To further confirm the hypothesis about the positive impact of solar panel implementation, we will conduct a financial analysis of KZS Glass. Despite the stable revenue growth dynamics, the cost dynamics are unstable. In 2021, EBIT was only 2% of revenues. The following years show an increase in EBIT to 34%, indicating an improvement in operating performance. This can result in a range of measures, but in 2023 – when KZS Glass installed solar panels – we can find evidence of a positive impact on costs and their structure. 2023 was the only year in the monitored period when revenue growth was accompanied by decreased expenses. The cost reduction in 2023 by UAH 25 million significantly exceeds the estimated savings from the implementation of

solar panels. However, given the significance and scale of this project, it is very likely that it has made a significant contribution to cost reduction.

Table 6. KZS Glass financial analysis

	2020	2021	2022	2023
Financial results				
Revenue	832 902	865 559	1 626 389	1 792 657
Expenses	-598 879	-767 311	-1 288 311	-1 091 694
Gross Profit	237 023	98 248	338 078	700 963
EBIT	185 928	17 504	289 966	624 306
EBIT/Revenue	22.3%	2.0%	17.8%	34.8%
Operating expenses				
Cost of goods sold	375 741	553 936	952 451	927 504
Cost of goods sold share	45.1%	64.0%	58.6%	51.7%
Cost of goods sold difference	-	178 195	398 515	-24 947
Cost of goods sold difference, %	-	47.4%	71.9%	-2.6%
Revenue difference, %	-	3.9%	87.9%	10.2%

Source: KZS Glass, own calculations

Solar panels allow to generation own electricity, reduce cost and enhance energy independence. The installation of solar modules can also be considered an investment project rather than a purely technical one. Even if a company has no urgent need to reduce costs or expand its sources of electricity supply, it can expand its business by selling the generated electricity to the state or to companies that supply electricity.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

The analysis of the Ukrainian energy industry reveals important aspects of its functioning and enables predictions about the conditions that enterprises will face in the near future. One key conclusion from the analysis is the uneven balance in the energy market throughout the year. This finding allowed to identify periods that have the most and least impact on enterprise activity, providing insights into when risks may increase and when preparedness is essential.

From 2022 to 2024, the Ukrainian power sector is marked by seasonal power shortages and blackouts, largely influenced by weather conditions. In 2023 and 2024, the most significant power shortages are expected to happen from January to April and from July to August. This pattern is primarily due to peak demand: high electricity usage during the cold winter months and the hot summer months. Solar panel generation can be quite uneven, with its highest output occurring during the summer months. As a result, photovoltaic systems are most effective in summer. This not only helps save costs but also helps in addressing the challenges posed by the crisis in the Ukrainian energy system during this time of year.

Solar panels and PV modules are most effective for small and medium-sized businesses, while large businesses can only partially utilize this tool, primarily for their individual units that are most suitable for this purpose, such as warehouses, offices, and large premises.

The efficiency of solar generation varies from region to region. The average annual solar irradiation in Ukraine is 1200-1400 kWh/m^2. The potential of solar generation in Ukraine is consequently only 50-60% of the possible global maximum.

In Ukraine, the generation of solar energy strongly depends on the time of year, with the most favorable months for generating electricity being June, July, and August due to the longest daylight hours.

Ukraine's potential for solar energy development is significant but currently constrained by the ongoing conflict. Detailed data indicates that the daily solar generation can reach 3.8-4 kWh/m^2, particularly in the southern regions, which are the most favorable for solar power operations. However, the war has severely impacted these areas, as key regions like Crimea and other southern oblasts are under occupation.

The occupation limits the geographical scope for new solar installations and reduces the operational capacity of existing infrastructure. Despite its technical potential for renewable energy expansion, the conflict imposes significant barriers to fully unleashing Ukraine's solar energy resources, affecting energy security and the transition to sustainable energy sources.

Renewable energy was considered a profitable investment well before the 2022 full-scale invasion and further business environment changes. The profitability of investing in a company's power generation capacity (using solar panels as an example) has become even more favorable after 2022 due to economic and other factors. This was confirmed by the results of the analysis showing the growth of the difference between the base tariff and PV system tariff in the 2022-2024 period, the decrease of the payback period, and the stable low cost of electricity generation.

With the rise in electricity prices in Ukraine due to military actions and occasional access issues, installing solar panels presents an alternative cost. It reduces the enterprise's dependence on external factors and allows to continue some energy-independent processes. In situations when an enterprise needs to import electricity or pay for Ukrainian electricity at the import price, solar generation helps to reduce the average cost of electricity, depending on its share in the total electricity consumption.

The base electricity tariff for companies is characterized by a gradual upward trend. While further growth is quite foreseeable under the current risks in the energy sector, the tariffs

obtained through solar panels not only do not increase but even slightly decrease at the end of the observation period.

Analysis of Ukraine's energy sector has shown that during crisis periods, even external assistance in electricity supplies cannot cover the entire deficit and prevent blackouts for businesses. Thus, in such conditions, the role of energy independence of companies increases. The analysis of technical and economic indicators of solar power plants has shown that they are an effective tool to diversify supplies and reduce electricity costs. It was calculated that the effective operating time of solar panels in Ukraine on average per year is 3 hours. In percentage terms, the indicator is 12.5%.

According to the results of the analysis, the annual financial benefit from installation of own generating capacities on the example of Rayton's projects varies from UAH 722 700 to UAH 7 692 375 depending on the capacity scale.

The analysis of Rayton's largest project for KZS Glass in Kostopil, which has an installed capacity of 1405 kWh, indicated positive cost reduction dynamics in the year of project implementation.

Depending on the share of electricity in the cost structure and the share of electricity substituted by own generation, it is possible to draw a precise conclusion about the impact of introducing PV systems, but this requires detailed data from the companies. Thus, it is possible to forecast cost reductions depending on the degree of PV system implementation. For example, if electricity accounts for 20% of the costs, the introduction of solar panels will replace 50% of the electricity demand, and the savings on electricity price will be 80%, it is possible to predict the cost reduction projection using the formula 0.2*0.5*0.8 = 8% of the total costs.

Solar panels allow to generation own electricity, reduce cost and enhance energy independence. The installation of solar modules can also be considered an investment project rather than a purely technical one. After all, even if a company has no urgent need

to reduce costs or expand its sources of electricity supply, it can expand its business by selling the generated electricity to the state or to companies that supply electricity.

Despite the prolonged crisis in the Ukrainian energy sector and the ongoing hostilities, the issue is primarily addressed in analytical reports. Practical methods for addressing economic and power shortage problems are mainly practiced by companies involved in installing renewable energy sources and interested in their development. This study contributed to previous research in this field by providing new practical insights considering the current conditions in Ukraine.

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APPENDIX