A Work Project, presented as part of the requirements for the Award of a Master's degree in Finance from the Nova School of Business and Economics.

ECONOMIC ANALYSIS OF ROOFTOP SOLAR PV PANELS IN CHELMZA, POLAND

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Keywords

#SolarPanels #RenewableEnergy #Sustainability #Chelmza #Poland #EnergyConsumption

Table of Contents

Summary of rooftop solar analysis

Location: Chelmza, Poland **Date of analysis**: December/2022

Recommendation*: install 2 solar panel (3.454 m^2), for a net present value of EUR 1,119.40 with a payback of 0.8 years.*

Main economic results:

Financing	NPV (EUR)	Payback (years)	IRR (%/year)	LCOE (EUR/kW)
Gov. subsidies and 75% debt	1,119.4	0.8	122.9	0.02
Gov. subsidies and 100% equity	1,127.8	2.1	50.9	0.02
No gov. subsidies and 100% equity	-629.3	15.7	5.9	0.13

Additional results:

A system of panels together with a battery of 5 kWh, which costs around EUR 4,000, requires an initial total investment of around EUR 14,000 of which EUR 9,500 are equity brings down the NPV from EUR 1,119.4 to EUR 286.18 with a payback period 12 years and an IRR of 10.02%. This considers the government subsidies of EUR 1,260 for the panels and EUR 3,150 for the batteries.

Main inputs and assumptions:

Household and Economics

Electricity Consumption	3280	kWh/year	Inflation	2%	per year
Electricity price – buy	0.11	EUR/kWh	Bank loan interest rate	8.99%	per year
Electricity price – sell *Selling price is until middle of 2024 then it goes to 0.09 EUR/kWh*	0.14	EUR/kWh	Bank loan maturity	5	years
			Equity cost of capital	6.795%	per year

PV panels chosen

Peak power	365	W/panel	System losses	14%	of output
Panel area	1.727	m^2/panel	Degradation with age	0.5%	per year
Useful life	25	Years	Maintenance costs	0	EUR/year
			Total cost of optimal installation size (without subsidies)	1469.86	EUR

Government subsidies:

The government subsidies as 15th December 2022 entail a discount of up to EUR 1,260 on the invoice price for the purchase of PV panels while they grant an additional EUR 3,150 for the purchase of batteries.

1 INTRODUCTION

In this essay, we'll examine the financial benefits of installing solar panels on the roof of a typical residential building. This essay is a component of a larger project in which the same analysis is applied to other sites around the globe. The project's goals are to encourage more thoughtful energy consumption and sensibilize people to the benefits of switching to solar energy.

The location of our analysis is Chelmza, a town of around 14,000 inhabitants, situated in north-central Poland, in the Torun County, Kuyavian-Pomeranian Voivodeship. The area of the city is spread over 7.84 km^2 and the population density is of around 1,800 ab./km^2. The average monthly available income pro capita is of PLN 1,932.22 or EUR 413.62 (GUS, November 2022)[i], the average annual temperature is 8.9°C and the average annual rainfall is 647mm (Climate data, 2022)[ii].

The economic worth of the investment is highly reliant on variables that change over time, such as government subsidies, bank loan interest rates, and raw material prices, as well as cost of energy, which the reader of this paper should bear in mind. The study, which is designed to be as exact as feasible, can be deemed reasonable for S2 2022 and correct as of that year.

In order to make a final decision on the investment to undertake, multiple economic factors such as NPV, IRR, Payback period, LCOE, etc. have been considered; nonetheless, the reader should not undervalue the environmental impact that a project like this can give. Everyone's exposure to the current shift toward green energy and sustainability varies, but because this is a factor that is solely personal, it is not taken into consideration in our study. Nevertheless, we advise the reader to consider this factor when coming to a choice.

2 DATA AND ASSUMPTIONS

2.1 Standard local household

In this study we will consider the typical investor to be the average household of the town. Thus, we will account for cashflows in the perspective of a household. Given the demographic data of the town we can assume that the typical local household is composed of four people, two parents and two children. Both parents are off to work during the day while both kids are at school. Consequently, the evenings, nights, and early mornings are when consumption is at its highest. We'll suppose that the family's home has an unlimited amount of roof space for the solar system installation because the roof is completely exposed to the sun. The average annual disposable income of the household is PLN 46,373.28, or EUR 9,926.88, which is composed by the salary of the two parents.

2.2 Consumption

Energy bills gathered from several households in the area have been used to compute the local household's annual consumption. In order to do the study with the greatest accuracy, it was required that we get hourly consumption data for a typical household of 4 persons, consisting of 2 parents and 2 children, in the project location. I requested the prior year's bills from numerous members of my family and acquaintances in order to do this. I gathered information from four Chelmza homes with various consumption profiles. The four were all gas heated. Then, using the Yearly Electricity Consumption (Formula 1 below) of an apartment in Chelmza, I averaged the 4 homes.

Formula 1:

Yearly Electricity Consumption= AVERAGE (Electricity Consumption Family 1+ Electricity Consumption Family 2+ Electricity Consumption Family 3+ Electricity Consumption Family 4) ***= 3280 kWh/year***

The profile of the 4 families is described in the following table 1.

Table 1 *Profile of the households took in the study*

Family number	Number of people	Type of house	Size of the house in sqm	Construction year	Main source of energy	Annual KWh	Average annual kWh
1	4	Apartment	150	2000	Gas	4227	3280
2	5	Apartment	129	1996	Gas	4612	
3	3	Apartment	84	1961	Gas	2340	
4	3	Apartment	76	1961	Gas	1941	

The 4 households from which I received the electricity bills are heated with gas, the average size of these four accommodations corresponds to 110 sqm accommodation in - or close to - the center of Chelmza and are all heated with gas. Appliances like dishwashers, washing machines, and hot water boilers use the majority of the electricity. Since gas is the primary fuel source for most heating appliances, our study excluded them. Now, to obtain an accurate estimation of electricity inflow and outflow (from house to grid and vice-versa) it is necessary to find out the yearly consumption on an hourly basis. To do so I used a top-down approach, this means that I used a consumption profile to allocate the total annual consumption to each hour of the calendar year (8760 values).

A load profile is a collection of coefficients that report the pattern of electricity usage over a year. As each of these factors is stated as a percentage of yearly consumption, they will add up to 1. Load profile data was created by Polskie Sieci Elektroenergetyczne[iii] (PSE), a Polish electricity transmission system operator and the sole operator of Poland’s high-voltage transmission lines, which also provides patterns of consumption for different profile classes. Then I divided the yearly consumption that I computed previously by 1000 and multiplied it by the static coefficient for each hour of the year. In this way I found the Adjusted Hourly Electricity

Consumption(Formula 2).

Formula 2

$$\mathit{Adjusted\ Hourly\ Electric\ consumption} = \frac{\mathit{Annual\ Electricity\ Consumption}}{1000} * \mathit{Coefficients\ of\ load\ profile}$$

2.3 Energy Price

Several energy bills from nearby families have been gathered in order to determine energy pricing. Energa, the energy provider for the four homes analyzed operates primarily in the north of the country and has a 17% share of the Polish energy distribution market, thus it makes a good reference for the rest of the country as Energa offers similar tariffs offered in the rest of Poland. The energy supplier offers a contract type with a single fixed price and four time slots prices for all four homes. To acquire a more accurate result for our analysis, we will use different pricing. The prices inclusive of 23% VAT are divided as follows:

- From 10pm to 6am and from 1pm to 3pm there is the “Cheap Hours Tariff” for which the price is 0.3840 PLN/kWh.
- From 6am to 1pm and from 3pm to 10pm there is the “More Expensive Hours Tariff” for which the price is 0.5921 PLN/kWh.

Furthermore, with a solar panels system it is possible to sell the excess of electricity to the grid that in the case of Poland is PSE at as of 1st July 2022 buys electricity for a fixed price of 0.65929 PLN/kWh. This price will be maintained until 1st of July 2024, thereafter the sale of electricity from micro-installations will be settled according to the average market price of electricity, for the purpose of this study I used the price calculated by the polish government of 404.9 PLN/MWh or 0.405 PLN/kWh (Polish Government, gov.pl)[iv]. This means that with the solar panels system, every kWh that is produced and not used for internal consumption is going to be sold to the grid for PLN 0.65929 until the 1st of July 2024. Since there hasn’t been any other announcements regarding the future selling price of electricity, we presume that this policy will not change during the course of the investment we are considering. Additionally, it’s worth mentioning that all these selling prices from the one started in July 2022 and for the one starting from July 2024 are only applicable to micro-installations no larger than 10 kWp. However, it is also important to note how, if at some point the system is unable to fulfill the household's energy needs, they will have to purchase it from Energa at a rate that depends on the time of day, in accordance with the prior price schedule. Homeowners also have the option of using batteries to store excess energy instead of selling it to the grid, although this choice will also be examined.

2.4 Solar Irradiance

The sun irradiation in our area is a crucial element to take into account in our investigation. The PVGIS European Union website, which offers hourly solar irradiance for every day of the year, can be used to acquire this information. (European Commission Database, 2016)[v] The average solar irradiance between 2018 and 2020 was calculated and used in the calculations to reduce the bias on a single year.

2.5 Solar Panels Prices

Important for an accurate study's result was contacting three local solar panels providers to decide the best option in the market. Starting the 15th December 2022, the Polish government will increase its subsidies for both photovoltaic installations to PLN 6,000 (EUR 1,260) and for energy storage to PLN 15,000 (EUR 3,150). Previously these subsidies started from 2019 and are only half of the amount that will be given to citizen in December 2022, the reason for these big increases come from the energy crisis triggered by Russia's invasion of Ukraine. Even though all the suppliers are more or less on the same line with the prices of the panels, the company that would provide the best service is "Sun Sol"[vi], a local company that operates mostly in the north of Poland. They would provide 60-cells monocrystalline LG "365W NeON ACe" panels with built-in Microinverter System and peak power of one panel of 365W. While polycrystalline solar panels use solar cells built from many silicon pieces fused together, monocrystalline solar panels use solar cells made from a single silicon crystal. The first kind is the most popular on the market and is generally more efficient. The system they offer is also made up of independent panels, so if one is damaged or loses power, it won't affect the efficiency of the other panels, always optimizing the amount of energy produced. This is made possible by the system's built-in inverter. Finally, we are taking a 0.5% annual degradation for the panels into consideration. (European Commission Database, 2016)[vii] Based on the quantity of panels, the following table summarizes the price, size, and power of the system:

Table 2: System price, size, and power. The actual quotes from Sun Sol are in bold.

Number of panels:	**Cost**		**kW**	**Sq meters**	
10	**29950**	**PLN**	**3.65**	**17.27**	**Real quote**
18	**53460**	**PLN**	**6.57**	**31.086**	**Real quote**
20	**58650**	**PLN**	**7.3**	**34.54**	**Real quote**

2.6 Battery

A battery may be a part of the system in a more sophisticated examination. This is an intriguing option since excess energy can be created, stored, and used at a later time without having to purchase it from the grid.

There are batteries of several sizes, but the one the panels' provider could install is a LG Chem RESU battery of 6.5kWh for a price of PLN 19000, the battery has a ten-year warranty and a fifteen-year anticipated lifespan. The battery has a depth of discharge, or percentage of discharge, of 95%, and its deterioration with cycle is 0.06% of its peak power. The battery's disassembly is handled by the provider, so we did not factor that cost into our research. The loss per cycle times the total number of cycles is multiplied to provide the yearly deterioration percentage, which is taken into account. The yearly degradation is then calculated by multiplying the annual degradation percentage by the residual efficiency. The battery is replaced for free within the first ten years of the guarantee if its efficiency falls below 60% of its peak level, restoring peak power to 100%. The battery is left to deteriorate until its life expires after the ten-year guarantee period has passed.

2.7 Financing

In this analysis we also consider different ways of funding the investment, we will consider these in the next section of this thesis, in part 3, under the economic analysis.

- 100% equity would require the household to pay for the full amount of the project.

Here we will see how this is the option that produces the highest NPV since cost of equity is lower than the cost of capital. In the case for Poland the cost of equity would be of 6.795% according to the 10-year Polish government yield as of 30 November 2022.

- A combination of debt and equity would necessitate the household to apply for a bank loan and utilize it to fund 75% of the project, with the remaining 25% coming from private sources.

Several local banks have been called to get an accurate estimate of the loan interest rate, and PKO BP is the one offering the lowest rate. They would offer a loan with a 5-year maturity and monthly payments at an interest rate of 8.99%. Using the French amortization method, the loan is paid off in regular, equal amounts.

Table 3 *Interest rates offered by local banks*

Bank	**Interest rate**
PKO BP	8.99%
Santander	9.99%
Pekao	12.99%
BNP	11.49%
Alior	9.69%
BPS	9.49%

3 ECONOMIC ANALYSIS

The study has continued to analyze several investment-related factors. The NPV of the project, the IRR, the Payback period, and the LCOE are the main key performance indicators (KPI) employed. These 4 significant numbers also include additional minor KPIs.

3.1 Levelized Cost of Energy

The average net present cost of electricity generation for a generating facility during its lifetime is measured by the Levelized Cost of Energy (LCOE). It is calculated as the ratio between all the discounted costs over the lifetime of an electricity generating plant divided by a discounted sum of the actual energy amounts delivered. In practice, it represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. (Lai, Chun Sing, McCulloch, Malcolm D., 2017)[viii] The formula is the following:

Formula 3

$$LCOE = \frac{Sum\ of\ costs\ over\ life\ time}{Sum\ of\ electrical\ energy\ produced\ over\ life\ time}$$

$$= \left. \sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t} \middle/ \sum_{t=1}^{n} \frac{E_t}{(1+r)^t} \right.$$

Where: I_t = *investment expenditures in the year t*

M_t = *operations and maintenance expenditures in the year t*

F_t = *electricity expenses in the year t*

E_t = *electrical energy generated in the year t*

r = *discount rate*

n = *expected lifetime of the system*

Since, as was already indicated, it must be the cost break-even point over the course of the project's financial life, in our study we calculate the LCOE by setting the NPV of the investment to zero. The lower it is, the better because it means we would have to pay less for power to recoup our investment.

3.2 Payback Period

The amount of time required to recover an investment (reach break-even) and begin producing a profit is known as the payback period. In our situation, it is the amount of time the investor must wait before seeing a profit from the solar system. The following formula was used to perform the calculation:

Formula 4

$$Payback\ Period = \frac{Cost\ of\ the\ investment}{Average\ annual\ cash\ flow}$$

The lower the value, the better because it indicates that the investor can get a return quickly.

3.3 IRR

In financial analysis, the internal rate of return (IRR) is a statistic used to calculate the profitability of possible investments. In actuality, the IRR is the discount rate that brings the NPV of all a project's cashflows to zero. Generally speaking, an investment is more desirable to make the higher the internal rate of return. (Fernando J., 2022)[ix] One of the key KPIs considered in this project is the IRR, which is used to compare the profitability of systems with various characteristics and panel counts. The following is the IRR calculation formula:

Formula 5

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1 + IRR)^t} - C_0$$

Where: C_t *=Net cash inflow during the period t*

C_0 *= Total initial investment costs*

IRR = Internal Rate of Return

t = number of time periods

It is easier to choose a project based solely on this statistic because, in our analysis, IRR is highly varied across all of our scenarios, ranging in fact from 5% to 40% approximately.

3.4 NPV

The difference between the present value of cash inflows and outflows over a period of time is known as the Net Present Value (NPV). It indicates the present value of a future stream of payments and is used to assess an investment's profitability. In order to assess similar investment options, NPV takes into consideration the time value of money and uses a discount rate that is determined from the investment's cost of capital. With the proper management, it is reasonable to believe that, barring exceptionally unforeseeable occurrences, a solar panel system's cashflow will be generally secure and predictable. The NPV is calculated using the following formula:

Formula 6

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Where: R_t *= Net cash inflow - outflows during a single period t*

i = Discount rate that could be earned in alternative investment

t = Number of time periods

The NPV is the primary KPI used in our study to determine the final investment decision because it is the one that we assume would be most important to a typical household.

3.5 How to get to the KPIs

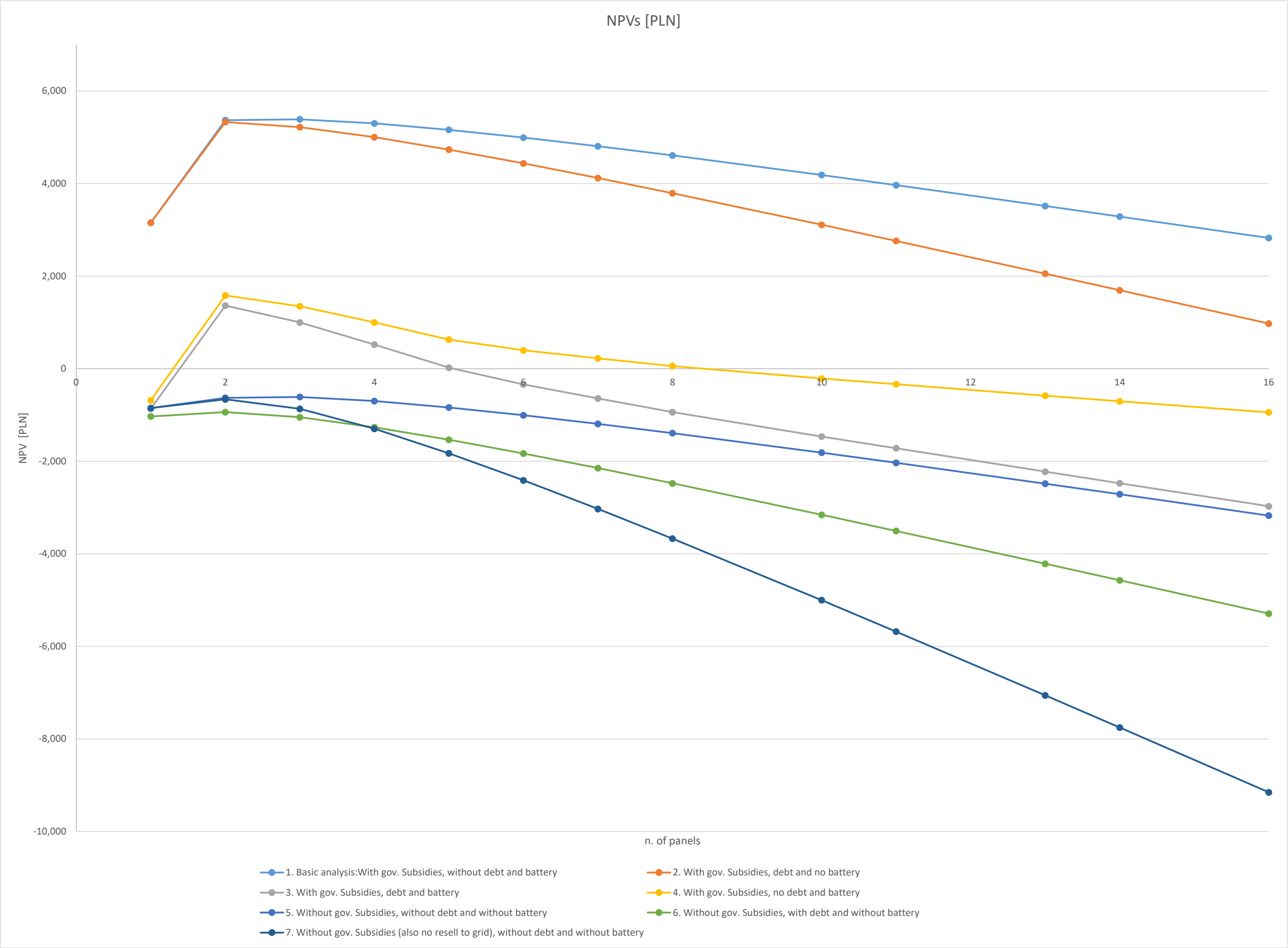
The values for energy output must be converted into economic figures in order to arrive at the findings for the various metrics.

We determine energy generation by multiplying the system's peak power by the radiation for 1 kW for every hour of the year. We then add these calculations to determine the total generation for the entire year. The next step was to calculate the year usage based on the hourly load profile previously stated multiplied by the consumption estimated from the electricity bills. The amount of energy arriving from solar panels, the amount purchased from the grid, and the amount sold to the grid without a battery may then be easily calculated. Applying the various energy prices for buying and selling positions, the cost without panels, the proceeds from the sale to the grid, the remaining cost of the energy that must be purchased from the grid, and finally the savings as a result of the project's implementation are all derived from this.

3.6 Scenarios

Different analysis scenarios have been taken into consideration in search of the optimal NPV result. This table summarizes the scenarios considered.

Table 3 *NPVs for the number of panels*



The Polish study reveals itself to be very interesting. In fact, we can see the role that the government subsidies play in shaping the profitability of solar panel investments, not only for the subsidies provided for the initial investment but also for the feed in tariffs of the Polish Government. In fact, as stated in section 2.3 this is true because since July 2022 PSE, the Polish grid, obliges owners to sell excess electricity for a high price, especially in comparison to the purchase price until 2024 and then it will buy electricity at market value for an indefinite period of time.

Additionally, we see that since the cost of equity is cheaper than the cost of debt, we see how all the scenarios for which we don’t have debt the curve is flatter.

Finally, with the number of panels increasing one would also expect to have a higher NPV with the use of a battery, this proves to be untrue for the case of Poland since it’s just better to directly sell all excess electricity to the grid and buying back the electricity when needed.

Seeing all this we can conclude that the only reason for which it is profitable to get solar panels is because of the intervention of the state from a mix of initiatives. In fact, an investor has the opportunity to utilize the subsidies to both install panels (PLN 6,000) and install a battery (PLN 15,000). But also, thanks to selling price to the grid, the investment proves profitable. In fact, the selling price could appear to some as subsidy, since PSE, which is the only electricity transmission system operator in Poland is owned 100% by the state, which might have decided on a high selling price to incentivize homeowners to switch to solar panels, otherwise if it weren’t for the revenue from selling there wouldn’t be any positive NPV for any number of panels. But this is only speculation, and it could also be that the high selling price is just caused by energy being very expensive right now and the decision from PSE was purely practical.

The subject of the first scenario, which may be regarded as the benchmark study, is the case of government subsidies, with the use of a bank loan that covers 75% of the investment, and it does not consider the use of a battery. It is clear that the overall profitability of this venture will not be the highest for the number of panels, since the cost of debt is higher than the cost of equity.

We can see that for all 16 panels in study the investment proves to have a positive NPV so we should take these into consideration. Here it can also be seen that the NPV as well as the IRR are decreasing with the increase in the number of panels, the LCOE slowly increases from 0.08 to 0.47 PLN/kWh and the payback proportionally increases with the number of panels installed. This leads to the single best choice of installing 2 panels.

The results are shown in the table below.

Table 4 *With gov subsidies, with debt and without battery*

Number of panels	NPV [PLN]	IRR	Payback [years]	LCOE [PLN/kWh]
1	3,155.50	#NUM!	0.0	0.0000
2	5,330.46	122.85%	0.8	0.0826
3	5,219.73	23.86%	6.7	0.2321
4	5,002.00	15.83%	8.9	0.3069
5	4,733.25	12.79%	10.4	0.3518
6	4,436.06	11.14%	11.4	0.3817
7	4,119.96	10.09%	12.1	0.4030
8	3,791.90	9.36%	12.7	0.4191
10	3,110.85	8.41%	13.6	0.4415
11	2,761.70	8.08%	13.9	0.4496
13	2,053.26	7.58%	14.4	0.4622
14	1,695.64	7.40%	14.6	0.4671
16	**975.73**	**7.09%**	**15.0**	**0.4751**

A second scenario takes into account the subsidies provided by the government with the only use of equity to pay for the investment, and it does consider the use of a battery. We can see that until 3 panels the investment proves to have a positive, increasing NPV and then decreases. For all number of panels taken into consideration the investment proves economically interesting. Here it can also be seen that the NPV as well as the IRR are decreasing with the increase in the number of panels, the LCOE slowly increases from 0 to 0.45 PLN/kWh and the payback proportionally increases with the number of panels installed. This leads to the single best choice of installing 3 panels.

The results are shown in the table below.

Table 5 *With government subsidies, without debt and with battery*

Number of panels	NPV [PLN]	IRR	Payback [years]	LCOE [PLN/kWh]
1	3,155.50	#NUM!	0.0	0.00
2	5,370.66	50.89%	2.1	0.08
3	5,389.24	18.77%	5.6	0.22
4	5,300.82	13.91%	7.2	0.29
5	5,161.38	11.82%	8.1	0.34
6	4,993.50	10.62%	8.7	0.37
7	4,806.71	9.83%	9.0	0.39
8	4,607.97	9.28%	9.3	0.40
10	4,185.54	8.54%	9.7	0.42
11	3,965.70	8.28%	9.8	0.43
13	3,515.89	7.89%	10.0	0.44
14	3,287.58	7.74%	10.1	0.45
16	**2,826.29**	**7.50%**	**10.2**	**0.45**

A third scenario considered doesn’t take into account the subsidies from the government, it includes the debt but not the use of battery. We can see that for no number of panels the investment proves to have a positive NPV so we shouldn’t take any into consideration. Here it can also be seen that the NPV has an inverse relationship with IRR, when the NPV is decreasing with the increase in the number of panels IRR increases, the LCOE slowly decreases from 0.736 to 0.544 PLN/kWh and the payback proportionally increases with the number of panels installed. This leads to the single best choice of installing 2 panels.

The results are shown in the table below.

Table 6 *Without government subsidies, with debt and without battery*

Number of panels	NPV [PLN]	IRR	Payback [years]	LCOE [PLN/kWh]
1	-1,032.54	3.57%	20.2	0.7369
2	-938.04	5.13%	17.5	0.6341
3	-1,048.76	5.48%	17.0	0.5998
4	-1,266.50	5.56%	16.9	0.5826
5	-1,535.25	5.56%	16.9	0.5724
6	-1,832.44	5.55%	16.9	0.5655
7	-2,148.54	5.53%	16.9	0.5606
8	-2,476.60	5.50%	17.0	0.5569
10	-3,157.64	5.46%	17.0	0.5518
11	-3,506.80	5.44%	17.1	0.5499
13	-4,215.24	5.41%	17.1	0.5470
14	-4,572.86	5.39%	17.1	0.5459
16	**-5,292.77**	**5.36%**	**17.2**	**0.5441**

Lastly, a scenario in which the investment is paid by equity, no battery is accounted for and there is no possibility to resell to the grid for the first 2 years when the resell price to the grid is much higher than the cost of purchase of electricity. In this case we finally see well defined concave function where NPV, IRR, LCOE decrease with the number of panels while payback period increases. This is what we would normally see in an investment and it's clear how the selling price to the grid plays a role in modifying the performance of the investments.

The following table sums up the main results:

Table 7 *Without government subsidies (also no resell to grid), without debt and without battery*

Number of panels	NPV [PLN]	IRR	Payback [years]	LCOE [PLN/kWh]
1	**-853.33**	**4.54%**	**18.4**	**0.7054**
2	-662.39	5.81%	16.4	0.6069
3	-868.05	5.90%	18.3	0.5741
4	-1,298.41	5.77%	21.1	0.5577
5	-1,828.87	5.63%	24.3	0.5478
6	-2,412.36	5.50%	27.5	0.5413
7	-3,031.52	5.39%	30.8	0.5366
8	-3,672.89	5.30%	34.1	0.5331
10	-5,001.34	5.16%	40.7	0.5281
11	-5,680.99	5.10%	44.0	0.5264
13	-7,058.38	5.01%	50.6	0.5236
14	-7,753.59	4.97%	54.0	0.5225
16	-9,153.22	4.90%	60.6	0.5208

4 FINAL RECOMMENDATION

4.1 Considerations

It is important to consider that the project is based on an average household from Chelmza, and that, due to the economic limitations of people living in this area, it might not be possible to undertake an investment in solar panels I considered a maximum of 16 panels (27sqm) because maximum that's the number at which a positive NPV can still be found in the case for the use of debt, with subsidies present and no battery. Even though 16 panels are not the option for which we optimize the NPV I believe that it should be taken into consideration for sake of completeness. At the same time, though, it seems like 16 panels would also prove to be too expensive for an average family living in that area. The average family of 4 people (2 working parents) in that area has a disposable income of around EUR 10,000 in a year. Installing 16 panels, although feasible in space, I don't think would be attainable for the average family since the end the investment would require EUR 8,500 which is 85% their yearly disposable income. For this reason, anyone interested in purchasing solar panels should consider applying for a loan, especially for higher amounts of solar panels.

Therefore, as it translates in the best NVP, what makes most sense for the average family is to invest in 2 panels. In fact, when considering 2 panels the family wouldn’t even have to put that much money upfront since part of it would be paid with the subsidies from the government and especially considering the economic difficulties of people here this option would be the one making most sense but in the case of a wealthier family it could make sense to make a larger investment as the price of electricity is very uncertain and as the war could drag on for longer, driving up energy prices even further.

According to the analysis, installing 2 panels for a total cost of EUR 188.65 and a power of 0.730kW would be the best choice without a battery, and using government subsidies. This would result in a levelized cost of energy (LCOE) of 0.02 EUR/kWh, a payback period of 0.8 years, annual savings of 92 EUR, and a total NPV of 1,119.40 EUR. The LCOE is a measure of the average net present cost of electricity generation for a generating plant during its lifetime. It is not advisable with the current price to sell to the grid to buy a battery to supplement the solar panels and it’s definitely not recommended to raise financing from banks as the cost of capital is higher than the cost of equity. As a conclusion, the analysis suggests that installing solar panels near Chelmza would be a wise investment and is strongly advised for all households since all of them have means to at least install one.

4.2 Conclusion

All things considered, the best decision is to purchase 2 solar panel (3.454 m^2), for a net present value of EUR 1,119.4 with a payback of 0.8 years.

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