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Problems and Opportunities for Cost-Effective Photovoltaic Systems for Private Use

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Abstract: The climate changes, rising world tensions, soaring energy prices and fossil fuel dependencies require an affordable green power solution to be found and applied. The PV systems seem to be such solution, but there are still many obstacles standing on their way, especially in Bulgaria. An analysis concerning the cost-effectiveness of PV systems is done. The results are that they are cost-effective for companies, but not so much for private users yet. There are already breakthroughs in battery technology that are expected to open wide the doors for many types of renewable energy systems. The Bulgarian regulation process is one of the main obstacles standing on the way of PV systems.

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1. Introduction

The world is on the brink of global climate changes which require urgent actions, but the rising international tensions and economic wars create even more challenges for humanity. The rising energy prices push many towards poverty and this could stop countries' economic developments. At the same time, the European Commission adopted a package of proposals to make the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels, [1]. The renewable energy sources seem to be a good solution for the changing climate and economic war challenges, but there are still many problems that stop their wide adoption. The aim of this work is to analyse the cost-effectiveness of photovoltaic systems in Bulgaria and to propose an affordable setup.

2. Methodology

The analysis includes current prices and types of photovoltaic systems more suitable for private use, concerning the overall cost of usage. Certain common parameters are reviewed for different system components. In order renewable energy sources to become widely used an economically viable project should be designed.

The analysis regards and the government regulations concerning new installations of renewable energy sources, because they could be an enormous obstacle standing in the way of their widespread use and often in Bulgaria they are. Clear, simple and cost-effective regulations for private installations should be created, because this is the only way the energy crisis to be solved and our country dependence on fossil fuels to be lowered. The analysis is done based on widely available to all customers' information.

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3. Types of photovoltaic systems

All photovoltaic (PV) systems consist mainly of PV panels and some type of smart energy converter. They could be two main types: stand–alone or grid connected, [2]. A typical block diagram of such a system is presented on Fig. 1. Both types could be with batteries or without batteries. The batteries are still too expensive and have many design deficiencies, so often their usage makes the PV systems unprofitable, so systems with less battery storage capacity are often with higher cost-effectiveness. This is about to change because the science society works hard towards improvement of battery technology and there are already declarations for significant achievements in the field. Both, stand–alone or grid connected PV systems, have advantages and disadvantages that affect their cost-effectiveness.

The stand–alone PV systems could be of DC or AC types. The AC type is more common because most electric appliances, people use nowadays, are designed to work with alternating current. They usually need certain battery storage capacity, depending on the usual power consumption, which increases their usage costs, but allows the solar cells to work in their optimal power point and assures more flexibility and power autonomy during temporary poor lighting conditions or in the dark times of the day.The grid connected PV systems are of AC type and often they don't require battery storage systems. In this case the extra generated electricity is being sold to the power grid operator instead of stored in batteries. If the generated power is not enough then additional energy is drawn from the grid which is done automatically and allows high flexibility and convenience for the users. The balance between generated and consumed energy is usually reported at the end of the month and the debtor pays the other party.

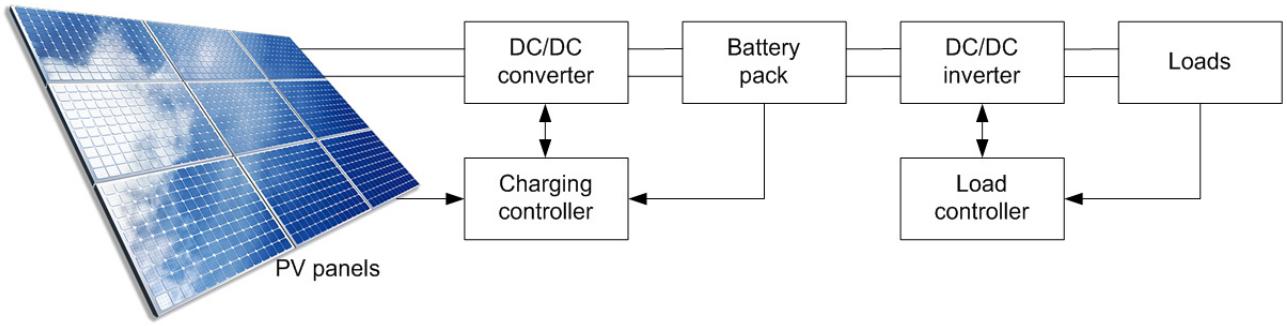


Fig. 1. Block diagram of PV system.

The possible lack of battery storage system improves their usage cost-effectiveness. The drawbacks of the grid connected PV systems usually come from the government regulations. They are often heavily regulated and the preparation of all documents concerning their commissioning is very expensive and time-consuming process. They also require a legal entity to be created because a contract should be created between their owner and the power grid operator. The legal entity has its taxes and maintenance costs. This makes these systems more attractive to companies than to private persons.

4. Photovoltaic systems with lower cost for private use

A good minimum for the average homeowner is a 5 kW PV system, which is enough for covering certain basic needs, at least in sunny days. These needs include entertainment, computer and communication equipment, cooking and certain minimum climatization. It doesn't include winter home heating and any season water heating. Solar thermal collectors for direct water heating are a good option for lower power consumption. If higher level of power autonomy is needed, then a 10 kW PV power should be enough in most weather conditions.

Because of the many regulations, only the stand-alone PV systems have a potential for lower cost for private use. Two types of such systems could be created – hybrid and grid connected without energy returning to the grid. The difference is that the hybrid system works in stand-alone operating mode if the generated power is enough to feed the current energy consumption. If the energy consumption is too high, then the hybrid inverter switches off the battery power and connects the load entirely to the grid power. The grid connected PV system uses the generated PV power and if it is not enough to feed the current load it can draw the difference from the grid. Such type of system should have the capability to detect the grid voltage and if it disappears the inverter must disconnect from the grid automatically, which is required for safety reasons.

One of the main problems for private users is the lack of enough space for the PV panels installation. In this case, PV panels with higher than the average efficiencies should be used for minimization of the required installation space. Panels with efficiencies around 20% are a good choice. The monocrystalline N-type solar cells are often used as they have high efficiencies, but higher prices too, [3]. The hybrid solar cells, consisting of inorganic and organic materials, seem to offer good price to quality ratio.

The peak power output of standard size high quality PV panels usually varies from 300W to 400W. The standard size is 1 m wide by 1.7 m long, which makes 1.7 m2 surface area. The higher efficiency panels are usually more expensive, but our research found some good deals. The Solarhouse offers 405 W standard size PV panels, produced by Risen, for the price of €162. The 375 W standard size panels of Longi cost €144. Both producers are Chinese companies. China is the world's largest manufacturer and consumer of PV cells and modules, and offers competitive prices, [4].

The research led to the conclusion that the Solarhouse company offers competitive prices for different sets of PV systems and components. Their 5 kW PV system comes with 14 PV panels Longi with 375 W peak power each. It also includes a grid Huawei inverter that allows stand-alone operations when the grid power is down. The price of the system is €3740 without battery pack and €7811 with 5 kW battery pack. This is a very high price for the average Bulgarian, but there are many people that can afford it.

The first problem is when this investment will pay off for the initial cost. Solarhouse presents data concerning the annual power production of their 5 kW power system, [5]. The energy generation varies from 292 kWh for December to 786 kWh for July. The average energy generation per month is 530.16 kWh. If we accept that the whole generated energy is used, then it could be calculated when this system is going to pay off the invested money. The electricity price per kWh for private Bulgarian users is €0.1045. The annual power generated by the PV system is 6362 kWh, which makes €664.83 per year. The pay off period of the PV system without battery pack is:

$$PayOff = 3740 / 664.83 = 5.625 \text{ years} \quad (1)$$

The pay off period of the PV system with battery pack is:

$$PayOff = 7811 / 664.83 = 11.75 \text{ years} \quad (2)$$

If the PV system is without battery pack the panels most likely won't work in their optimal power point and the generated power will be less. If the system is with batteries, they are supposed to be alive for 10 years and most likely by that time they will have to be replaced. The inverter and the PV panels could survive for 20

years. Furthermore, the PV system price doesn't include the installation cost and other additional costs, but at the same time the electricity prices are supposed to grow with time. The electricity prices for private users in Bulgaria have grown with 1.91% per year on average for the last 10 years. The historical data is from the Bulgarian National Statistical Institute. The world tensions and economic wars caused havoc on the energy market and the electricity prices are expected to rise a lot at least in the short term.

From this investigation it could be fairly concluded that the PV system most likely won't pay off the investment, but in the best-case scenario it could guarantee the current electricity price for the next 20 years. For legal companies, which electricity prices are currently 3 to 4 times higher, the system is supposed to pay off for about 2-3 years with all costs included. As of now, the PV system is cost-effective for private use by legal entities only. In this case, it would be better the PV system to be without batteries and the extra generated electricity to be sold to the grid operator.

The investigated 5 kW PV system comes with 14 standard size PV panels Longi with 375 W peak power each. 14 panels by 1.7 m2 surface area for each, makes 23.8 m2. The required surface area allows south roof installation for the average Bulgarian house owner which will save needed space. The space could be optimized if 405 W Risen panels are used instead.

During June 2022 there were powerful hailstorms in Bulgaria and it was reported that the hail broke photovoltaic panels installed in the affected region. Such storms are rare, but the climate changes worsen the weather conditions and the storms are expected to become more powerful in the near future, so a PV panel protective cover might be designed and used in the rare cases of powerful storm forecasts.

As of today, the best type of PV system for private use in Bulgaria is the stand-alone one because soon it is expected its installation to be possible with simple notification. This option will save a lot of installation costs and time. Unfortunately, this is not done yet. This type of system works better with batteries and for each separate case the minimum autonomy needed could be calculated based on the average power consumption. For higher cost effectiveness lower battery pack capacities are needed. The problem is that the batteries are still too expensive. The battery pack capacity could be estimated based on the maximum expected current consumption. The current drawn from the battery shouldn't exceed the recommended one for the types of cells used because this will extend the battery life and will lower the overall usage cost of the PV system. In this case more convenient would be a grid connected inverter to be used that allows entirely stand-alone operation of the PV system, which has an option to stop the battery pack draining when the voltage falls under certain minimum, and allows additional grid power energy consumption. If the price of such controller is too high, a regular battery management controller could be used, which will disconnect the battery when its power is low, and then the grid power must be switched on manually. This could lower the price and the payoff period of the whole system.

The battery problem is expected to be solved in the up-coming years because a lot of money are invested for the development of battery technology. There are already breakthroughs in the field. The NMC532 Li battery cell have been projected to have 100 years of lifetime for 20°C work temperature, [6]. The real lifetime is expected to be lower, but this is amazing achievement considering that the current Li battery technology allows 15 years of calendar lifetime. At the same time the NMC532 Li battery cell shows no sudden failure and no signs of capacity loss after nearly 2000 cycles, [6]. The near future is expected to offer Li batteries with high calendar and cycle lives, which will allow cheaper electric vehicles and PV systems to be designed, that may not require battery change for their lifetime. This will lead to lower costs and higher affordability for greener technologies.

5. Photovoltaic systems - problems and opportunities

There aren't many private renewable energy systems in Bulgaria in contrast to other European countries. The main problem is the heavy regulation process that makes them too expensive and stops their widespread use. It takes over a year even for small PV system to be approved. Even if the PV system is for own needs everyone must go through all regulation steps as if registering a photovoltaic power plant for electricity sale. The investor needs even to register his solar power plant as a tax warehouse and pay excise duty to customs for the electricity he produces for himself. The whole legislation in this field is unclear and creates many hindrances, [7]. This problem must be eliminated and the registration of stand-alone systems for private use must be simplified as much as possible. It is enough the installation, registration and preparation of the documentation of such sites to be left entirely in the hands of licensed companies. They could take care of this, but they must have the opportunity to quickly prepare the documentation. This will allow fast and widespread use of PV systems which will create many new workplaces, it will increase the people's standard of life and will improve country's economy.

The companies should be responsible for the safe and reliable installation design of PV systems. They must pay special attention to the risk of fire, because fire accidents involving PV systems during the last few years have shown an increasing trend worldwide, [8]. An effective lightning protection system is also necessary for PV systems, depending on the location, construction type and utilization, [9].

The fast development process of PV systems and battery technologies create many opportunities for safer, greener, healthier and abundant future for everyone. There is a great opportunity to tackle the intensifying climate changes. The rising global conflicts and energy crises revealed the high level of dependence of the free world on fossil fuels coming from militarized dictatorial regimes. This increases their income and power and creates chances for future militarized actions that could destroy the whole world. Now, there are great opportunities for freeing the world from such dependencies. All mentioned problems require all

obstacles to the widespread use of PV systems to be completely eliminated.

6. Conclusions

The current PV systems are still too expensive and the investigation based on current energy prices leads to the conclusion that they are not cost-effective for private users. In the best-case scenario, they could guarantee the current energy price for the next 20 years for them. The PV systems are cost-effective for private use by legal entities because their energy prices are 3 to 4 times higher and the investment will pay off for 2-3 years. On top of that the heavy regulation process creates additional hindrances in front of PV systems widespread use in Bulgaria. There are signs that a policy change is coming that could solve partially this problem. The battery technology develops fast nowadays and it is expected the expensive battery problem to be solved in the following 5 to 10 years. The future is bright for PV systems and they are soon expected to offer energy freedom to all countries.

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