ЗЕМАК

ЗДРУЖЕНИЕ НА ЕНЕРГЕТИЧАРИТЕ НА МАКЕДОНИЈА

MACEDONIAN ENERGY ASSOCIATION - ZEMAK

Зборник на трудови

Conference proceedings

МЕЃУНАРОДНА КОНФЕРЕНЦИЈА „ЕНЕРГЕТИКА 2024"

INTERNATIONAL CONFERENCE "ENERGETICS 2024"

СТРУГА
02 - 04 Октомври, 2024г.

STRUGA
02 - 04 October, 2024

ул.„Орце Николов“ 6б, 1.000 Скопје, Македонија • тел/факс: + 389 2 3 149 093; + 389 2 3 238 213 • info@mepso.com.mk

ЗДРУЖЕНИЕ НА ЕНЕРГЕТИЧАРИТЕ НА МАКЕДОНИЈА

MACEDONIAN ENERGY ASSOCIATION

МЕЃУНАРОДНА КОНФЕРЕНЦИЈА „ЕНЕРГЕТИКА 2024”

INTERNATIONAL CONFERENCE “ENERGETICS 2024”

Зборник на реферати
Conference proceedings

СТРУГА
02 - *04 Oktomvri, 2024*

STRUGA
02 - 04 October, 2024

Издавач/Publisher:

ЗДРУЖЕНИЕ НА ЕНЕРГЕТИЧАРИТЕ НА МАКЕДОНИЈА
ул. Даме Груев бр.14а, 1000 Скопје
MACEDONIAN ENERGY ASSOCIATION
st. Dame Gruev no.14a, 1000 Skopje

Уредници/Editors:

Проф. Невенка Китева-Роглева*/ Prof. Nevenka Kiteva-Rogleva*
Проф. Вангел Фуштиќ*/ Prof. Vangel Fustik*
Проф. Софија Николова-Поцева*/ Prof. Sofija Nikolova-Poceva*

Тех. уредник/Technical Editor:
Крешимир Манојловски/*Kreshimir Manojlovski*

Печати/Print:
„2-ри Август” - Штип"*/”2nd August" - Shtip*
Место и година на издавање/Place and year of issue: **Скопје/Skopje, 2025**
Тираж: 50 примероци

© **ЗДРУЖЕНИЕ НА ЕНЕРГЕТИЧАРИТЕ НА МАКЕДОНИЈА/**
MACEDONIAN ENERGY ASSOCIATION

CIP - Каталогизација во публикација
Национална и универзитетска библиотека "Св. Климент Охридски", Скопје
620.9(062)

МЕЃУНАРОДНА конференција "Енергетика 2024" (2024 ; Струга)
Зборник на реферати / Меѓународна конференција "Енергетика 2024", Струга, 02-04 октомври 2024 ; [уредници: Невенка Китева-Роглева, Вангел Фуштиќ, Софија Николова-Поцева] = Conference proceedings / International Conference “Energetics 2024”, Struga, 02-04 October, 2024 ; [editors: Nevenka Kiteva-Rogleva, Vangel Fustik, Sofija Nikolova-Poceva]. - Скопје : Здружение на енергетичарите на Македонија - ЗЕМАК =Skopje : Macedonian Energy Association - ZEMAK, 2025 (Штип : 2-ри Август). - 372 стр. : илустр. ; 25 см

Дел од трудовите се на англиски јазик. - Библиографија кон трудовите
ISBN 978-608-4764-15-1
а) Енергетика – Собири
COBISS.MK-ID 65501957

ОРГАНИЗАЦИОНЕН ОДБОР

Претседател
Борко Алексоски (Претседател на ЗЕМАК)

Членови
Драган Мијалковски (Потпретседател на ЗЕМАК)
Вангел Фуштиќ (Претседателство на ЗЕМАК)
Игор Шешо (Претседателство на ЗЕМАК)
Илија Хаџидаовски (Претседателство на ЗЕМАК)
Беќаровска Елеонора (ОКТА)
Претставник (ЕВН)
Елеонора Јовановска (МАКСТИЛ)
Тијана Шалева (МАКСТИЛ)

МЕЃУНАРОДЕН ПРОГРАМСКИ ОДБОР

Проф. Невенка К.Роглева - Претседател (С.Македонија)

Членови

Проф. Вангел Фуштиќ	(С.Македонија)
Проф. Никола Попов	(Канада)
Проф. Харалд Вебер	(Германија)
Проф. Славе Арменски	(С.Македонија)
Проф. Петар Гверо	(Босна иХерцеговина)
Проф. Томо Церовсек	(Словенија)
Проф. Томас Фунтик	(Словачка)
Проф. Христина Спасевска	(С.Македонија)
Проф. Зоран Панов	(С.Македонија)
Проф. Антон Чаушевски	(С.Македонија)
Проф. Магдалена Крстановски	(САД)
Проф. Петар Јанига	(Словачка)
Проф. Мирослава Смитков	(Словачка)
Проф. Софија Н. Поцева	(С.Македонија)
Проф. Марјан Попов	(Холандија)
Проф.Џеф Бојер	(САД)
Проф. Ристо Филковски	(С.Македонија)
Проф. Марко Чепин	(Словенија)
Проф. Атанас Илиев	(С.Македонија)
Проф. Димитар Димитров	(С.Македонија)
Проф. Зоран Марков	(С.Македонија)
Проф. Имер Зенку	(С.Македонија)
Проф. Драган Миновски	(С.Македонија)

ORGANIZING BOARD

Chairman
Borko Aleksoski (President of ZEMAK)

Members
Dragan Mijalkovski (Vice President of ZEMAK)
Vangel Fustik (Presidency of ZEMAK)
Igor Shesho (Presidency of ZEMAK)
Ilija Hadzidaovski (Presidency of ZEMAK)
Eleonora Bekarovska (OKTA)
EVN (Delegate)
Eleonora Jovanovska (MAKSTIL)
Tijana Shaleva (MAKSTIL)

INTERNATIONAL PROGRAMME COMMITTEE

Prof. Nevenka K. Rogleva- Chairman (N.Macedonia)

Members

Prof. Vangel Fustik	(N.Macedonia)
ProfNikola Popov	(Canada)
Prof. Harald Weber	(Germany)
Prof. Slave Armenski	(North Macdonia)
Prof. Petar Gvero	(Bosnia & Hercegovina)
Prof. Tomo Cerovsek	(Slovenia)
Prof. Tomas Funtik	(Slovakia)
Prof. Hristina Spasevska	(N.Macedonia)
Prof. Zoran Panov	(N.Macedonia)
Prof. Anton Causevski	(N.Macedonia)
Prof. Magdalena Krstanoski	(USA)
Prof. Peter Janiga	(Slovakia)
Prof. Miroslava Smitkova	(Slovakia)
Prof. Sofija Nikolova Poceva	(N.Macedonia)
Prof. Marjan Popov	(Netherlands)
Prof. Jeff Boyer	(USA)
Prof. Risto Filkoski	(N.Macedonia)
Prof. Marko Cepin	(Slovenia)
Prof. Atanas Iliev	(N.Macedonia)
Prof. Dimitar Dimitrov	(N.Macedonia)
Prof. Zoran Markov	(N.Macedonia)
Prof. Imer Zenku	(N.Macedonia)
Prof. Dragan Minovski	(N.Macedonia)

МЕЃУНАРОДНА КОНФЕРЕНЦИЈА „ЕНЕРГЕТИКА 2024”

ТЕМАТСКИ ОБЛАСТИ

1. ЕНЕРГЕТСКА ЕФИКАСНОСТ И ПАМЕТНИ ЕНЕРГЕТСКИ СИСТЕМИ

2. ПРЕНОСНИ И ДИСТРИБУТИВНИ ЕНЕРГЕТСКИ СИСТЕМИ

3. ОБНОВЛИВИ ИЗВОРИ НА ЕНЕРГИЈА

4. ОДРЖЛИВ ЕНЕРГЕТСКИ РАЗВОЈ И ЗАШТИТА НА ЖИВОТНАТА СРЕДИНА

5. ПРОЕКТЕН МЕНАЏМЕНТ И ДИГИТАЛНА ТРАНСФОРМАЦИЈА ВО ЕНЕРГЕТИКАТА

6. ЕНЕРГЕТСКА ТРАНЗИЦИЈА И ДЕКАРБОНИЗАЦИЈА

7. УРЕДИ И СИСТЕМИ ЗА СКЛАДИРЊЕ НА ЕНЕРГИЈА

8. ЕНЕРГЕТСКО ИНЖЕНЕРСТВО И ОБРАЗОВАНИЕ ВО ОПШТЕСТВО ЗАСНОВАНО НА ЗНАЕЊЕ

INTERNATIONAL CONFERENCE "ENERGETICS 2024"

CONFERENCE TOPICS

1. ENERGY EFFICIENCY AND SMART ENERGY SYSTEMS

2. TRANSMISSION AND DISTRIBUTION ENERGY SYSTEMS

3. RENEWABLE ENERGY SOURCES

4. SUSTAINABLE ENERGY DEVELOPMENT AND ENVIRONMENTAL PROTECTION

5. PROJECT MANAGEMENT AND DIGITAL TRANSFORMATION IN ENERGY SECTOR

6. ENERGY TRANSITION AND DECARBONIZATION

7. ENERGY STORAGE DEVICES AND SYSTEMS

8. POWER ENGINEERING AND EDUCATION IN KNOWLEDGE-BASED SOCIETY

ЦЕЛИ НА КОНФЕРЕНЦИЈАТА

Главна цел на конференцијата беше да обезбеди можност за демократска и стручна презентација на: искуства, важни информации, професионални постигнувања и истражување на експертите и професионалците од областа на енергетиката. Поканети беа релевантни енергетски компании, претставници од индус¬тријата, истражувачките центри, универзи¬тетите и останати субјекти, како и експерти од земјата и странство. Конференцијата претставуваше форум за споделување и размена на искуства и планови на локално, регионално и глобално ниво.

Според тематските области, на конференцијата беа презентирани и дискутирани предизвиците со кои се соочува енергетскиот сектор, особено компаниите, инвеститорите и корисниците. Со планираните дискусии и реферати се овозможи реална можност за идентификација на соодветните механизми и активности со цел надминување на проблемите во земјата и регионот, како и зајакнување на меѓусебната соработката.

СЕРТИФИКАТИ ЗА УСПЕШНО УЧЕСТВО

На конференцијата се одвиваа паралелно презентациски и постер сесии. Трудовите беа рецензирани од страна на Меѓународниот програмски одбор и категоризирани во три категории: Информација, Стручен труд и Научен труд. За секој рецензиран и презентиран труд (без оглед на категоријата) Програмскиот одбор издаде Сертификат за успешно учество на конференцијата. Посебно беа охрабрени да земат активно учество младите истражувачи и студентите на сите три циклуси студии (додипломски, постдипломски и докторски студии), млади професионалци и истражувачи.

4. Јаз во вештините за мапирање за електромонтер за да се овозможи декарбонизација на градежниот сектор **303**
[1]Стојан Спасевски, [2]Лихнида Стојановска Георгиевска-
[1]Електродисдрибуција-Скопје, [2]Факултет за електротехника и информациски технологии, УКИМ – Скопје

7. УРЕДИ И СИСТЕМИ ЗА СКЛАДИРЊЕ НА ЕНЕРГИЈА

1. КВАЛИТЕТ НА ЕНЕРГИЈА ВО МРЕЖАТА СО БАТЕРИИ ЗА СКЛАДИРАЊЕ НА ЕНЕРГИЈА..**313**
Јозеф Трхан, Петер Јанига - *Словачки универзитет за технологија во Братислава, Факултет за електротехника и информациски технологии, Институт за енергетика и применета електротехника*

2. СИСТЕМИ ЗА СКЛАДИРАЊЕ НА ЕЛЕКТРИЧНА ЕНЕРГИЈА КАКО АЛАТКА ЗА ФЛЕКСИБИЛНОСТ НА ПРЕНОСНА МРЕЖА..**319**
Стефанија Симовска, Кристина Гинова, Фросина Голабовска, Живорад Серафимоски - *АД МЕПСО Скопје*

3. ФОТОВОЛТАИЧНА ЕЛЕКТРАНА ЗА ДОМАЌИНСТВО СО И БЕЗ БАНКА ЗА БАТЕРИИ...**325**
Младен Митковски , Влатко Чингоски - *Електротехнички факултет, Универзитет „Гоце Делчев" Штип, Македонија*

8. ЕНЕРГЕТСКО ИНЖЕНЕРСТВО И ОБРАЗОВАНИЕ ВО ОПШТЕСТВО ЗАСНОВАНО НА ЗНАЕЊЕ

1. ПОСТАПКАТА ЗА ПРЕТХОДНА СОГЛАСНОСТ ЗА ЛОКАЦИЈА – КАМЕН НА СОПНУВАЊЕ ВО РЕАЛИЗАЦИЈА НА НОВИТЕ ИНВЕСТИЦИИ ВО МК............**337**
Мирко СТОЈАНОВСКИ, д.м.и - *Филбис Дооел-Скопје*

2. ИНЖЕНЕРИТЕ И ПРОФЕСИОНАЛНАТА ЕТИКА ВО 21 ВЕК............................**343**
Проф. д-р Вангел Фуштиќ

3. СИСТЕМ ЗА СКЛАДИРАЊЕ НА ЕНЕРГИЈА КОЈ ИНТЕГРИРА ВИСОКО-ТЕМПЕРАТУРЕН СКЛАД ЗА ТОПЛИНСКА ЕНЕРГИЈА ВО КОМБИНАЦИЈА СО ГАСНА ТУРБИНА СО ЗАТВОРЕН ЦИКЛУС..**355**
Јане Јаневски - *ЕВН Македониа АД, Скопје*

4. ЕМИСИИТЕ НА ЈАГЛЕРОД ДИОКСИДОТ И МЕХАНИЗМОТ ЗА ГРАНИЧНО ЈАГЛЕРОДНО ПРИЛАГОДУВАЊЕ..**363**
Љубомир Пејовски, Елена Ивановска-Видинова - *Макстил АД-Скопјеа*

Зборник на трудови ЕНЕРГЕТИКА 2024

Proceedings of the International Conference ENERGETICS 2024
October 02 - 04, Struga

Научен труд/Scientific Paper

PHOTOVOLTAIC POWER PLANT FOR HOUSEHOLD WITH AND WITHOUT BATTERY BANK

Mladen Mitkovski [1], Vlatko Chingoski [2]

[1]Faculty of Electrical Engineering, University "Goce Delcev" Shtip, Macedonia,
mladen.20234@student.ugd.edu.mk

[2]Faculty of Electrical Engineering, University "Goce Delcev" Shtip, Macedonia,
vlatko.cingoski@ugd.edu.mk

Abstract

There are several short-term and long-term investments aimed at reducing household electricity costs. An example of a long-term investment is the installation of photovoltaic power plants on the roof. The installation of photovoltaic power plants placed on the roof is gaining more and more application both in industry and in households, especially if the households are heated by electricity.

In this paper, the sizing of a photovoltaic plant installed on the roof of a household with an installed power in panels of 7.2 kWp and a nominal power of an inverter of 6 kW, connected to the electricity distribution network, with and without a battery, as well as a comparison of the amount of electricity energy that is used to supply the consumption of that household, directly from photovoltaics, from a battery, as well as transmitted and received electrical energy from the network. A comparison of annual electricity costs with and without a battery is also provided.

Keywords: renewable energy, household, photovoltaic plant, photovoltaic panel, battery, electricity.

1. INTRODUCTION

The household is heated by electricity and in order to reduce electricity costs, it is planned to install a photovoltaic system. In this paper, a calculation has been made of how much electricity costs would be if a photovoltaic system without a battery was installed, with a 10 kWh battery bank and a 15 kWh battery bank.

18 panels with a power of 400W from the manufacturer Pikcell Group and a hybrid inverter from the manufacturer Huawei with a nominal power of 6 kV were selected. The battery bank is also from the manufacturer Huawei

2. TECHNICAL DESCRIPTION OF THE PROJECT

On the roof of a family house in Strumica, it is planned to install photovoltaic panels with a total installed power of 7.2 kWp. The roof of the building is double-pitched, made of a sandwich panel with a slope of 5° in the north-south direction, so all 18 photovoltaic panels will be placed in the south direction and will occupy a total area of 40.48 m^2. It is planned to install one inverter with a nominal output power of 6 kW. The inverter and other equipment will be located in the building's premises.

In the calculations, we will consider four cases:

- Case A – without photovoltaics;
- Case B – photovoltaic plant with an installed power of 7.2 kWp;
- Case C – photovoltaic plant with an installed power of 7.2 kWp + battery with a capacity of 10 kWh;
- Case D – photovoltaic plant with an installed capacity of 7.2 kWp + battery with a capacity of 15 kWh.

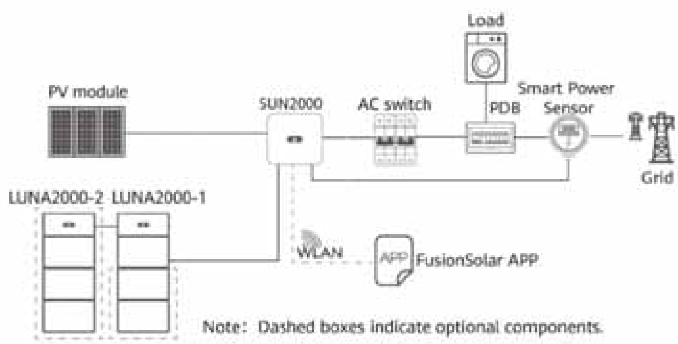


Figure 1 - Block diagram of the photovoltaic plant

2.1. Selection of photovoltaic panels

As the most favorable economic and technical solution for the project, monocrystalline panels from the manufacturer PIKCELL GROUP with an installed power of 400 W of the type PiK400M(72) were adopted. 18 photovoltaic panels with a power of 400 W are selected, so that the total installed power will be 7.2 kWp.

The electrical, mechanical and temperature characteristics are given in the tables.

Table 1 – Electrical data for module PIK400M(72)

ELECTRICAL DATA	
Parameters	PIKCELL GROUP – PIK400M (72)
Peak Power	400 W
Open Circuit Voltage (Uoc)	49,2 V
Maximum Power Voltage (Ump)	40,5 V
Short Circuit Current (Isc)	10,23 A
Maximum Power Current (Imp)	9,88 A
Module Efficiency (η)	20,16 %
Power Tolerance	0 ~ + 5 W
STC: irradiation 1000W/m^2, module temperature 25°C, AM=1,5	

Table 2 – Mechanical data for module PIK400M(72)

MECHANICAL DATA	
Parameters	PIKCELL GROUP – PIK400M (72)
Cell Type	Monocrystalline
Weight	22 kg
Dimensions	1980 x 1002 x 35 mm
Number of Cells	72
Junction Box	IP 67, 3 bypass diodes
Cable cross section	4 mm^2

Table 3 – Temperature characteristics

TEMPERATURE CHARACTERISTICS	
Parameters	PIKCELL GROUP – PIK400M (72)
Temperature Coefficient of Uoc (α)	-0,27 %/°C
Temperature Coefficient of Isc (β)	0,045 %/°C
Temperature Coefficient of Pmax (γ)	-0,408 %/°C

2.2. Selection of inverter

Inverters are devices that convert direct current into alternating current. For the project, one inverter from the manufacturer HUAWEI, model SUN2000-6KTL-M1, with a nominal output power of 6 kW is selected. According to the parameters of the panels and the inverter, they are connected, so that all 18 series-connected panels with a power of 400 W are connected to MPPT1.

Table 4 – Technical specification of inverter

Inverter HUAWEI SUN2000 - 6KTL - M1			
DC parameters		**AC parameters**	
Maximum input PV power	9 kW	**Rated output power**	6 kW
Maximum input voltage	1.100 V	**Maximum apparent power**	6.6 kVA
Operating MPPT voltage range	140 V - 980 V	**Maximum output current**	10,1 A
Maximum input current per MPPT	13.5 A	**Output voltage**	230/400 V
Number of MPP trackers / Max. input number per MPP tracker	2 / 1	**Rated AC grid frequency**	50 / 60 Hz

2.3. Choosing a battery bank

A LUNA2000-10-S0 battery bank with 2 or 3 modules of 5kWh each is planned for electricity storage. The charge/discharge coefficient is 0.95.

2.4. Distribution boards and cables

One switchboard is provided, intended for AC installation. The board is made of polycarbonate. A three-pole automatic fuse C 20A, 3p is provided in the AC board. A NYM-J 5x4 mm^2 cable is placed from the GRT to the AC board and from the AC board to the inverter, and a PV.1-F 1x6 mm^2 solar cable is used to connect the strings, from the panels to the inverter.

2.5. Construction above which the photovoltaic panels are mounted

The construction on which the photovoltaic panels are mounted is made of aluminum, the so-called aluminum profiles. The roof of the building is made of a roofing sandwich panel, so aluminum clamps with self-tapping screws are screwed to the ribs of the sandwich panel. Photovoltaic panels are attached to the aluminum profiles with the help of middle and end clamps.

2.6. Installation for equalization of potential

To equalize the potential of the subconstruction on which the panels are mounted, an aluminum conductor φ=8mm is used, which is connected to the existing lightning protection installation of the building.

3. CALCULATIONS

Calculations are made on the basis of a standard load curve for the annual distribution 2022, as well as electricity bills of a customer who is heated by electricity for the year 2022 In the calculations, we will consider four cases:

- Case A – without photovoltaics;
- Case B – photovoltaic plant with an installed power of 7.2 kWp;
- Case C – photovoltaic plant with an installed power of 7.2 kWp + battery with a capacity of 10 kWh;
- Case D – photovoltaic plant with an installed capacity of 7.2 kWp + battery with a capacity of 15 kWh.

The household where we will install photovoltaic panels during one year has the following electricity consumption. energy:

Table 5 – Electricity consumption without photovoltaics

ELECTRICITY CONSUMPTION WITHOUT PHOTOVOLTAICS				
Month	**Consumed electricity in a high tariff [kWh]**	**Consumed electricity in a low tariff [kWh]**	**Total electricity consumption [kWh]**	**Total price [denars]**
January	1,429.72	1,474.58	2,904.30	25,224
February	533.72	535.03	1,068.75	7,312
March	960.25	850.55	1,810.80	13,105
April	1,032.64	738.56	1,771.20	13,379
May	498.81	388.14	886.95	6,289
June	465.74	336.91	802.65	5,757
July	406.61	315.79	722.40	5,129
August	445.31	313.54	758.85	5,460
September	413.55	301.65	715.20	5,128
October	421.55	347.95	769.50	5,414
November	910.93	706.07	1,617.00	11,397
December	1,339.35	1,114.20	2,453.55	21,458
TOTAL:	**8,858.17**	**7,422.98**	**16,281.15**	**125,052.00**

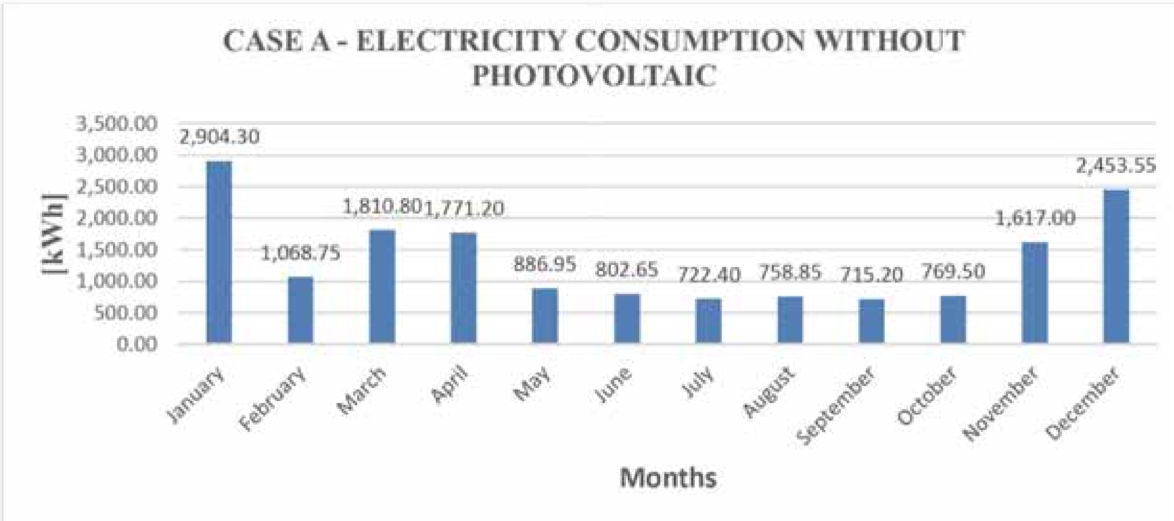


Diagram 1 – Monthly consumption of electricity without photovoltaics

If we install a photovoltaic system with an installed power of 7.2 kWp, we get the following production, i.e. electricity consumption:

Table 6 – Production and consumption of electricity with a photovoltaic plant with an installed power of 7.2 kWp

ELECTRICITY CONSUMPTION WITH PHOTOVOLTAICS								
Month	Produced electricity from photovoltaics	Prosumer	Total electricity taken from the grid [kWh]	Electricity taken from the grid in a high tariff [kWh]	Electricity taken from the grid in a low tariff [kWh]	Total price for purchased electricity [denars]	Delivered electricity [kWh]	Total price for delivered electricity [denars]
January	492.43	2,411.87	2,465.42	1,056.02	1,409.40	16,771	53.55	6,720.49
February	529.69	539.06	775.81	299.23	476.58	4,955	236.75	
March	753.34	1,057.46	1,311.57	535.11	776.46	8,456	254.11	
April	919.46	851.74	1,167.98	527.43	640.55	7,748	316.25	
May	1,112.17	-225.22	481.71	194.56	287.15	3,128	706.93	
June	1,091.14	-288.49	441.58	191.60	249.97	2,926	730.01	
July	1,215.70	-493.30	379.31	147.26	232.05	2,481	872.60	8,630.19
August	1,175.88	-417.03	406.92	165.18	241.74	2,674	823.94	
September	956.94	-241.74	424.13	179.85	244.28	2,804	665.87	
October	672.27	97.23	494.38	197.72	296.65	3,199	405.22	
November	469.23	1,147.77	1,272.78	621.02	651.76	8,630	125.01	
December	383.57	2,069.98	2,127.83	1,055.96	1,071.86	15,166	57.85	
TOTAL:	**9,771.81**	**6,509.34**	**11,749.40**	**5,170.96**	**6,578.45**	**78,938.00**	**5,248.10**	**15,350.68**

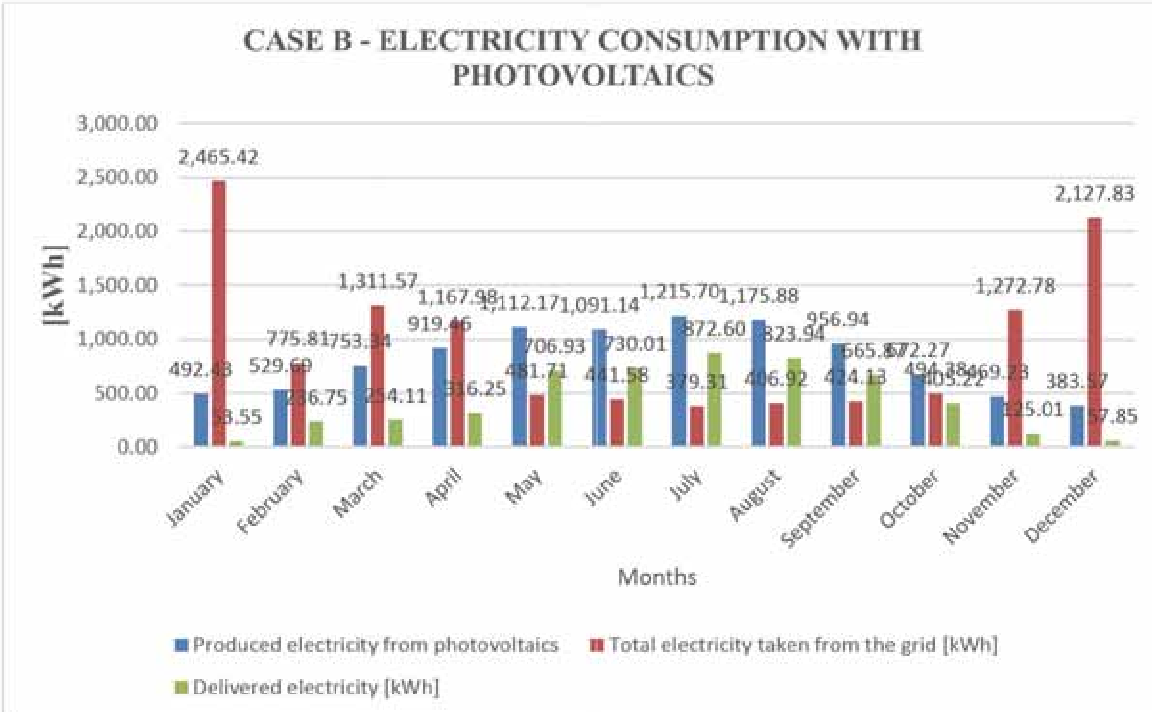


Diagram 2 – Monthly production and consumption of electricity with a photovoltaic plant with an installed capacity of 7.2 kWp

If we add a 10 kWh battery bank to the installed photovoltaic system of 7.2 kWp, we get the following production, i.e. electricity consumption:

Table 7 – Production and consumption of electricity with a photovoltaic plant with an installed power of 7.2 kWp and a battery of 10 kWh

ELECTRICITY CONSUMPTION WITH PHOTOVOLTAIC SYSTEM OF 7.2 kWp AND BATTERY OF 10kWh										
Month	Produced electricity from photovoltaics	Prosumer	Electricity used from photovoltaics [kWh]	Total electricity taken from the battery [kWh]	Total electricity taken from the grid [kWh]	Electricity taken from the grid in a high tariff [kWh]	Electricity taken from the grid in a low tariff [kWh]	Total price for purchased electricity [denars]	Delivered electricity [kWh]	Total price for delivered electricity [denars]
Јануари	492.43	2,411.87	434.58	63.35	2,406.37	1,008.22	1,398.14	16,212	0.00	3,198.21
Февруари	529.69	539.06	292.94	160.27	615.54	173.55	442.00	3,692	53.91	
Март	753.34	1,057.46	499.23	154.17	1,157.41	398.03	759.38	7,159	77.54	
Април	919.46	851.74	603.22	184.45	983.54	360.82	622.71	6,185	110.76	
Мај	1,112.17	-225.22	405.24	260.96	220.75	3.43	217.32	1,245	399.24	
Јуни	1,091.14	-288.49	361.12	235.17	206.35	27.48	178.87	1,257	451.95	
Јули	1,215.70	-493.30	343.00	253.90	125.51	3.65	121.86	793	568.48	4,782.10
Август	1,175.88	-417.03	351.93	257.98	148.94	0.00	148.94	892	515.84	
Септември	956.94	-241.74	290.12	233.80	191.29	37.01	154.27	1,218	380.11	
Октомври	672.27	97.23	266.52	212.50	290.48	32.75	257.73	1,674	156.14	
Ноември	469.23	1,147.77	344.22	101.16	1,171.62	535.49	636.13	7,797	13.49	
Декември	383.57	2,069.98	325.72	52.52	2,075.31	1,003.77	1,071.54	14,615	0.83	
ВКУПНО:	9,771.81	6,509.34	4,517.85	2,170.20	9,593.10	3,584.21	6,008.90	62,739.00	2,728.31	7,980.32

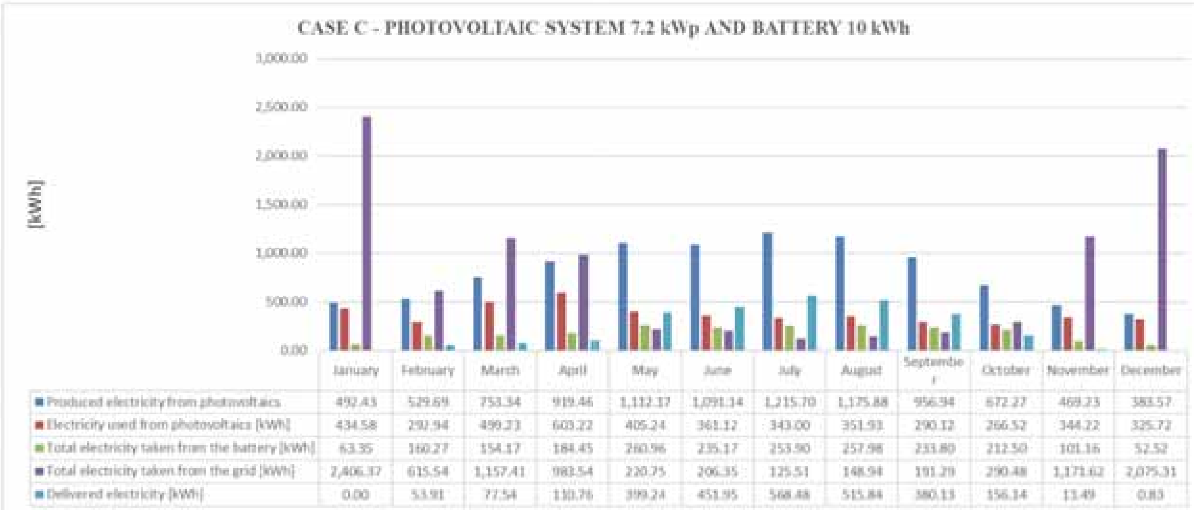
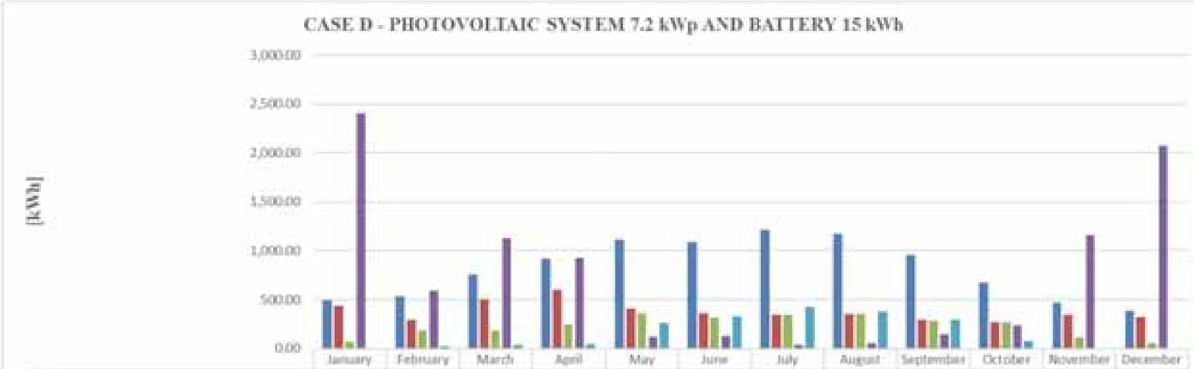


Diagram 3 – Monthly production and consumption of electricity with a photovoltaic plant with an installed power of 7.2 kWp and a battery of 10 kWh

If we add a 15 kWh battery bank to the installed photovoltaic system of 7.2 kWp, we get the following production, i.e. electricity consumption:

Table 8 – Production and consumption of electricity with a photovoltaic plant with an installed power of 7.2 kWp and a battery of 15 kWh

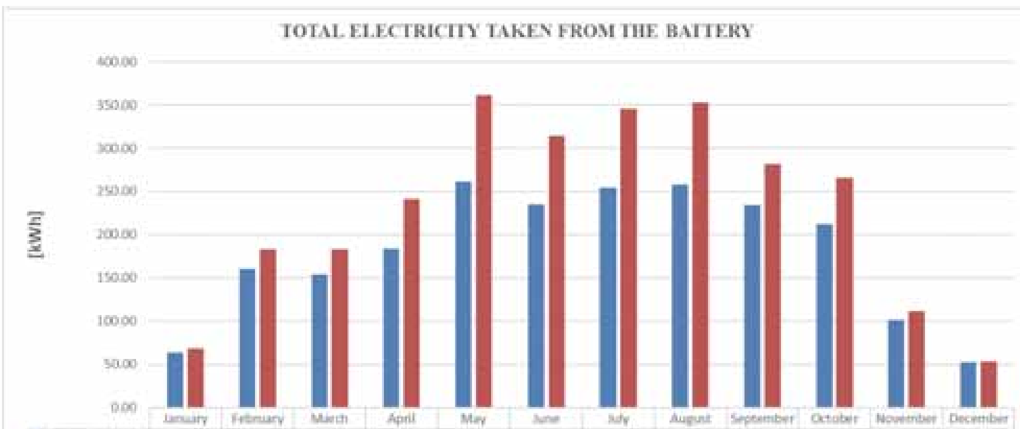
ELECTRICITY CONSUMPTION WITH PHOTOVOLTAIC SYSTEM OF 7.2 kWp AND BATTERY OF 15 kWh										
Month	Produced electricity from photovoltaics	Prosumer	Electricity used from photovoltaics [kWh]	Total electricity taken from the battery [kWh]	Total electricity taken from the grid [kWh]	Electricity taken from the grid in a high tariff [kWh]	Electricity taken from the grid in a low tariff [kWh]	Total price for purchased electricity [denars]	Delivered electricity [kWh]	Total price for delivered electricity [denars]
January	492.43	2,411.87	434.58	67.77	2,401.95	1,008.22	1,393.72	16,191	0.00	2,026.70
February	529.69	539.06	292.94	183.54	592.26	166.87	425.39	3,559	22.64	
March	753.34	1,057.46	499.23	182.88	1,128.70	388.20	740.50	6,983	37.82	
April	919.46	851.74	603.22	240.99	926.99	312.84	614.16	5,719	43.04	
May	1,112.17	-225.22	405.24	361.00	120.71	1.70	119.01	763	258.14	
June	1,091.14	-288.49	361.12	314.03	127.49	20.85	106.65	859	331.25	
July	1,215.70	-493.30	343.00	345.97	33.44	3.65	29.78	356	423.71	3,405.90
August	1,175.88	-417.03	351.93	352.70	54.22	0.00	54.22	441	374.09	
September	956.94	-241.74	290.12	281.24	143.84	24.96	118.89	951	288.51	
October	672.27	97.23	266.52	265.92	237.06	32.61	204.45	1,419	76.97	
November	469.23	1,147.77	344.22	111.42	1,161.36	526.48	634.88	7,712	1.13	
December	383.57	2,069.98	325.72	53.19	2,074.63	1,003.09	1,071.54	14,607	0.00	
TOTAL:	9,771.81	6,509.34	4,517.85	2,760.64	9,002.66	3,489.47	5,513.19	59,560.00	1,857.30	5,432.61



	January	February	March	April	May	June	July	August	September	October	November	December
Produced electricity from photovoltaics	492.41	529.69	753.34	919.46	1,112.17	1,091.14	1,215.70	1,175.88	956.94	672.27	469.23	383.57
Electricity used from photovoltaics [kWh]	434.58	292.94	499.23	603.22	405.24	361.12	343.00	351.93	290.12	266.52	344.22	325.72
Total electricity taken from the battery [kWh]	67.77	183.54	182.88	240.99	361.00	314.03	345.97	352.70	281.24	265.92	111.42	53.19
Total electricity taken from the grid [kWh]	2,401.95	592.26	1,128.70	926.99	120.71	127.49	33.44	54.22	143.84	237.06	1,161.36	2,074.63
Delivered electricity [kWh]	0.00	22.64	37.82	43.04	258.14	331.25	423.71	374.09	288.51	76.97	1.13	0.00

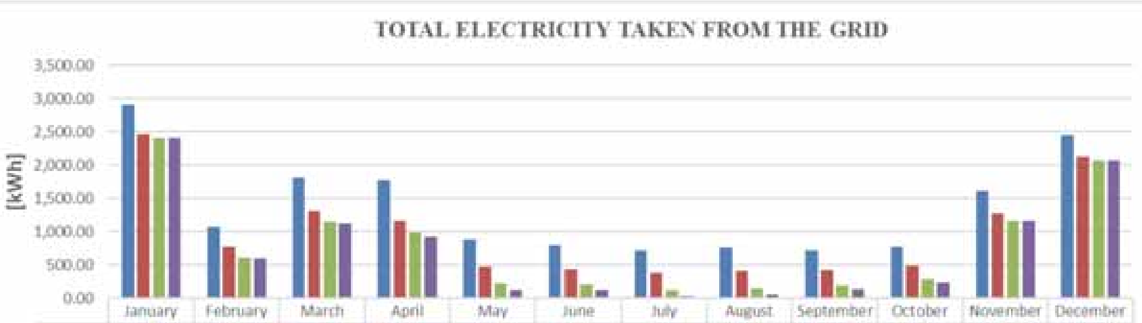
Diagram 4 – Monthly production and consumption of electricity with a photovoltaic plant with an installed power of 7.2 kWp and a battery of 15 kWh

The following diagrams represent a comparison between Case A, Case B, Case C and Case D:



	January	February	March	April	May	June	July	August	September	October	November	December
BATTERY 10 kWh	63.35	160.27	154.17	184.45	260.96	235.17	253.90	257.98	233.80	212.50	101.16	52.52
BATTERY 15 kWh	67.77	183.54	182.88	240.99	361.00	314.03	345.97	352.70	281.24	265.92	111.42	53.19

Diagram 5 – Taken electricity from a battery



	January	February	March	April	May	June	July	August	September	October	November	December
CASE A	2,904.30	1,068.75	1,810.80	1,771.20	886.95	802.65	722.40	758.85	715.20	769.50	1,617.00	2,453.55
CASE B	2,465.42	775.81	1,311.57	1,167.98	481.71	441.58	379.31	406.92	424.13	494.38	1,272.78	2,127.83
CASE C	2,406.37	615.54	1,157.41	983.54	220.75	206.35	125.51	148.94	191.29	290.48	1,171.62	2,075.31
CASE D	2,401.95	592.26	1,128.70	926.99	120.71	127.49	33.44	54.22	143.84	237.06	1,161.36	2,074.63

Diagram 6 – Electricity taken from the grid

	January	February	March	April	May	June	July	August	September	October	November	December
CASE B	53.55	236.75	254.11	316.25	706.93	730.01	872.60	823.94	665.87	405.22	125.01	57.85
CASE C	0.00	53.91	77.54	110.76	399.24	451.95	568.48	515.84	380.13	156.14	13.49	0.83
CASE D	0.00	22.64	37.82	43.04	258.14	331.25	423.71	374.09	288.51	76.97	1.13	0.00

Diagram 7 – Electricity delivered to the grid

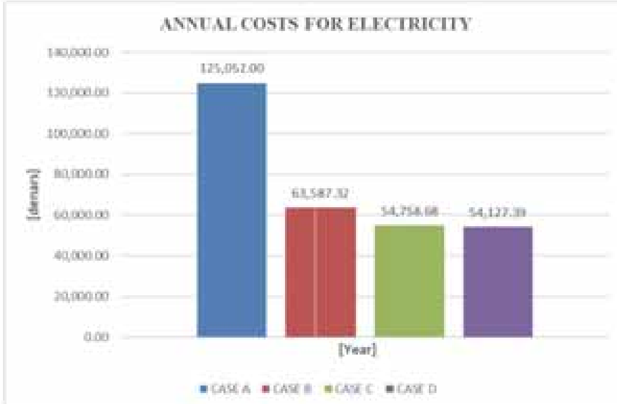


Diagram 8 – Annual costs

4. CONCLUSION

Since the installed power from photovoltaic panels is 7.2 kWp and the nominal output power of the inverter is 6 kW, the photovoltaic plant is well dimensioned according to the consumption. In our case, it is not profitable to store electricity in batteries. Storing electricity in batteries would be more cost-effective if the system were oversized, i.e. if a larger amount of electricity would be transmitted to the grid than it would be taken from the grid, because in that case the price for delivered electricity would be lower than the price which is in our case.

REFERENCE

[1] PIKCELL GROUP, type PiK400M(72), Data Sheet https://www.enfsolar.com/pv/panel-datasheet/crystalline/54782

[2] HUAWEI, type SUN2000-6KTL-M1, Datasheet, https://www.enfsolar.com/pv/inverter-datasheet/13796

[3] HUAWEI Smart String Energy Storage System, type LUNA2000-10/15-S0, Datasheet, https://solar.huawei.com/en-GB/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Feu%2Fdatasheet%2FLUNA2000-5-15-S0.pdf

[4] Calculator, https://www.erc.org.mk/page.aspx?id=478

[5] Standard load curve annual distribution 2022, https://snabduvanje.evn.mk/Documents/Download-center.aspx