GOCE DELCEV UNIVERSITY, SHTIP, NORTH MACEDONIA
FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2021

FIRST INTERNATIONAL CONFERENCE

19-21 OCTOBER, 2021

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ

UNIVERSITY „GOCE DELCHEV” - SHTIP
FACULTY OF ELECTRICAL ENGINEERING

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PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA*.**
ETIMA has a goal to gather the scientists, professors, experts and professionals from the field of technical sciences in one place as a forum for exchange of ideas, to strengthen the multidisciplinary research and cooperation and to promote the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.
Conference ETIMA was held as online conference where contributed more than sixty colleagues, from six different countries with forty papers.
We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA’21 by presenting the results of their current research activities and by launching the new ideas through many fruitful discussions.
We invite you and your colleagues also to attend ETIMA Conference in the future. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information in direct contact, as well as to enjoy the social events together.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот Гоце Делчев.
ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да претставува форум за размена на идеи, да го зајканува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.
Конференцијата ЕТИМА се одржа online и на неа дадоа свој допринос повеќе од шеесет автори од шест различни земји со четириесет труда.
Сакаме да ја искажеме нашата благодарност до сите колеги кои допринесоа за успехот на ЕТИМА’21 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Ве покануваме Вие и Вашите колеги да земете учество на ЕТИМА и во иднина. Веруваме дека следниот пат ќе имаме можност да се сретнеме, да размениме идеи, знаење и корисни информации во директен контакт, но исто така да уживаме заедно и во друштвените настани.

Организационен одбор на конференцијата

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ENERGY-EFFICIENT STREET LIGHTING SYSTEM OF THE CITY OF SHTIP USING SOLAR ENERGY AND LED TECHNOLOGY

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Abstract

This paper deals with two currently very important energy issues, the increase of energy efficiency and sustainable energy development. For living standards, street lighting is unavoidable conformity that, in general, consumes a significant amount of electric power due to prolonged utilization period, and many lighting sources with significant-rated power and modest life expectancy.

In this paper, the authors proposed the replacement of the existing street lighting system of the part of the city of Shtip with a new, energy-efficient, and environmentally friendly, and energy sustainable system. The proposed system utilizes renewable solar energy sources and the replacement of the existing and obsolete streetlight bulbs with new and highly efficient light bulbs based on LED technology. The comparative analysis is given from technological and financial viewpoints proving that this new system could easily repay investments in the period less than two years. Although the initial investments might look too large, the operation and maintenance of the proposed system including payment for consumed electricity justify not partial, but replacement of the entire city street lighting system.

Keywords: *renewable energy sources, solar energy, street lighting, LED bulbs*

Introduction

The gradually growing requirement of energy and the limited resource of traditional energy sources has become a challenge for both developed and developing countries. Until now, people around the globe depend on fossil fuels for their energy needs. Fossil fuels are limited in amount, expensive, and polluting the environment. Therefore, a lot of research and developments have been proposed to solve those serious problems. One of the ways is to utilize renewable energy resources. Such resources are free of cost and available in abundance. Solar energy is the amplest, direct, and clean form of renewable energy. Total solar energy absorbed by the Earth is about 3,850,000 (EJ) in one year, which is even twice as much as all the non-renewable resources on the earth found and used by a human being, including coal, oil, natural gas, and uranium. [1], [5].

Taking this idea into consideration, we are proposing the replacement of the existing street lighting system of the part of the city of Shtip with a new, energy-efficient, and environmentally friendly, and energy sustainable system. In this project, we are incorporating an "all-in-one" light monitoring system. [3], [2]

A solar street lighting system is a system consisting of LED lamps, and they can be dimmed or illuminated to any certain level depending on the user's profile. The following are some of the present advantages of the use of solar street lighting over conventional lighting: [9], [10].

- 80% less energy use in addition to savings from high-efficiency lamps.
- 50% or more savings per year in operating and maintenance costs.
- Better living environments with more reliable and safer lighting.
- The ability to mix lamp technologies to suit the needs of the city and accommodate new lamp types.
- A tremendous reduction in CO_2 emissions.
- Longer lifespan of LED lamps compared to HPS lamps.
- Does not take any time for dimming and it is an instant process.

The solar street lighting system also has disadvantages which are as follows:

- The higher initial investment cost for upgrading from conventional lamps to LEDs.

1. Literature review

Macedonia has a very favorable geographical position where solar irradiation is large and convenient for installing solar systems for the use of solar energy, but unfortunately, it is rarely used. With about 280 sunny days per year and about 1,500 kWh/m^2 of solar irradiation, Macedonia is one of the countries with the highest solar irradiation in Europe, but not in the countries using that energy the most. For example, Germany and Austria produce 100 times more electricity from solar energy, though they have 30-40% less solar irradiation compared to Macedonia [13].

The Municipality of Shtip is in the central-eastern part of the Republic of Macedonia between 41°31'15 " and 41°44'25 " north latitude and 22°10 'and 22°13' east longitude. The area of the Municipality of Shtip is characterized by increased duration of the solar irradiation. On average, there are 2,370 sunny hours per year or an average of 6.5 sunny hours per day. The maximum number of sunny days is observed in July and the minimum in December. The distribution of sunny days and other meteorological data for this region are given in Table 1, [13].

Table 1: Meteorological data including solar insolation at the location of city of Shtip [13]

Shtip Macedonia	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation [kWh/m^2/day]	1.69	2.33	3.31	4.09	5.20	6.14	6.38	5.58	4.09	2.66	1.69	1.37
Clearness, 0-1	0.44	0.44	0.45	0.43	0.48	0.53	0.57	0.56	0.50	0.44	0.40	0.40
Temperature, ºC	-2.65	-0.89	3.70	9.26	14.76	18.52	21.01	21.06	16.37	10.36	3.68	-1.61
Wind speed, m/s	4.12	4.24	4.02	3.89	3.51	3.33	3.57	3.57	3.67	3.92	3.93	4.21
Precipitation, mm	34	33	38	42	61	53	42	36	35	43	55	44
No. of Wet days	8.9	9.0	9.6	10.6	11.9	9.6	6.7	6.4	5.6	7.1	9.2	10.3

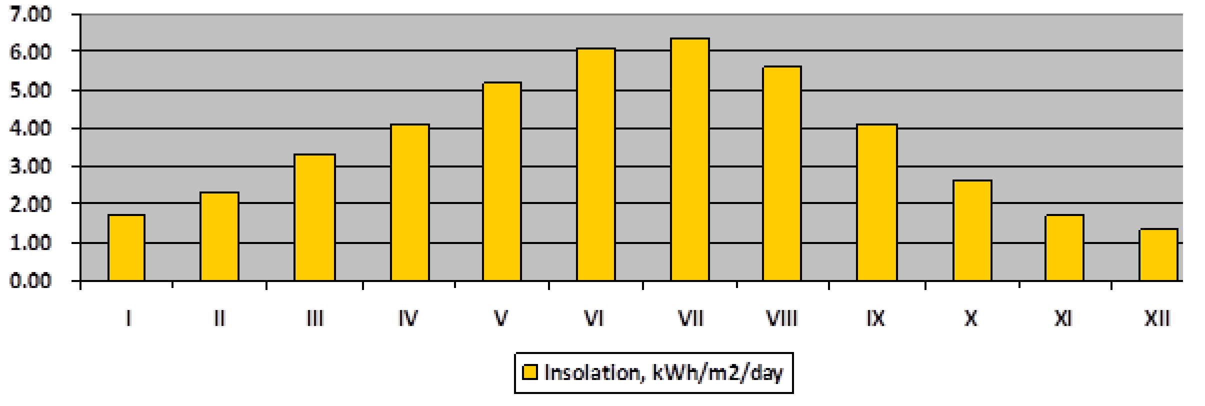

Fig. 1: Average kWh/ m^2 per day by months of 2016, the city of Shtip [13]

2. Data collection and analysis

In this project, we are investigating the potential replacement of the existing street lighting system at the central part of Shtip with an energy-efficient photovoltaic (PV) LED lighting system. This street represents the city/center area, along the river Otinje. Besides this part are the building of the Municipality of Shtip, Basic Court Shtip, Rectorate of UGD, Hotel Oaza, and many other buildings and institutions, where there is constant movement and where the conditions for the street lighting should be without any defects and interventions and to be constant in function [4].

Fig. 2. Aerial view of the location under investigation.

Source: *http://www.google.maps.com*

Table 2: Basic data for the investigated location.

Street	Poles	Lamps
2,030m length	68 poles; Height 10m each; Distance between them: 30m	68 lamps; HPS = 23 (400W) Mercury bulbs = 45 (250W)

3. Technical data for the SSL system under investigation

For replacing the existing traditional solar lighting system based on mercury/HPS lamps, we are providing LED lamps with solar panels and battery attached or built into it, shortly called solar street lighting system (SSLS).

The proposed high-quality LED lamps powered by a solar panel shown in Fig. 3, are made of high-quality materials and can be rotated and adjusted according to local needs, i.e., to be in a position where most of the day the sun's rays can fall on it. Other main properties of this streetlight system are: [14]

- Connector for rain protection - Aluminum cable output screw with a rubber plug, 2-level water protection that allows the lamps to withstand even the heaviest rain for a long period.
- Solar panels are made of high-quality material with a lifespan of about 25 years.
- Diamond Reflector - a glossy base that is made of light aluminum material and at the same time increases the light intensity by 30%.
- Li LiFePO4 battery - a very durable battery. About 2000 times charge and discharge cycle, 4 times more than lithium battery, 8 times more than a lead-acid battery.

Fig. 3: Proposed LED street lights with solar panels.

Source: *http://www.minsenslight.com/sale-12389543-remote-control-integrated-solar-led-street-light-50w-100w-200w-300w-longlife.html*

The main technical characteristics of the proposed equipment for this SSLS system are given in Table 3: [6], [7], [14].

Table 3: Technical data for the proposed SSL system including solar panels.

Model	MINSENS MS 32 C - 50W
Lamp	50W
Solar panel	High-efficiency polysilicon Solar Panel – 6V 20W
Lithium iron phosphate build-in battery	LiFePO4 battery – 18AH
Lighting angle	120 degrees
Number of working hours	12-14 hours per day
Battery discharge time	3-5 days without sun
Lamp life expectancy	50,000 hours

Operation at low/high temp.	From -20 to 60
Battery charging time	6-8 hours
Price	115euro / 7049.5denars
Guarantee provided	3 years

According to the principle of the photovoltaic effect, these solar panels receive solar radiation during the daytime and then convert it into electrical energy through the charge and discharge controller, which is finally stored in the battery. When the light intensity is reduced to about 10 lx during the night and the open-circuit voltage of the solar panels reaches a certain value, the controller has detected voltage value and then acts. The battery offers the energy to the LED light to drive the LED to emit visible light in a certain direction. Battery discharges after a certain time passes, the charge and discharge controller will act again to end the discharging of the battery to prepare the next charging or discharging again [6], [8].

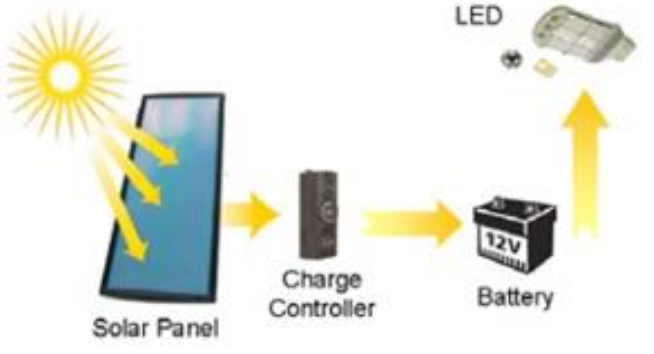

Fig. 4: Basic operation principle of the proposed street lighting system.

Source: https://www.elprocus.com/solar-powered-led-street-light-control-circuit/

4. Project economics

Table 4 presents the cost for the operation of the existing (traditional) lighting.

Table 4: Existing cost for operation of the existing lighting system.

Traditional street lighting consumption	Quantity	Consumption [kWh] Monthly / Annual	Costs Annual
Mercury lamps	45 (250W)	3.37 / 41.06 MWh	228,307.5 MKD /3,724.4 euro
HPS lamps	23 (400W)	2.76 / 33.58 MWh	186,704.8 MKD / 3,045.7 euro
Maintenance & repairing	57,120 MKD / 931.8 euro		
Total	**68 lamps**	**74.64 MWh**	**472,132.3 MKD / 7,701.9 euro**

We can see from Table 4, that the annual consumption and costs from traditional street lighting are 74.64 MWh, or 472,132.3 denars (app. 7,701.9 euro). These costs are constant each year with changes in the amount of app. 1-2%. due to year-by-year changes in the maintenance & repairing costs.

To be able to make a comparison and calculate what is a difference between the existing traditional street lighting system and our new proposed SSL, we projected that in the last 3 years there was already installed our new SSL system [4].

Data from our research, e.g., number of sunny days, sunny hours, and rainy days in Shtip in the last 3 years, have been considered and it has been calculated how many days per year we will need electricity from the distribution network. The estimated data is presented in Table 6, including the initial investment cost for the replacement of the existing street lighting system with the proposed SSL system in 2018.

Table 5: Projected operation characteristics for the newly proposed lighting system.

	2018			2019			2020		
	Sunny days	Sunny hours	Duration of the day	Sunny days	Sunny hours	Duration of the day	Sunny days	Sunny hours	Duration of the day
January	23	200	10	14	117	10	25	250	10
February	15	138,5	11	22	170,5	11	21	237,5	11
March	10	229	13	26	286	13	13	175,5	13
April	13	336,5	14	18	297	14	16	216	14
May	18	378	15	14	333,5	15	15	247	15
June	16	347	15	13	334,5	15	7	232,5	15
July	22	378,5	15	15	347	15	14	278,5	15
August	27	387,5	13	24	377	13	18	347,5	13
September	29	305	12	19	279	12	22	285	12
October	26	251	10	25	224	10	22	274	10
November	20	187	9	16	145	9	26	327	9
December	24	209,5	9	16	140	9	17	257	9

Table 6: Estimated data for the proposed SSL system.

SSL System	2018	2019	2020
Number of days the system needs electricity from a distribution network	15	11	11
Annual consumption [kWh]	669.39	608.6	489.59
Annual cost	3,705.15 MKD (60.44 euro)	3,383.85 MKD (55.2 euro)	2,722.17 MKD (44.4 euro)
Procurement & installation cost	479,366 denars 7820 euro	/	/
Annual total cost	483,071.15 MKD (7,880.55 euro)	3,383.85 denars / 55.2 euro	2,722.17 denars / 44.4 euro

Table 7: Cost comparison between both street lighting systems for three years period.

	2018	2019	2020
Proposed SSLS	483,071.15 MKD (7,880.55 euro)	3,383.85 MKD (55.2 euro)	2,722.17 MKD (44.4 euro)
Conventional SLS	472,132.3 MKD (7,701.9 euro)	472,132.3 MKD (7,701.9 euro)	472,132.3 MKD (7,701.9 euro)

Difference: (- loose, + gain)	-10,938.85 MKD (-178.4 euro)	468,748.4 MKD (7,646.7 euro)	469,410 MKD (7,657.5 euro)

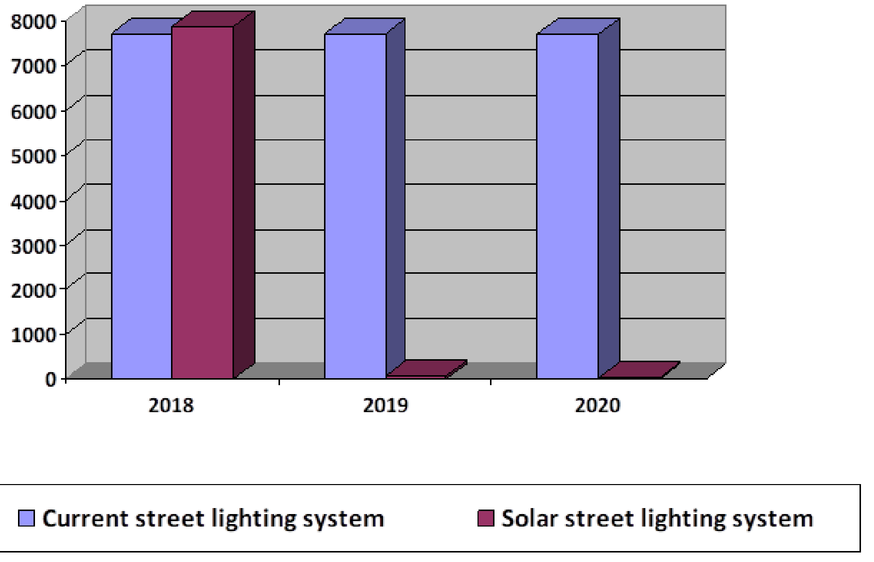

Fig. 5: Comparison between conventional (existing) SLS and the proposed SSLS for a projected period of 3 years including initial investments during the first year.

5. Conclusions

According to all projections, analyzes, and calculations, one can see that our proposed SSLS in place of the traditional sodium and mercury bulbs, is a very good investment.

The proposed SSL system provides the following benefits:

1. Reduce electricity consumption, and thus bills will be lower. This means that the funds can be saved or reallocated to other purposes.
2. Reduce the percentage and frequent breakdowns, and thus dark and unsafe streets.
3. Increased Street safety. In addition to traffic safety, reducing traffic accidents also reduces the number of thefts due to good lighting.
4. Significantly reduced the number of emissions of polluting particles, and thus cleaner air in the winter, where there is a lot of polluted air due to heating and exhaust fumes from cars.

Speaking about the investments, the Municipality of Shtip can easily manage and deal with this whole project. In respect of funding the project, the Municipality of Shtip can afford this investment. Additionally, there are other ways for partial or entire financing this project such as NGO's grants, various Embassies, and other international organizations that approve funding for projects related to the use of renewable energy and solar energy, or through a public-private partnership, as is the case for some other cities in Macedonia for such and similar projects realized in the past.

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