

**GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA
FACULTY OF ELECTRICAL ENGINEERING**

ETIMA 2023

**SECOND INTERNATIONAL CONFERENCE
27-29 SEPTEMBER, 2023**



**TECHNICAL SCIENCES APPLIED IN ECONOMY,
EDUCATION AND INDUSTRY**



УНИВЕРЗИТЕТ
ГОЦЕ ДЕЛЧЕВ

ЕЛЕКТРОТЕХНИЧКИ
ФАКУЛТЕТ



ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ,
УНИВЕРЗИТЕТ „ГОЦЕ ДЕЛЧЕВ”, ШТИП, СЕВЕРНА
МАКЕДОНИЈА

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

ВТОРА МЕЃУНАРОДНА КОНФЕРЕНЦИЈА
SECOND INTERNATIONAL CONFERENCE

ЕТИМА / ETIMA 2023

ЗБОРНИК НА ТРУДОВИ
CONFERENCE PROCEEDINGS

27-29 септември 2023 | 27-29 September 2023

ISBN: 978-608-277-040-6

DOI: <https://www.doi.org/10.46763/ETIMA2321>



Главен и одговорен уредник / Editor in Chief

проф. д-р Сашо Гелев
Prof.d-r Saso Gelev

Јазично уредување / Language Editor

Весна Ристова / Vesna Ristova

Техничко уредување / Technical Editing

Дарко Богатинов / Darko Bogatinov

Издавач / Publisher

Електротехнички факултет, Универзитет „Гоце Делчев“, Штип, Северна
Македонија
Faculty of Electrical Engineering, Goce Delcev University, Stip, North Macedonia

Адреса на организационен комитет / Address of the organising committee

Универзитет „Гоце Делчев“, Штип, Северна Македонија
Goce Delcev University, Stip, North Macedonia

Електротехнички факултет / Faculty of Electrical Engineering

Адреса: Крсте Мисирков, 10 А 2000, Штип/ Address: Krste Misirkov, 10A, 2000 Stip

E-mail: conf.etf@ugd.edu.mk

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

62-049.8(062)

004-049.8(062)

МЕЃУНАРОДНА конференција ЕТИМА (2 ; 2023)

Зборник на трудови [Електронски извор] / Втора меѓународна конференција
ЕТИМА 2023, 27-29 септември 2023 = Conference proceedings / Second
international conference, 27-29 September 2023 ; главен и одговорен уредник
Сашо Гелев]. - Штип : Универзитет "Гоце Делчев", Електротехнички факултет ;
Stip : "Goce Delcev" University, Faculty of Electrical engineering, 2024

Начин на пристапување (URL): <https://www.doi.org/10.46763/ETIMA2321>. -

Текст во PDF формат, содржи 200 стр.илустр. - Наслов преземен од екранот. -

Опис на изворот на ден 25.03.2024. - Трудови на мак. и англ.

јазик. - Библиографија кон трудовите. - Содржи и: Appendix

ISBN 978-608-277-040-6

а) Електротехника -- Примена -- Собири б) Машинство -- Примена -- Собири
в) Автоматика -- Примена -- Собири г) Инфоматика -- Примена -- Собири

COBISS.MK-ID 63335173





Втора меѓународна конференција ЕТИМА
27-29 септември 2023
Second International Conference ETIMA
27-29 September 2023

**ОРГАНИЗАЦИОНЕН ОДБОР
ORGANIZING COMMITTEE**

Василија Шарац / Vasilija Sarac

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Сашо Гелев / Saso Gelev

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Тодор Чекеровски / Todor Cekеровски

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Маја Кукушева Панева / Maja Kukuseva Paneva

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Билјана Читкушева Димитровска / Biljana Citkuseva Dimitrovska

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Дарко Богатинов / Darko Bogatinov

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia



Втора меѓународна конференција ЕТИМА
27-29 септември 2023
Second International Conference ETIMA
27-29 September 2023

**ПРОГРАМСКИ И НАУЧЕН ОДБОР
SCIENTIFIC COMMITTEE**

Со Ногучи / So Noguchi

Висока школа за информатички науки и технологии
Универзитет Хокаидо, Јапонија
Graduate School of Information Science and Technology
Hokkaido University, Japan

Диониз Гашпаровски / Dionýz Gašparovský

Факултет за електротехника и информациони технологии,
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Антон Белан / Anton Belán

Факултет за електротехника и информациони технологии
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Георги Иванов Георгиев / Georgi Ivanov Georgiev

Технички Универзитет во Габрово, Бугарија
Technical University in Gabrovo, Bulgaria

Ивелина Стефанова Балабанова / Ivelina Stefanova Balabanova

Технички Универзитет во Габрово, Бугарија
Technical University in Gabrovo, Bulgaria

Бојан Димитров Карапeneв / Boyan Dimitrov Karapenev

Технички Универзитет во Габрово, Бугарија
Technical University in Gabrovo, Bulgaria

Сашо Гелев / Saso Gelev

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Влатко Чингоски / Vlatko Cingoski

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Божо Крстајиќ / Bozo Krstajic
Електротехнички факултет
Универзитет во Црна Гора, Црна Гора
Faculty of Electrical Engineering,
University in Montenegro, Montenegro

Милован Радуловиќ / Milovan Radulovic
Електротехнички факултет
Универзитет во Црна Гора, Црна Гора
Faculty of Electrical Engineering,
University in Montenegro, Montenegro

Гоце Стефанов / Goce Stefanov
Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Мирјана Периќ / Mirjana Peric
Електронски факултет
Универзитет во Ниш, Србија
Faculty of Electronic Engineering,
University of Nis, Serbia

Ана Вучковиќ / Ana Vuckovic
Електронски факултет
Универзитет во Ниш, Србија
Faculty of Electronic Engineering,
University of Nis, Serbia

Тодор Чекеровски / Todor Cekerovski
Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Далибор Серафимовски / Dalibor Serafimovski
Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Мирослава Фаркаш Смиткова / Miroslava Farkas Smitková
Факултет за електротехника и информации технологии
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Петер Јанига / Peter Janiga
Факултет за електротехника и информации технологии
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Јана Радичова / Jana Raditschová

Факултет за електротехника и информации технологии
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Драган Миновски / Dragan Minovski

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Василија Шарац / Vasilija Sarac

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Александар Туцаров / Aleksandar Tudzarov

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Владимир Талевски / Vladimir Talevski

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Владо Гичев / Vlado Gicev

Факултет за информатика,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Computer Science,
Goce Delcev University, Stip, North Macedonia

Марија Чекеровска / Marija Cekerovska

Машински факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Mechanical Engineering,
Goce Delcev University, Stip, North Macedonia

Мишко Цидров / Misko Dzidrov

Машински факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Mechanical Engineering,
Goce Delcev University, Stip, North Macedonia

Александар Крстев / Aleksandar Krstev

Факултет за информатика,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Computer Science,
Goce Delcev University, Stip, North Macedonia

Ванчо Аџиски / Vancho Adziski

Факултет за природни и технички науки,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Natural and Technical Sciences,
Goce Delcev University, Stip, North Macedonia

Томе Димовски / Tome Dimovski

Факултет за информатички и комуникациски технологии,
Универзитет „Св. Климент Охридски“, Северна Македонија
Faculty of Information and Communication Technologies,
University St. Climent Ohridski, North Macedonia

Зоран Котевски / Zoran Kotevski

Факултет за информатички и комуникациски технологии,
Универзитет „Св. Климент Охридски“, Северна Македонија
Faculty of Information and Communication Technologies,
University St. Climent Ohridski, North Macedonia

Никола Рендевски / Nikola Rendevski

Факултет за информатички и комуникациски технологии,
Универзитет „Св. Климент Охридски“, Северна Македонија
Faculty of Information and Communication Technologies,
University St. Climent Ohridski, North Macedonia

Илија Христовски / Ilija Hristovski

Економски факултет,
Универзитет „Св. Климент Охридски“, Северна Македонија
Faculty of Economy,
University St. Climent Ohridski, North Macedonia

Христина Спасовска / Hristina Spasovska

Факултет за електротехника и информациски технологии,
Универзитет „Св. Кирил и Методиј“, Скопје, Северна Македонија
Faculty of Electrical Engineering and Information Technologies,
Ss. Cyril and Methodius University, North Macedonia

Роман Голубовски / Roman Golubovski

Природно-математички факултет,
Универзитет „Св. Кирил и Методиј“, Скопје, Северна Македонија
Faculty of Mathematics and Natural Sciences,
Ss. Cyril and Methodius University, North Macedonia

Маре Србиновска / Mare Srbinovska

Факултет за електротехника и информациски технологии,
Универзитет „Св. Кирил и Методиј“, Скопје, Северна Македонија
Faculty of Electrical Engineering and Information Technologies,
Ss. Cyril and Methodius University, North Macedonia

Билјана Златановска / Biljana Zlatanovska

Факултет за информатика,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Computer Science,
Goce Delcev University, Stip, North Macedonia

Александра Стојанова Илиевска / Aleksandra Stojanova Pievska

Факултет за информатика,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Computer Science,
Goce Delcev University, Stip, North Macedonia

Мирјана Коцалева Витанова / Mirjana Kocaleva Vitanova

Факултет за информатика,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Computer Science,
Goce Delcev University, Stip, North Macedonia

Ивана Сандева / Ivana Sandeva

Факултет за електротехника и информациски технологии,
Универзитет „Св. Кирил и Методиј“, Скопје, Северна Македонија
Faculty of Electrical Engineering and Information Technologies,
Ss. Cyril and Methodius University, North Macedonia

Билјана Читкушева Димитровска / Biljana Citkuseva Dimitrovska

Електротехнички факултет,
Универзитет „Гоце Делчев“, Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delcev University, Stip, North Macedonia

Наташа Стојковиќ / Natasa Stojkovic

Факултет за информатика,
Универзитет „Гоце Делчев“, Штип, Северна Македонија;
Faculty of Computer Science,
Goce Delcev University, Stip, North Macedonia;



Втора меѓународна конференција ЕТИМА Second International Conference ETIMA

PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the Second 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 exchanging the ideas, strengthening the multidisciplinary research and cooperation, and promoting 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. More than sixty colleagues contributed to this event, from five different countries with more than thirty papers.

We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'23 by presenting the results of their current research and by launching the new ideas through many fruitful discussions.

We invite you and your colleague to attend ETIMA Conference in the future as well. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information as well as to involve as much as possible the young researchers into this scientific event.

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 придонес повеќе од шеесет автори од пет различни земји со повеќе од триесет труда.

Сакаме да ја искажеме нашата благодарност до сите колеги кои придонесоа за успехот на ЕТИМА'23 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Организационен одбор на конференцијата

СОДРЖИНА / TABLE OF CONTENTS:

ANALYTICAL ESTIMATION OF OPTIMAL PV PANEL TILT BASED ON CLEAR-SKY IRRADIANCE MODEL	13
ENVIRONMENTAL AND ENERGY UTILIZATION OF MUNICIPAL WASTE – ONE PRODUCT, TWO SOLUTIONS	14
INTELLIGENT POWER MODULE CONTROLLED BY MICROCOMPUTER AND IMPLEMENTED IN AC MOTOR SPEED REGULATOR	22
COMPARATIVE ENVIRONMENTAL ANALYSIS BETWEEN CONVENTIONAL AND COGENERATION GAS-FIRED CENTRAL HEATING SYSTEMS	32
COMPARATIVE ANALYSIS BETWEEN BIFACIAL AND MONOFACIAL SOLAR PANELS USING PV*SOL SOFTWARE	44
TECHNO-ECONOMIC EVALUATION OF RETROFITTING A 210 MW THERMAL HEAVY-OIL POWER PLANT WITH A PHOTOVOLTAIC SOLAR THERMAL ENERGY STORAGE SYSTEM USING MOLTEN SALT: A CASE STUDY OF TEC NEGOTINO.....	45
CHARGING STATIONS CONNECTED TO STREET LIGHT POWER SYSTEM	46
ELECTRICITY PRODUCTION OF PVPP FOR ELECTRICITY MARKET	47
ENERGY MIX OF THE SLOVAK REPUBLIC.....	55
SWOT ANALYSIS OF HYDROGEN ECONOMY.....	59
PHYSICAL LIMITATIONS OF DIMMING OF 400 W RATED HALIDE LAMPS (A CASE STUDY).....	60
ФУНКЦИОНИРАЊЕ НА ПАЗАРИ НА ЕЛЕКТРИЧНА ЕНЕРГИЈА: МОДЕЛИ НА ПАЗАРИ НА ЕЛЕКТРИЧНА ЕНЕРГИЈА	68
EASY AND FAST ESTIMATION OF THERMAL STABILITY OF HTS MAGNETS UNDER SIMPLE SITUATION.....	76
INVESTIGATION OF TURN-TO-TURN CONTACT RESISTANCES OF LARGE-SCALE D-SHAPED NO-INSULATION HIGH-TEMPERATURE SUPERCONDUCTING MAGNETS TO ACHIEVE SHORT CHARGING DELAY AND HIGH THERMAL STABILITY.....	77
IMPACT OF CORE SATURATION ON OPERATING CHARACTERISTICS OF THREE-PHASE SQUIRREL CAGE MOTOR.....	84
PRINCIPLES AND APPLICATIONS OF ORAL ELECTROSURGERY	93
MOLTEN SALT THERMAL ENERGY STORAGE FOR RENEWABLE ENERGY: SYSTEM DESIGN, MATERIALS, AND PERFORMANCE	100
ДЕНТАЛНИТЕ ЛАСЕРИ - ПРЕДИЗВИК НА СОВРЕМЕНАТА СТОМАТОЛОГИЈА.....	110
ANALYSIS OF DEVELOPING NATIVE ANDROID APPLICATIONS USING XML AND JETPACK COMPOSE	118
ENSURING INFORMATION SECURITY IN THE DIGITAL AGE	119
CLOUD COMPUTING AND VIRTUALIZATION: CAN CLOUD COMPUTING EXIST SEPARATELY FROM VIRTUALIZATION?.....	124

THE IMPACT OF ONLINE TEACHING ON THE DENTAL STUDENTS' EXAM SUCCESS.....	131
КОМПАРАТИВНА АНАЛИЗА НА СТАНДАРДИ И МЕТОДОЛОГИИ ЗА УПРАВУВАЊЕ СО ИНФОРМАЦИСКО-БЕЗБЕДНОСНИ РИЗИЦИ НА ТЕХНИЧКИТЕ И ЕЛЕКТРОНСКИТЕ СИСТЕМИ ОД КРИТИЧНАТА ИНФРАСТРУКТУРА.....	139
УЧЕЊЕ СО ПОМОШ НА МОБИЛНИ УРЕДИ – ПРИДОБИВКИ И ПРЕДИЗВИЦИ НА НОВОТО ВРЕМЕ	140
TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION METHOD IN PATIENTS WITH XEROSTOMIA	147
БИОТЕХНОЛОШКА ПРОЦЕДУРА НА ДОБИВАЊЕ НА АВТОЛОГЕН ДЕНТИНСКИ ГРАФТ ЗА СТОМАТОЛОШКИ И МЕДИЦИНСКИ ЦЕЛИ	148
PHYSIODISPENSER – AND ITS USE IN DENTAL MEDICINE.....	149
BIOMECHANICAL BEHAVIOR OF ENDOSONICS	153
ДИГИТАЛНИ ОТПЕЧАТОЦИ-СОВРЕМЕН ТРЕНД НА ДЕНЕШНИЦАТА	158
DESIGN AND IMPLEMENTATION OF SCADA SYSTEMS	167
ПРЕДНОСТИ И НЕДОСТАТОЦИ ПРИ ИЗВЕДУВАЊЕ ONLINE НАСТАВА ПО МАТЕМАТИКА	174
ALGORITHMIC METHOD IN DYNAMIC DOSING SYSTEMS BASED ON WEIGHT MEASURING PRINCIPLES	181
IMPLICATIONS FOR THE ENVIRONMENTAL-ENGINEERING COMPROMISE AS A RESULT OF POWER AND ECONOMY TUNING A DIESEL ENGINE	189
AUTONOMOUS ROBOTIC VACUUM CLEANER	190



ENERGY MIX OF THE SLOVAK REPUBLIC

Miroslava Farkas Smitkova¹, Frantisek Janicek²

¹Institute of Power and Applied Electrical Engineering, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Ilkovičova 3, 812 19, Bratislava, Slovak Republic
e-mail: miroslava.smitkova@stuba.sk,

²Institute of Power and Applied Electrical Engineering, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Ilkovičova 3, 812 19, Bratislava, Slovak Republic
e-mail: frantisek.janicek@stuba.sk

Abstract

This paper deals with the energy mix of the Slovak Republic with a focus on renewable energy sources and their development in recent years. The share of renewable energy sources in electricity production in Slovakia rose from 310 GWh in 2011 to 2 380 GWh in 2021. This number does not include hydro energy, which has had a very good position in Slovakia for many years and its installed capacity is almost unchanged, in 2021 it was 2 546 MW, and electricity production was at about 4 600 GWh. The energy sector in Slovakia, as well as in other European countries, must reflect worldwide changes and challenges. It needs to consider problems in many fields, such as technical, economic, ecological, legislative, social, and political.

The current situation in the Slovak energy system is described with a focus on energy dependence and the usage of renewables. Some energy statistics are shown in this paper. Finally, possible scenarios and plans for the reduction of energy dependence are discussed.

Key words

energy, renewable energy sources, energy consumption and production, energy dependency

Introduction

European Union (EU) is one of the major players in global energy consumption. Despite its leading position, the EU has a very small influence on energy price markets. Moreover, the EU and Slovakia as one of the EU's member states, must be independent of one monopoly supplier, as well as boosts the production from renewable energy sources (RES). Many of the EU's countries are already successfully implementing this strategy. This is not only about minimizing our dependence on fossil fuels (and with its connected monopoly supplier), but also about the necessary increase in renewable energy production. The current energy mix in Slovakia could be considered as a good, which consists mostly of nuclear power plants and hydropower plants. Nowadays, political authorities are searching for new, stable, and environmentally friendly energy sources that could be able to cover all energy demands and moreover assign energy safety and sustainable development of the energy industry.

Slovakia has untapped potential for renewables. However, its utilization must go hand in hand with legislation and regulation. It is important to diversify the sources and to come up with systematic solutions that consist of sensible steps and considering the opinions of experts.

1. Energy in Slovakia

Slovakia is located in east Europe, between latitudes 47° and 50° N, and longitudes 16° and 23° E. It has an area of 49 035 km² and 5 428 792 inhabitants (data from 31 December 2022), [2]. The Slovak climate lies between the temperate and continental climate zones with relatively warm summers and cold, cloudy, and humid winters. The Slovak landscape is primarily mountainous nature, extending across most of the northern half of the country. The average temperature is 8.7 °C, the warmest average maximum temperature is 26 °C in July and the coolest average minimum temperature is -7 °C in January. Slovakia receives on average 605 mm of precipitation annually or 50 mm each month [1].

Slovakia is highly dependent on energy commodities import. The energy dependence of the Slovak Republic (56%, without nuclear energy) is only 2% lower than EU average - in 2020, the EU imported 57.5% of the energy it consumed. When nuclear energy is included, Slovakia with 81% is the fifth most dependent EU country after Malta (98%), Cyprus (92%), Luxembourg (91%) and Greece (81%) [3].

The energy mix represents an overview of individual energy sources in the total electricity production. Slovak energy sector structure is diversified in terms of fossil and nuclear fuels and renewable energy sources (RES) including water. Considering t electricity production, Slovakia was an exporter till the end of 2006 when unit 1 of the nuclear power plant Jaslovské Bohunice was shut down. The second unit was shut down in 2008. The reason for shutting down was the condition of Slovakia's accession to the European Union. Nowadays, Slovakia is an electricity importer, electricity balance is low, in 2011 it was 2.5%, and in 2021 it was very similar [5]. In 2021, the total installed capacity in Slovakia reached 7 779 MW, with total electricity consumption at 30 867 GWh and total electricity production at 30 093 GWh [5], see table 1. The share of RES at electricity production is increasing, but excluding large hydroelectric plants, the share of RES is at about 8%. In the last decade the highest new installed capacity was from the photovoltaic power plants, the share of wind energy is very low.

Table 1 Share of energy sources covering electricity production in GWh in Slovakia, in 2006, 2011, and 2021

	Nuclear Power Plants	Fossils	Hydro Power Plants	RES	Others	Production	Consumption
2021	15 730	7 274	4 604	2 380	105	30 093	30 867
2011	15 441	5 726	4 006		2 992	28 165	28 862
2006	18 013	5 935	4 447		2 832	31 227	29 624

Source: Ročenka SED 2021. National Control Centre of Slovakia. Online. Available at: <https://www.sepsas.sk/media/6115/rocenka-sed-2021.pdf>

2. Power Plants in Slovakia

The energy mix of the Slovak Republic is diversified in terms of fossil and nuclear fuels and renewable energy sources and hydro energy, see fig. 1.

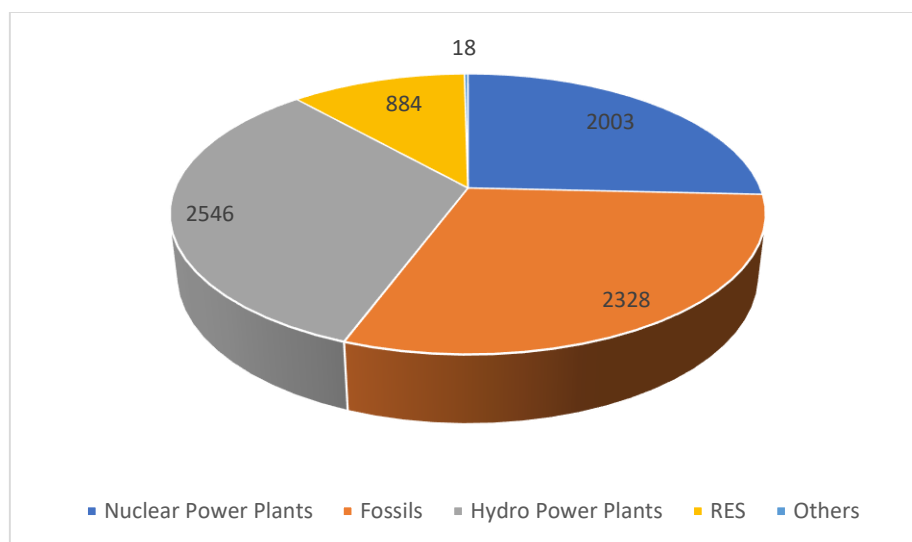


Fig. 1 Installed Capacity of Slovak Power Plants in MW, 2021

Source: Ročenka SED 2021. National Control Centre of Slovakia. Online. Available at: <https://www.sepsas.sk/media/6115/rocenka-sed-2021.pdf>

There are two thermal power plants in Slovakia, in Vojany and in Nováky. Despite coal, both plants also use biomass, in Vojany since 2009 and in Nováky since 2011. One black coal fired 110 MW unit can avoid about 21 000 tons of CO₂ emissions annually when co-firing biomass. Because they provide reliable electricity generation both for the baseload as well as for peak load demand, they play a very important role in the power grid. Recent years, the main role of fossil fuels has played natural gas. The history of coal mining is long, brown coal mining started in Slovakia in 1913, but at the end of the 20th century, coal and lignite mining began to decrease. After February 2022, several countries resumed their coal production due to gas supply complications, but it is no longer possible in Slovakia because the process of transformation of the region and termination of mining has begun. In addition, the state will no longer support it.

Two nuclear power plants, one in Jaslovské Bohunice with 2 units of pressurised water reactors, type WWER 440, and one in Mochovce also with 2 units same type, are currently in operation. Two new units, located in Mochovce, being planned, Unit 3 is now in a start-up phase and Unit 4 is still under construction. The electric power of each new unit will be 471 MW_e and will cover 13% of the electricity demand in Slovakia [4].

The installed capacity of hydropower plants in Slovakia was 2 546 MW in 2021, including pumped storage power plants (there are four of them - Čierny Váh 734,4 MW, Liptovská Mara 98 MW, Dobšiná 24 MW and Ružín 60 MW). There are currently 234 hydropower plants in operation, but only 24 are large hydropower plants. The share of hydropower plants in annual production is on average 15%. Due to their flexibility and rapid changes in output, they can cover power requirements at the top of the daily load diagram, and they are therefore also suitable for covering emergency conditions in the grid [6].

In 2021, a share of energy from renewables was 17.4% (houses heated by wood are also included, what cannot be considered as inappropriate), considering only electricity from renewables without water, it was only 8%. Compared to recent years, the improvement is only marginal. The installed capacity of RES (without water) was 884 MW in 2021, while in 2016 it was 876 MW. When we consider also hydropower, in 2021 RES achieved a share of 22.9% in electricity production (6 984 GWh, water 2 380 GWh, and other RES 4 604 GWh), while in 2020 it was 7 205 GWh, and in 2016 it was 7 274 GWh, what represents 26.5% (overall production was 27 452 GWh).

The main share has solar energy, followed by biomass, see table 2. In addition to energy from water and sun, biogas or wood, geothermal energy can also be a suitable option to increase the share of renewables in the overall energy mix. There are several areas, e.g., around Galanta, veľký Meder, Žiar nad Hronom, Prešov or Košice, which have the potential not only for heat production but also for electricity.

Table 2 Share on the installed capacity of RES in MW in Slovakia in 2021

Solar	Biomass	Biofuel	Wind	Others	Total
532	234	104	3	11	884 MW

Source: Ročenka SED 2021. National Control Centre of Slovakia. Online. Available at: <https://www.sepsas.sk/media/6115/rocenka-sed-2021.pdf>

Upon bigger installed power in RES, their impact is manifested in the overall ES management, especially from the view of assurance of the necessary volume of particular kinds of supportive services. The establishment of the necessary volume of particular kinds of supportive services is solved based on the methodology of transmission system operator in the Slovak Republic (SEPS, a.s.). Renewables increase the necessary volume for supportive services in secondary power regulation and tertiary power regulation.

Conclusion

Renewable energy sources alone are not able to cover all our demands. Obviously, they are environmentally friendly, and they help to decrease fossils consumption. In a short time, it is not realistic and not economically reasonable to replace all conventional (nuclear and thermal) power plants with RES due to their unpredictable behaviour and high investment costs. However, recent months have shown us we should look at our natural resources and because of the lack of other sources, the improvement of RES is welcome.

The instability of supplies, security of supplies, environmental concerns as well as economic constraints the energy issues must be solved. It is important to mention that for RES support are many EU grants that provide research, development, and innovation in the field of renewable energy sources.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-20-0157.

References

- [1] Klimatické pomery Slovenskej republiky. Slovenský hydrometeorologický ústav. [online]. [cit: 2023-05-05] Available at: <<https://www.shmu.sk/sk/?page=1064>>
- [2] Stav obyvateľstva v SR k 31. decembru 2022. Štatistický úrad SR. [online]. [cit: 2023-05-07] Available at: <<https://slovak.statistics.sk/>>
- [3] Statistics underplay Slovak dependence on energy imports. Statistics underplay Slovak dependence on energy imports. [online]. [cit: 2023-05-07] Available at: <<https://www.euractiv.com/>>
- [4] Nuclear Power Plants. [online]. Available at: <<https://www.seas.sk/en/about-us/our-power-plants/nuclear-power-plants/>>
- [5] Ročenka SED 2021. National Control Centre of Slovakia. [online]. [cit: 2023-05-05] Available at: <<https://www.sepsas.sk/media/6115/rocenka-sed-2021.pdf>>
- [6] Vodné elektrárne v SR. [online]. [cit: 2023-05-07] Available at: <<https://www.energie-portal.sk/Dokument/vodne-elektrarne-v-sr-100207.aspx>>