UNIVERSITY OF BELGRADE
TECHNICAL FACULTY IN BOR

BOOK OF ABSTRACTS

8th INTERNATIONAL STUDENT CONFERENCE ON TECHNICAL SCIENCES

www.tfbor.bg.ac.rs

ISC 2023

8th INTERNATIONAL STUDENT CONFERENCE on Technical Sciences

20-21 October, Bor Lake, Serbia

Editor: Uroš Stamenković

Book of Abstracts,
8th International Student Conference on Technical Sciences ISC 2023

Editor:
Doc. dr Uroš Stamenković
University of Belgrade - Technical Faculty in Bor

Technical Editors:
Milan Nedeljković, dipl. ing.
Avram Kovačević, dipl. ing.
University of Belgrade - Technical Faculty in Bor

Publisher: *University of Belgrade - Technical Faculty in Bor*
For the publisher: *Dean, Prof. dr Dejan Tanikić*
Circulation: 50 copies
Year of publication: *2023*

Printed by "*GRAFIKA GALEB DOO" NIŠ, 2023*

ISBN 978-86-6305-141-6

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

622(048)
669(048)
66(048)
66.017/.018(048)

INTERNATIONAL Student Conference on Technical Sciences (8 ; 2023 ; Borsko jezero)
Book of abstracts / 8th International Student Conference on Technical Sciences ISC 2023, 20-21 October, Bor Lake, Serbia ; [organized by University of Belgrade, Technical Faculty in Bor] ; editor Uroš Stamenković. - Bor : University of Belgrade, Technical Faculty, 2023 (Niš : Grafika Galeb). - VII, 51 str. ; 24 cm

Tiraž 50. - Bibliografija uz većinu apstrakata.

ISBN 978-86-6305-141-6

a) Рударство -- Апстракти b) Металургија -- Апстракти v) Хемијска технологија -- Апстракти g) Технички материјали -- Апстракти

COBISS.SR-ID 126594825

8th International Student Conference on Technical Science, ISC 2023.

Is organized by

UNIVERSITY OF BELGRADE, TECHNICAL FACULTY IN BOR

and co-organized by

University of Zenica, Faculty of engineering and natural sciences, Zenica, Bosnia and Herzegovina

**University in Priština, Faculty of Technical Science, Kosovska Mitrovica,
Serbia;**

University of Montenegro, Faculty of Metallurgy and Technology, Podgorica, Montenegro;

University of Tuzla, Faculty of Technology, Tuzla, Bosnia and Herzegovina;

University of Chemical Technology and Metallurgy, Faculty of Metallurgy and Material Science, Sofia, Bulgaria;

TABLE OF CONTENTS

DEVELOPMENT OF GEOTHERMAL ENERGY IN THE WORLD

Student: Nikolay Palienko

Mentor: Tamara Tikhomirova

Belgorod State Technological University. V.G. Shukhov, Belgorod, Russia

Abstract

According to the materials of the World Geothermal Congress 2015 provides an overview of the development of geothermal energy in the world. Over the past five years, the energy industry began a rapid development: geothermal power installed capacity increased by 16 %, and production of geothermal heat power plants increased by 45 %. Inexhaustibility of the energy source, new technology and drilling technology of geothermal heat in central heating systems has attracted significant investment in this sector. Cost of energy produced by geothermal plants is much lower compared to other renewable energy sources and conventional stations. Geothermal plants are environmentally friendly systems.

Oil and gas will eventually lie in such difficult geological conditions that their production will become more and more expensive. Thus, it is necessary to develop alternative energy industries using renewable energy sources. Such industries include: geothermal energy – the use of the deep heat of the Earth; the use of wind energy; solar energy; the use of tidal energy; bioenergy. When it comes to renewable energy sources, the first thing that comes to mind is solar panels and wind turbines. Geothermal sources are recalled much less often. Meanwhile, they are a powerful and clean source, differing from the wind and sun in greater stability. Geothermal energy is by far the most developed and cost-effective. Geothermal resources represent an almost inexhaustible, renewable and environmentally friendly source of energy that will play a significant role in the energy of the future. One of the important characteristics of geothermal energy is the high load factor, which means that each MW (Megawatt) of power produces significantly more electricity during the year than the MW of a wind or solar power plant. In the last few years, there has been a great interest in the development of geothermal energy in the world, as evidenced by the rapid growth of installed capacity. This is due to the countries' desire for energy independence from the external fuel market. More than 80 countries in the world use geothermal energy to produce heat and electricity. The total capacity of geothermal and electric power plants is almost 83 GW (Gigawatt), of which 15% is for electricity production, and 85% is for heat production.

Electricity production - In 24 countries of the world, geothermal energy is used to generate electricity. The total capacity of all geothermal power plants is 12.6 GW. Annual electricity generation at geothermal power plants in the world in 2014 amounted to 73.55×10^3 GWh [1, 2], which in gas equivalent is 7.94×10^9 m^3 of natural gas. Over the past five years, 2010-2015, the installed capacity of geothermal power plants in the world has increased by 1.7 GW (about 16%), on average about 350 MW per year (in the period 2000 – 2005, the increase in capacity was 200 MW). According to forecasts of the International Geothermal Agency (IGA), by 2020 the installed capacity of geothermal power plants will reach more than 21 GW. The leaders in installed electric capacity of geothermal plants are the USA – 3098 MW, the Philippines – 1931 MW, Mexico – 958 MW, Indonesia – 1197 MW, New Zealand – 762 MW.

Heat production - 82 countries in the world use geothermal energy to produce heat. The installed capacity of heat generating units is 70.38 GW, which produces $163{,}29 \times 10^3$ GWh of heat per year. Compared to 2010, the capacity of thermal power plants increased by almost 45%, heat production increased by 6.8% per year [3]. At a water temperature of less than 100 °C, geothermal energy is used for local heating of buildings and structures, after heating up to 100 °C, it can be used in district heating

systems. By at a temperature of 50-60 °C, geothermal water is used in hot water supply systems, and below 40 °C – for heating greenhouses and in geothermal refrigeration units (heat in cold). In the period from 2010 to 2015, 42 countries had 2,218 wells that have been drilled, and US$ 20 billion has been invested in geothermal projects in 49 countries. Areas of use of geothermal heat. A wide range of applications of heat produced by geothermal systems. The diagram in Fig. 3 shows how the power consumption of geothermal energy increases in various fields of use [3]. The most dynamic development in recent years has received geothermal heat supply and central heating. 11.5% of the generated heat is used for heating the premises. New central geothermal heating systems are being installed; old ones are being reconstructed. For example, a network of geothermal heat stations is being created around Paris. Already 170,000 buildings are heated by geothermal energy, by 2016 it is planned to provide geothermal heat supply to 50 % of the city's population [4,5,6]. Also, heat from geothermal plants is used for heating greenhouses, in industry, in agricultural drying, for sidewalk heating, snow melting, cooling, etc. Technologies for the use of low-potential georesources and geothermal heat pumps are developing at a rapid pace. 55.3% of the geothermal heat produced in the world is used in heat pump technologies (Fig. 4) [3]. The total installed capacity of heat pump systems is 15,723 MW, with annual heat generation of 86673 TJ. In such systems, low-potential thermal water (temperature up to 55 °C) and the energy of the upper layers of the Earth's crust are used as the primary source of heat. When using the heat of the soil, ground heat exchangers are used, placed either in vertical wells up to 300 m deep, or at some depth horizontally. Geothermal heat pump heat supply systems are used in 32 countries of the world with an average conversion coefficient of Kp = 3.5. These technologies have received the greatest development in the USA, Germany, Canada. In the USA, 69% of the total direct use of geothermal resources is realized through the use of heat pumps. In Germany, the total thermal capacity of geothermal systems is 505 MW, of which 400 MW – based on the use of heat pumps using the heat of the soil. Economic indicators of geothermal plants. The production of heat and electricity at geothermal plants depends on many factors, such as the geology and geochemistry of the area, the infrastructure in the construction area and the quality of energy resources (debit, salinity of water, its temperature, etc.). As a rule, the construction of geothermal plants is associated with a long-term strategy and has a certain financial risk. Therefore, when creating geothermal power plants (GEOS), most countries prefer to build medium–power stations – 30-60 MW. Construction GEOS usually takes 3-7 years, depending on the specific conditions and capacity of the station, and its life cycle is 30 years. Table 1 shows an average (minimum-maximum) estimate of the cost of construction of a GeoEC with an electric capacity of 50 MW with a construction period of 7 years [7,8,9]. The total cost of construction is US$ 196 million, or US$ 3,920 per 1 kW of installed capacity, in accordance with the data provided [3].

Areas of use and dynamics of consumption growth of geothermal heat for 20 years - Distribution of the use of geothermal heat for various applications in % in 2015 mi cost of 1 kW of installed capacity GEPP does not exceed the cost of thermal power plants. System of complete purification of combustion products, which today amounts to $ 5,000, the cost of nuclear power plants (with a system for recycling waste products) – $ 5,000, the cost of powerful hydroelectric power plants with a power utilization factor of 60% – $ 4,400. The costs of operating a geo-power plant are quite stable, because they are practically not for- they depend on the conjuncture of market prices for organic energy. With the annual load of the GEPP at the level of 80%, capital and operating costs amount to $444 per 1 kWh of electricity produced. For diesel power plants, this figure is $868. US$ per 1 kWh, for coal – 658 USD. US$ per 1 kWh and for natural gas combined cycle gas turbines – US$ 453 per 1 kWh. Despite the highest capital investments in the use of geothermal energy carriers, the cost of heat produced is the lowest in comparison with other renewable energy sources: 2.5-3.0 cents 5). Compared with traditional power plants, the construction of geothermal plants requires less capex, and the cost of electricity produced is lower than at traditional stations [10,11]. Thus, geothermal energy is competitive with other power plants in terms of cost and construction time. Advantages of geothermal energy. The latest energy technologies using geothermal resources are environmentally friendly and are approaching the traditional ones in efficiency. This is due to the inexhaustibility of this type of energy and the almost constant electrical loading of the GEPP throughout the entire life cycle. At modern geo-power plants,

the coefficient increased to 92% in power, which is 3 or 4 times higher than for technologies using other renewable energy sources and traditional plants (nuclear power in the world – 90%, coal – 85%, wind – 38%, solar – 20%). The main advantages of geothermal energy are relatively low emissions of carbon dioxide and carcinogenic products into the atmosphere - 91 g per 1 kWh, whereas when burning coal at thermal power plants, this value is 955 g per 1 kWh. GEO-power plants using circulation technology and binary the cycle completely eliminates carbon dioxide emissions into the atmosphere, which is the most important environmental advantage of such power plants. In the world, energy savings by geothermal plants amount to 58.3 × 109 m^3 in gas equivalent, 46 million tons of coal, heat production by geothermal plants in the world reduces carbon dioxide emissions by 148 million tons of CO_2 per year [8]. Large areas, on average it occupies 0.4 m^2 per 1 MW · hour of generated electricity, while for coal–fired thermal power plants - this value is 9 to 10 times more.

Conclusions - Currently, the problem of replacing hydrocarbon fuels with renewable energy sources, including geothermal, is extremely urgent. The advantages of geothermal energy are its ubiquity, accessibility and proximity to the consumer. World experience shows that the use of the deep heat of the earth's interior is possible for the production of heat and electricity. Ukraine has all the prerequisites for the development and creation of significant capacities based on geothermal circulation systems. Currently, the direction of research on the extraction of the deep heat of the Earth, the unification of technological schemes and equipment of geothermal circulation systems is poorly developed in Ukraine. The development and development of intensive technologies for the extraction of heat carriers and the creation of efficient systems for the use of subsurface heat is the main scientific and engineering problem of energy, which can partially solve the problem of natural gas substitution.

Keywords: *Energy, Wind, Solar, Geothermal, Bioenergy*

REFERENCES

[1] R. Bertani, Geothermal Power Generation in the World 2010-2014 Update Report (Electronic resource) / Bertani R. // Proceedings World Geothermal Congress – 19-25 April 2015, Melbourne, Australia. – Mode of access: www. geothermal-energy.org; https://pangea.stanford.edu
[2] World energy council (Electronic resource) – Mode of access: www.worldenergy.org
[3] J.W. Lund, L. Tonya, Boyd Direct Utilization of Geothermal Energy 2015 Worldwide Review (Electronic resource) // – Mode of access: https://pangea.stanford.edu; http://www.geothermalenergy.org
[4] French know-how in the field of GEOTHERMAL ENERGY District heating and electricity genera-tion systems // – Mode of access: www.ademe.fr
[5] Drilling of the geothermal doublet at Gentilly: marking the rebirth of geothermal in France (Electronic resource) // – Mode of access: www.engie. com/geothermal l'expert de la géothermie au service des villes durables (Electronic resource) // – Mode of access: http://www.cofelyreseaux-gdfsuez.com
[6] Geothermal_Handbook (Electronic resource) // – Mode of a access: http://www.esmap.org/esmap/Geothermal_Handbook
[7] Medium-Term Renewable Energy. Market Report 2014 (Electronic resource) – Mode of access: http://www.bp.com/statisticalreview; www.iea. Org
[8] Walter Gerardi, Stephen Hinchliffe. Valuing Geothermal Projects Using an Enhanced Levelised Cost Framework (Electronic resource) // Proceedings World Geothermal Congress – 19-25 April 2015, Melbourne, Australia. – Mode of access: http://www. geothermal-energy.org/
[9] Electronic resource – Mode of access: http:// www.bp.com/statisticalreview.
[10] V.E. Fortov, O.S. Popel, Renewable energy in the world and in Russia // Proceedings of the First International Forum "Renewable Energy. Ways to improve the energy and economic efficien-cy REENFOR-2013." 22-23 October 2013 / ed. dts OS Popiel - M .: High Temperatures Russian Academy of Sciences, 2013. - S. 12-22. (Rus.)

www.tfbor.bg.ac.rs

8th INTERNATIONAL STUDENT CONFERENCE on Technical Sciences

20-21 October, Bor Lake, Serbia

ISBN 978-86-6305-141-6