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IV INTERNATIONAL CONFERENCE ON ADVANCES IN
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PROCEEDINGS COAST 2025

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BOOK OF PROCEEDINGS

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CONTENT

SADRŽAJ

ENGINEERING, TECHNOLOGY AND MATERIALS	1
ITERATIVE DETECTION OF CHANGE IN MEDICAL IMAGES USING BEE COLONY OPTIMIZATION AND BLOCK DIVISION	2
<i>Nataša Milosavljević, Nebojša Ralević, Dejan Ćebić, Dušan Denčić, Vladimir Ilić</i>	
IMPACT OF REVOLUTION 4.0 ON BURNOUT OF EMPLOYEES IN IT SECTOR AND MAPPING OF KEY FACTORS	11
<i>Katarina Karić, Miloš Papić, Dušan Garabinović</i>	
O TOTALNOJ INTEGRABILNOSTI U R^2	22
<i>Branko Sarić</i>	
PRIMJENA 3D SKENIRANJA I 3D ŠTAMPE U OČUVANJU KULTURNE BAŠTINE	32
<i>Andelko Obradović, Matija Miljanić, Mihailo Jovanović, Milena Đukanović</i>	
MULTI-CRITERIA ANALYSIS TO SELECT THE BEST RAW MATERIALS FOR BIODIESEL PRODUCTION IN SERBIA	40
<i>Aleksandar Stanković, Goran Petrović, Jelena Mihajlović, Milica Stanković</i>	
APPLICATION OF OPTIMIZATION ALGORITHMS IN FIRE PROTECTION SYSTEMS.....	51
<i>Goran Bošković, Marko Todorović, Marina Bošković, Bojana Zoraja, Zoran Čepić</i>	
PROJEKTOVANJE PROCESA PROIZVODNJE PRIMENOM DIJAGRAMA U POSLOVNOM SISTEMU „ATTRIUM HOME CENTER”	58
<i>Jasmina Ćurčić, Zoran Nešić, Neda Nikolić, Milan Vesković, Nebojša Denić</i>	
THERMAL IMAGING SPECTROMETRY AND THERMOGRAPHIC SNAPSHOTS FOR THREE BUILDING BLOCKS OF DIFFERENT AGES.....	70
<i>Jovana Jovanović, Ivan Stevović, Milena Đukanović</i>	
THE IMAGE AND THE KERNEL OF A LINEAR COMBINATION OF TWO $\{K, s + 1\}$ – POTENT MATRICES	86
<i>Marina Tošić</i>	
SUSTAINABLE DEVELOPMENT AND CIRCULAR ECONOMY SUPPORTED BY ARTIFICIAL INTELLIGENCE TOOLS	92
<i>Ivan Stevovic, Jovana Jovanovic, Mihailo Jovanovic</i>	
VIŠEKRITERIJUMSKI PRISTUP IZBORU ELEKTRIČNIH DOSTAVNIH VOZILA KORIŠĆENJEM AHP-ELECTRE METODA.....	104

Jelena Mihajlović, Goran Petrović, Aleksandar Stanković

DINAMIČKA ANALIZA ARMIRANOBETONSKOG OKVIRA SA ZIDANOM
 ISPUNOM..... 112

Timur Curić, Demir Vatić, Nebojša Ralević, Anka Starčev-Ćurčin, Igor Džolev

CRUDE OIL FIRST PURCHASE PRICE FORECAST BASED ON THE MONTE
 CARLO METHOD 123

Adrijana Jevtić, Miša Tomić, Dejan Riznić

OPTIMIZATION OF QUALITY AND PRECISION IN PRODUCTION USING
 CONTROL CHARTS 138

Goran Nestorović, Obrad Anicic

ANALYSIS OF CORRELATION AND LINEAR MODELS IN QUALITY
 CONTROL OF SERIAL PRODUCTION 146

Goran Nestorović, Obrad Anicic

ANALYSIS OF THERMAL CHARACTERISTICS OF AIR RIFLE BARRELS
 AFTER MULTIPLE FIRINGS 152

Darko Jankovic, Ljubisa Tomic, Marina Simovic Pavlovic, Martin Ochsenhofer, Lana
 Milosavljević, Nenad Djordjevic, Darko Vasiljevic*

**ARTIFICIAL INTELLIGENCE, COMPUTER SCIENCE AND INFORMATION
 TECHNOLOGY 157**

ULOGA FAZI MATEMATIKE U SEGMENTACIJI I ANALIZI PODATAKA... 158

Nataša Milosavljević, Julija Ščekić, Irma Ibrišimović, Nebojša Ralević, Damir Bajrić

SHALLOW GEOTHERMAL POTENTIAL IN THE DANUBE REGION – CAN
 CHATBOTS HELP PLAN THE WAY FORWARD?..... 169

*Filip Nastić, Davor Končalović, Dubravka Živković, Dušan Gordić, Vladimir Vukašinović,
 Mladen Josijević*

BIMODAL SPEECH RECOGNITION BASED ON CLASSICAL MEL AND
 WAVELET MEL CEPSTRAL COEFFICIENTS..... 179

Branko Marković, Gordana Marković

THE SPHERICAL FAHP METHOD FOR DEVELOPING SUCCESSFUL E-
 COMMERCE PLATFORM..... 189

Mimica Milošević, Dušan Milošević and Miloš Nikolić

DATA STRUCTURE FOR MODELING INTELLIGENT AGENTS IN THE
 EVACUATION SIMULATION 200

*Srdjan Popov, Tanja Vranić, Jovana Simić, Djordje Cosić, Suzana Draganić, Milena
 Zeljković*

LLM CODE GENERATION: THE CHALLENGE OF ACCURATE SCORING . 206

Lazar Krstic, Marija Jolovic, Branko Arsic

PATIENT-SPECIFIC INTERNAL FIXATION PLATES FOR MANDIBULAR SYMPHYSIS RECONSTRUCTION: A DIGITAL DESIGN APPROACH	218
<i>Jelena Mitić, Zoran Stamenković, Marta Petrović, Filip Petrović</i>	
PERFORMANCE ANALYSIS OF SPECTRAL BANDS AND INDICES IN SEMANTIC SEGMENTATION OF SENTINEL-2 IMAGERY USING ATTENTION U-NET ARCHITECTURE.....	229
<i>Jelena Mitić, Milan Grujev</i>	
THE ROLE OF ARTIFICIAL INTELLIGENCE IN THE DEVELOPMENT OF MACHINE SYSTEMS AND ENGINEERING DESIGN THROUGH MACHINE LEARNING	237
<i>Obrad Anicic, Goran Nestorović</i>	
RAZVOJ INFORMACIONIH SISTEMA U ERI INDUSTRIJE 5.0.....	245
<i>Olga Dukić , Miloš Papić</i>	
UTICAJ VJEŠTAČKE INTELIGENCIJE NA NAUČNOISTRAŽIVAČKI RAD: PREDNOSTI, IZAZOVI I ETIČKE DILEME	256
<i>Milica Vulević</i>	
ARTIFICIAL INTELLIGENCE FOR AGRICULTURE DIGITALIZATION: A REVIEW	266
<i>Marija Blagojević, Danijela Milošević, Marko Petković</i>	
BIOLOGY, PHISICS, CHEMISTRY AND MATHEMATICS.....	274
LICHENS COMMUNITY STRUCTURE ON THE ROCKS OF THE BEČIĆI BEACH, MONTENEGRO	275
<i>Gordana R. Aleksić*, Tatjana R. Jakšić, Predrag S. Vasić, Slavica S. Ćirić , Gordana Subakov – Simić</i>	
ANTI-INFLAMMATORY PROPERTIES OF CABERNET SAUVIGNON GRAPE-SKIN EXTRACT	284
<i>Danijela Stojković, Edina Avdović, Dušica Simijonović, Sandra Jovičić Milić, Dejan Milenković, Zoran Marković, Dušan Dimić</i>	
EXAMINATION OF THE ANTIOXIDANT ACTIVITY OF RED WINES FROM ŠUMADIJA REGION.....	289
<i>Danijela Stojković, Edina Avdović, Dušica Simijonović, Sandra Jovičić Milić, Marko Antonijević, Zoran Marković, Dušan Dimić</i>	
FOOD ADDITIVES.....	294
<i>Gordana Jovanović, Ana Vasić, Bojan Damnjanović</i>	
BIOMOLECULAR INTERACTIONS OF NOVEL RUTHENIUM(II) HALF-SANDWICH COMPLEXES.....	309
<i>Ana Rilak Simović, Nenad Janković, Lazar Milović, Milica Mededović</i>	

NEW RUTHENIUM (II) POLYPYRIDYL COMPLEXES; INTERACTIONS WITH BIOMOLECULES	316
<i>Milica Medjedović Stefanović, Ana Rilak Simović, Biljana Petrović</i>	
BUDUĆNOST E-FARMACIJE DO PHARMA 5.0.....	322
<i>Tatjana Stojadinović, Marija Branković, Ilija Antović, Lara Stojadinović</i>	
BIOINDIKACIJA KVALITETA VAZDUHA U BANJSKOJ, UPOTREBOM LIŠAJEVA KAO BIOINDIKATORA.....	329
<i>Gordana R. Aleksić*, Tatjana R. Jakšić, Predrag S. Vasić, Slavica S. Ćirić, Teodora N. Aleksić, Mila Z. Jakšić, Gordana Subakov – Simić</i>	
ECONOMY, MANAGEMENT, TOURISM AND HOSPITALITY	340
THE LEASING CONTRACT - NEW ALTERNATIVE FINANCING	341
<i>Veselin Hristov</i>	
FINANCIAL SUCCESS ANALYSIS OF COMPANIES OPERATING IN THE BIST HEALTH SECTOR USING THE TOPSIS METHOD.....	352
<i>Selçuk KENDİRLİ, Zekeriya LEK</i>	
THE CORRELATION OF EMPLOYEE DEVELOPMENT AND JOB SATISFACTION: EVIDENCE FROM THE INSURANCE INDUSTRY	363
<i>Aleksandar Glišić</i>	
THE IMPACT OF BUSINESS STRATEGIES ON HUMAN RESOURCE MANAGEMENT WITH SPECIAL REFERENCE TO THE TERMINATION OF EMPLOYMENT CONTRACTS	371
<i>Ivica Opačak, Tihomir Vujčić</i>	
INNOVATION SUPPORT IN SERBIA: MAPPING THE INSTITUTIONAL AND FINANCIAL INFRASTRUCTURE OF THE STARTUP ECOSYSTEM	377
<i>Nikola Radosavljević, Gordana Rendulić Davidović, Cariša Bešić, Snežana Dragičević</i>	
ULOGA I ZNAČAJ HRM U RJEŠAVANJU PROBLEMA NEDOSTATKA RADNE SNAGE U TURISTIČKIM PREDUZEĆIMA U CRNOJ GORI.....	389
<i>Jovan Spaić, Dragan Klarić</i>	
THE IMPORTANCE OF A STRATEGIC PROCESS IN IMPROVING THE COMPANY'S PERFORMANCE.....	400
<i>Neda Nikolić, Bojana Đalović, Jasmina Ćurčić, Miodrag Zečević, Milan Vesković</i>	
STRATEGIC MANAGEMENT OF SALES TEAMS AS A GUARANTOR OF SALES SUSTAINABILITY	411
<i>Zvonimir Filipović, Natko Klanac Sinisa Bilic</i>	
THE EVOLUTION AND GROWTH OF SMALL ENTERPRISES IN THE UNITED STATES	427
<i>Bogdan Vukolić</i>	

CLUSTER ANALYSIS OF EUROPEAN COUNTRIES BASED ON INNOVATION PERFORMANCE	433
<i>Ivica Nikolić, Lidija Krstić, Anđelka Stojanović</i>	
FROM SCIENCE TO MARKET: CHALLENGES AND DEVELOPMENT OPPORTUNITIES OF ACADEMIC SPIN-OFF COMPANIES IN SERBIA	444
<i>Nikola Radosavljević, Gordana Rendulić Davidović, Cariša Bešić</i>	
QUALITY OF INSTITUTIONS AS A TOOL FOR UNLOCKING POTENTIAL OF TECHNOLOGICAL AND ECONOMIC DEVELOPMENT OF WESTERN BALKANS COUNTRIES.....	455
<i>Đorđe Kotarac, Simo Stevanović,</i>	
DOTOK SVEŽEG KAPITALA U FUNKCIJI STABILNOSTI FINANSISKOG SISTEMA.....	466
<i>Doc. dr Ognjen Bakmaz¹, Prof. dr Dragan Vukasović², Prof. dr Aco Bobić¹ ¹Visoka škola za uslužni biznis, Istočno Sarajevo – Sokolac ²Nezavisni Univerzitet Banja Luka</i>	
DIGITALIZATION OF BANKS AS A FACTOR IN CONSUMER EXPERIENCE	472
<i>Dragana Nikolić Ristić¹, Tatjana Mamula Nikolić², Radomir Stojković</i>	
PRIMENA VEŠTAČKE INTELIGENCIJE U OPTIMIZACIJI MARKETINŠKIH STRATEGIJA U KONTEKSTU UPRAVLJANJA PROJEKTIMA	484
<i>Bojana Ostojić, Maja Cogoljević, Dragan Klarić, Slađana Vujičić, Milena Cvjetković, Jelena Ružić</i>	
ULOGA NAPREDNIH TEHNOLOGIJA PERSONALIZACIJE U DIGITALNOM MARKETINGU KROZ UPRAVLJANJE PROJEKTIMA	495
<i>Bojana Ostojić, Vladan Cogoljević, Milena Cvjetković Esma Otović</i>	
EXPLORING THE NEXUS OF TOURISM AND FEMALE ENTREPRENEURSHIP IN MONTENEGRO: CHALLENGES AND OPPORTUNITIES FOR GROWTH	506
<i>Ljiljana Rakočević, Aleksandra Vujko</i>	
IMPLIKACIJE DEMOGRAFSKE TRANZICIJE NA EKONOMSKI RAST U REPUBLICI SRBIJI	518
<i>Edvard Jakopin</i>	
THE ROLE OF ARTIFICIAL INTELLIGENCE IN OPTIMIZING MARKETING STRATEGY	528
<i>Jelena Jevtić, Mira Vidaković, Tamara Jevtić</i>	
AUTOMATIZACIJA I DIGITALIZACIJA MENADŽMENTA LJUDSKIH RESURSA.....	534
<i>Jovan Spaić, Dragan Popović...</i>	
LEGAL AND POLITICAL SCIENCES, SOCIOLOGY, PSYCHOLOGY	542

CRNA GORA I AI ACT: IZAZOVI REGULATORNE TRANZICIJE, GEOPOLITIČKE I EKONOMSKE IMPLIKACIJE	543
<i>Nina Vuksanović</i>	
POVREDA PRAVA NA IMOVINU – DA/NE U IZVRŠNOM POSTUPKU	550
<i>Doc. dr. Jasmina Tahirović, mag. iur. Adis Mehić</i>	
HUMANITIES: PHILOSOPHY, PHILOLOGY, HISTORY, THEOLOGY	555
KRITIKE OBRAZOVNOG SISTEMA I PEDAGOŠKE PARADIGME KROZ HISTORIJU	556
<i>Muzafer Bibić</i>	
TRADITION OF INTANGIBLE CULTURAL HERITAGE: THE INFLUENCE OF THE MEDIA ON THE PROMOTION OF FOLK CREATIVITY INSPIRED BY THE GRAPE HARVEST	565
<i>Branislav Sančanin, Aleksandra Penjišević, Ognjen Bakmaz</i>	
AUDEN AND TECHNOLOGY	577
<i>Tomislav Pavlović, Faculty of Philology and Arts, University of Kragujevac 34000</i>	
SUSTAINABLE DEVELOPMENT, ECOLOGY, ENERGY EFFICIENCY AND RENEWABLE ENERGY SOURCES	587
UPRAVLJANJE OTPADOM SA PRIMERIMA IZ PROIZVODNIH PREDUZEĆA	588
<i>Jelena Lazarević, Dragan Rajković, Zoranka Malešević, Milica Đeković Šević</i>	
THE ROLE OF PSYCHOLOGICAL FACTORS IN THE FUNCTION OF DIGITAL PROMOTION OF SUSTAINABLE BEHAVIOR	600
<i>Dragana Nikolić Ristić¹, Tatjana Mamula Nikolić², Radomir Stojković</i>	
VALORIZACIJA SMEŠE SKROBNOG PREHRAMBENOG OTPADA IZ STUDENTSKIH RESTORANA ZA PROIZVODNJU BIOETANOLA	611
<i>Vesna Vučurović, Jelena Filipović, Bojana Bajić, Damjan Vučurović, Siniša Dodić</i>	
JARAM PEAT BOG (MT. KOPAONIK, SERBIA) AS A BIODIVERSITY HOTSPOT – INSIGHTS INTO ALGAE, PLANTS AND INVERTEBRATES	621
<i>Sanja Šovran, Katarina Stojanović, Eva Kabaš, Dalibor Stojanović, Vukašin Gojšina, Ivana Živić, Miroslav Živić, Ana Knežević Predrag Lazarević</i>	
DYNAMIC SIMULATION OF WIND TURBINE SYSTEMS	630
<i>Snežana Dragičević, Milan Marjanović</i>	
PRIMENA HIDROUGLJA MODIFIKOVANOG AZOTNOM KISELINOM ZA UKLANJANJE CEFALEKSINA I BEZAFIBRATA IZ VODE	641
<i>Marija Šobić, Mirjana Petronijević, Sanja Panić, Igor Antić, Jelena Živančev, Nataša Đurišić-Mladenović</i>	

THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN ENVIRONMENTAL PROTECTION	649
<i>Anđela Vasović, Nebojša Denić</i>	
APPLICATION OF ARTIFICIAL INTELLIGENCE AND NEURAL NETWORKS IN MATERIALS PROTECTION AND DEVELOPMENT OF SUSTAINABLE TECHNOLOGIES IN ENVIRONMENTAL ENGINEERING	658
<i>Obrad Anicic, Goran Nestorović</i>	
EDUCATION, ONLINE EDUCATION – ELEARNING	669
PERCEPCIJE I ISKUSTVA UČENIKA SREDNJIH ŠKOLA U PRIMENI VEŠTAČKE INTELIGENCIJE (CHATBOT) U UČENJU	670
<i>Stanislava Olič Ninković, Jasna Adamov, Tihomir Lazarević</i>	
BLOG U NASTAVI BIOLOGIJE I STAVOVI UČENIKA O PRIMENI OVOG VEB ALATA U NASTAVI	678
<i>Tihomir Lazarević, Vera Županec, Jelena Lazarević</i>	
ASSESSING THE CHEMISTRY EDUCATIONAL OUTCOMES USING DIGITAL ESCAPE ROOM. ANALYSIS OF GRAMMAR SCHOOL STUDENTS' ACHIEVEMENTS	685
<i>Filip Stašević, Milica Tasić, Jelena Đurđević Nikolić, Aleksandra Marković</i>	
A STUDY ON THE IMPACT OF DIGITAL MARKETING STRATEGIES ON THE EDUCATION SECTOR: THE IMPACT OF DIGITAL MARKETING ON STUDENT AND EDUCATOR BEHAVIOUR	696
<i>Esma Cerinan Otovic, Bojana Ostojic</i>	

SHALLOW GEOTHERMAL POTENTIAL IN THE DANUBE REGION – CAN CHATBOTS HELP PLAN THE WAY FORWARD?

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ABSTRACT:

The utilization of artificial intelligence in decision-making is increasing every day, raising the question of its reliability in complex assessments. Therefore, this study examines the potential of chatbots to assess the feasibility of shallow geothermal resources across 8 European countries (Austria, Bosnia and Herzegovina, Croatia, Hungary, Romania, Serbia, Slovakia, and Slovenia). The results provided by chatbots are analyzed in detail and compared against expert evaluations to identify their reliability. The study will provide the following: 1) insight into market differences of the mentioned countries, 2) insights into the limitations of AI-based assessments, and 3) a discussion on the potential of chatbots as tools for preliminary feasibility studies in everyday shallow geothermal system planning.

Keywords: *Shallow geothermal energy, Artificial Intelligence, Chatbots, Decision-making*

1. INTRODUCTION

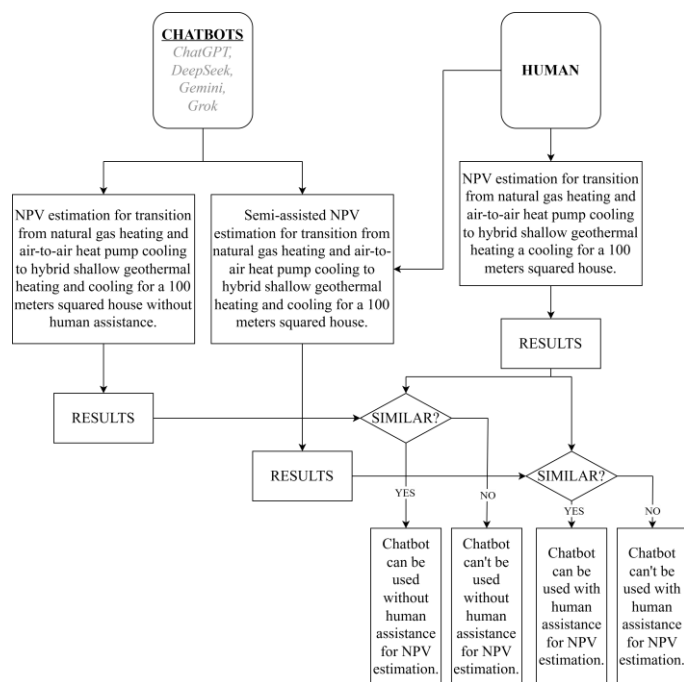
The continual worsening of the climate, followed by the current geopolitical situations, makes renewable energy utilization an imperative. On the other hand, heating and cooling of both residential and industrial buildings rely mostly on fossil fuels, consequently influencing greenhouse gas (GHG) emissions significantly. According to the International Energy Agency (IEA), heating in buildings alone is responsible for 10% of global CO₂ emissions [1]. Correspondingly, using renewable energy sources in the heating and cooling sector, such as shallow geothermal energy, is a crucial step towards a healthy environment and energy security. According to the IEA, using geothermal energy, the district heating network could be decarbonized, as it can meet current global heating demands [1]. Unfortunately, despite the potential of geothermal energy, there are various obstacles to its implementation, among which is a lack of public awareness and knowledge [2].

One of the most popular implementations of AI is chatbots. A chatbot is a software that can interact with humans in textual or vocal form on a certain topic. They are developed in a way that creates effective digital assistants able to give information, answer questions,

discuss a specific topic, or perform a certain task. Chatbots did not only infiltrated everyday life, but also a wide range of industries, including healthcare [3–5], information technologies [6–8], finance [9–11], tourism [12,13], etc. Additionally, Ng et al. [14] examined the utilization of chatbots in medical research, the results showed that among 2165 respondents, 60.5% were familiar with the concept of chatbots, while 44.5% of them used them in their scientific careers. Overall, it is noticeable that chatbots have gained a lot of momentum, and soon they will be part of both everyday and professional life of every average individual. Everything mentioned brings a question: Can chatbots help us to mitigate the lack of public awareness and knowledge toward shallow geothermal energy?

2. METHODOLOGY

The workflow of the study includes the following steps: 1) Requesting chatbots (ChatGPT, DeepSeek, Gemini, and Grok) to estimate Net Present Value (NPV) for transition from gas heating and air-to-air heat pump cooling to a hybrid shallow geothermal system for a 100 m² house without and with human assistance¹, 2) Comparison of obtained results (from chatbots) with human (expert) estimations of NPV, 3) Decision on the capability of chatbots to estimate NPV. The workflow of the study is illustrated in Fig. 1.



¹ Human assistance means a series of expert-level sub-questions that aim to increase the accuracy of the NPV estimation.

Fig. 1. Workflow of the study

3. RESULTS

3.1. Chatbot estimation

Tables 1 and 2 give the estimated NPVs with assumed input data by chatbots (without and with human assistance). Figures 2 and 3 visualise the annual savings and NPVs estimated by chatbots per country. In the case of NPV estimations without human assistance (Fig. 3), it is noticeable that the chatbot whose results differ the most from others for Serbia, Slovenia, and Bosnia is DeepSeek, for Romania, Croatia, Austria, and Hungary is Gemini, and for Slovakia is ChatGPT. On the other hand, in the case of NPV estimations with human assistance (Fig. 5), it is noticeable that for Serbia, Austria, and Bosnia Herzegovina, Grok varies the most, Gemini for Romania and Hungary, and DeepSeek for Croatia, Slovenia, and Slovakia.

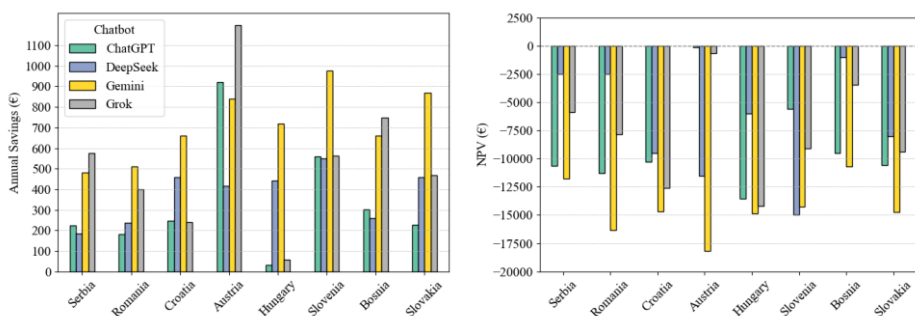


Fig. 2. Estimation of annual savings and NPV per country without human assistance

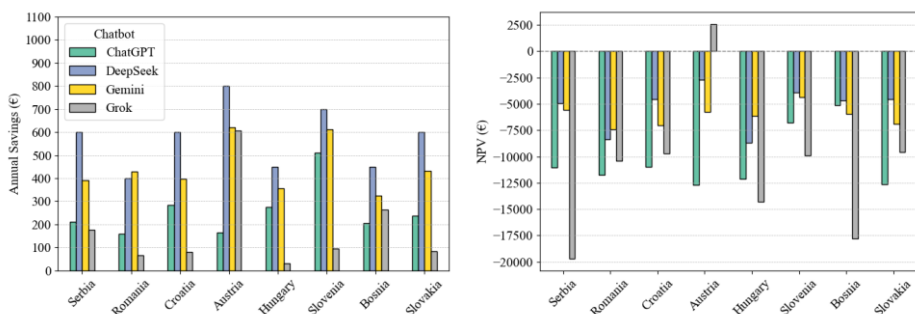


Fig. 3. Estimation of annual savings and NPV per country with human assistance

Fig. 6 presents an illustration of Pairwise distance analysis, showing that Gemini differed the most from others in the case of estimation without human assistance, with an average distance of 17,082.37 €, while in the case of human-assisted estimation, Grok varies the most with an average distance of 17,155.614 €.

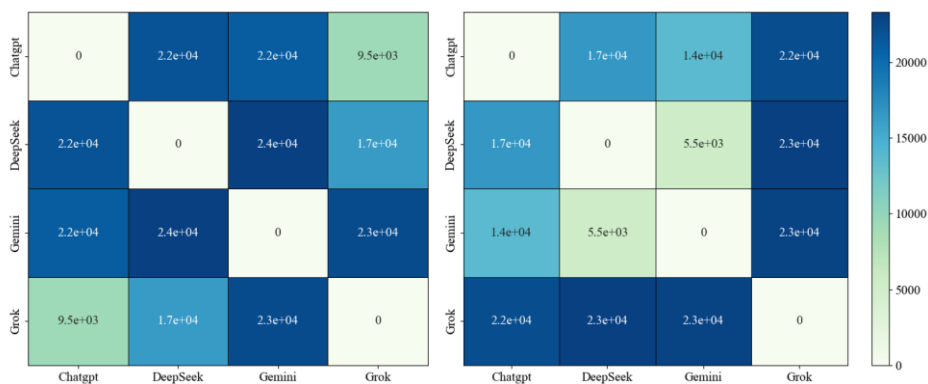


Fig. 6. Pairwise distance analysis (without human assistance – left, with human assistance – right)

Table 1. Chatbot NPV estimation without human assistance

Country	Chatbot	Gas price [€/kWh]	Electricity price [€/kWh]	Annual savings [€]	Net Investment [€]	NPV (25 years) [€]
Serbia	ChatGPT	0.045	0.11	225	14,000	-10,610
	DeepSeek	0.05	0.12	183	20,000	-5,000 – 0
	Gemini	0.07	0.12	480	18,500	-11,734.88
	Grok	0.06	0.09	577	14,000	-5,868
Romania	ChatGPT	0.0581	0.1863	179.92	14,000	-11,289
	DeepSeek	0.06	0.15	237	20,000	-2,000 – 3,000
	Gemini	0.085	0.17	510	23,500	-16,312.06

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	Grok	0.0581	0.14	400	13,500	-7,862
	ChatGPT	0.0447	0.10	246.67	14,000	-10,285
	DeepSeek	0.08	0.18	458	20,000	7,000 – 12,000
	Gemini	0.10	0.18	660	24,000	-14,698.96
	Grok	0.0447	0.13	241	16,000	-12,603
	ChatGPT	0.1379	0.2437	921.86	14,000	-130
	DeepSeek	0.10	0.28	417	20,000	8,000 – 15,000
	Gemini	0.12	0.24	840	30,000	-18,161.04
	Grok	0.1379	0.25	1,197	17,500	-629
	ChatGPT	0.0275	0.11	30.56	14,000	-13,540
	DeepSeek	0.07	0.14	442	20,000	4,000 – 8,000
	Gemini	0.11	0.20	720	25,000	-14,852
	Grok	0.0275	0.11	58	15,000	-14,183
	ChatGPT	0.093	0.189	560.83	14,000	-5,560
	DeepSeek	0.09	0.20	550	20,000	12,000 – 18,000
	Gemini	0.13	0.22	975	28,000	-14,258.35
	Grok	0.078	0.18	561	17,000	-9,093
	ChatGPT	0.05	0.102	300.56	14,000	-9,480
	DeepSeek	0.05	0.10	258	20,000	-3,000 – 1,000
	Gemini	0.08	0.1	660	20,000	-10,698.96
	Grok	0.07	0.08	748	14,000	-3,458
	ChatGPT	0.063	0.189	227.50	14,000	-10,580
	DeepSeek	0.08	0.18	458	20,000	6,000 – 10,000
	Gemini	0.12	0.19	870	27,000	-14,738.22
	Grok	0.065	0.15	468	16,000	-9,404

Table 2. Chatbot NPV estimation with human assistance

Country	Chatbot	Gas price [€/kWh]	Electricity price [€/kWh]	Annual savings	Installation costs	Incentives	Net Investment [€]	NPV (25 years) [€]
	ChatGPT	0.0500	0.1300	211.67	16,000	2,000	14,000	-11,016.78
	DeepSeek	0.06	0.10	600	14,000	1,500	12,500	-4,946
	Gemini	0.045	0.09	390	13,000	1,000	12,000	-5,589
	Grok	0.045	0.08	175	22000	0	22000	-19700
Romania								

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	DeepSeek	0.05	0.15	400	16,000	2,000	14,000	-8,364
	Gemini	0.055	0.11	430	15,000	1,500	13,500	-7,441
	Grok	0.0581	0.184	67	22000	3000	19000	-10400
Croatia	ChatGPT	0.0600	0.1472	284.80	20,000	5,000	15,000	-10,986.04
	DeepSeek	0.07	0.18	600	18,000	5,000	13,000	-4,546
	Gemini	0.060	0.13	398	16,000	1,600	14,400	-7,015
	Grok	0.041	0.122	80	18000	4250	13750	-9700
Austria	ChatGPT	0.0700	0.2200	163.33	24,000	9,000	15,000	-12,697.99
	DeepSeek	0.09	0.25	800	22,000	8,000	14,000	-2,728
	Gemini	0.070	0.10	621	18,000	1,800	16,200	-5,770
	Grok	0.1379	0.245	606	17000	7500	9500	2600
Hungary	ChatGPT	0.0600	0.1500	275.00	19,000	3,000	16,000	-12,124.17
	DeepSeek	0.06	0.16	450	18,000	3,000	15,000	-8,659
	Gemini	0.050	0.10	357	14,000	1,200	12,800	-6,132
	Grok	0.034	0.109	32	18000	0	18000	-14300
Slovenia	ChatGPT	0.0930	0.2084	510.60	21,000	7,000	14,000	-6,803.63
	DeepSeek	0.08	0.20	700	20,000	6,000	14,000	-3,937
	Gemini	0.090	0.19	612	17,000	1,700	15,300	-4,377
	Grok	0.0733	0.165	96	17000	2000	15000	-9900
Bosnia	ChatGPT	0.0400	0.0940	204.33	10,000	2,000	8,000	-5,120.14
	DeepSeek	0.05	0.12	450	12,000	1,000	11,000	-4,660
	Gemini	0.052	0.12	323	12,000	800	11,200	-5,938
	Grok	0.05	0.09	264	22000	0	22000	-17800
Slovakia	ChatGPT	0.0650	0.1800	236.67	20,000	4,000	16,000	-12,664.43
	DeepSeek	0.07	0.18	600	19			

In equation 1, Q_H represents the annual energy needed for heating per m^2 , A represents the heated area in m^2 , and P_G represents the price of gas.

The total annual costs for air-to-air heat pump cooling are calculated using equation 2, in which Q_C represents the annual energy needed for cooling per m^2 (assumed to be around 25 kWh/ m^2), P_E represents electricity price, while COP represents coefficient of performance of the heat pump, which is around 4 for climate conditions of Serbia [17].

$$C_C = Q_C \cdot A \cdot P_E \cdot \frac{1}{COP} \quad (2)$$

Total annual costs for scenario 1 (gas heating and air-to-air heat pump cooling) are calculated using equation 3.

$$C_T = C_H + C_C \quad (3)$$

The total annual energy need (heating + cooling) can be calculated using equation 4. As already mentioned, the reference object needs 75 and 25 kWh/ m^2 for heating and cooling, respectively, which is in total 100 kWh/ m^2 .

$$Q_A = Q_H + Q_C \quad (4)$$

The total costs of a hybrid shallow geothermal system are calculated using equation 5. Taking into account the climate conditions of Serbia, the coefficient of performance is assumed to be around 4 on average during the whole year [17,18].

$$C_T = Q_A \cdot A \cdot P_E \cdot \frac{1}{COP} \quad (5)$$

Considering total energy costs for both scenarios, annual savings can be calculated as their subtraction (equation 6).

$$S_A = C_{T1} - C_{T2} \quad (6)$$

By the authors' experience, it is estimated that the installation of a shallow geothermal heat pump for a 100 m^2 building costs around 8000 euros. The annual gas and electricity price increase rate is assumed to be 5%, while the discount rate is assumed to be 3.5%. The calculations of NPV are shown in Table 3.

Table 3. Human NPV estimation

Year	Gas price	El. Price	C_{T1}	C_{T2}	S_A	PV	NPV	Notes
0	0	0	0	0	0	0	-8000	
1	0.030	0.110	293.750	275.000	18.750	18.094	-7981.906	
2	0.032	0.116	308.438	288.750	19.688	18.333	-7963.573	
3	0.033	0.121	323.859	303.188	20.672	18.576	-7944.996	
4	0.035	0.127	340.052	318.347	21.705	18.823	-7926.174	

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5	0.036	0.134	357.055	334.264	22.791	19.072	-7907.102	
6	0.038	0.140	374.908	350.977	23.930	19.325	-7887.777	
7	0.040	0.147	393.653	368.526	25.127	19.581	-7868.196	
8	0.042	0.155	413.336	386.953	26.383	19.840	-7848.356	
9	0.044	0.163	434.003	406.300	27.702	20.103	-7828.253	
10	0.047	0.171	455.703	426.615	29.087	20.369	-7807.884	Maintenance ¹
11	0.049	0.179	478.488	447.946	1030.542	696.412	-7111.472	
12	0.051	0.188	502.412	470.343	32.069	20.913	-7090.559	
13	0.054	0.198	527.533	493.860	33.672	21.190	-7069.370	
14	0.057	0.207	553.909	518.554	35.356	21.471	-7047.899	
15	0.059	0.218	581.605	544.481	37.124	21.755	-7026.144	
16	0.062	0.229	610.685	571.705	38.980	22.043	-7004.101	
17	0.065	0.240	641.219	600.291	40.929	22.335	-6981.765	
18	0.069	0.252	673.280	630.305	42.975	22.631	-6959.134	
19	0.072	0.265	706.944	661.820	45.124	22.931	-6936.203	
20	0.076	0.278	742.292	694.911	-1452.620	-712.358	-7648.560	Maintenance ²
21	0.080	0.292	779.406	729.657	49.749	23.543	-7625.017	
22	0.084	0.306	818.377	766.140	52.237	23.855	-7601.162	
23	0.088	0.322	859.295	804.447	54.849	24.171	-7576.992	
24	0.092	0.338	902.260	844.669	57.591	24.491	-7552.500	
25	0.097	0.355	947.373	886.902	60.471	24.816	-7527.685	

3. CONCLUSION

When comparing chatbot and expert NPV estimations, from the aspect of the estimation without human assistance, it can be concluded that:

- All chatbots overestimated installation costs significantly.
- Gas prices were overestimated by all chatbots.
- Annual savings were calculated to be too high by all chatbots.</

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