International Energy Transition and Sustainability Conference (ETSC'26)

7–9 January 2026 / Istanbul, Türkiye

ABSTRACT BOOK

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Meltem Kasapoğlu Çalık
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İSTANBUL GEDİK ÜNİVERSİTESİ YAYINLARI

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INTERNATIONAL ENERGY TRANSITION AND SUSTAINABILITY CONFERENCE (ETSC'26) Abstract Book

İSTANBUL GEDİK ÜNİVERSİTESİ YAYINLARI

No: 17 | Abstract Book: 9

Editörler: Utku Canci Matur, Meltem Kasapoğlu Çalık, Redvan Ghasemlounia, Gözde Konuk Ege, Ali Köse, Cansu Tüysüz

Publication Coordinator: Şafak Çelik

Editing: Ali Köse, Cansu Tüysüz, Sonad Tanyel

Cover Design: Seda Müftüoğlu

Layout Design: Şafak Çelik

E-ISBN: 978-625-92345-0-2

DOI: https://doi.org/10.61150/gedikyay.2603

1. Baskı: Mart 2026

Yayıncı Sertifika No: 44794

İSTANBUL GEDİK ÜNİVERSİTESİ YAYINLARI

Adres: Cumhuriyet Mah. İlkbahar Sok. No: 1 34876 Yakacık, Kartal, İstanbul

Tel: 444 5 438 - **Web:** www.gedik.edu.tr - www.press.gedik.edu.tr

İstanbul Gedik University Library Cataloging-in-Publication Data

International Energy Transition and Sustainability Conference (ETSC'26) Abstract Book

132 p. 14.8x21 cm.

E-ISBN: 978-625-92345-0-2

Classification Number: TJ 808/.I58

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FOREWORD

Advancing technology, population growth, and industrialization have accelerated the increase in energy demand both in our country and globally. From the perspective of sustainable energy, it is of vital importance to produce energy using new technologies that are environmentally friendly, preserve ecological balance, and ensure equitable sharing for all humanity. In today's World, renewables are at the hub of almost all energy policy transitions to meet the increased energy needs within the global developing economy and technology. The risk of depletion and the negative environmental impact of fossil fuels, which currently meet a large portion of energy demand, impose significant limitations on their use. Conversely, due to the climate crisis and the greenhouse effect, the shift towards renewable and eco-friendly sustainable energy sources has accelerated. To provide solutions about the energy transition and sustainability, it is essential to conduct numerous R&D and P&D (Product Development) projects regarding both conventional and alternative energy sources.

The Energy Transition and Sustainability Conference, initiated by Istanbul Gedik University Energy Technologies Application and Research Center in 2024 and organized nationally in 2025, will be held **internationally** this year.

The aim of our conference, which is open to original academic studies from different branches of science on energy transition and sustainability, is to bring together scientists working in different disciplines, to ensure knowledge interaction between disciplines, and to draw the attention of the scientific world to qualified studies. I extend my gratitude to all the professors on the organizing team who contributed to the 1st International Energy Transition and Sustainability Conference, and to all university units that supported us throughout this process.

The abstract book published within the scope of the 1st International Energy Transition and Sustainability Conference (ETSC'26) is a unique academic compilation in terms of its content structure, thematic integrity, and interdisciplinary approach. Because it was held within the framework of Energy Efficiency Week, this work represents not only theoretical academic outputs but also the product of a strategic scientific platform where energy transition, sustainability, and efficiency policies are integrated with the current global agenda. This context is a significant element of originality that distinguishes the book from classic conference proceedings. 100 papers were presented at this conference. Abstracts of all presented papers are published in our abstract book.

I hope this conference will offer new insights into energy conversion and sustainability, guiding us toward a better future. I firmly believe that the concepts, results, and recommendations derived from this will illuminate the energy future of our nation.

You can reach the organization and publication details from https://etsc.gedik.edu.tr/.

Asst. Prof. Utku Canci Matur

Director of the Energy Technologies Application and Research Center

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Assoc. Prof. Dr. Ayşe Nur ESEN	Istanbul Technical University	Türkiye
Assoc. Prof. Dr. Berk KÜÇÜKALTAN	University of Bradford	United Kingdom
Assoc. Prof. Dr. Çağdaş ALLAHVERDİ	Toros University	Türkiye
Assoc. Prof. Dr. Doğan AKCAN	Bahcesehir University	Türkiye
Assoc. Prof. Dr. Eda TURAN	Yıldız Technical University	Türkiye
Assoc. Prof. Dr. Elif ALTINTAŞ KAHRİMAN	Bartin University	Türkiye
Assoc. Prof. Dr. Gordhan Das VALASAI	Quaid-Awam University of Engineering, Science and Technology	Pakistan
Assoc. Prof. Dr. Görkem KÖKKÜLÜNK	Yıldız Technical University	Türkiye
Assoc. Prof. Dr. Gülsen BAYTEMİR	Maltepe University	Türkiye
Assoc. Prof. Dr. Hadi GENCELİ	Yildiz Technical University	Türkiye
Assoc. Prof. Dr. Hirad ABGHARI	Urmia University	Iranian
Assoc. Prof. Dr. İzzet Paruğ DURU	Istanbul Gedik University	Türkiye
Assoc. Prof. Dr. Kemal KOCA	Abdullah Gül University	Türkiye
Assoc. Prof. Dr. Mehdi Shahedi ASL	University of Kyrenia	Northern Cyprus
Assoc. Prof. Dr. Mehmet GÜRDAL	Kastamonu University	Türkiye
Assoc. Prof. Dr. Mevlüt Sedat DÖNMEZ	Süleyman Demirel University	Türkiye
Assoc. Prof. Dr. Neslihan YUCA DOĞDU	Istanbul Technical University	Türkiye
Assoc. Prof. Dr. Nicola VARRONE	Pegaso Telematica University	Italy
Assoc. Prof. Dr. Onur OĞUZ	Batman University	Türkiye
Assoc. Prof. Dr. Özlem BELİR	Istanbul Gedik University	Türkiye
Assoc. Prof. Dr. Polat TOPUZ	Istanbul Gedik University	Türkiye

Assoc. Prof. Dr. Redvan GHASEMLOUNIA	Istanbul Gedik University	Türkiye
Assoc. Prof. Dr. Seçkin DÜNDAR GÜNAY	Yıldız Technical University	Türkiye
Assoc. Prof. Dr. Senem ŞENTÜRK LÜLE	Istanbul Technical University	Türkiye
Assoc. Prof. Dr. Mirosław SZALA	Lublin University of Technology	Poland
Asst. Prof. Dr. Aksu SAMET	International Balkan University	North Macedonia
Asst. Prof. Dr. Arif KARABUĞA	Istanbul Atlas University	Türkiye
Asst. Prof. Dr. Aslı İşler KAYA	Turkish-German University	Türkiye
Asst. Prof. Dr. Ayşe Nur ÖRNEKCİ	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Aytaç Uğur YERDEN	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Begüm ERTEN MAHMUTOĞLU	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Bestem ESİ	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Burcu BEKTAŞ GÜNEŞ	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Bülent İMAMOĞLU	Nisantasi University	Türkiye
Asst. Prof. Dr. Cevher AK	Toros University	Türkiye
Asst. Prof. Dr. Doruk GÜRKAN	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Ece ZEYBEK YILMAZ	Istanbul Gelişim University	Türkiye
Asst. Prof. Dr. Emine BOZOKLAR	Iskenderun Technical University	Türkiye
Asst. Prof. Dr. Esra İŞBİLEN DURU	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Fahriye Enda TOLON	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Farooq SHER	Nottingham Trent University	United Kingdom
Asst. Prof. Fatma Didem TUNÇEZ	KTO Karatay University	Türkiye
Asst. Prof. Dr. Gizem KAHRIMAN	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Gözde KONUK EGE	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Gülay GÜNDAY KONAN	Sakarya University	Türkiye
Asst. Prof. Dr. Güler KARAPINAR	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Hatice Kübra AKBEN	Yeditepe University	Türkiye
Asst. Prof. Dr. Hüseyin YÜCE	Marmara University	Türkiye
Asst. Prof. Dr. İrem ALTAN AKSU	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. İsmail TEMİZ	Marmara University	Türkiye
Asst. Prof. Dr. Kıvanç Ali ANIL	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Marija Miloshevka JANAKIESKA	International Balkan University	North Macedonia

Asst. Prof. Dr. Mehrnoush KOHANDEL	Cyprus International University	Cyprus
Asst. Prof. Dr. Mehmet Ali AKTAŞ	Toros University	Türkiye
Asst. Prof. Dr. Mehmet Can ALPHAN	Bahcesehir University	Türkiye
Asst. Prof. Dr. Meltem KASAPOĞLU ÇALIK	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Mert TOLON	Maltepe University	Türkiye
Asst. Prof. Dr. Merve Nazlı BORAND	Yalova University	Türkiye
Asst. Prof. Dr. Mustafa Berker YURTSEVEN	Istanbul Technical University	Türkiye
Asst. Prof. Dr. Mücahit EGE	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Nesli ÇANKIRI	Beykoz University	Türkiye
Asst. Prof. Dr. Nilüfer ÇELİKKOL	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Olga UNTILA KAPLAN	Istanbul Medipol University	Türkiye
Asst. Prof. Dr. Özge AKAY SEFER	Marmara University	Türkiye
Asst. Prof. Dr. Özgür YURTSEVER	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Parisa HEIDARNEJAD	Yıldız Technical University	Türkiye
Asst. Prof. Dr. Seda MÜFTÜOĞLU	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Selin SARAÇ GÜLERYÜZ	Toros University	Türkiye
Asst. Prof. Dr. Sevilay UÇAR YÜZBAŞ	Nişantaşı University	Türkiye
Asst. Prof. Dr. Seza Özge GÖNEN	Uskudar University	Türkiye
Asst. Prof. Dr. Tuğbay Burçin GÜMÜŞ	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Tuğçe Sena ALTUNTAŞ	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Tülay KARABUĞA	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Utku CANCİ MATUR	Istanbul Gedik University	Türkiye
Asst. Prof. Dr. Yaşar MUTLU	Beykent University	Türkiye
Asst. Prof. Dr. Zohre AHMADI	University of Kyrenia	Northern Cyprus
Dr. Dilek KARS	Kartal Municipality	Türkiye
Dr. Elena Mirela SAMFIRA	University of Life Sciences "King Mihai I" from Timisoara	Romania
Dr. İlker MÜFTÜOĞLU	Aklı Fikri Advertising Agency	Türkiye
Dr. Selahattin NAZLI	Eskisehir Osmangazi University	Türkiye
Dr. Stefano LANDINI	University of East Anglia	United Kingdom
Dr. Syed Ahsan Ali SHAH	University of Salamanca	Spain
Dr. Utku KÖKER	Usak Provincial Disaster and Emergency Directorate	Türkiye

CONFERENCE PROGRAM

UTC+3 Türkiye Time	**1st Day:** Session Information
10:00-10:10	National Anthem and Moment of Silence
10:10-10:20	**Opening Address:** Prof. Dr. Feriha Erfan Kuyumcu Rector of Istanbul Gedik University
10:20-10:30	**Welcome Address:** Asst. Prof. Dr. Utku Cancı Matur Director of ETARC & Conference Chair of ETSC'26
10:30-11:00	**Invited Talk:** "Energy Transition, Sustainability and the Social Future in the Age of Artificial Intelligence" Tayfun İşbilen, Head of Information Technology Department, ISKI
11:00-12:00	Presentation Session 01: Main Hall
	Moderator: Asst. Prof. Dr. Meltem Kasapoğlu Çalık, Director of Gedik Vocational School & Conference Chair of ETSC'26 **ID: 111,** "Energy Efficiency and Sustainability in Pneumatics" Efekan Şeşen **ID: 101,** "Silicon Nanowire/Borophene Composite Gas Sensor for VOC Detection" Gülsen Baytemir, Gözde Konuk Ege, Özge Akay **ID: 30,** "Learning Integrated School Model: Impacts of ISO 14001–9001–45001 on School Culture, Student Behavior and Sustainable Educational Governance" Nuray Eran Türedi, Muhsin Köse, Suzan Çiner **ID: 114,** "Development of a Current Model for the Türkiye Reference Energy System" Ceren Aydın, Egemen Sulukan
11:00-12:00	Presentation Session 02: Green Hall
	Moderator: Asst. Prof. Dr. Enda Tolon, Director of Sustainability Office, Istanbul Gedik University **ID: 45,** "The Impact of Climate Change on the Black Sea Ecosystem: Artificial Intelligence-Supported Analysis of the Relationship Between Sea Surface Temperature and Chlorophyll-a" Arda Burak Selek, Cansu Tüysüz, Ali Köse **ID: 44,** "A Systematic Review and Bibliometric Analysis of Performance Factors in EEG-Based Brain–Computer Interfaces" İlkay Yıldız, Ali Köse, Gözde Konuk Ege **ID: 89**, "Support Vector Regression-Based Prediction of Syngas Composition from Biomass Downdraft Gasification" Dicle Eren, Uğur Özveren **ID: 96,** "Prediction of Syngas Composition from Updraft Biomass Gasification Using XGBoost" Uğur Özveren, Dicle Eren, İdil Sena Bayrak **ID: 17,** "Stackelberg Game–Driven Energy Coordination of Offshore Amusement Parks with Green–Blue Hydrogen and Carbon Capture Integration" Hossein Shayeghi, Peyman Zare, Babak Mohamadi, Nicu Bizon
11:00-12:00	Presentation Session 03: Blue Hall
	Moderator: Asst. Prof. Dr. Tuğçe Sena Altuntaş, Head of Electrical and Energy Department, Gedik Vocational School **ID:71,** "Theoretical Investigation on Reducing Carbon Emissions in Combi Boilers:The Potential of Quicklime Filtration" Eylül Selçuk, Rahşan Özüpek, Aytaç Uğur Yerden **ID:68,** "Machine Learning-Based Smart Agriculture System" , Yusuf İslam Budak, Ardacan Baysal, Kaan Özdemir, Aytaç Uğur Yerden **ID:95**, "Process Automation with a Corporate AI Assistant: Productivity and Sustainability Impacts of the Buddy Implementation" Caner Boyraz **ID:20,** "Sustainable Risk Analysis Applications with Data-Driven and Resource-Efficient Artificial Intelligence in Renewable Energy Systems" Tuğçe Sena Altuntaş, Begüm Erten

12:00-13:00	**Lunch Break**
13:00-14:15	**Panel:** "Current Applications in Energy Technologies in the Word and Türkiye"
14:15-14:45	**Invited Talk:** "Innovations Needed for More Effective Renewable Energy Integration, European Union Missions 2030, The Role of Local Governments, Civil Society Organizations, Industry Associations, and Universities" Prof. Dr. Tanay Sıdkı Uyar, Eurosolar Türkiye
14:45-15:00	**Coffe Break**
15:00-16:00	Presentation Session 04: Main Hall **Moderator:** Prof. Dr. Egemen Sulukan, Dean of the Faculty of Engineering, Istanbul Gedik University & Honorary President of ETSC'26 **ID: 88,** "Thermal Degradation Kinetics of Hazelnut Shell Biomass Based on TGA/DTG and Starink Analysis" Dicle Eren, Uğur Özveren **ID: 72**, "The Role of Local Governments in the Field of Renewable Energy: An Example of Gaziantep Metropolitan Municipality" Zehra Ünal
15:00-16:00	Presentation Session 05: Green Hall **Moderator:** Asst. Prof. Dr. Seda Müftüoğlu, Head of Design Department, Gedik Vocational School **ID: 43,** "The Role of Designers in Shaping Circular Design Frameworks For a Sustainable Future" Pınar Aslanbay, Seza Sinanlar Uslu **ID: 77,** "Development of a Knee-Controlled Bionic Lower Limb Prosthesis with A Novel Control Algorithm" Burak Kaan Durukan, Eliz Sakallıoğlu, Mücahit Ege **ID: 93**, "The Problem of Schematic Accuracy in the Visual Representation of Sustainable Energy Systems: A Comparative Analysis of Solar and Wind Energy" Sonad Tanyel **ID: 63,** "Minimalist Packaging Design: Sustainability-Focused Material and Design Decision" Seda Müftüoğlu, İlker Müftüoğlu
15:00-16:00	Presentation Session 06: Blue Hall **Moderator:** Asst. Prof. Dr. Esra İşbilen Duru, Head of Finance, Banking and Insurance Department, Gedik Vocational School **ID: 46,** "Data-Driven Analysis of the Physicochemical Properties of Phosphoramid-Benzoazole Compounds Using a Machine Learning Approach" Yusuf Özdemir, Fatma Ceren Kırmızıtaş, Ali Köse **ID: 121,** "Evaluation Of Türkiye's Energy System In Line With Energy Transition And Sustainability Targets" Ceren Aydın **ID: 54,** "Qualitative Investigation into the Impact of Sustainability Activities of Publicly Traded Professional Sports Clubs on University Students Perceptions of Corporate Reputation: The Case of Istanbul Gedik University" Esra İşbilen Duru, Havva Aydoğan

16:00-17:00	Presentation Session 07: Main Hall
	Moderator: Assoc. Prof. Dr. İzzet Paruğ Duru, Head of the Department of Medical Services and Techniques, Gedik Vocational School **ID: 87,** "Machine Learning-Based Performance Prediction of Solid Oxide Fuel Cells Using Support Vector Regression with Radial Basis Function Kernel" Uğur Özveren, Sahragul Charharyyeva **ID: 94,** "XGBoost Machine Learning Approach for Proton Exchange Membrane Fuel Cell Performance Prediction" Uğur Özveren, Sahragul Charyyeva, Tuğçe Diricanlı **ID: 90,** "Assessment of Smart Grid Stability with LightGBM and Decentralized Control Modeling" Uğur Özveren, Sahragul Charharyyeva **ID: 32,** "Structural, Optical and Electrical Investigation of Sn and Cu Doped ZnO Thin Films Prepared by Sol–Gel Method" Cansu Tüysüz, Utku Canci Matur, Ali Köse, Doğan Akcan
16:00-17:00	Presentation Session 08: Green Hall
	Moderator: Asst. Prof. Dr. Gözde Konuk Ege, Head of the Department of Electronics and Automation, Gedik Vocational School & Co-Chair of ETSC'26 **ID: 91,** "Digital Twin-Based Predictive Maintenance: A Comparative Analysis with Other Maintenance Approaches'' Faruk Açmalı **ID: 110,** "The Use of Deep Learning Algorithms in Industry: A Bibliometric Evaluation" Elif Boz, Hilal Öztemel, Ali Köse **ID: 23,** "Recycled Metal Utilization on the Microstructure and Mechanical Properties of Casting Alloys" Doruk Gürkan
16:00-17:00	Presentation Session 09: Blue Hall
	Moderator: Assoc. Prof. Dr. Polat Topuz, Head of the Department of Machinery and Metal Technologies, Gedik Vocational School **ID: 86,** "A New Motion Intention Recognition Method Using IMU Sensor Data" Mücahit Ege, Mustafa Kurubal, Sude Biber **ID: 31,** "A Physics-Informed and Prescriptive XAI Framework for Electrical Grid Stability'' Nilgün Eftalya Akgül **ID: 12**, "Sustainable Composite Material Development: Recycled Carbon Fiber and Pine Needle-Based Hybrid Structure'' Polat Topuz, Meltem Kasapoğlu Çalık
17:00-18:00	Presentation Session 10: Main Hall
	Moderator: Assoc. Prof. Dr. Redvan Ghasemlounia, Director of the Institute, İstanbul Gedik University & Conference Co-Chair of ETSC'26 **ID: 51,** "Intelligent Image Processing–Based Recognition System for Color-Coded Zero Waste Separation Units" Enes Buğra Efiloğlu, Ali Köse, Gözde Konuk Ege **ID: 40,** "The Effect of Material Selection in Micro UAVs on Structural Behavior under Different Force Conditions" Çağan Arca Özen, Ali Köse, Gözde Konuk Ege

17:00-18:00	Presentation Session 11: Green Hall
	Moderator: Asst. Prof. Dr. Begüm Erten Mahmutoğlu, Department of Occupational Health and Safety Program, İstanbul Gedik University & Member of the Board of Directors of the ETARC **ID: 79,** "A Specialized K-Means Framework for Identifying Characteristic Energy Community Operation Scenarios Considering Distributed Generation from PV, Residential Consumption, EV Charging, Real-time Prices, and Grid Carbon Intensity" İlyas Arslanoğlu, Mustafa Alparslan Zehir **ID: 81,** "Autonomous Coastal Waste Detection and Localization Using UAV" Eyüp Koyun, Berke Akdoğan, Nur Hazal Çufalcı, Aytaç Uğur Yerden **ID: 107,** "Data-Driven Analysis and Bibliometric Review of Sustainable Diet Approaches" İlke Aycan Yıldız, Derya Avan Çınar, Ali Köse **ID: 21,** "Risks and Preventive Approaches Focused on Occupational Health and Safety in Renewable Energy Systems" Begüm Erten, Tuğçe Sena Altuntaş
17:00-18:00	Presentation Session 12: Blue Hall
	Moderator: Asst. Prof. Dr. İrem Altan Aksu, Department of Child Care and Youth Services Department Chair, Gedik Vocational School **ID: 119,** "Inclusivity in Sustainable Development: Focusing on Preschool Children" **ID: 113,** "An Examination of Preschool Teacher Competencies Across Different Regions of the World" Fatma Şükran Kaplan **ID: 108,** "Bibliometric Analysis of Inefficiencies in Digital Twin Based Smart Factory Management" Melike Zümra Özen, Gülçin Yıldırım, Ali Köse

UTC+3 Türkiye Time	**2nd Day:** Session Information
10:00-11:15	Presentation Session 13: Main Hall
	Moderator: Assoc. Prof. Dr. İzzet Paruğ Duru, Head of the Department of Medical Services and Techniques, Gedik Vocational School **ID: 10,** "Agent-Based Modeling for Green Hydrogen Adoption in Heavy-Duty Freight: A Policy Analysis for Pakistan" Gordhan Das Valasai **ID: 11,** "Assessing Techno-Economic Constraints of Green Hydrogen Production in Pakistan: A Modelling-Based Benchmarking Study" Saad Raza, Gordhan Valasai, Abdul Arain **ID: 92,** "Passive Energy Efficiency Strategies in the Conservation of Listed Historic Buildings in Türkiye: An Expert-Based Evaluation" Gülşah Kaba, Fatih Yazıcıoğlu
10:00-11:15	Presentation Session 14: Green Hall
	Moderator: Assoc. Prof. Dr. Doğan Akcan Head of the Mechatronics Engineering Department, Bahçeşehir University **ID: 33,** "Pyrolysis Kinetics of Chlorella Vulgaris Using Coats–Redfern Model" Aleyna Yalçı, Sevgi Polat **ID: 100,** "Adaptive Droop-Controlled DC Micro Grid for Electric Vehicle Fast DC Charging with Photovoltaic Integration Under Partial Shading Conditions" Mehmet Alphan **ID: 65,** "Chemical Disruption of Saliva Buffer Systems and Resting Pulse Rate in Tobacco Users" Aksu Samet, Valentina Velkovski, Can Berk Gunes, Merita Islami Ramadan, Muhammed Abazi, Sezen Samet, Stojan Petrovski **ID: 66,** ''Hydration, Educational Level, and Body Mass Index: Gender Differences in Water Consumption" Valentina Velkovski, Aksu Samet, Sezen Samet, Stojan Petrovski, Merita Islami Ramadani, Muhammed Abazi, Can Berk Gunes

10:00-11:30	Presentation Session 15: Blue Hall **Moderator:** Asst. Prof. Dr. Mücahit Ege, Head of the Software Engineering Department, İstanbul Gedik University **ID: 35,** "Digital Pneumatic Systems in the Industry 4.0 Era: Energy Efficiency and Carbon Footprint Analysis with App-Based Valve Terminals" Ekrem Keleş **ID: 102,** "Development of a Modular Test System for Gas Sensor Performance Analysis" Umut Çavlan, Gözde Konuk Ege **ID: 48,** "From National Technology to a Sustainable Future: Energy and Environmental Management with Autonomous Area Scanning Drones" Mümin Efehan Girişmen, Ekrem Keleş, Gözde Konuk Ege
11:30-12:00	**Coffee Break**
12:00-13:00	Presentation Session 16: Main Hall **Moderator:** Assoc. Prof. Dr. İzzet Paruğ Duru, Head of the Department of Medical Services and Techniques, Gedik Vocational School **ID: 10,** "Agent-Based Modeling for Green Hydrogen Adoption in Heavy-Duty Freight: A Policy Analysis for Pakistan" Gordhan Das Valasai **ID: 11**, "Assessing Techno-Economic Constraints of Green Hydrogen Production in Pakistan: A Modelling-Based Benchmarking Study" Saad Raza, Gordhan Valasai, Abdul Arain **ID: 92**, "Passive Energy Efficiency Strategies in the Conservation of Listed Historic Buildings in Türkiye: An Expert-Based Evaluation" Gülşah Kaba, Fatih Yazıcıoğlu
12:00-13:00	Presentation Session 17: Green Room **Moderator:** Asst. Prof. Dr. Enda Tolon, Director of Sustainability Office, Istanbul Gedik University **ID: 50,** "New Legal Approaches for the Sustainable Development. Some Theoretical Considerations" Kutluhan Bozkurt, Przemyslaw Osobka **ID: 36,** "Addressing Energy Poverty Through Climate Finance and Digitalization: Lessons From Developing Countries" Syed Anees, Haider Zaidi, Rana Umair Ashraf **ID: 80,** "Determination of Materials Used in Green Roofs in Sustainable Structures via Value Engineering Method" Ahmet Eren Çelik, Şenay Atabay
12:00-13:00	Presentation Session 18 : Blue Hall **Moderator:** Asst. Prof. Dr. Tuğçe Sena Altuntaş, Head of Electrical and Energy Department, Gedik Vocational School **ID: 47**, "A Comparative Time Series Analysis of Türkiye's Energy Dynamics Using ARIMA and Prophet Models" Selin Saraç Güleryüz **ID: 52**, "The Impact of Recycled Raw Material Usage on Process Capability and Energy Efficiency" İpek Bilmez, Selin Saraç Güleryüz **ID: 64**, "Comparative Analysis of Deep Learning Architectures for Thermal Image-Based Anomaly Detection in High-Voltage Equipment" Mehmet Burak Tunç, Muhammet Fatih Aslan **ID: 61**, "Machine Learning-Based Passenger Demand Forecasting for Sustainable and Energy-Efficient Smart Transportation Systems in Istanbul Rail Systems" Yusuf Ali Gün, Hikmet Canlı
13:00-13:30	Lunch Break

13:30-14:45	**Panel:** "The Stage of Social Impact: Sustainability through Finance, Civil Initiatives, and Art''
14:45-15:15	**Invited Talk:** "Agent-Based Modeling for Green Hydrogen Adoption in Heavy-Duty Freight: A Policy Analysis for Pakistan" Dr. Gordhan Valasai, Quaid-Awam University of Engineering, Science and Technology
15:15-16:30	Presentation Session 19: Main Hall
	Moderator: Asst. Prof. Dr. Mert Tolon, Vice Dean of Faculty of Engineering and Natural Sciences & Sustainability Office Coordinator Maltepe University **ID: 120**, "Integrating Renewable Energy and Sustainable Materials in Urban Housing Design for Semi-Arid Regions" Meryem Kadri **ID: 26**, "Investigation of Thermal Mass Properties in Vernacular Buildings in the Context of Energy Efficiency'' Esra Yılmaz, Gökhan Genç **ID: 16**, "Evaluating the Impact Assessment of Architectural Design of Solar Photovoltaics on Sustainability in Educational Buildings'' Sema Ebibi Arifi, Viktorija Mangaroska **ID: 82**, "Sustainability-Oriented Approaches in Geotechnical Engineering: A Conceptual Framework'' Mert Tolon
15:15-16:30	Presentation Session 20: Green Hall
	Moderator: Asst. Prof. Dr. Gizem Kahrıman, Head of Computer Technologies Department, Gedik Vocational School **ID: 106,** "Interactive Gamified Learning in Primary Education'' Yunus Emre Akat, Gizem Kahrıman **ID: 73**, "A Conceptual Model of Distributed Motion and Conditional Continuity'' Garbi Hasanov, Mustafa Yağımlı **ID: 34,** "Spatio-Temporal Analysis of Daily Meteorological Parameters in Turkish Cities Using Artificial Intelligence'' Hilal Öztemel, Ali Köse **ID: 105,** "Category Theory and Sustainability in Mathematics'' Gizem Kahrıman
15:15-16:30	Presentation Session 21: Blue Hall
	Moderator: Asst. Prof. Dr. Bestem Esi, Deputy Head of the Industrial Engineering Department, İstanbul Gedik University **ID: 25**, "The Future of Hydrogen Energy: A Conceptual Review of Storage Technologies'' Emirhan Çıbık, Ceren Aydın **ID: 24**, "The Future of Battery Energy Storage in Electric Grids: A Global Trends and Opportunities for Türkiye'' Fatih Selim Gölbaşı, Ceren Aydın **ID: 84**, "The Role of Automation in Logistics Warehousing Processes on Occupational Accidents, Employee Health, and Human-Centered Sustainability'' Sevilay Uçar Yüzbaş, Cahit Yılmaz **ID: 7,** "A Total Cost of Ownership Comparison of Alternative Bus Technologies for Sustainable Public Transport'' Anıl Can Duman
16:30-17:00	**Invited Talk:** "Energy-Efficient Manufacturing: How Fast Sintering Techniques Revolutionize Sustainable Material Production" Asst. Prof. Dr. Zohre Ahmadı, University of Kyrenia

UTC+3 Türkiye Time	**3rd Day:** Session Information
10:00-11:15	Presentation Session 22: Main Hall
	Moderator: Asst. Prof. Dr. Utku Cancı Matur **ID:18,** "Data-Driven Fault Detection and Diagnosis of Wind Turbines Using Machine Learning Approaches" Giuseppe Ciaburro **ID:76,** "Drinking Water Treatment Plant for Educational Purposes" Adem Kara, Uğur Keskin, Utku Canci Matur
10:00-11:15	Presentation Session 23: Green Hall
	Moderator: Asst. Prof. Dr. Tuğbay Burçin Gümüş, Deputy Director of the Institute, İstanbul Gedik University **ID:58,** "An AI-Based Venture Readiness and Innovation Maturity Assessment System for Entrepreneurship" Tuğbay Burçin Gümüş **ID:97,** "Impacts of Renewable Energy Systems on Urban Fire Safety" Çağrı Akgün **ID:109,** "A Next-Generation Firefighting Drone for Emergency Response Operations" Tahir Gültekin, Umut Oğuz, Eren Çırak, Mücahit Ege
10:00-11:15	Presentation Session 24: Blue Hall
	Moderator: Dr. Merve Esra Gülcemel, Department of Management and Organization / Human Resource Management Program **ID: 69,** "Political Energy Cycles: Ideology-Conditioned Electoral Returns of Renewable Energy Policies in Scandinavian Democracies (1980–2024)" Ali Kaya **ID: 83,** "Energy Transition Index and Renewable Energy Transition Process" Hamide Yılmaz, Esin Kılıç **ID: 42,** "A Bibliometric Analysis on Green Finance and Climate Change" Merve Esra Gülcemal **ID: 112,** "A Machine Learning–Based Model for Predicting Tensile Behavior in PDMS, PVC, and PU Polymers" Ali Köse, Elif Altıntaş Kahriman, Meltem Kasapoğlu Çalık
11:15-11:45	**Invited Talk:** "Hybrid Immersion Cooling of Light Electric Vehicle Battery Packs" Dr. Stefano Landini, University of East Anglia Norwich
11:45-13:00	Presentation Session 25: Main Hall
	Moderator: Asst. Prof. Dr. Hatice Kübra Akben, Materials Science and Nanotechnology Engineering, Yeditepe University **ID: 98,** "Investigation of Chain Extender Effects on Recycled Polyamide 6.3 and Process Parameter Optimization" Merve Güneş, Gokhan Temel, Alper Kaşgöz **ID: 116,** "Investigation of the Effects of Different grain refiners on the microstructure and mechanical properties of Etial-171 Alloy" Yiğit Güleryüz, Serkan Gündoğdu, Hakan Gaşan **ID: 104,** "Fabrication of CZTS Thin-Film Sensing Layers on Gold Electrodes Using Dip-Coating Technique" Utku Canci Matur, Ali Köse, Özge Akay Sefer, Cansu Tüysüz, Hüseyin Yüce, Gözde Konuk Ege **ID: 117**, "Development of Cu-Sn Coatings Using Waste Copper Cable Scraps" Hatice Kübra Akben, Bayram Güneş, Umut Doğan Gürkan

11:45-13:00	Presentation Session 26: Green Room **Moderator:** Asst. Prof. Dr. Begüm Erten Mahmutoğlu, Department of Occupational Health and Safety Program, İstanbul Gedik University & Member of the Board of Directors of the ETARC **ID: 99,** "Energy and Exergy Analysis of Organic Rankine Cycles for Waste Heat Recovery in Heat Exchanger Networks" Burak Işık, Erdem Baydır, Alp Er Ş. Konukman **ID: 75,** "Life Cycle Assessment of Hybrid Rapid Tooling in Injection Molding: An Energy-Efficient Approach for Low-Volume Production" Melih Yiğit, Mustafa Cemal Çakır **ID: 49,** "Analysis of the Contribution of Vertical Façade Photovoltaic Applications to Rooftop PV Generation in Istanbul Using PVGIS-Based Simulation" Ahmet Süslü
11:45-13:00	Presentation Session 27: Blue Hall **Moderator:** Dr. İlker Müftüoğlu, Aklı Fikri Digital Advertising Agency **ID:78,** "Predicting Student Academic Performance Using Machine Learning: A Case Study On Educational Data From Bangladesh Towards Sustainable Education (Sdg 4)" Tuka Albonny, İzzet Paruğ Duru **ID:74,** "A Sustainable Hybrid Thermal Management System for Lithium-Ion Batteries Using Phase Change Material, Liquid Cooling, and Thermoelectric Modules" Burhan Baran Günder, Ali Köse
13:00-13:30	**Invited Talk:** "Current Activities of the Turkish Nuclear Engineers Association" Assoc. Prof. Dr. Senem Şentürk Lüle, President of Turkish Nuclear Engineers Association & ITU Energy Institute
13:30-14:45	**Panel:** "The Integrated Management of Governance, Safety, and Smart Systems in Energy Transition"
14:45-15:15	**Invited Talk:** "Turkish Renewable Energy Outlook" Sedef Budak, Chief Growth Officer, Usens Energy Solutions
15:15-15:30	Coffee Break
15:30-16:00	**Invited Talk:** "Ultrahigh Temperature Ceramics: Enabling Next-Generation High-Efficiency Systems" Assoc. Prof. Dr. Mehdi Shahedi Asl , University of Kyrenia
16:00-16:30	ETSC'26 Closing Session

A Total Cost of Ownership Comparison of Alternative Bus Technologies for Sustainable Public Transport

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Abstract

The decarbonization of public transport is a key priority for sustainable urban mobility. Battery electric buses (BEBs) and compressed natural gas (CNG) buses have emerged as promising alternatives to conventional diesel buses (DBs), offering lower emissions and potential operational cost reductions. However, large-scale adoption of these technologies is often constrained by high upfront costs and infrastructure requirements. This study presents a comparative total cost of ownership (TCO) analysis of DBs, BEBs, and CNG buses under different charging and fueling strategies. The framework incorporates vehicle purchase price, infrastructure investment, fuel and electricity consumption, battery replacement, operation and maintenance (O&M), and residual values. For CNG buses, fueling station costs and maintenance considerations specific to natural gas engines are included. The analysis is based on realistic operational parameters, such as route lengths, daily duty cycles, and energy consumption per kilometer. For diesel buses, fuel prices and O&M costs are modeled according to current regional data. For BEBs, battery degradation and replacement cycles are considered to capture long-term performance, and electricity costs are evaluated under both flat and off-peak tariffs to reflect the impact of charging time management. Sensitivity analyses are conducted on key factors, including energy and fuel prices, discount rate, and infrastructure costs, to assess the robustness of the findings under varying operational and market conditions. The findings provide insights for policymakers and transit operators, highlighting how strategic planning of bus technology and charging or fueling infrastructure can reduce operational costs, lower emissions, and support the transition toward economically viable, sustainable urban public transport systems.

Keywords: Battery electric bus; Diesel bus; CNG bus; Total cost of ownership; Sustainable mobility.

Leveraging Blockchain Smart Contracts for a Secure and Automated Peer-to-Peer Energy Trading System

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Abstract

The transition towards a sustainable energy future is heavily reliant on the integration of distributed renewable resources. However, existing centralized energy markets are inadequate for managing the scale and complexity of peer-to-peer (P2P) energy trading, often suffering from transparency issues, high transaction costs, and security vulnerabilities. This paper will propose and develop a novel framework for a secure, remote, and automated P2P energy trading platform utilizing blockchain technology and smart contracts. The proposed system aims to eliminate trusted third parties by automating the entire trading lifecycle - including energy listing, order matching, transaction settlement, and real-time payment - through self-executing smart contracts deployed on a blockchain network. This approach is projected to significantly reduce operational overhead and enhance trust among participants. To validate the conceptual framework, a functional proof-of-concept will be implemented. This implementation will simulate a remote microgrid environment were multiple prosumers trade surplus solar energy. The results are anticipated to quantitatively demonstrate the platform's operational efficacy, showcasing secure transaction execution, immutable ledger recording, and autonomous settlement. Furthermore, the study will discuss the platform's potential to accelerate renewable energy adoption by empowering prosumers and its implications for building a more resilient and decentralized energy infrastructure. The findings of this research are expected to provide a valuable blueprint for practical blockchain applications in the energy sector, directly contributing to the goals of energy transition and sustainability.

Keywords: Peer-to-peer energy trading; Blockchain; Smart contract; Energy transition; Sustainability; Decentralization.

Agent-Based Modeling for Green Hydrogen Adoption in Heavy-Duty Freight: A Policy Analysis for Pakistan

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Abstract

Pakistan's transport sector accounts for 30% of national energy consumption, with heavy-duty freight dependent on imported diesel, causing foreign exchange losses and air quality degradation. Existing energy system models (TIMES, LEAP) provide techno-economic assessments but cannot represent behavioral dynamics and market interactions needed to understand technology adoption. This research develops an agent-based model (ABM) to evaluate policy interventions for green hydrogen adoption in heavy-duty freight along the Karachi-Lahore-Islamabad corridor (2025-2040). The model uses the Mesa framework in Python with four agent classes: government regulators, fleet operators (50 agents), infrastructure investors (10 agents), and technology suppliers (5 agents). Fleet operators base decisions on total cost of ownership, infrastructure investors use net present value criteria, and technology suppliers follow price learning curves. The model incorporates spatial networks and temporal dynamics, calibrated with data from the National Transport Research Centre, industry partners, and expert surveys. Validation includes face validity, historical calibration, and sensitivity analysis. Eight policy scenarios are examined: baseline, subsidies, infrastructure support, carbon taxation, combined incentives, technology mandates, technical standards, and information campaigns. The model quantifies adoption rates, infrastructure needs, economic costs, and emission reductions for each policy configuration. This is the first ABM application for hydrogen policy in Pakistan. Outcomes include a policy decision-support tool, enhanced national capacity in behavioral modeling, an evidence base for transport decarbonization, and a foundation for future alternative fuel research.

Keywords: Agent-based modeling; Green hydrogen; Heavy-duty freight; Energy policy; Transport decarbonization.

Assessing Techno-Economic Constraints of Green Hydrogen Production in Pakistan: A Modelling-Based Benchmarking Study

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Abstract

Green hydrogen is increasingly being viewed as a key vector for decarbonisation and international energy trade. However, the feasibility of large-scale production and exports from emerging economies remains uncertain. This study developed a Python- and Julia-based techno-economic modelling framework to evaluate the cost, efficiency, and policy constraints of green hydrogen production in Pakistan. The analysis integrates renewable resource potential, electrolyser performance, energy and water requirements, and levelised cost of hydrogen (LCOH) estimation under realistic financial and technical assumptions. Scenario simulations explore combinations of solar, wind, and hybrid systems using the current and projected costs for alkaline, PEM, and SOEC electrolysers. The results indicate that, even under optimistic assumptions, renewable electricity at 25 USD/MWh, a capacity factor of 45%, and a weighted average cost of capital (WACC) of 10%, the minimum achievable LCOH remains above 3.5-4.0 USD/kg at the plant gate. When transportation, conversion, and shipping losses are included, the costs delivered to the EU exceed 6 USD/kg, rendering exports uncompetitive against established suppliers from the Gulf and North Africa. The findings highlight the need to reorient Pakistan's hydrogen strategy from export ambitions to domestic applications in fertiliser production, steel, and transport. Policy recommendations focus on reducing capital risk, improving grid reliability, and developing a framework for hydrogen certification and financing. This study provides a transparent, data-driven basis for realistic hydrogen planning in developing economies.

Keywords: Green hydrogen; Techno-economic modelling; Levelized cost of hydrogen; Renewable integration; Policy feasibility; Python; Julia.

Sustainable Composite Material Development: Recycled Carbon Fiber and Pine Needle-Based Hybrid Structure

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Abstract

The pursuit of sustainable composite materials has become a critical focus in modern material science, aiming to reduce environmental impact while maintaining high-performance characteristics. This study introduces a hybrid composite structure developed from recycled carbon fibers and pine needle-based fillers integrated within a polymer matrix. Recycled carbon fibers provide exceptional mechanical strength and lightweight properties, whereas pine needle particles contribute to thermal insulation and ecological sustainability. The manufacturing process involves fiber recovery, surface treatment, filler preparation, resin impregnation, and controlled curing to ensure optimal bonding and structural integrity. Mechanical and thermal evaluations reveal that the hybrid composite exhibits an improved strength-to-weight ratio, dimensional stability, and enhanced thermal resistance compared to conventional composites. Furthermore, the incorporation of natural and recycled components significantly reduces the environmental footprint, aligning with circular economy principles. Potential applications include automotive components, construction panels, and interior design elements where lightweight, durability, and sustainability are essential. This research demonstrates that combining recycled carbon fibers with bio-based fillers can create innovative, eco-friendly materials without compromising performance, offering a viable pathway toward sustainable material innovation in industrial sectors.

Keywords: Sustainable composites; Recycled carbon fiber; Pine needle filler; Hybrid structure; Circular economy.

Evaluating the Impact Assessment of Architectural Design of Solar Photovoltaics on Sustainability in Educational Buildings

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Abstract

This study examines the effects of solar photovoltaic (PV) systems on sustainability and energy efficiency impacts in educational buildings and intends to inform future long-term environmental and operational performance in Higher Education. As the pressure continues to rise for academic institutions to reduce carbon emissions, and move away from fossil fuels toward renewables, solar PV systems can be identified as a solution that can enhance energy resilience, provide a reduction in operating expenses, and serve institutional sustainability initiatives. This study applies a mixed-methods research design and assesses the performance of PV systems from quantitatively analyzing energy production and consumption as well as architecture, environmental, and site-specific factors that influence PV system performance; this study focuses on broader sustainability benefits from PV systems including reduced consumption of grid electricity, reduced lifecycle impact, and greater alignment on international sustainability initiatives and certification systems. The study demonstrates that energy performance and sustainable benefits can be tested to provide optimal panel orientation and configuration, and while integrating the system with the form of the building and orientation, through a collective implementation in educational buildings. This study explores opportunities for evidence based design guidance and policy recommendations for preventative frameworks of impact for the scale up of solar technologies in academic institutions as part of overall sustainability and operational change.

Keywords: Educatonal buildings; Sustainability; Solar panels; Energy efficiency.

Stackelberg Game–Driven Energy Coordination of Offshore Amusement Parks with Green–Blue Hydrogen and Carbon Capture Integration

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Abstract

This work formulates a Stackelberg game-based coordination framework for Offshore Amusement Parks (OAPs) featuring green–blue hydrogen and carbon capture, utilization, and storage (CCUS) in the context of multi-energy system. The methodology mitigates the complexity of low-carbon, cost-effective operation in hybrid marine systems coupling tourism and energy facilities. Pyomo with CBC solver was used to formulate a leader–follower hierarchical optimization model, in which the park operator leads by determining energy and carbon pricing, whereas subsystems (e.g., hydrogen production units, CCUS units, leisure facilities) respond optimally. Simulation results obtained from three case studies demonstrate that the hybrid configuration can decrease total operational cost by more than 25% and CO_2 emissions by over 80% compared to the benchmark. The results show that employing Stackelberg game theory and carbon–hydrogen coupling can remarkably improve the energy efficiency, flexibility and sustainability of next generation offshore amusement–energy systems.

Keywords: Offshore amusement park; Stackelberg game theory; Green–blue hydrogen; Carbon capture utilization and storage (CCUS); Multi-energy optimization.

Data-Driven Fault Detection and Diagnosis of Wind Turbines Using Machine Learning Approaches

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Abstract

Wind energy nowadays is considered one of the cornerstones in the movement toward renewable and sustainable power generation worldwide. Wind turbines have gained popularity as a way to reduce greenhouse gas emissions and replace outdated, polluting methods of producing electricity because people want more clean energy. Let's face it, though, these turbines are rather intricate. They have a difficult job because they work nonstop in inclement weather. It's not a simple fix if only one component breaks. High repair costs, lost energy, and turbines that sit motionless for an extended period of time are all consequences. Predictive maintenance is now essential for wind farms because of this. It enables them to keep everything operating smoothly, identify issues before they arise, and maximize the performance of each turbine. In the last few years, ML combined with large-scale data analysis has opened new possibilities regarding wind turbines' health monitoring. Given historical operating data, ML models learn from subtle deviations in performance that precede a fault; these patterns often elude conventional diagnostic methods. This has been made possible through the increase in the availability of public data sets collected from SCADA systems and can enable the development and testing of those diagnostic models without industrially restricted information, therefore encouraging reproducibility and transparency in research studies. The paper proposes a data-driven framework for detecting abnormal operating conditions in wind turbines based on publicly available datasets. Data cleaning, feature selection, and training of supervised machine learning models to differentiate between normal and faulty states are some of the steps involved. Numerous algorithms, including random forests, decision trees, support vector machines, and neural networks, are developed, which have been tested and compared according to their classification performance, robustness, and computational efficiency. Standard metrics employed in model performance evaluation include precision, recall, F1-score, and confusion matrices that ensure objectivity in the assessment. This work shows how open data and machine learning can work together to make predictive maintenance in wind energy to move the industry toward smarter, more reliable renewable energy systems so wind power can last longer, adapt better, and keep up with what the world needs.

Keywords: Wind turbine; Fault diagnosis; Machine learning; Predictive maintenance; Renewable energy.

Sustainable Risk Analysis Applications with Data-Driven and Resource-Efficient Artificial Intelligence in Renewable Energy Systems

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Abstract

The share of renewable energy systems (RES) in the rapidly growing global energy portfolio is critical for ensuring both environmental and economic sustainability. However, these systems pose significant occupational health and safety (OHS) risks during both installation and operation. In solar power plants, high temperatures, electrical arcs, and the risk of falling during maintenance; in wind turbines, mechanical rotor blade failures and the necessity of operating at high altitudes; and in biomass and geothermal power plants, chemical exposure, high pressure, and explosion risks are among the primary risks frequently reported in the literature. Accurate and continuous monitoring of these risks is essential not only for employee safety but also for the long-term operational efficiency of these facilities. Recent studies indicate that artificial intelligence (AI)-based solutions are rapidly gaining prominence in proactively managing these risks. Deep learning and machine learning-based predictive models can predict the likelihood of failures, fires, or workplace accidents in real time by feeding into large volumes of data collected from sensor networks and unmanned aerial vehicles (UAVs). For example, deep neural networks processing vibration and acoustic signals in wind turbines optimize both life safety and maintenance costs by detecting bearing failures at an early stage. In solar power plants, images captured by thermal cameras use convolutional neural networks to analyze hot spots, revealing fire risks in advance. Similarly, predictive models working with data from gas sensors in biomass plants can instantly assess the risks of explosions or toxic leaks. A prominent trend in literature is to design these solutions in a data-driven and resource-efficient manner: low-cost sensor infrastructures, energy-efficient algorithms, and edge computing architectures reduce both energy consumption and processing costs, while aligning with sustainability goals. Consequently, these next-generation AI-powered risk analysis frameworks offer scientifically sound contributions to building a proactive safety culture in the renewable energy sector that both protects employees' health and enhances business continuity. This study emphasizes the contribution of risk assessments and analyses of technical issues such

as performance, maintenance and repair requirements, and efficiency in renewable energy systems, leveraging artificial intelligence solutions. In this context, the contribution of OHS studies and risk assessments to sustainable systems and solutions is particularly emphasized. Literature analyses and the impact of sustainable risk analysis studies on the installation, operation, testing and commissioning, maintenance, and repair processes in energy systems are explained.

Keywords: Sustainable artificial intelligence; Sustainable risk analysis; Green artificial intelligence; Predictive risk management; Renewable energy technologies.

Risks and Preventive Approaches Focused on Occupational Health and Safety in Renewable Energy Systems

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Abstract

While the potential of renewable energy systems to meet rapidly increasing global energy demand offers significant opportunities for environmental sustainability, the unique risks posed by this field in terms of occupational health and safety (OHS) are becoming increasingly apparent. Facilities based on diverse resource types, such as solar, wind, biomass, and geothermal, pose multifaceted hazards to workers, the environment, and infrastructure during both construction and operation. Recent research has demonstrated that interdisciplinary and preventative approaches to risk management are essential for the safe operation of these systems. In solar power plants, significant risks include high temperatures, electric arcs, working at heights during panel installation and maintenance, and panel efficiency loss due to dust and contamination. In wind turbines, mechanical fatigue, vibration, and blade fractures of rotor blades are prominent, as are the risks of falls or equipment overturning due to working at high altitudes and strong winds during maintenance activities. In biomass and geothermal plants, high-pressure fluids, flammable gases, toxic chemicals, and the potential for explosions are critical for worker health and environmental safety. These risks include: It can lead to serious consequences such as heat stress, noise-induced hearing loss, musculoskeletal disorders, chemical exposure, and fire. Furthermore, cyberattacks on SCADA and other industrial control systems pose an indirect but high-impact threat, with the potential to disable emergency warning and security mechanisms. The most current preventive strategies against these multifaceted risks include regular maintenance and periodic equipment inspections, standardizing personal protective equipment (PPE) for high-altitude work, monitoring noise and vibration exposure, keeping emergency plans up-to-date through drills, and strengthening cybersecurity protocols. Furthermore, artificial intelligence-based monitoring and predictive maintenance solutions, developed in recent years, add value to risk analysis processes by processing sensor-based big data such as vibration data and thermal imaging to provide early warnings. Thus, the combined use of traditional OHS measures and data-driven predictive technologies provides a holistic protection framework that strengthens both worker safety and operational continuity in renewable energy systems. This study presents a literature review on

the OHS framework in renewable energy technologies. It also highlights the importance of risk assessment studies specific to the type of energy source, its operating principles, and the areas of installation and use. In this context, sample applications for risk assessment studies are presented. Finally, the importance of identifying common and unique hazards and risks across systems is emphasized. It also highlights the contributions of technology-focused approaches such as digitalization and artificial intelligence.

Keywords: Sustainable artificial intelligence; Sustainable risk analysis; Green artificial Intelligence; Predictive risk management; Renewable energy technologies.

Recycled Metal Utilization on the Microstructure and Mechanical Properties of Casting Alloys

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Abstract

Recycled metals have become a strategic resource for the casting industry in the transition toward sustainable manufacturing and circular material flows. This review summarizes the present understanding of using 100% recycled alloys in foundry applications, covering microstructural evolution, mechanical properties and energy efficiency. The aim is to make an integrated assessment of the scientific findings and industrial practices that underpin the wider adoption of recycled feedstock in metal casting. This review summarizes what is known about the influence of impurities, oxide formation and melt treatment on the resultant microstructure. Various observations are reported that trace impurities of alloying elements may modify the dendritic morphology, eutectic phases, and porosity of recycled metals; often these can be minimized by proper refining and filtration. The mechanical performance results vary depending on the alloy type, recycling route and melting practices; nevertheless, a considerable number of research findings prove that tensile strength, hardness and fatigue resistance of castings manufactured from 100% recycled feedstock remain comparable to those produced from primary metals when proper process control is applied. This review also points out the importance of melt cleanliness, degassing procedures and alloy chemistry stabilization in achieving consistent quality. Overall, the collected research indicates that 100% recycled metals can be effectively integrated into the casting processes and are an essential part of sustainable foundry operations. In this context, the utilisation of recycled metals brings considerable benefits in terms of energy consumption reduction, minimising carbon emissions, and supporting circular economy principles. This review is expected to help future studies and industrial practices by summarising challenges, key technological developments, and opportunities for full-scale implementation.

Keywords: Recycled metals; Casting alloys; Microstructure; Mechanical properties; Energy efficiency.

The Future of Battery Energy Storage in Electric Grids: A Global Trends and Opportunities for Türkiye

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Abstract

The rapid global expansion of renewable energy sources has increased the need for flexibility within energy systems and positioned battery energy storage systems as essential components of modern electric grids. The integration of intermittent resources such as solar and wind leads to sudden fluctuations in power generation, making battery storage technologies characterized by fast response times and high cycle efficiencies a strategic solution for maintaining grid stability. According to the literature, the cost of lithium-ion batteries has decreased by nearly 80% over the past decade, significantly accelerating the adoption of these systems in both utility-scale and distributed generation applications. In regions such as the United States, the European Union, and the Asia-Pacific, battery-based storage systems have become integral to peak load management, frequency regulation, demand-side participation, and renewable energy integration. In the case of Türkiye, the increasing installed capacity of renewable energy, the need for grid modernization, the rapid growth of the electric vehicle ecosystem, and the implementation of the Energy Storage Regulation create significant opportunities for battery storage deployment. Mandatory storage requirements for licensed power plants, the potential integration within YEKA projects, and the support for commercial storage investments are critical for enhancing Türkiye's energy supply security and grid flexibility. Moreover, battery storage systems are expected to contribute substantially to national carbon-reduction goals, thereby accelerating the sustainable energy transition. This study evaluates the current state of battery energy storage technologies within the context of global trends and examines emerging investment dynamics. It also discusses the strategic opportunities that battery storage can offer Türkiye, providing a conceptual framework for understanding its role in future energy systems.

Keywords: Battery energy storage; Lithium-ion batteries; Grid flexibility; Renewable energy integration; Energy transition.

The Future of Hydrogen Energy: A Conceptual Review of Storage Technologies

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Abstract

Hydrogen energy is considered one of the most important energy carriers playing a critical role in achieving global carbon-neutral targets within the framework of sustainable energy transitions. Green hydrogen, which can be produced from renewable energy sources, holds a central position in future sustainable energy systems due to its potential to reduce CO_2 emissions, enhance energy supply security, and strengthen sectoral integration. However, one of the major barriers to the widespread adoption of hydrogen is the need for safe, economical, and high-density storage technologies. In this context, the literature categorizes hydrogen storage methods into four main groups: high-pressure compressed gas storage, cryogenic liquid hydrogen storage, absorption-based storage using metal hydrides, and chemical storage such as ammonia and liquid organic hydrogen carriers (LOHC). Each storage method offers distinct advantages and limitations in terms of energy density, safety, cost, infrastructure requirements, and applicability. While compressed hydrogen technology is the most mature and commonly used method in current industrial applications, liquid hydrogen storage is expected to gain greater importance in the future, particularly in sectors such as aviation, space technologies, and heavy transportation, where high energy density is crucial. Metal hydride-based storage systems present significant long-term potential due to their high safety profile and stable structure. Meanwhile, ammonia and LOHC-based chemical storage technologies provide strategic alternatives by enabling long-distance hydrogen transport and compatibility with existing fuel infrastructures. This study conceptually evaluates the current state of hydrogen storage technologies and highlights the critical role they will play in shaping the future hydrogen economy.

Keywords: Hydrogen energy; Storage technologies; Compressed hydrogen; Liquid hydrogen; Carbon neutrality; Sustainable energy systems.

Investigation of Thermal Mass Properties in Vernacular Buildings in the Context of Energy Efficiency

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Abstract

The significant increase in energy consumption and the deepening of environmental problems associated with climate change have made energy-efficient design approaches in the construction sector inevitable. Furthermore, global goals aimed at reducing carbon emissions and addressing the depletion of energy resources necessitate a reassessment of the energy performance of building materials. In this context, the thermal mass properties of natural and local materials used in vernacular buildings are of great importance in terms of re-evaluating passive climate control strategies under current conditions. Thermal mass is a physical property that refers to a material's capacity to absorb, store and release heat with a delay. Walls and floors with high thermal mass reduce indoor temperature fluctuations, thereby increasing thermal comfort. This contributes to energy efficiency by reducing heating and cooling requirements in buildings. With this characteristic, thermal mass has the potential to balance the energy load in buildings during times of high energy demand. This study aims to examine the thermal mass properties of building elements made from vernacular building materials such as wood, stone, adobe and brick, and the effects of these properties on energy efficiency, using a literature-based analysis method. The study comparatively analysed the thermophysical behaviour of traditional building elements used in different climate zones through tables. The findings reveal that building elements with high thermal mass reduce energy consumption by balancing indoor temperature fluctuations and enhance passive climate control performance. Consequently, traditional building materials, thanks to their thermal mass properties, provide a strong design data source for architectural applications in terms of energy-efficient and sustainable building design. Highlighting these properties is important not only for the preservation of building elements related to local architectural heritage but also for contributing to the construction of sustainable, energy-efficient buildings using local materials in the modern era.

Keywords: Thermal mass; Energy efficiency; Vernacular architecture; Climatic adaptation; Sustainable design.

Sustainable and Energy Efficient Agriculture with Artificial Intelligence Adoption

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Abstract

Agriculture is crucial for global food security. Traditional farming methods can't keep up with the growing demands from population growth, climate change, and limited resources. With the world's population expected to reach almost 9 billion in the next decade, food systems, water resources, and agricultural productivity will face more pressure. This thesis looks at how AI can help develop efficient and sustainable farming systems based on data. AI can improve crop monitoring, yield predictions, soil analysis, and pest management by using various weather data, including rainfall, temperature, humidity, wind, and storm forecasts, allowing for timely actions. A major focus of this study is how AI can optimize resource use, especially in irrigation and weed control. Research shows that soil-water sensing technologies in AI-based smart irrigation systems can cut water usage by up to 25%. This is important for areas dealing with water shortages. Robotic and AI-driven precision weeding methods decrease reliance on herbicides and manual labor, lowering energy use and improving environmental sustainability. Using drones for spraying and crop monitoring boosts efficiency by accurately targeting problem areas, reducing chemical waste, and minimizing production losses. This study reviews the existing literature and analyzes the benefits, challenges, and practical issues of adopting AI in agriculture. It considers international examples, such as India's AI4AI initiative, AI-supported weeding systems in Africa, and a proposed AI framework for agriculture in the Konya Plain in Türkiye. The findings show that while AI could greatly improve food security, resource use, and climate resilience, barriers like low digital literacy, high implementation costs, and infrastructure issues limit its wider use. Overall, the study concludes that AI is not merely a technological upgrade; it is essential for creating sustainable and energy-efficient agricultural systems in the future.

Keywords: Artificial intelligence; Sustainable agriculture; Energy efficiency; Precision farming; Food security.

Learning Integrated School Model: Impacts of ISO 14001–9001–45001 on School Culture, Student Behavior and Sustainable Educational Governance

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Abstract

In educational settings, management processes are increasingly expected not only to provide regulatory compliance but also to ensure quality-driven, safe and sustainable learning environments. This study investigates the influence of the integrated implementation of ISO 14001 Environmental Management System, ISO 9001 Quality Management System and ISO 45001 Occupational Health and Safety Management System on school culture, student behavior and stakeholder engagement across preschool, primary, lower secondary and special education schools in Duzce, Türkiye. The research introduces the original Learning Integrated School Model (LISM), which conceptualizes these standards as a learning-oriented ecological system that contributes to educational transformation. A qualitative case study design was adopted. Using maximum variation sampling, semi-structured interviews were conducted with 10 school administrators and 18 teachers. Data were analyzed through thematic content analysis, while credibility and trustworthiness were established via dual coding, expert review and participant confirmation. Findings indicate that integrated management systems: (i) reinforce environmental responsibility and safety-oriented behavioral patterns among students, (ii) strengthen planning and monitoring practices in instructional processes, and (iii) cultivate cooperation, procedural awareness and a culture of shared responsibility among staff. Additionally, parent involvement in sustainability initiatives increased, enhancing school–community engagement. However, documentation load, time pressure, budget limitations and resistance to change continue to pose challenges during implementation. The study concludes that the Learning Integrated School Model enables a synergistic learning cycle by aligning environmental, quality and safety efforts, thereby contributing to sustainable school culture. Strengthening digital documentation infrastructures, expanding role-based professional development and establishing networks for sharing good practices are recommended to enhance implementation quality. This research provides

a novel theoretical contribution to the field by examining integrated management systems in education through a holistic and transformative lens, offering strategic implications for policymakers and practitioners.

Keywords: ISO 14001 – Environmental Management and Sustainability; ISO 9001 – Process and Quality Assurance; ISO 45001 – Risk and Occupational Health & Safety Management; Integrated Management Systems; Learning Integrated School Model (LISM).

A Physics-Informed and Prescriptive XAI Framework for Electrical Grid Stability

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Abstract

The increasing integration of renewable energy sources into the grid can lead to stability problems in modern decentralized smart grid control systems. Although existing artificial intelligence models are quite good at predicting instability with high accuracy, they generally operate as opaque "black boxes" lacking transparency. This situation leads to insufficiency in real-time decisions. In the study, the UCI Electrical Grid Stability Simulated Dataset, consisting of 10,000 samples and 12 dynamic features covering reaction times, power values, and price elasticities, was used. To ensure the physical consistency of the model, the "Power Imbalance" index, mathematically derived from the power balance principle based on energy conservation, was included in the model as the 13th feature. On the dataset, the performances of XGBoost, LightGBM, and Random Forest algorithms were compared using the 10-fold cross-validation method. As a result of the analyses performed, the XGBoost model surpassed the other two algorithms with an accuracy rate of 94.75 percent. The confusion matrix applied to the XGBoost model supported the model's accuracy by showing that it kept "False Negative" errors, which cause high costs that could lead to grid blackouts, at a low level. The fundamental original value of this study is that it goes beyond the state of mere prediction and gains the ability to intervene in the system by producing necessary solutions with Explainable Artificial Intelligence (XAI). The performed SHAP analysis quantitatively showed that the root cause of grid instability is not producer dynamics as expected, but rather reaction delays on the consumer side (specifically tau2 and tau4). In this context, to provide the system with actionable intervention capability, a genetic algorithm-based Counterfactual Explanation method integrated into the XGBoost model was used. This method offers optimized intervention vectors in cases of system instability. The model prescribed a precise control strategy predicting an increase of 1.83 seconds in consumer reaction delay and a reduction of 0.96 p.u. in active power imbalance to restore system stability. Consequently, this study provides the foundations of a transparent, measurable, and actionable decision support mechanism for sustainable energy infrastructures by integrating data-driven prediction algorithms with physical control parameters.

Keywords: Counterfactual explanations; Explainable AI (XAI); Physics-informed machine learning; Smart grid stability; XGBoost.

Structural, Optical and Electrical Investigation of Sn and Cu Doped ZnO Thin Films Prepared by Sol–Gel Method

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Abstract

Zinc oxide (ZnO) thin films were good candidates for transparent conductive oxides (TCOs) rather than TCO materials such as indium tin oxides (ITO) due to their non-toxicity, low cost, and good optical and electrical properties. The structural, optical, and electrical properties of ZnO thin films can be improved by doping with suitable dopant materials. In this study, tin (Sn) and copper (Cu) doped ZnO thin films were grown on soda-lime glass substrates using the sol-gel dip-coating method, and their effects on the microstructure and electrical properties of the thin films were investigated. $Zn(CH_3COO)_2 \cdot 2H_2O$ (zinc acetate dihydrate, 99.5% purity) was used as the starting material. Ethanol was used as the solvent, diethanolamine as the pH buffer, and extra-pure tin chloride dihydrate ($SnCl_2 \cdot 2H_2O$) and copper chloride dihydrate ($CuCl_2 \cdot 2H_2O$) at 1% and 2% concentrations as additives. The prepared solutions were coated onto glass substrates using the dip-coating method, and then heat treatment was applied to obtain thin films. The structural properties of the thin films were investigated by X-ray diffraction (XRD) analysis, their optical properties by ultraviolet-visible (UV-VIS) spectroscopy, and their defect levels and recombination mechanisms by photoluminescence (PL) spectroscopy. The electrical properties were evaluated using appropriate electrical characterisation techniques to reveal the effect of doping on charge transport behaviour. A comparative analysis was performed to determine the effects of Sn and Cu doping on the crystal structure, optical response, and electrical performance of ZnO thin films. This study aims to comparatively reveal the effects of Sn and Cu-doped ZnO thin films produced by the sol-gel method on crystal structure, band gap behaviour, and electrical performance, providing an important foundation for the development of low-cost and environmentally friendly transparent electrode materials. The findings are expected to contribute to the development of ZnO-based thin film technologies and the design of materials.

Keywords: ZnO thin films; Transparent conducting oxide; Sol-gel method; Sn doping; Cu doping.

Pyrolysis Kinetics of Chlorella vulgaris Using Coats–Redfern Model

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Abstract

The depletion of fossil fuels and growing environmental concerns have accelerated the search for sustainable energy sources. Microalgae, especially *Chlorella vulgaris*, demonstrate great potential due to their fast growth, high photosynthetic efficiency, and varied biochemical makeup, making them ideal for bioenergy production. This study investigates the pyrolysis of *C. vulgaris* to evaluate its thermal breakdown behavior, kinetic parameters, and reaction mechanisms. Thermogravimetric analysis (TGA) was conducted at a heating rate of 20 °C/min to examine mass loss and identify major devolatilization regions, noting that experimental conditions can influence kinetic results. The results indicated that the active pyrolysis zone was between 200 and 500 °C, corresponding with substantial volatile release and the quick breakdown of biomass components, including proteins, lipids, and carbohydrates. To determine the kinetic parameters, the integral Coats–Redfern method was used with various reaction mechanism functions *g(x)* representing diffusion-controlled, reaction-order, and nucleation-growth models. This technique allowed the calculation of the activation energy (E) and pre-exponential factor (A) for each proposed mechanism, enabling a comparison to determine the best kinetic description of *C. vulgaris* pyrolysis. Among the tested models, reaction-type mechanisms matched the experimental data best in the active pyrolysis region, with $R^2 = 0.9946$ and reaction order $n = 2$. Overall, the findings provide important insights into the degradation kinetics of *C. vulgaris*, aiding the optimization of thermochemical conversion processes for microalgal biomass. The calculated kinetic parameters and mechanism interpretations can assist in reactor design, process modelling, and the development of more efficient biofuel production strategies. This work lays the foundation for future research aimed at enhancing bioenergy conversion efficiency.

Acknowledgements: This study was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) under Project No. 224M617.

Keywords: Chlorella vulgaris; Thermogravimetric analysis; Kinetic analysis; Energy.

Spatio-Temporal Analysis of Daily Meteorological Parameters in Turkish Cities Using Artificial Intelligence

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Abstract

The analysis of daily meteorological datasets using artificial intelligence and machine learning techniques has become increasingly important for understanding climate variability, detecting long-term climate change trends, and supporting sustainable urban planning. Key atmospheric parameters such as temperature, wind speed, wind direction, and relative humidity directly influence natural ecosystems, energy demand, water resources, agricultural productivity, and public health. Through spatio-temporal analysis, it becomes possible to reveal both the temporal evolution of climate variables and their spatial differences across regions with higher accuracy than conventional statistical approaches. In this study, a comprehensive daily weather dataset covering multiple cities across Türkiye is evaluated using artificial intelligence–based methods. The dataset includes daily average, maximum, and minimum temperature, daily average, maximum, and minimum wind speed, dominant wind direction, and average relative humidity. Based on these parameters, a spatio-temporal analysis is performed to investigate seasonal cycles, interannual variability, long-term warming trends, and the frequency of extreme heat events (heatwaves). Machine learning–based analytical approaches are utilized to compare regional climate behavior and identify city-level climate dynamics. The results indicate statistically significant warming trends in many urban regions of Türkiye, along with noticeable shifts in seasonal temperature patterns. Variations in wind speed and relative humidity further reflect increasing climatic stress, particularly in densely populated cities. The combined spatio-temporal evaluation of daily temperature, wind, and humidity parameters provides critical insights into urban heat island effects, thermal comfort conditions, energy consumption patterns, and public health risks associated with extreme heat. In addition, rising temperatures are found to intensify evaporation processes and impose additional pressure on water resources and urban energy systems. Overall, daily meteorological parameters, especially temperature, wind, and humidity emerge as robust, interpretable, and actionable indicators for sustainability-oriented climate assessment. The integration of spatio-temporal analysis with artificial intelligence and machine learning offers a powerful scientific framework for enhancing regional climate resilience, supporting sustainable urban planning, and guiding climate adaptation and mitigation strategies in Türkiye.

Keywords: Spatio-temporal analysis; Machine learning; Climate change; Sustainability; Climate analysis.

Digital Pneumatic Systems in the Industry 4.0 Era: Energy Efficiency and Carbon Footprint Analysis with App-Based Valve Terminals

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Abstract

With a growing population and developing technology, energy consumption and costs are increasing daily. Our country has limited fossil energy resources and is dependent on foreign sources. Meeting energy needs in a reliable, economical, and sufficient manner is the primary objective. In this context, the efficient use of energy is among the issues that require significant emphasis. Energy efficiency is the minimization of energy consumption without reducing production capacity and quality, or hindering economic development and social welfare. The rapid digitalization of industrial automation has transformed pneumatic systems from mere mechanical work elements into intelligent, data-driven, and software-managed production components. Application-based pneumatic valve terminals enable multiple valve functions to be modified with software on a single hardware, offering increased flexibility, energy transparency, and predictive maintenance capabilities compared to traditional pneumatic terminals. These next-generation terminals; It integrates with sensors that monitor pressure, flow, and leakage in real time, optimizing pressure levels with self-adjusting control algorithms based on process requirements, thus improving cycle times and significantly reducing energy losses caused by frequently overlooked micro-leaks. Recent studies in the literature show that in traditional pneumatic systems, 30–40% of total compressed air consumption can be wasted due to pressure errors, higher operating pressures than necessary, and undetected leaks; digital pneumatic terminals can directly measure these losses and instantly correct them with software-based functions. Thanks to Open Platform Communications Unified Architecture (OPC UA)-based communication infrastructures, cloud and edge-based data processing solutions, energy monitoring panels, and CO_2 calculation functions, systems can instantly report the kWh consumed per production unit, the amount of emissions resulting from compressed air production, and cycle-based maintenance needs. Within the context of sustainable production goals and carbon-neutral factory transformations, the transition from traditional valve terminals to digital pneumatic terminals creates significant environmental and economic value by providing measurable reductions in energy consumption, increased process continuity, and reduced

maintenance costs. This study comprehensively examines the impact of app-based pneumatic valve terminals on energy efficiency, carbon footprint reduction, and the pneumatic system lifecycle, and demonstrates the scientific contributions of leak detection, adaptive pressure control, and software-defined valve behavior to sustainable and flexible manufacturing processes.

Keywords: Digital pneumatics; Application-based valve terminal; Energy efficiency; Predictive maintenance; Sustainable manufacturing; Industry 4.0.

Addressing Energy Poverty through Climate Finance and Digitalization: Lessons from Developing Countries

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Abstract

Energy poverty, defined as the lack of access to modern, reliable, and affordable energy services, continues to hinder socioeconomic progress across the Global South, with rural communities disproportionately affected. While international climate finance and the rapid advancement of information and communication technology (ICT) have emerged as key enablers of clean energy access, but their individual and joint effects on energy poverty remain underexplored. This study examines how climate finance; disaggregated into adaptation, mitigation, and aggregate flows; and ICT readiness influence energy poverty across 136 developing countries from 2002 to 2022. Using panel least squares estimation with Driscoll–Kraay standard errors to address heteroscedasticity and cross-sectional dependence, we analyze six energy poverty indicators, including rural and urban access to electricity and clean cooking technologies. The findings reveal that both climate finance and ICT exert a statistically significant and positive impact on reducing energy poverty. Adaptation finance is particularly effective in expanding access to clean cooking fuels, while mitigation finance supports broader electrification goals. ICT readiness, measured through a composite index contributes to energy access, especially in rural regions. The results highlight the need for combined digital and financial strategies to speed up progress toward SDG 7. Future efforts should focus on ICT-based, climate-financed programs in underserved areas and on building stronger institutions to support their success.

Keywords: Climate finance; ICT; Energy poverty; Sustainable development goal; Developing countries.

The Effect of Material Selection in Micro UAVs on Structural Behavior under Different Force Conditions

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Abstract

In recent years, micro-scale unmanned aerial vehicles (UAVs) have been widely used, particularly in surveillance, environmental monitoring, search and rescue, and civil applications. Structural lightness, strength, and vibration behavior are critical factors in the design of such aerial vehicles. Due to the limited payload capacity of micro UAVs, material selection is a decisive factor in terms of both flight performance and airframe safety. In this study, the structural effects of different engineering materials on the micro UAV airframe were analyzed in detail using the finite element method. In the study, a typical X-shaped UAV body was modeled, and both static and modal analyses were performed in the ANSYS finite element analysis environment for five different materials (Carbon Fiber Reinforced Plastic (CFRP), ABS Plastic, PLA (Polylactic Acid), Nylon (PA6/PA12), and Aluminum (6061-T6)) were subjected to both static and modal analyses in the ANSYS finite element analysis environment. In the static analysis, total deformation values were obtained under thrust forces up to 2 N; in the modal analyses, the first six natural frequencies and mode shapes of the structure were determined. The analysis results were compared in terms of maximum deformation, vibration frequencies, and the weight-strength relationship. As a result, the structural responses of materials under different loading conditions were evaluated, and optimal material recommendations for micro UAVs were presented, taking into account weight-stiffness performance. Where necessary, strategies for reducing deformations through design optimization were also addressed. This study aims to provide a structural analysis-focused and numerically based approach to material selection in micro UAV design processes.

Keywords: Micro UAV; Finite element methods; Total deformation; Tensile stress; Design analysis.

A Bibliometric Analysis on Green Finance and Climate Change

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Abstract

Increasing climate change–related problems on a global scale have necessitated the re-evaluation of financial systems within the scope of sustainability policies. This situation has led the academic literature to focus on financial instruments that take environmental impacts into account and on climate change. In addition, green finance stands out as an important research area in terms of reducing the effects of climate change–related problems on financial systems and supporting sustainable development goals. The aim of this study is to analyze the structural and thematic characteristics of the green finance and climate change literature through bibliometric methods. The analyses were conducted using a total of 621 publications available in the WoS database between the years 1996 and 2025. While a total of 56 publications were produced between 1996 and 2020, the number of publications on this subject increased significantly after 2020. In particular, a major turning point occurred in 2023, with an annual average of 147 publications produced. In 2025, a total of 175 publications were produced. With a total of 256 publications, China became the most studied country in this field. China is followed by the United Kingdom with 44 publications. India ranks third with 27 publications. When citations to the publications are examined, it is determined that the highest number of citations was again received by China (8,150 citations), followed again by the United Kingdom (2,647 citations). In terms of citations, France ranks third with 1,650 citations. Among the most frequently used keywords are green finance (321 times), climate change (150 times), and climate finance (54 times). From this, it can be interpreted that the topics of green finance and climate change will evolve over time toward climate finance. The results of the study reveal that the green finance and climate change literature exhibited a dynamic structure during the 1996–2025 period, gained significant momentum, and that academic interest increased rapidly, especially after 2020. Country-based analyses show that China holds a leading position in literature in terms of both the number of publications and citation impact. Keyword and thematic analyses reveal that the literature is mainly shaped around the axes of green finance and climate change; however, in recent years, climate finance has increasingly emerged as a prominent research theme.

Keywords: Green finance, Climate change, Bibliometric analysis.

The Role of Designers in Shaping Circular Design Frameworks for a Sustainable Future

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Abstract

Sustainability has moved to the forefront of the global agenda due to challenges such as global warming, resource depletion and the climate crisis. The traditional linear model, which relies on converting raw materials into products and discarding them after use, is placing increasing pressure on natural ecosystems. In this context, the circular economy, which aims to extend product life cycles, minimize waste and regenerate natural systems has gained significant importance. For the future of the planet and humanity, not only the transition to a circular economy but also the fundamental transformation of the design paradigm that enables it is a strategic necessity. As a core component of the circular economy, circular design has become a strategic focus within the design discipline supported by European Union policies and action plans. This approach redefines the designer's role, moving beyond aesthetics and functionality to position designers as active agents of transformation towards a sustainable future. Most of a product's environmental impact is determined during the early design stages, making design decisions extremely important in today's world. Circular strategies aim to prevent unnecessary natural resource use and waste generation, promote maintenance and reuse and keep products in the cycle for as long as possible. In this regard, the widely recognized R-strategies serve as a practical roadmap for designers and include smarter production and use; reuse, repair, refurbishment, remanufacturing and repurposing to extend product lifespans, as well as recycling and recovery to ensure material reuse. Adopting these approaches enables designers to drive cultural change in consumption, make repair and reuse practices accessible and foster sustainable behaviors that create meaningful social impact. Designers stand at the core of a sustainable future as key agents of transformation. Achieving this future requires more than aesthetic and functional focus; it demands a systemic and holistic perspective, expertise in circular material knowledge, environmental impact analysis and life cycle oriented thinking. Accordingly, this study examines the impact of the shift from a linear to a circular model from the design perspective, explores the evolving role of designers and identifies the competencies and skill sets necessary to enable this transition. This paradigm shift calls for redefining the designer's role and proposing the redesign of educational programs to align with new circumstances. Strengthening systemic thinking and effectively applying circular strategies will accelerate progress toward an environmentally, economically and socially sustainable future.

Keywords: Circular design; Circular economy; Sustainability; Designer's role; R strategies.

A Systematic Review and Bibliometric Analysis of Performance Factors in EEG-Based Brain–Computer Interfaces

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Abstract

Electroencephalography (EEG)-based brain–computer interfaces (BCIs) are innovative systems that enable individuals to interact with computers, robotic systems, and assistive technologies solely through brain activity, without relying on muscular or motor neural pathways. Due to its non-invasive nature, portability, and relatively low cost, EEG has become the most widely used brain signal acquisition technique in BCI applications. However, the low-amplitude and noise-prone characteristics of EEG signals constitute one of the primary factors that directly limit system performance. Therefore, a comprehensive evaluation of performance in EEG-based BCIs is of critical importance. In this study, performance evaluation in EEG-based brain–computer interfaces is addressed using two complementary approaches: (i) a bibliometric analysis conducted exclusively using the Scopus database to reveal the scientific development of the field, and (ii) a fishbone (Ishikawa) causal analysis method to systematically identify the factors leading to low performance. Within the scope of the bibliometric analysis, publications indexed in Scopus were examined in terms of annual publication trends, leading authors, countries, institutions, journals, and keyword co-occurrence networks. The fishbone analysis systematically classified the causes of low performance in EEG-based BCIs under six main categories: hardware, data and signal quality, methods and algorithms, user-related factors, environmental and application conditions, and management–ethics–regulatory issues. The findings demonstrate that the performance of EEG-based BCIs is not solely dependent on the selected classification algorithms; rather, factors such as signal-to-noise ratio, appropriate preprocessing and feature extraction techniques, user-specific physiological and behavioral variations, and the application environment play decisive roles in overall system performance. Furthermore, Scopus-based bibliometric results indicate that research trends in recent years have prominently focused on deep learning-based methods, motor imagery paradigms, and rehabilitation applications. This study presents a holistic performance evaluation framework that uniquely integrates a Scopus-based bibliometric analysis with a fishbone causal approach for EEG-based brain–computer interfaces.

Keywords: EEG; Brain–Computer interface; BCI performance; Evaluation metrics; Bibliometric analysis; Fishbone diagram; Motor imagery; Deep learning.

The Impact of Climate Change on the Black Sea Ecosystem: Artificial Intelligence-Supported Analysis of the Relationship Between Sea Surface Temperature and Chlorophyll-a

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Abstract

Global climate change is creating irreversible environmental pressures on marine ecosystems, and this situation is felt much more severely and rapidly in semi-enclosed basins with limited water exchange, such as the Black Sea. Increases in sea surface temperature (SST) triggered by atmospheric warming prevent oxygen in the water column from being transported to deeper levels and nutrients from being transported to the surface, making it difficult for nutrients to reach the surface and severely limiting the production of phytoplankton (chlorophyll-a), which forms the basis of the marine food chain. This study aims to quantitatively reveal the warming trend in the Black Sea and its devastating effects on biological productivity using high-resolution satellite data covering the 30-year period (1993–2023) accepted as standard for climate analysis by the World Meteorological Organization. The results of the study demonstrate that the Black Sea has been subjected to a sustained warming process over recent decades, leading to pronounced changes in seasonal temperature patterns and the increasing frequency of extreme thermal conditions. This long-term warming has altered the physical structure of the water column, weakening vertical mixing processes that are essential for the transport of oxygen and nutrients. As a consequence, the ecological balance of the marine system has been increasingly disrupted. The analyses reveal a strong negative relationship between sea surface temperature and chlorophyll-a concentration, indicating that rising temperatures play a direct role in suppressing primary biological productivity and weakening. The findings further suggest the presence of a critical thermal threshold, beyond which ecosystem responses become increasingly nonlinear and biological productivity rapidly declines. Such changes point to a heightened risk of ecosystem degradation and the gradual transformation of productive marine areas into biologically impoverished zones. In this context, the study emphasizes that conventional monitoring approaches may be insufficient to capture the complex and non-linear interactions between physical and biological variables. Therefore, the integration of artificial intelligence-based analytical and monitoring tools emerges as a key re-

quirement for timely detection of ecological stress, improved forecasting capability, and the development of adaptive management strategies aimed at preserving marine ecosystem resilience under ongoing climate change.

Keywords: Black Sea; Climate change; Sea surface temperature; Chlorophyll-a; Artificial intelligence.

Data-Driven Analysis of the Physicochemical Properties of Phosphoramid-Benzoazole Compounds Using a Machine Learning Approach

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Abstract

In this study, the physicochemical, spectral, and thermodynamic properties of phosphoramid-benzoazole derivatives, which are potentially important from the perspective of medicinal chemistry and materials science, were comprehensively analyzed using experimental data in conjunction with machine learning-based approaches. As an alternative to time-consuming and costly traditional experimental methods, the effectiveness of ensemble learning algorithms in determining molecular structure-property relationships has been evaluated.The dataset created within the scope of the study included pH-dependent circular dichroism (CD) spectra, Gibbs free energy values, pKa behaviors,related spectral and thermodynamic parameters.. The performance of the models was compared using coefficients of determination and RMSE metrics. Additionally, Principal Component Analysis (PCA) was applied to examine the statistical structure of the spectral data, and correlations between variables were visually assessed. PCA results revealed that a large portion of the total variance could be explained by the first two components and that information concentrated in specific wavelength regions of the CD spectra showed meaningful relationships with molecular stability and thermodynamic parameters.Error distribution analyses have confirmed that the XGBoost model provides stable predictions across different CD intervals without creating systematic bias. These findings demonstrate that CD spectral data are not merely a qualitative characterization tool but also provide inputs with high information content for quantitative and predictive modeling studies. The presented approach offers an effective framework that enables a reduction in the amount of experimental data required to predict the properties of similar phosphorus-nitrogen and heterocyclic systems and accelerate the screening of candidate compounds.Overall, this study has demonstrated that the integrated use of experimental measurements, thermodynamic calculations, and machine learning methods provides a robust and reliable approach for predicting the properties of phosphoramid-benzoazole systems.

Keywords: Bioactivity; Molecular docking; Machine learning; QSAR; Bioactivity prediction.

A Comparative Time Series Analysis of Türkiye's Energy Dynamics Using ARIMA and Prophet Models

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Abstract

In developing economies like Türkiye, accurate energy forecasting is not merely a statistical exercise but a cornerstone for ensuring energy security and shaping sustainable development policies. As the gap between energy demand and supply fluctuates due to population growth and economic expansion, the need for robust predictive models becomes critical. This study presents a comprehensive analysis of Türkiye's energy landscape by examining monthly data on electricity production, electricity consumption, and coal production from January 2010 to December 2024. The primary objective is to forecast future trends to guide strategic planning and evaluate the country's progress toward energy sustainability. The methodology employs two distinct time series forecasting approaches: the traditional statistical ARIMA model and the modern machine learning-based Prophet model. The study utilizes an 80-20 train-test split to evaluate performance metrics, including Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE). The comparative analysis reveals that the Prophet model significantly outperforms ARIMA across all three datasets, offering narrower uncertainty bands and better handling of seasonality and non-linear trends inherent in Türkiye's energy data. The forecasting results present a striking outlook for the next three years. While electricity consumption is projected to grow annually by approximately 4.39%, electricity generation is expected to increase by 6.03%, suggesting a potential easing of supply deficits. However, the study uncovers a critical sustainability challenge: coal production is forecast to rise by a substantial 10.96% annually. This finding highlights a persistent dependency on fossil fuels, which contradicts global decarbonization goals. The research concludes that while Türkiye is expanding its generation capacity, the qualitative transition to renewable sources lags behind quantitative growth. These insights provide policymakers with actionable data to prioritize renewable investments and energy efficiency action plans, ensuring that future energy security does not come at the expense of environmental sustainability.

Keywords: Energy forecasting; ARIMA; Prophet model; Türkiye; Sustainability.

From National Technology to a Sustainable Future: Energy and Environmental Management with Autonomous Area Scanning Drones

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Abstract

Fires that we frequently encounter in daily life and that seriously affect both human life and nature. Despite the efforts made in our country to fight fires, uncontrolled forest fires still cause significant damage. Forest fires are among the most destructive consequences of these events, as they threaten not only human life but also natural ecosystems. The burning of forests reduces oxygen levels in the atmosphere, harms the ozone layer, and leads to the loss of plant and animal life in the affected areas. To reduce these negative effects, the technologies developed in our country mainly focus on early detection and rapid response. Firefighting helicopters are a well-known example of this approach**.** In the same context, the DronATK project was developed as a drone-based system to detect forest fires at an early stage and to quickly assess the size of the affected area. The drone is controlled by a KK2 flight controller, which helps maintain balance by sending appropriate signals to the motors. This controller also allows different flight modes to be selected. In this study, the quadcopter X mode was preferred because the drone has an X-shaped structure and uses four motors. For the propulsion system, 1000 KV motors and 30 A electronic speed controllers (ESCs) were used to keep the design simple and lightweight. Two-bladed 10×4.5 propellers were selected to ensure stable flight. Along with the flight system, a Raspberry Pi 3B+ was used for image capture and fire detection. By using the YOLO algorithm, the drone can detect fire areas in the images it captures and display them on the screen by marking the fire regions. The images are transmitted wirelessly via Wi-Fi. The system works with two separate power sources: one for the drone's flight components and another for the image processing unit. This separation increases reliability and allows the system to operate more independently. Overall, this study aims to draw attention to the effects of forest fires on both human life and natural ecosystems, while also presenting a practical and effective technological solution developed during the project.

Keywords: Drone; YOLO; Autonomous; Quadcopter x; Rasberry Pi.

Analysis of the Contribution of Vertical Façade Photovoltaic Applications to Rooftop PV Generation in İstanbul Using PVGIS-Based Simulation

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Abstract

In İstanbul, where urban development is characterized by high-density vertical growth, a significant portion of the existing building stock is not well suited for rooftop solar photovoltaic (PV) installations due to limited roof area, architectural constraints, and structural limitations. In contrast, building façades represent a largely untapped resource for urban renewable energy generation, especially as the cost of PV technologies has declined substantially in recent years. This study aims to quantitatively assess the potential contribution of vertical façade-integrated PV systems to overall on-site energy production in the context of İstanbul, where tall and aging buildings dominate the urban landscape and usable rooftop surfaces are scarce. Using PVGIS-SARAH3 irradiance data, a three-year simulation (2021–2023) was conducted for the coordinates of Yıldız Technical University's Davutpaşa Campus. Two configurations were analyzed: (i) a 1 kW rooftop PV system oriented horizontally at 0° tilt, and (ii) a 1 kW vertical PV system mounted at 90° tilt facing the South–Southwest direction (azimuth: 45°). A system loss factor of 14% was applied to both configurations, and hourly irradiance-derived power values were used to calculate daily, monthly, and annual energy production. The results show that vertical PV systems can achieve remarkably high annual performance under İstanbul's climatic conditions, reaching 70.8% of the total annual production of the horizontal system. Over the three-year period, the horizontal installation produced 3572.2 kWh, while the vertical façade system produced 2530.4 kWh. Notably, during winter months when solar altitude is lower, the vertical system occasionally outperformed the horizontal configuration. These findings indicate that vertical PV installations can play a significant complementary role to rooftop PV, particularly during autumn and winter, thereby contributing to a more balanced annual production profile. Given İstanbul's limited roof availability and high-rise urban fabric, these results provide strong technical motivation for incorporating façade-integrated PV into building energy strategies. In real applications, the ratio of rooftop to façade PV capacity will vary from building to building; thus, system design and investment decisions should be optimized according to architectural, orientational, and operational conditions. Fu-

ture research may include long-term experimental measurements at similar coordinates to validate simulation outcomes and extended simulations involving multi-aspect façade orientations. Such investigations would enable the development of a practical dataset for comparing real-world deviations from modeled performance.

Keywords: BIPV; Vertical PV; Façade photovoltaics; PVGIS; Micro-grid.

New Legal Approaches for the Sustainable Development Some Theoretical Considerations

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Abstract

The international community has come to define sustainable development as a dynamic state of equilibrium between the environment, economy, and society. The Brundtland Commission defined it as meeting the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs. However, the growing needs and aspirations of humanity from generation to generation compel us to ask questions about the goals of sustainable development, its legal foundations, and the redefinition of ways to harmonise the relationship between humans and nature. The 2030 Agenda for Sustainable Development puts forward a broad and ambitious agenda for global action on sustainable development. But the scale and ambition of the Sustainable Development Goals (SDG) require innovation in development and innovation for development. That is why while the 2030 deadline for the SDG is fast approaching, international community needs a long-term vision, providing policymakers with insights that go beyond 2030 with planning for the challenges and opportunities that will arise after 2030. New approaches to Sustainable Development should focus on integrated, human-centered development and circular strategies, moving beyond basic environmentalism to include social equity and economic viability, emphasizing SDG, green innovation, empowerment of underrepresented communities, circular economy models, and strong partnerships for systemic change. All these aspects require new theoretical and legal foundations, particularly in international law. Therefore, the presented article presents new theoretical approaches and proposed de lege ferenda regulations in international law. Article shows key new approaches & concepts like: Human-Centered Development, Circular Economy Models, Green Innovation & Technology, Integrated Policy & Governance, Feminist Environmentalism, Partnerships & Multi-Stakeholder Collaboration, Empowerment of Underrepresented Communities and Experience of KiwiGrow. Methodologically, the article presents research conducted using the formal-dogmatic method, analysis of international case law, and case study analysis.

Keywords: Sustainable development; Human-centered development; Climate change; 2030 Agenda; KiwiGrow; Empowerment of underrepresented communities.

Intelligent Image Processing–Based Recognition System for Color-Coded Zero Waste Separation Units

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Abstract

The proper separation of solid waste at the source is one of the fundamental components of sustainable waste management and circular economy practices. However, user-related errors and insufficient monitoring mechanisms significantly reduce the effectiveness of color-coded zero waste systems. In this study, an image processing–based intelligent recognition system founded on an innovative smart block system design is presented for color-coded zero waste sorting units. Within the scope of the study, the mechanical and functional design of a modular and scalable smart block system has been developed, and the sensing and decision-making processes of the system have been completed using image processing algorithms implemented with the Python programming language. Through a camera-based image acquisition module, waste types and the corresponding color-coded sorting units are detected in real time, while feature extraction and classification processes are carried out using classical image processing techniques and machine learning–based methods. The system has been designed to operate robustly under varying lighting conditions and diverse user interaction scenarios.The developed innovative smart block system design will be implemented as a prototype within İstanbul Gedik University. The findings indicate that the proposed system contributes to increasing recycling efficiency, reducing waste contamination, and improving the sustainability performance of zero waste infrastructures. This study contributes to smart and sustainable waste management solutions by enhancing resource efficiency and reducing environmental impacts, particularly within the framework of SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

Keywords: Image processing; Smart waste management; Color-coded waste sorting; Sustainable development.

The Impact of Recycled Raw Material Usage on Process Capability and Energy Efficiency

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Abstract

Global climate goals and energy transition policies are compelling the manufacturing sector to shift from the traditional "take-make-dispose" model to circular economy principles. However, there is a prevalent concern in the industry that integrating recycled raw materials into production processes will compromise product quality and raise energy consumption due to processing difficulties. This study aims to analyze these concerns using statistical methods and machine learning algorithms based on real-time data obtained from Smart Manufacturing systems. A comprehensive dataset comprising various machine types, material categories, and production quantities was utilized in the study. Descriptive statistics, hypothesis tests (t-Test, ANOVA), and k-means Clustering, an unsupervised learning method, were applied to the data. Additionally, machine-based Statistical Process Control (SPC) charts were generated to measure the stability of the production process against raw material variability. The research findings revealed no statistically significant correlation between the rate of recycled material usage and the defect rate. Machine-based P-Control charts confirmed that production lines utilizing recycled materials remained within control limits, exhibiting a stable process behavior. The most striking result of the study emerged from the k-means analysis: The cluster with the highest recycling rate (34.3%) was found to have a lower defect rate (2.52%) compared to the cluster using almost exclusively virgin raw materials (0.6% recycled, 3.77% defect rate). These results demonstrate that processes managed with Industry 4.0 principles exhibit high robustness against raw material variability. The study statistically validates that businesses can successfully implement "Green Manufacturing" strategies without compromising quality standards or energy efficiency, proving that sustainability is not an operational risk but a manageable process.

Keywords: Sustainable manufacturing; Energy efficiency; Recycling; Industry 4.0; Statistical process control (SPC); K-means clustering.

Qualitative Investigation into the Impact of Sustainability Activities of Publicly Traded Professional Sports Clubs on University Students' Perceptions of Corporate Reputation: The Case of İstanbul Gedik University

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Abstract

The present study aims to examine university students' levels of interest and awareness regarding the sustainability activities of publicly traded professional sports clubs and to reveal the effect of these activities on students' perceptions of corporate reputation. The population of the study consists of students at İstanbul Gedik University. Adopting a qualitative research approach, the study focuses on determining the extent to which students who support a professional sports club are informed about the sustainability activities of the clubs they support and how these activities shape their perceptions of the clubs' corporate reputation. The research data were collected through in-depth interviews. In this context, the primary data source comprised İstanbul Gedik University students who stated that they support a professional sports club, with particular emphasis on members of sports-related student clubs operating within the university. Participants deemed appropriate to represent the research population were selected using a random sampling method. Data were gathered through in-depth interviews conducted with a semi-structured interview form. The qualitative data obtained from the interviews were subjected to content analysis. During the analysis process, participants' statements were classified and interpreted within the framework of themes and sub-themes. Throughout the interview process, students' awareness of the sustainability activities carried out by professional sports clubs, their level of interest in these activities, the meanings they attribute to the concept of sustainability, and their knowledge regarding the environmental, social, and governance practices of the sports clubs they support were examined. In addition, the study evaluated whether sustainability activities have an impact on students' perceptions of the corporate reputation of the sports clubs they support.

Keywords: Strategic management; Corporate reputation; Sustainability management; Sport management and policy.

Who Governs Water in the 21st Century? Comparing the United States, Türkiye, and the European Union

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Abstract

Water scarcity is no longer a distant risk of the 21st century. Climate change, recurrent droughts, and increasing agricultural and industrial demand are placing unprecedented pressure on freshwater systems. These actions show the structural limits of existing legal frameworks. As water stress intensifies, the way legal systems allocate authority over water resources has become central to sustainability and environmental protection. This contribution looks at water governance in the United States, Türkiye, and the European Union. It compares how each system approaches power, property, and sustainability in the regulation and management of water resources. In the United States, water allocation is mainly handled at the state level and shaped by a mix of legal traditions, including riparian rights, prior appropriation, and various hybrid arrangements. Türkiye follows a more centralized path, placing all waters under state control as part of a public ownership system tied to sovereign authority. The European Union takes a different approach altogether, as they rely less on property-based allocation and more on regulatory coordination, with environmental objectives structured around the Water Framework Directive. Looking across these systems, it becomes clear that each runs into structural limits as climate change intensifies. In the United States allocation offers stability and legal certainty, but it often proves slow and inflexible when water shortages persist. Türkiye's centralized system allows for broad planning and national coordination, yet it tends to limit accountability as well as meaningful public involvement. The European Union's regulatory approach places stronger emphasis on ecological protection, but its success depends heavily on how consistently member states implement these rules. Taken together, these experiences suggest that no single model is sufficient on its own. Managing water under conditions of scarcity increasingly requires governance arrangements that are adaptive, participatory, and capable of treating water as a shared and finite resource.

Keywords: Water governance; Comparative law; Prior appropriation; Riparian rights; Public ownership; Sustainability; Climate change; Türkiye; United States; EU.

A Brief Analysis of Türkiye's Climate Law in Terms of Sustainabilitiy and Renewable Energy Policies

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Abstract

The Climate Law was recently adopted and came into force in Türkiye. Many provisions have been the subject of public debate both during the preparation of the law and after its entry into force. However, the scope of this study is limited to assessing the law in terms of sustainability policies, energy efficiency, and the shift towards renewable energy sources. In terms of sustainability, it must be stated that the decarbonisation target for energy use and the policies developed for alternative and renewable energy sources have once again highlighted the importance of legal regulations at international and national levels. The international regulations that have been and will be implemented in this context undoubtedly constitute an area of international law. However, the same approach should be considered for the European Union, as it is a supranational organisation. This is because the EU's legislation contains additional regulations on sustainability and renewable energy sources to combat climate change and global warming, in addition to international legal regulations. Therefore, given that Türkiye is a candidate country on the path to EU membership, its sustainability and renewable energy policies and legal regulations must be evaluated not only at the national level, but also in terms of international law and EU law. One of the main reasons why the European Union (EU) priorities renewable energy policies is its reliance on imported energy. To this end, the EU has issued numerous regulations and directives urging member states and candidate countries to shift towards renewable energy sources and encouraging them to take action. The legal standards established by these measures play an important role in achieving objectives such as shifting towards renewable energy, ensuring energy supply security, increasing efficiency and protecting the environment and nature. Within the scope of energy policy, Türkiye has developed a number of primary and secondary legal regulations concerning the use of alternative and renewable energy sources. However, looking at the adopted climate law, the concept of renewable energy is only mentioned in one place. In its current form, the climate law is inadequate and insufficient regarding renewable energy and sustainable, environmentally and nature-friendly development goals. This also creates a risk of negatively impacting Türkiye's EU accession process. Climate law raises concerns regarding the country's compliance

with its international and EU legal obligations, particularly regarding sustainability and renewable energy, as well as more broadly in terms of combating global warming and climate protection. These issues form the main focus of this paper.

Keywords: Climate law; Global warming and climate change; Renewable energy; Sustainability and Türkiye's obligations; The energy chapter in EU–Türkiye relationships.

An AI-Based Venture Readiness and Innovation Maturity Assessment System for Entrepreneurship

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Abstract

Innovative entrepreneurship plays a critical role in transforming creative ideas into sustainable and scalable business ventures. However, one significant challenge for entrepreneurs is the lack of systematic, objective, and data-driven tools to evaluate a venture idea throughout its lifecycle, from the initial idea stage to firm formation. Existing tools, such as business model canvases, business plans, and feasibility studies, are generally static, fragmented, and dependent on subjective assessments, which limits their effectiveness in guiding entrepreneurial decision-making. To address this gap, this study proposes an AI-based Venture Readiness and Innovation Maturity Assessment System to measure and support holistic innovation processes. The proposed system integrates artificial intelligence techniques with multi-criteria decision-making approaches to evaluate entrepreneurial ventures across multiple dimensions. These dimensions include idea and innovation quality, business model maturity, market and financial feasibility, team and execution capability, and overall venture readiness level. Natural language processing techniques analyze textual inputs, such as business model canvases, business plans, and feasibility reports, while a scoring engine generates quantitative readiness and maturity scores. The system dynamically identifies critical gaps, risk areas, and improvement priorities, and provides AI-driven recommendations to support venture progression. Unlike existing tools, the proposed model introduces a structured Venture Readiness Level framework that tracks a venture's evolution from idea generation to company establishment. This enables continuous monitoring of entrepreneurial development and supports evidence-based decision-making for entrepreneurs, incubators, investors, and innovation support organizations. The findings suggest that the proposed system offers a scalable, objective approach to assessing innovative entrepreneurship, while providing a technically grounded foundation for future software-based implementations and intellectual property protection. The study contributes to the literature by integrating artificial intelligence, innovation management, and entrepreneurship evaluation within an integrated decision-support framework.

Keywords: Innovative entrepreneurship; Artificial intelligence; Venture readiness; Innovation maturity; Decision support systems.

Machine Learning-Based Passenger Demand Forecasting for Sustainable and Energy-Efficient Smart Transportation Systems in İstanbul Rail Systems

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Abstract

The aim of this study is to establish a high-accuracy prediction model by enriching the transit data from İstanbul's rail systems between 2022 and 2024 with meteorological and historical factors. Within the scope of the study, station-based passenger transit counts were modeled using Random Forest, XGBoost, and LightGBM machine learning methods. As a result of the experimental analyses, Random Forest showed the highest performance compared to other models, with an R2 value of 0.996, an RMSE value of 519.0, and an MAE value of 253.0. In the study, external factors such as daily rainfall amount, sunshine duration, and cloud cover duration are used along with calendar data such as holiday-workday and weekday-weekend to determine the system's busy and quiet days. This aims to optimize energy consumption efficiency and operational optimization by optimizing density, thereby achieving a more environmentally friendly urban planning approach.

Keywords: Innovative entrepreneurship; Artificial intelligence; Venture readiness; Innovation maturity; Decision support systems.

Minimalist Packaging Design: Sustainability-Focused Material and Design Decisions

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Abstract

Packaging design serves multiple functions, such as enhancing visibility on shelves or interfaces and protecting the product. It is a complex design problem that directly connects to the environmental, economic, and social dimensions of sustainability through material choices, printing processes, logistical efficiency, and post-consumption scenarios. This paper aims to evaluate minimal packaging design (characterized by a limited color palette/single color, reduced ink usage, ample negative space, simple typographic hierarchy, and low visual intensity) within the context of sustainability. The discussion advocates for a holistic approach to sustainable packaging, arguing that it should not solely focus on the goal of "reduction." Instead, it should balance criteria such as product protection, distribution costs, market acceptance, and user-friendliness alongside environmental impact (Svanes et al., 2010). The literature indicates that perceptions of sustainability are shaped by both structural (material) and graphic (visual language) cues present in packaging, which can influence product evaluations and selection behavior (Steenis et al., 2017). In this framework, minimal design can be associated with practical benefits for environmental sustainability, such as reducing printing complexity, minimizing ink/color usage, and simplifying materials. In terms of social sustainability, it may enhance readability in information design, making content, usage, and disassembly instructions clearer. Furthermore, minimal aesthetics operate on a perceptual level: negative space can evoke associations of value and quality (Pracejus et al., 2006), and reducing design complexity may be linked to purity and willingness to pay for certain product categories (Ton et al., 2024). Additionally, visual simplicity can strengthen the perception of a brand as being more "authentic" (Wang et al., 2023). This paper presents a discussion framework by methodically gathering the conceptual framework of relevant literature, which connects minimal packaging decisions (color/ink density, typographic hierarchy, negative space, information density) with sustainability indicators. Ultimately, it emphasizes that the contribution of minimal packaging to sustainability cannot be reduced to merely achieving a "minimal appearance." Design decisions must be considered alongside considerations of function, life cycle, and verifiable claims of sustainability.

Keywords: Packaging design; Sustainability Communication; Minimal design; Negative space; Typographic Hierarchy; Greenwashing.

Comparative Analysis of Deep Learning Architectures for Thermal Image-Based Anomaly Detection in High-Voltage Equipment

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Abstract

Equipment used in electrical transmission and distribution systems may develop thermal anomalies over time due to continuous operating conditions, environmental effects, and load variations. These anomalies are early indicators of faults such as loose connections, phase imbalance, and insulation degradation, and if not detected in a timely manner, they may lead to equipment damage and risks to human safety. Traditional maintenance approaches are generally periodic and rely on operator experience, which makes them insufficient for early fault detection. Therefore, the combined use of infrared thermal imaging techniques, which enable non-contact measurements, and artificial intelligence-based automated analysis methods has gained increasing importance in recent years. In this thesis study, a deep learning-based decision support system was developed for anomaly detection in high-voltage equipment using thermal images. Within the scope of the study, a dataset consisting of thermal images of transformers and electric motors in a switchyard was prepared, and the images were labeled as normal and anomalous conditions. The dataset was divided into training, validation, and test subsets, and models were trained using different convolutional neural network architectures. The performances of ResNet, EfficientNet, ConvNeXt, and Vision Transformer-based models were compared using metrics such as accuracy, F1-score, and precision. In addition, hybrid classification approaches were evaluated by applying traditional machine learning methods, such as support vector machines and k-nearest neighbors, using deep features extracted from the most successful deep learning model. Experimental results showed that the ViT B/16 and EfficientNet-B0 hybrid model outperformed the other models with an accuracy of 96.04% and an F1-score of 0.9375. The fine-tuned ViT B/16 achieved higher performance than the hybrid model, with an accuracy of 97.03% and an F1-score of 0.9538. The best overall result was obtained using the fine-tuned EfficientNet-B0-based model, achieving an accuracy of 98.02% and a high F1-score of 0.9714. The obtained results demonstrate that artificial intelligence-based systems supported by thermal imaging provide an effective and practical solution for early anomaly detection, predictive maintenance applications, and the enhancement of operational safety in high-voltage equipment.

Keywords: Thermal imaging; Classification; Deep learning; Anomaly detection; Predictive maintenance.

Chemical Disruption of Saliva Buffer Systems and Resting Pulse Rate in Tobacco Users

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Abstract

The present study examined the biochemical effects of smoking on acid-base equilibrium and other physiological parameters in saliva among young adults. A total of 346 samples were tested, with 62% female and 53% belonging to the 21 to 30 years age group, and 57% were current smokers. Unstimulated saliva samples were carefully extracted under carefully standardized conditions to eliminate any external chemical factor that might otherwise affect saliva chemical composition. The pH value of saliva was determined using a calibrated digital pH meter to determine quantitatively the effectiveness of natural buffering systems in saliva, which are basically bicarbonate, phosphate, and protein buffers. The descriptive statistical methods used in this study were mean and percentage for the description of demographic variables, salivary pH measurements, and pulse rate measurements. The statistical test that was conducted on smokers and non-smokers in this research was the independent sample. The results showed that there is a lower salivary pH among smokers compared to non-smokers. The best salivary pH among individuals was achieved by 78 non-smokers, which was higher compared to 58 smokers.nWith respect to oral biochemical changes, heart rate was measured as a parameter for the degree of systemic physiological phenomena. Normal heart rate, at values from 60 to 80 per minute, has been observed in 48% for the non-smoker total population, but only in 34% for those who smoke, suggesting heightened stimulation for autonomic nerves because of systemic nicotine stress. The chemicals present in tobacco smoke, which are acid, reactive oxygen, and nicotine, alter ionic values and bicarbonate-based neutrality reactions in saliva, causing saliva to be more acid and disturbing pH homeostasis. Systemic physiological phenomena are strongly influenced by smoking and alter pH values and buffering capacities in saliva. The results show how strongly smoking impacts saliva acid-base changes and how strongly systemic physiological phenomena are influenced. Prevention is again emphasized because smoking cessation is reinforced, and this is for maintaining oral and biochemical homeostasis among youth and adults.

Keywords: Saliva pH; Nicotine; Pulse rate; Buffering systems: Adults.

Hydration, Educational Level, and Body Mass Index: Gender Differences in Water Consumption

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Abstract

Hydration has become more visible as a determinant in body weight management, yet the mediator effect between hydation and Body Mass Index has remained unexamined. This study analyzed the impact of daily water intake on BMI with respect to stratification by sex, education, and BMI groups to determine their effect on 346 adults. Participants were categorized on the bases of sex, education level, BMI, and individual water intake on a day-by-day level, which included hydation level on three categories: low, moderate, and high, in addition to BMI, which was calculated using formulae. In this study, 60% of participants had normal BMI, 26% were overweight, 8% were obese, and 6% were underweight. Also, 35% of the participants were reported to drink 3-5 glasses, 29% drank 6-8 glasses, 21% drank more than 8 glasses, and 15% drank less than 3 glasses, indicating the study participants' lack of proper hydation. Most participants were highly educated, with 171 females and 113 males possessing a Bachelor's degree, 30 females and 8 males possessing a postgraduate level, 11 females and 9 males possessing secondary education, and 1 female and 1 male possessing vocational education. In the postgraduate level, 50% females drank 3–5 glasses of water, with 30% consuming 6-8 glasses, in contrast to 37.5% men in both groups, respectively. In the secondary education level, 41.7% females drank 3-5 glasses with no consumption in 6-8 glasses, in contrast to 25% men in 3-5 glasses, with 33.3% in 6-8 glasses. These results draw attention to the co-existence of undernourishment and overnutrition and the need for gender-sensitive and education-sensitive strategies in the field of public health to promote healthy weight and hydration.

Keywords: Body mass index; Water intake; Education level; Gender differences; Nutritional status.

Machine Learning-Based Smart Agriculture System

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Abstract

Global climate change and increasing food demand necessitate resource efficiency in agricultural production. Therefore, the integration of IoT and AI technologies into modern greenhouse cultivation becomes a critical activity. However, the raw data obtained from sensors within greenhouse environments may be inconsistent due to environmental noise, hardware drift, and transmission errors. These may lead to erroneous decisions by automation systems and result in resource wastage. In this project, a hybrid decision support system that combines the Kalman Filter with machine learning algorithms for improving the accuracy of greenhouse microclimate parameters like temperature, humidity, light, and CO2 to optimize resource usage was proposed and developed. For this project, instead of directly sending the gathered environmental data with Arduino-based sensor nodes via LoRa communication infrastructure to the control mechanism, this data was passed through a data refinement layer. The instantaneous noise in measurements was minimized, and data stability was ensured using the Kalman Filter, as has been suggested in sensor data fusion approaches. Refined data were fed as input to an AI model trained for generating control commands for irrigation, ventilation, and lighting in optimizing the plant growth pattern. This approach is to reduce plant stress and increase productivity by offering greater precision than the traditional water-energy management technique of operating either above or below given thresholds. The results of this study indicate that the proposed system improves sustainability and automation reliability in agricultural production, even in the event of data loss or sensor error.

Keywords: Smart greenhouse; Kalman filter; Artificial intelligence; IoT; Precision agriculture; Data validation.

Political Energy Cycles: Ideology-Conditioned Electoral Returns of Renewable Energy Policies in Scandinavian Democracies (1980–2024) Machine Learning-Based Smart Agriculture System

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Abstract

This study investigates whether renewable energy policies generate electoral returns and whether these effects vary systematically across parties' ideological identities. While the political business cycle and environmental policy literatures increasingly recognize energy transition as a strategic policy domain, empirical evidence on its electoral consequences remains inconclusive. This paper argues that renewable energy policies do not produce homogeneous and direct electoral returns on their own; rather, their political effects are conditioned by ideological party families. In this context, the study introduces the concept of Political Energy Cycles (PEC), which conceptualizes energy policies as being transmitted to voter behavior through ideological filters rather than through uniform policy effects. Using party-level data from Denmark, Norway, and Sweden, the analysis employs a three-stage linear modeling strategy estimated with robust standard errors. Model 1 examines the direct relationship between renewable energy consumption and vote shares, showing that energy policies alone do not generate statistically significant electoral gains. Model 2 incorporates ideological party families and left–right ideological positioning, revealing that electoral outcomes are largely structured by ideology rather than by energy policy variables. Model 3, which constitutes the core empirical contribution of the study, introduces interaction terms between renewable energy consumption and ideological party families. The results demonstrate that renewable energy policies generate vote gains for some ideological party families, while producing neutral or even vote-losing effects for others. The models further control for economic growth, population size, electricity production dynamics, and energy import dependence to account for broader macroeconomic and structural conditions. The findings suggest that energy transition becomes electorally meaningful only when renewable energy policies are aligned with parties' institutionalized ideological identities. By framing energy policies not as a homogeneous public policy domain but as an ideologically conditioned dynamic political cycle, the study extends the political business cycle literature into the field of energy politics. The proposed PEC framework offers a novel perspective for explaining why similar renewable energy policies lead to divergent electoral outcomes across parties and countries.

Keywords: Political energy cycles; Renewable energy; Voting behavior; Party ideology; Scandinavia.

Theoretical Investigation on Reducing Carbon Emissions in Combi Boilers: The Potential of Quicklime Filtration

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Abstract

In this study, a theoretical method is proposed to reduce carbon dioxide emissions generated by combi boilers used in domestic heating systems. The focus of the study is to capture carbon dioxide molecules using calcium oxide filters installed in combi boiler's flue outlets. Quicklime reacts with carbon dioxide, forming calcium carbonate as the resulting compound. This methodology enables both to reduce the carbon dioxide emissions and eco-friendly reusing of wastes. During the case of study, the existed literature has been conducted, the pros and limits of the method has been examined. In this study, the research problem was investigated through a comprehensive review of the existing literature. Relevant studies were systematically examined in order to identify the main characteristics, advantages, and limitations of the proposed approach. The analysis was conducted at a theoretical level, without performing experimental measurements or simulations. Therefore, the outcomes of this study are limited to qualitative evaluations based on previously published data. Nevertheless, the findings indicate that the approach discussed in this research has potential applicability, and future experimental or numerical studies are required to quantitatively assess its performance.

Keywords: Combi boilers; Carbon dioxide capture, Calcium oxide; Carbon capture; Domestic heating.

The Role of Local Governments in the Field of Renewable Energy: An Example of Gaziantep Metropolitan Municipality

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Abstract

Türkiye has long been a country that meets its rapidly increasing energy demand predominantly through external sources. This high dependence on energy imports not only heightens economic vulnerabilities and deepens the current account deficit but also creates significant risks for national energy security. Moreover, fossil fuel–based energy production contributes to rising greenhouse gas emissions, posing a major threat to environmental sustainability. For these reasons, increasing the share of renewable energy sources has become one of the strategic national priorities in Türkiye energy policies. In this context, the role of local governments in the field of renewable energy has gained increasing importance. The Gaziantep Metropolitan Municipality has implemented renewable energy power plant investments with a total installed capacity of 47.5 MW to reduce energy dependency and ensure environmental sustainability. Within the scope of the project, solar power plants (SPPs), biogas facilities, and cogeneration units at waste management plants stand out; and an integrated circular economy model is applied that links municipal waste management policies with energy production processes. This approach not only reduces the environmental impact of waste but also contributes to local energy supply security. The case of Gaziantep demonstrates that local administrations in Türkiye can act as key drivers in the national energy transition. The municipality's renewable energy investments provide significant long-term benefits, such as reducing energy costs, lowering the carbon footprint, and supporting local economic development. Additionally, such projects foster a culture of energy efficiency and environmental awareness within the community. In conclusion, the Gaziantep Metropolitan Municipality's 47.5 MW renewable energy investment represents a model example that strengthens Türkiye's energy supply security, supports environmental sustainability, and highlights the potential role of local governments in the energy transition.

Keywords: Energy policies; Energy transition process; Renewable energy sources.

Conceptual Model of Distributed Motion and Conditional Continuity

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Abstract

This study introduces a conceptual framework aimed at interpreting motion continuity, distributed energy transfer, and coordination within open systems through a paradox-inspired perspective. The framework is illustrated by a metaphorical model in which a moving entity progresses continuously along a fixed trajectory without generating motion autonomously, instead advancing through successive external contributions. While each contribution provides only a finite displacement, their uninterrupted sequence results in the appearance of sustained and potentially unbounded motion from the internal frame of reference. The proposed model demonstrates that continuous motion does not require an internally self-sufficient energy source, but may emerge from coordinated external inputs operating within an open system. Under this interpretation, continuity is not an intrinsic property of the moving entity but a relational outcome of systemic organization. Motion persists not due to energetic autonomy, but because the surrounding structure enables ongoing transfer, compensation, and replacement of contributing elements. Beyond its physical interpretation, this framework also offers philosophical and ethical implications regarding participation within complex systems. Individual contributors play limited yet essential roles in maintaining continuity, illustrating how localized actions gain significance through their integration into a broader structural process. Importantly, continuity in this context does not depend on intentional agency or moral motivation, but arises from structural necessity and cooperative alignment within the system. As a conceptual model, this work provides an intuitive basis for understanding how apparent persistence and endurance can arise without violating fundamental physical principles. It emphasizes the role of distributed support, coordination, and relational dynamics in sustaining motion-like phenomena across physical, biological, and technological domains. The framework thus serves as an explanatory foundation for broader theoretical discussions concerning conditional persistence, energetic interaction, and the relational nature of motion.

Keywords: Conditional motion framework; Distributed energy dynamics; Energy transfer metaphor; Systemic continuity model.

A Sustainable Hybrid Thermal Management System for Lithium-Ion Batteries Using Phase Change Material, Liquid Cooling, and Thermoelectric Modules

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Abstract

Rechargeable batteries play a critical role in the development of sustainable electric vehicle technologies by reducing fossil fuel consumption and carbon emissions. However, during high C-rate charging and discharging processes, heat generation resulting from ionic and electronic transport mechanisms causes severe thermal stresses within battery cells; this accelerates degradation, shortens cycle life, and increases safety risks. Therefore, an effective battery thermal management system is of great importance not only for performance and safety but also for environmental sustainability. In this study, a hybrid battery thermal management system integrating phase change material (PCM), liquid cooling, and a thermoelectric (Peltier) module is proposed. In the proposed design, the battery pack is encapsulated with PCM to suppress sudden temperature rises through latent heat storage, while heat is transferred to the liquid cooling circuit via cooling channels and fins embedded within the PCM. The temperature of the coolant is actively controlled by a Peltier-assisted heat exchanger that operates only under critical thermal conditions. The system was analyzed using ANSYS Workbench Fluent for 54 V $LiFePO_4$ batteries and a commercial CP14-71-045-L1-EP-W4.5 Peltier module under 10C fast-charging conditions. To evaluate the contribution of the Peltier module to the liquid cooling performance, separate analyses were conducted for a Peltier-assisted liquid cooling system and a liquid cooling system without Peltier integration, and the results were compared. The findings indicate that the Peltier-assisted system provides both faster cooling and an improvement in cooling capacity of up to approximately 10 °C compared to the conventional liquid cooling system. The results demonstrate that the proposed hybrid system offers a compact and energy-efficient solution with the potential to extend battery lifetime and mitigate thermally induced degradation under high charge and discharge conditions. In addition, it was determined that achieving homogeneous cooling requires not only cooling of the battery cells but also effective thermal management of the battery tabs.

Acknowledgements: This study was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) under Project No.1139B412302795.

Keywords: Battery thermal management; Hybrid cooling system; Phase change material (PCM); Thermoelectric cooling; Liquid cooling; Electric vehicles; Sustainability.

Life Cycle Assessment of Hybrid Rapid Tooling in Injection Molding: An Energy-Efficient Approach for Low-Volume Production

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Abstract

The goal of this research is to evaluate whether a hybrid Stereolithography Tooling system could provide a technologically and environmentally feasible option for sustainable tooling of small batch production of product prototypes and functional parts) in place of a typical CNC Machined Steel Mold. The goal of this research is to eliminate the high cost and long production delays associated with the creation of CNC Machined Steel Molds, by proposing a method that combines High-Temperature Resistant Photopolymer Inserts placed inside a conventional Steel Frame. By combining these two technologies, we can provide a High Precision Injection Molding system for producing Small Batch Products and Functional Prototypes. The preliminary results of our research indicate that Hybrid Tooling may reduce the time required to fabricate a mold from several weeks to only a few hours, and the overall initial capital costs for manufacturing and hardware associated with Hybrid Tooling could be reduced by approximately 70% to 80% when compared to Conventional Steel Mold production methods. Based upon this initial LCA assessment, the preliminary conclusions are that for small production runs, Hybrid Tooling made using SLA technology has a lower Environmental Impact than Conventional Steel Molds because of the material waste that is eliminated through the use ofAdditive Manufacturing Technology. In addition to these initial findings, further analyses have led us to explore the potential disadvantage(s) of lower thermal conductivity of thermal polymer inserts for Hybrid Tools in terms of increased cooling time when used to produce higher quantities of parts. Overall, the investigation into Hybrid Tooling will establish the methods by which Hybrid Tooling can be utilized as an environmentally friendly and economically viable means of supporting Small to Medium Enterprises (SMEs) or Managing Research and Development (R&D) activities associated with producing parts on a Small-scale level.

Keywords: Life cycle assessment (LCA); Sustainable manufacturing; Rapid tooling, Stereolithography; Energy efficiency.

Drinking Water Treatment Plant for Educational Purposes

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Abstract

This study presents an educational water purification system designed to allow students to learn about drinking water treatment processes through hands-on experience. Water is an indispensable resource for sustaining life. However, access to clean drinking water is becoming increasingly difficult due to the growing population, industrialization, and environmental pollution. This situation increases the importance of drinking water treatment processes, both technically and educationally. This project aims to develop an educational drinking water treatment plant where students can learn about the stages of drinking water treatment through practical applications. Within the scope of the project, the basic processes found in a real treatment plant have been implemented on a small-scale and safe model. Through this project, students can design and implement an exemplary drinking water treatment plant suitable for educational settings and observe the water treatment process on-site, understand the importance of water resource conservation and clean water for human health, and develop scientific thinking skills. This plant is a small-scale model of a real treatment system. The project is designed to allow observation and implementation of fundamental processes such as aeration, sedimentation, sand filtration, and chlorination. It will contribute to students' ability to translate theoretical knowledge into practice, understand the importance of water for life, and gain environmental awareness. Furthermore, the project aims to raise awareness of environmental and water management issues in schools and to establish a model application laboratory for students interested in pursuing a career in this field. In this respect, the study provides not only scientific but also educational and social benefits. Finally this project experimentally demonstrate how water purification systems work and their physical and chemical principles; to teach the effects of clean drinking water on human health and to show the harms of contaminated water; to ensure that this model becomes a permanent educational material that can be used in different schools in the future; and to teach students the stages of the drinking water purification process (aeration, sedimentation, filtration, chlorination) through practical application.

Keywords: Purification water; Energy; Sustainability; Water purification.

Development of a Knee-Controlled Bionic Lower Limb Prosthesis with A Novel Control Algorithm

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Abstract

Transfemoral lower limb amputation significantly disrupts natural gait mechanics, leading to increased energy consumption, reduced stability, and limited mobility during daily activities. Although powered and bionic knee prostheses have been developed to address these challenges, many existing solutions depend on high-cost actuators, complex sensor configurations, and computationally intensive control strategies, which restrict their accessibility and practical implementation, especially at the prototyping level. This study presents the development of a low-cost bionic knee control system intended for a transfemoral lower limb prosthesis, with an emphasis on simplicity, real-time operation, and experimental feasibility. The proposed system employs a potentiometer-based knee angle measurement and foot-mounted force-sensitive resistor or button sensors to identify gait events, avoiding the use of advanced biosignal-based sensing approaches. A Finite State Machine (FSM) framework is implemented to divide the gait cycle into four fundamental phases: heel contact, stance, push-off, and swing. Transitions between these phases are determined directly from sensor inputs, enabling phase-dependent knee control. Knee actuation is achieved using a stepper motor, while a PID control algorithm is employed to ensure stable and accurate tracking of target knee angles. The control system is implemented on an Arduino Mega microcontroller and integrated with a stepper motor driver to provide reliable, deterministic, and low-latency communication suitable for real-time control applications. The mechanical components of the prosthesis are manufactured using 3D printing techniques to support rapid prototyping and cost reduction. System evaluation is conducted using a custom test setup and simulation environment rather than human trials, allowing safe analysis of motor torque response, gait phase transition behavior, and angle tracking performance. The proposed control architecture offers a practical and accessible solution for bionic knee prosthesis development and provides a solid foundation for future experimental validation and system expansion.

Keywords: Bionic knee prosthesis; Transfemoral amputation; Finite State Machine; PID control; Low-cost embedded system.

Predicting Student Academic Performance Using Machine Learning: A Case Study On Educational Data From Bangladesh Towards Sustainable Education (SDG 4)

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Abstract

Educational sustainability is a global priority. Because of the rapid digital transformation that we are seeing, it is necessary to integrate modern technologies to achieve inclusive, equitable, and high-quality education. Despite this, there is still a limitation in applying Machine Learning, as one of the modern technologies, to educational data within institutions. This research addresses this gap by providing practical evidence that predicting academic performance via Machine Learning is both achievable and highly effective. Two main objectives were generated from the main goal. The first one is to compare four ML models, while the second is to determine the most important factors affecting academic performance. To achieve the previous goals, the study used data from more than 8,000 secondary school students from Bangladesh. Based on the given dataset, students' academic performance was represented by the average grades of five common courses, where the study tried to predict it without relying on the existence of previous grades. The study depends on the contextual, behavioral, and other variables that are available in that dataset. Three of the models used were shallow: MLR, DT, and RF, while one was deep: Feedforward DNN. The whole process was implemented in the R environment, and the results revealed some interesting points. The shallow RF model was more accurate than the deep one with a small margin (R^2 = 93.3 vs. R^2 = 93.0). The most important factor affecting student performance is the student group (arts, commerce, or science), which dominated the predictive power of the models. Study time and attendance can also not be ignored as important behavioral modifiable factors. In addition to the results presented, this study contributes to educational sustainability by developing two Early Warning Systems (EWS): a simplified system for quick group screening and a full EWS for individual predictions. The results and the contributions of this study will help to find the most at-risk subgroups—particularly in the arts track—and allocate resources to provide proactive support based on modifiable behaviors or other factors. Ultimately, this research provides a scalable framework to enhance equity and efficiency in education. It is aligned with UN Sustainable Development Goal 4 (SDG 4): Quality Education.

Keywords: Educational sustainability; Machine learning; Early warning systems; SDG 4; Resource optimization; Academic performance prediction; Random forest; Regression analysis; Feature importance.

A Specialized K-Means Framework for Identifying Characteristic Energy Community Operation Scenarios Considering Distributed Generation from PV, Residential Consumption, EV Charging, Real-time Prices, and Grid Carbon Intensity

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Abstract

Realistic time-series profiles are critically needed in investigation of novel technologies for energy communities. Residential electricity consumption profiles, solar irradiation related to photovoltaic (PV) panels, hourly dynamic retail electricity prices, EV charging sections information and unit grid carbon intensity information are provided by different organizations with data and file format, different resolution and in different databases. It is a challenging for the researcher to determine representative scenarios that cover different cases in long term operation .This study proposes a generic specialized K-means clustering method to determine characteristically different energy community daily operation scenarios combining long-term data of local generation from PV, residential electricity demand of multiple houses, charging demand of EV with different brand and models, carbon emission rates of grid electricity mix and hourly retail electricity prices. Exploring different clustering options up to 10 clusters and using elbow method to select the most suitable cluster number. Each considered daily time-series profile ranging from 1 month to 1 year are clustered under 3 to 5 clusters. Each cluster represents 7 to 90 percent of the whole dataset. Each identified cluster can be represented by a single profile that is closest to the average values of the cluster. The developed method reduces time and effort for the long-term analysis by reducing the number of scenarios to be explored, still ensuring consideration of wide range of operational cases in the field. The representative single profiles for each cluster enables determination of wide range of replicable and scalable realistic scenarios in future studies that focus on energy community power and energy management solutions. The future work will be on multiple energy communities facilitation of synergies for power and energy management using distributed energy resources such as EV charger, PV panel smart inverter, batteries and flexible loads.

Keywords: Carbon emission; Distributed generation; Electric vehicle; Energy community; Real-time pricing.

Determination of Materials Used in Green Roofs in Sustainable Structures via Value Engineering Method

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Abstract

Global climate change and uncontrolled urbanization have compelled the construction industry to seek a challenging balance between environmental responsibilities and economic constraints. Emerging as a critical solution from this search, green roofs reduce the carbon footprint of buildings, mitigate the urban heat island effect, and ensure energy efficiency. However, they fail to achieve expected widespread adoption due to the prevailing perception of high initial investment costs in the sector and import dependent material solutions. This study aims to overcome this cost barrier and demonstrate the economic feasibility of green roofs by integrating Value Engineering methodology with Life Cycle Cost analysis. Within the scope of the research, a Shopping Center project with large terrace areas located in Balikesir province was selected as a case study. Three distinct scenarios were constructed in the study, which are the Conventional Roof representing the current market standard, the Standard Imported Green Roof based on common specifications in the sector, and the Optimized Local Green Roof developed using the value engineering methodology. During the function analysis and creativity phases of the Value Engineering Job Plan, a hybrid system was designed by substituting Balikesir Pumice, a rich local resource of the region, for imported plastic drainage plates and peat-based substrates, which increase system costs and have high logistics-based carbon emissions. The findings indicate that this hybrid system, optimized with local materials, achieved a 42 percent saving in Initial Investment Costs compared to the standard imported green roof. More importantly, the 40-year Life Cycle Cost projection revealed that, due to energy savings and the extended lifespan of the waterproofing, the proposed system is more economical than even the Conventional Roof, amortizing the initial investment difference within approximately 6 to 7 years. Consequently, this study demonstrates with concrete data that the Value Engineering approach transforms green roofs from an import dependent luxury option into a high value added, sustainable, and profitable engineering investment constructed with local resources.

Keywords: Value engineering; Green roof; Life cycle cost; Sustainability; Local material.

Autonomous Coastal Waste Detection and Localization Using UAV

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Abstract

Coastal pollution has become a critical environmental threat, necessitating efficient and scalable monitoring solutions. Traditional methods of coastal waste management often rely on manual labor or high-cost aerial surveillance equipped with specialized hardware. This study proposes an autonomous and cost-effective system for detecting and geolocating coastal litter using standard Unmanned Aerial Vehicles (UAVs) and deep learning. The primary objective is to identify various waste types, such as plastic, metal, and glass, from high-definition video feeds and map their geographical coordinates. While the system targets high-precision localization, the accuracy is inherently constrained by the drone's onboard GNSS module, resulting in a reliable positioning margin of approximately 3 to 6 meters. A key technical advantage of this system is its energy-efficient offboard processing architecture. By offloading the heavy computational requirements of the YOLOv12 deep learning model to a local workstation, the system significantly reduces the drone's power consumption, thereby extending flight endurance. The methodology utilizes a custom-developed synchronization module in Python to align video timestamps with UAV flight logs, ensuring effective data integration even with standard commercial drones like the DJI Mini 3. This approach eliminates the need for expensive onboard AI chips, making the system both financially accessible and operationally sustainable. Experimental results indicate that the system achieves a mean Average Precision (mAP50) of at least 0.65 and maintains over 90% accuracy in temporal synchronization. The output of the system is a comprehensive pollution heat map presented via a web-based dashboard, facilitating targeted waste collection for local authorities, municipalities, and NGOs. By minimizing human intervention and optimizing energy usage, this project offers a scalable solution for sustainable marine ecosystem management, aligning with national strategic goals for artificial intelligence and environmental protection.

Keywords: Coastal waste detection; Offboard processing; YOLOv12 object detection; Geospatial mapping.

Sustainability-Oriented Approaches in Geotechnical Engineering: A Conceptual Framework

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Abstract

In recent decades, accelerating urbanization on a global scale, expanding infrastructure investments, geo-hazards intensified by climate change, and the rapid depletion of natural resources have elevated sustainability to a central principle in engineering design and decision-making processes. As one of the core sub-disciplines of civil engineering, geotechnical engineering plays a decisive role in shaping the environmental, economic, and social impacts of infrastructure projects through its involvement in ground improvement, foundation systems, underground structures, waste management, and energy geotechnics applications. Within this context, sustainability in geotechnical engineering extends beyond the mitigation of environmental impacts to encompass a holistic approach that promotes resource efficiency throughout the life cycle, reduces ecological footprints, fosters climate-adaptive and resilient systems, and ensures long-term engineering performance. This paper aims to examine sustainability-oriented approaches in geotechnical engineering within a conceptual framework and to systematically review the methods, applications, and research trends that have gained prominence in the recent literature. To this end, a systematic literature review methodology is employed, and sustainable geotechnical engineering practices are discussed under four principal themes: carbon footprint and life cycle assessment-based analyses, the use of recycled and alternative materials in ground improvement techniques, energy geotechnics applications, including energy piles, geothermal foundations, and thermo-active structures, and climate-resilient geotechnical design and risk management approaches. The findings of the literature review indicate a clear transition from traditional design philosophies focused primarily on safety and serviceability toward multi-criteria, performance-based approaches that explicitly account for environmental considerations. In particular, integration of life cycle thinking into the geotechnical design process enables a quantitative comparison of environmental and economic differences among alternative solutions. Nevertheless, while recycled materials and biotechnical ground improvement methods offer substantial environmental benefits, uncertainties related to their long-term performance and field-scale implementation remain areas requiring further investigation. Meanwhile, energy geotechnics has emerged as one of the most innovative domains within sustainable geotechnical engineering, demonstrating that foundation

systems can function not only as load-bearing elements but also as components for energy generation and storage. Furthermore, studies addressing the effects of climate change on soil behavior emphasize that sustainability should be understood not merely as environmental impact reduction, but also as enhancement of long-term safety and resilience of infrastructure systems. In conclusion, this study presents sustainable geotechnical engineering within a comprehensive conceptual framework that integrates environmental, economic, and social dimensions with technical safety and performance criteria, aiming to provide a guiding reference for both academic research and engineering practice.

Keywords: Sustainable geotechnical engineering; Energy geotechnics; Ground improvement techniques; Climate-resilient geotechnical design; Low-carbon geotechnical materials.

Energy Transition Index and Renewable Energy Transition Process

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Abstract

Globally, combating climate change, strengthening energy supply security, and achieving sustainable development goals necessitate a fundamental transformation in energy systems. Indicators developed to measure the effectiveness of this transformation process and enable cross-country comparisons play a critical role for policymakers and researchers. The main objective of this study is to analyze global energy transition performance within the framework of the Energy Transition Index (ETI) developed by the World Economic Forum and to comparatively examine the renewable energy transition process across selected countries. The study aims to contribute to the literature by addressing energy transition not only through environmental impacts but also through economic efficiency, energy security, and institutional capacity dimensions. This study first examines the conceptual framework and calculation method of the Energy Transition Index in detail. It reveals that the ETI consists of two main components: "energy system performance" and "readiness for transition"; these components encompass numerous sub-indicators such as energy security, environmental sustainability, economic development, and the policy and investment environment. The research methodology is based on the analysis of Global Energy Transition Index data from 2019-2023 through secondary data analysis. In this context, comparisons between countries were made, differences in scores between country groups were analyzed, and the contributions of the index components to overall performance were evaluated. The findings show that, in general, high-income countries rank highly in the ETI ranking, but there are significant differences between countries in terms of the speed and structural depth of energy transition. Finland is among the leading countries in the index thanks to its high use of renewable energy, low carbon intensity, and strong institutional structure. The US, despite its advanced technological infrastructure and investment capacity, exhibits a more moderate performance due to high carbon emissions and limitations in policy consistency. China, while having made significant progress in energy supply security and renewable energy investments, struggles to approach the top group in the ETI ranking due to its dependence on fossil fuels.

Keywords: Energy transition Index (ETI); Renewable energy; Global energy transition; Sustainable energy policies; Carbon emissions.

The Role of Automation in Logistics Warehousing Processes on Occupational Accidents, Employee Health, and Human-Centered Sustainability

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Abstract

Sustainability, in its fundamental sense, refers to the capacity to endure continuously. Conceptually, it encompasses economic development achieved through rational use of limited resources—particularly natural resources—not only for the benefit of present generations but also future ones, while preventing waste and ensuring balanced growth. Although sustainability originally concentrated on environmental and ecological concerns, the concept has evolved into a tripartite structure consisting of economic, environmental, and social dimensions. The most recent and relatively underexplored layer within this framework—social sustainability—primarily emphasizes employee well-being, occupational health and safety, equitable working policies, workforce satisfaction, and community welfare. The sustainability of automation systems should be evaluated not only in economic terms, but also in terms of their environmental and social dimensions. Automation in logistics can contribute to environmental goals such as energy efficiency, waste reduction, and lower carbon emissions. Human-centered sustainability, emerging within this social component, introduces a contemporary lens that focuses on the preservation of employee health, the provision of ergonomically safe working environments, prevention of occupational accidents and diseases, and the psychological protection of workers. This research aims to illuminate the impact of warehouse automation systems on workplace accidents and occupational illnesses in logistics operations, while critically examining how automation investments contribute to employee well-being and workforce continuity. The future of sustainability will not be secured solely through environmental energy conservation; rather, it fundamentally depends on the physical and psychological resilience of the human body. No system can remain sustainable if the human body that sustains it collapses.

Keywords: Logistics; Automation; Occupational accidents; Employee health; Human sustainability.

A New Motion Intention Recognition Method Using IMU Sensor Data

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Abstract

Individuals who have experienced limb loss due to illness, accidents, or congenital conditions require prosthetic systems to perform activities of daily living. While conventional prosthetic devices provide basic functionality, they generally lack the ability to adapt effectively to the user's movements. For this reason, the development of artificial intelligence (AI)–assisted smart prosthetic systems has gained increasing attention. The realization of such systems requires continuous and accurate sensor-based motion data, as well as AI models capable of processing and interpreting these data. This study aims to develop an artificial intelligence model using acceleration and angular velocity data obtained from an Inertial Measurement Unit (IMU). The collected data will be used for motion intention recognition and processed using a deep learning–based approach. The proposed model is intended to enable prosthetic systems to respond to user movements more rapidly and accurately. The outcomes of this study are expected to contribute not only to the development of smart prosthetic devices for individuals with disabilities, but also to AI-supported exoskeleton systems applicable in industrial and medical domains.

Keywords: IMU; Motion intention recognition; Deep learning; AI-assisted smart prosthetic systems.

Machine Learning-Based Performance Prediction of Solid Oxide Fuel Cells Using Support Vector Regression with Radial Basis Function Kernel

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Abstract

Solid oxide fuel cells (SOFCs) are a popular energy source due to their high efficiency. Traditional analytical approaches struggle to predict SOFC performance. This study predicts SOFC performance metrics using Support Vector Regression (SVR) with a Radial Basis Function (RBF) kernel, utilizing cell voltage, power density, and efficiency parameters. In this study, a comprehensive dataset containing 1,770 valid data points was created using equations employed in the mathematical modeling of the solid fuel cell. This dataset includes operating temperature (873-1273 K), pressure (1-5 atm), fuel mole percentage (0.70-0.99), current density (100-20,000 A/m²), electrolyte thickness (5-200 μm), and electrode porosity (0.2-0.5). After training the SVR machine learning approach using 80% of the generated dataset, a 5-fold cross-validation was applied to the remaining 20% to evaluate the performance of the SVR-RBF model. The model's accuracy in predicting cell voltage was 0.0285 V, and the correlation coefficient (R^2) was calculated as 0.9907. Efficiency predictions reached an R^2 value of 0.9908 with an RMSE of 1.91%, while power density predictions produced an R^2 value of 0.9902 with an RMSE of 38.70 mW/cm². Based on all evaluation results, the model developed in this study was able to simulate the fuel cell very well with cross-validated R^2 values exceeding an average of 0.988. This study demonstrates that the RBF core is very good at identifying the complex interdependencies seen in SOFC systems and capturing nonlinear correlations between operational parameters and electrochemical performance.

Keywords: Solid oxide fuel cell; Support vector regression; Radial basis function kernel; Machine learning; Performance prediction; Electrochemical modeling.

Thermal Degradation Kinetics of Hazelnut Shell Biomass Based on TGA/DTG and Starink Analysis

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Abstract

Lignocellulosic fiber stands out as an acceptable energy source due to its biomass content and high carbon neutrality. Hazelnut shells, an abundant waste product from agricultural production, are an important raw material for thermochemical conversion. This study aims to investigate in detail the pyrolysis processes of the main biocomponents (hemicellulose, cellulose, and lignin) found in hazelnut shells. For this purpose, a three-stage decomposition approach in conjunction with the Starink isoconversion method was used. For the thermogravimetric analysis of hazelnut shells, a NETZSCH 449 F3 STA instrument was used for oxidation in an argon atmosphere. Non-isothermal pyrolysis experiments were performed with three different heating applications up to 800 °C (10, 20, and 40 K/min). With varying heating rates, model-independent isoconversion kinetics could be applied, thus enabling a more reliable calculation of the chemical activation energy depending on the reaction model. The obtained TGA and DTG curves were evaluated using the Starink method, which is considered more accurate than the classical Flynn-Wall-Ozawa and Kissinger-Akahira-Sunose methods due to its more precise approximation of the temperature integral. Using a triple parallel reaction model, the overlapping decomposition peaks of hemicellulose, cellulose, and lignin were separated. This allowed the derivation of separate "kinetic triple" values (activation energy Ea, pre-coefficient k, and reaction order n) for each product. The kinetic results show that the so-called components have different decomposition properties. Hemicellulose has the lowest activation energy due to its amorphous structure, high instability, and low decomposition point of its acetyl groups. Cellulose requires a moderate level of energy due to its β-1,4-glycosidic bonds and semi-crystalline structure. Lignin has the highest activation energy among the three. This is due to its complex, three-dimensional aromatic network structure and the significant amount of heat required to break the C-C bonds with the ether within it. Furthermore, the degradation of lignin over a wide temperature range already demonstrates this heterogeneous and stable structure.

Keywords: Lignocellulosic biomass; Hazelnut shell; Pyrolysis; Thermogravimetric analysis (TGA); Starink isoconversional method.

Support Vector Regression-Based Prediction of Syngas Composition from Biomass Downdraft Gasification

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Abstract

This study aims to develop and test a Support Vector Regression (SVR) based model to predict the composition of synthesis production obtained downstream of biomass gasification. In this context, a thermodynamic-kinetic model was constructed using Gibbs free energy minimization and Arrhenius-type reaction kinetics. The model utilizes thermochemical data obtained from NIST-JANAF tables and kinetic effects reported in the literature (Basu, 2010; Zainal et al., 2001; Giltrap et al., 2003). The gasification process was considered in four regions: drying, pyrolysis, combustion, and reduction; mass-energy balances were evaluated separately for each region. A dataset of 800 samples was created using this validated model. Here, biomass characteristics (carbon 42–55%, hydrogen 4.5–7%, oxygen 35–48%, matter 65–90%, moisture 5–20%) and operating conditions (temperature 700–1000 °C, equilibrium ratio 0.20–0.45, fuel feed rate 50–200 kg/h) are given. The SVR model was classified with radial basis core (RBF); C=100, epsilon=0.1 and gamma="scale" settings were used. The model was found to be quite successful in predicting synthesis gas emissions and some performance indicators. For carbon monoxide, the training R^2 value was 0.9937, the test R^2 value was 0.9703; and the crossover was 0.9681; for hydrogen prediction, the training R^2 value was 0.9934 and the test R^2 value was 0.9659. Carbohydrate values were calculated as 0.9931 and 0.9593. The training R^2 value for the cold gas yield of the model was 0.9931, and the test R^2 value was 0.9383; the lower calorific value of the gas was found to be 0.9935 and 0.9685. The test R^2 value reached 0.9764, showing one of the best values among the results obtained for the gas. The model predicted 14.75% CO, 15.56% H_2, 18.09% CO_2, and 51.65% N_2 on a dry basis in a repair scenario using wood pellets (C= 50.2%; H= 5.8%; O= 42.5%; LHV= 17.0 MJ/kg) at 850 °C and 0.30 equivalent ratio. The lower calorific value of the gas was found to be 3.56 MJ/Nm^3, and the cold gas yield was 42.5%. The H_2/CO ratio was 1.05, which is considered consistent with the ranges reported in downstream gasification systems under similar conditions. Overall, the results demonstrate that SVR is a useful method for predicting the composition of synthesis gas produced from biomass gasification.

Keywords: Biomass gasification; Downdraft gasifier; Support vector regression; Syngas composition prediction; Machine learning.

Assessment of Smart Grid Stability with LightGBM and Decentralized Control Modeling

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Abstract

One of the biggest challenges in ensuring grid stability is the integration of renewable energy into the existing electricity system. This study aims to predict smart grid stability using LightGBM. For this purpose, a DSGC (Decentralized Smart Grid Control) model consisting of 10,000 samples was used, and the features included response times (τ_1–τ_4), nominal power values (p_1–p_4), and price elasticity coefficients (γ_1–γ_4). Furthermore, the system was assumed to be a 4-node, star-type grid. A highly systematic approach, such as scaling with Z-score, was followed by performing a grid search to find the best hyperparameters. Five-fold cross-validation was analyzed to evaluate the model. The results of the study show that LightGBM achieved the following accuracy: 93.65%, sensitivity: 92.70%, recall: 89.50%, F1: 91.08%, and AUC-ROC (Area Under the Receiver Operating Characteristic Curve): 98.62%. A comparison was made with six different algorithms: XGBoost, Random Forest, Gradient Boosting, SVM, MLP, and the default LightGBM. MLP was found to provide higher accuracy rate (95.60%) compared to the other algorithms. However, this resulted in significantly longer training time. According to feature importance analysis, response times (τ) contributed the most with 54.9%, followed by price elasticity (γ) with 34.9% and power values (p) with 10.2%. This indicates that the dynamic behavior of the system is very decisive in stability.Statistical control was also founded using the McNemar test. According to this control, LightGBM was statistically almost the same as XGBoost and Gradient Boosting ($p > 0.05$), while it was significantly better than Random Forest ($p = 0.0002$). The proposed LightGBM approach impact a good balance between accuracy, speed (0.48 s training time), and interpretability. Therefore, it appears suitable for real-time smart grid stability monitoring. These findings also contribute to the body of knowledge in the field of smart grid management and could lay the groundwork for more proactive systems for stability control in the future.

Keywords: Smart grid stability; LightGBM; Renewable energy integration; Decentralized smart grid control (DSGC); Machine learning.

Digital Twin-Based Predictive Maintenance: A Comparative Analysis with Other Maintenance Approaches

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Abstract

Maintenance strategies in industrial systems play a decisive role in equipment reliability, operational continuity, and total cost of ownership. Among traditional maintenance approaches, preventive maintenance, based on predetermined time intervals, often fails to adequately reflect the system's actual operating conditions and can lead to unnecessary maintenance activities. This situation brings with it significant problems such as unplanned downtime, increased maintenance costs, and inefficient use of resources. In this study, the digital twin-based predictive maintenance approach is examined in comparison with preventive maintenance, proactive maintenance, and opportunistic maintenance strategies. Predictive maintenance aims to predict equipment failures before they occur, using real-time sensor data obtained from the system and condition monitoring techniques. This approach reduces maintenance frequency and extends equipment life by allowing maintenance activities to be performed only when needed. Preventive maintenance offers a planned approach aimed at reducing the likelihood of failure, but it can still be limited in terms of flexibility due to its reliance on fixed intervals. Opportunistic maintenance, on the other hand, allows for multiple maintenance activities to be performed simultaneously by evaluating planned or unplanned system downtime, but this approach is not as effective as predictive maintenance in terms of failure prediction. In this context, predictive maintenance offers a more proactive, data-driven, and adaptable structure compared to other types of maintenance. The study also evaluates the contributions of the digital twin concept to predictive maintenance processes. Digital twins, as dynamically updated models of physical systems in a virtual environment, enable real-time data integration and scenario analysis. This structure increases fault prediction accuracy, makes maintenance decisions more reliable, and allows maintenance strategies to be dynamically optimized. As a result, it has been demonstrated that the digital twin-based predictive maintenance approach offers significant advantages in terms of system reliability, cost-effectiveness, and operational efficiency compared to protective, preventive, and opportunistic maintenance strategies.

Keywords: Predictive maintenance; Digital twin; Maintenance strategies; Industrial systems.

Passive Energy Efficiency Strategies in the Conservation of Listed Historic Buildings in Türkiye: An Expert-Based Evaluation

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Abstract

Improving the energy performance of the existing building stock has become a central objective of the global energy transition agenda; however, this challenge is particularly multifaceted in the context of listed historic buildings in Türkiye. Such structures are primarily managed through conservation-oriented frameworks, including survey (rölöve), restitution, and restoration projects, where the preservation of cultural significance, material integrity, and architectural authenticity is prioritized. Within this legal and technical framework, energy efficiency considerations are generally treated as secondary and conditional measures, subject to conservation priorities and the approval of the Regional Conservation Boards for Cultural Heritage, rather than being systematically integrated into decision-making processes. Consequently, energy-related interventions in listed historic buildings require methodologies that are fully compatible with conservation principles and regulatory constraints, prioritizing passive, low-risk, and reversible strategies. This study focuses on passive energy efficiency strategies for listed historic buildings in Türkiye and examines expert perspectives within the scope of conservation and restoration practices. To this end, a structured questionnaire was administered to a diverse group of professionals involved in heritage-related decision-making, including architects, engineers, conservation specialists, and representatives of public institutions. The survey explores expert perceptions regarding the relevance, feasibility, and prioritization of passive strategies, such as thermal buffering spaces, enhancement of natural ventilation, daylight optimization, and building-compatible insulation approaches that do not compromise the original fabric of historic structures. The collected data are examined using descriptive and exploratory analytical methods to identify prevailing tendencies and shared viewpoints among different stakeholder groups. Preliminary evaluations suggest that passive and low-intervention strategies are widely perceived as appropriate means of improving energy performance, primarily due to their alignment with conservation ethics and their limited impact on heritage values. In contrast, more intrusive interventions tend to be approached with caution, reflecting concerns related to regulatory frameworks, material compatibility, and the risk

of irreversible change. These observations indicate that energy efficiency in the historic environment should be understood not merely as a technical challenge, but as a governance issue shaped by institutional roles and expert judgment. By highlighting expert-based evaluations, this study contributes to ongoing discussions on integrating energy efficiency into conservation-led processes for listed historic buildings.

Keywords: Listed historic buildings; Passive energy efficiency; Conservation; Energy transition; Expert-based assessment.

The Problem of Schematic Accuracy in the Visual Representation of Sustainable Energy Systems: A Comparative Analysis of Solar and Wind Energy

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Abstract

The transition to sustainable energy depends not only on technological advancements but also on the accurate communication of these technologies to the public and decision-makers. Today, solar and wind energy systems are predominantly represented through infographics and schematic visualizations. However, a significant portion of these visual representations excessively simplify the technical and physical complexity of energy systems, thereby weakening schematic accuracy and leading to misconceptions about energy processes. This study aims to comparatively examine popular infographics and scientific illustrations used in the visual representation of sustainable energy systems. The research is conducted through selected visual materials representing photovoltaic solar energy and wind energy systems. A comparative visual analysis method is employed, using schematic accuracy, proportional consistency, process continuity, visibility of energy losses, and the construction of causal relationships as the primary evaluation criteria. The findings indicate that popular infographics tend to depict both energy systems as linear, uninterrupted, and lossless processes, while system boundaries, conversion losses, and variability related to environmental conditions are largely excluded from visual narratives. Such representations present energy production as an automatic and problem-free process, rendering the technical constraints of the systems invisible. In contrast, scientific illustrations portray solar and wind energy systems as layered, condition-dependent structures that explicitly incorporate conversion losses. Semiconductor processes within photovoltaic cells, as well as aerodynamic and mechanical conversion mechanisms in wind turbines, are visualized within a clear cause–effect framework. The findings demonstrate that popular infographics weaken the epistemic integrity of energy knowledge in the name of pedagogical simplicity, whereas scientific illustration provides a more accurate, reliable, and critical mode of visual representation in sustainable energy communication. In this context, the study argues that visual materials used in sustainable energy policies and public awareness processes should be re-evaluated on the basis of scientific accuracy.

Keywords: XGBoost; Machine learning; Electrochemical modeling; Cell voltage prediction; Fuel cell.

XGBoost Machine Learning Approach for Proton Exchange Membrane Fuel Cell Performance Prediction

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Abstract

In this study, a hybrid approach to predict PEMFC cell voltage is developed by combining a physics-based electrochemical model with the XGBoost (Extreme Gradient Boosting) machine learning algorithm. The following components were considered together to implement this hybrid approach: Nernst-based thermodynamic equilibrium potential, Butler-Volmer activation kinetics, Springer membrane conductivity model, and concentration overpotential. To perform machine learning, a synthetic dataset consisting of 3000 samples with 13 input parameters was created using a physics-based approach, consistent with experimental ranges reported in the literature. These inputs include operating and material properties such as temperature, pressure, current density, membrane water content, membrane thickness, anode and cathode exchange current densities, transfer coefficients, limiting current density, and contact resistance. Model selection was performed using 5-fold cross-validation, and hyperparameter tuning for XGBoost was performed using Randomized SearchCV over 100 trials. In the test dataset, the XGBoost model produces very accurate predictions (R^2 = 0.9818). The mean absolute percentage error (MAPE) was calculated as 3.21%, while the root mean square error (RMSE) was found to be 0.0206. The cathode transfer coefficient (27.46%) and cathode exchange current density (10.13%) parameters confirm that the oxygen reduction reaction (ORR) is one of the key steps limiting PEMFC performance, and that optimizing the electrochemical processes on the cathode side should be a critical goal in future design and material development studies.

Keywords: XGBoost; Machine learning; Electrochemical modeling; Cell voltage prediction; Fuel cell.

Process Automation with a Corporate AI Assistant: Productivity and Sustainability Impacts of the Buddy Implementation

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Abstract

AI assistant Buddy, developed within Etiya, is a digital transformation initiative designed to increase operational efficiency by automating repetitive tasks in internal workflows, while concurrently enabling time savings and reducing energy consumption. Although training AI models requires computational infrastructure and entails energy use, the gains delivered by Buddy in terms of speed, error reduction, and automation capability create a long term effect that offsets this consumption and, in certain scenarios, can even compensate for it. Within this context, the project contributes to reducing the organizational carbon footprint and aligns with corporate sustainability objectives. Buddy also promotes employee engagement through its volunteer based approach, strengthening satisfaction and organizational commitment by making contributions and ideas more visible. Moreover, a democratic governance model ensures that decision making processes are conducted transparently, and that implementation and improvement activities are shaped by needs and feedback originating from the field. This governance framework positions the solution not only as a technical tool but also as a participatory mechanism for organizational learning and continuous improvement. Implementation outcomes indicate that Buddy has delivered an average productivity increase of 12 percent across the company by accelerating recurring work and integrating with existing sub systems to minimize errors in the software, analysis, testing, and operations departments. In the software development department, the largest unit in the organization, the use of coding assistants reduced the error rate by 4 percent and increased code production speed by 8 percent. In addition, the ai coder tool used for code review shortened review durations by 22 percent. In conclusion, Buddy represents an AI driven transformation example that enhances the effectiveness of business processes while remaining aligned with environmental and organizational goals, by combining measurable performance gains with sustainability contributions and a participatory governance approach.

Keywords: Corporate AI assistant; Process automation; Operational efficiency; Sustainability; Carbon footprint reduction.

Prediction of Syngas Composition from Updraft Biomass Gasification Using XGBoost

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Abstract

This study proposes a novel Extreme Gradient Boosting (XGBoost)-based machine learning framework for predicting syngas composition with high accuracy in updraft biomass gasification. In this study, a physics-based data generation model is developed that combines thermodynamic equilibrium principles with empirical kinetic corrections appropriate to the updraft gasifier behavior. The input parameters of the model are: The final biomass analysis components (carbon 38–54%, hydrogen 5–7%, oxygen 32–48%, plus nitrogen, sulfur, and ash content), proximate analysis data (volatile matter 60–88%, fixed carbon), moisture content (5–35%), equivalent ratio (0.18–0.45), and gasification temperature (750–1150 °C) are included as critical variables. The training data, consisting of 3,014 samples generated with this approach, was validated using 14 experimental data points compiled from peer-reviewed studies between 1988 and 2023. XGBoost models were trained with 5-fold cross-validation and hyperparameter optimization; High accuracy was achieved in predicting CO (R^2=0.985, RMSE=0.83%), H_2 (R^2=0.943, RMSE=0.81%), CO_2 (R^2=0.983, RMSE=0.53%), and CH_4 (R^2=0.976, RMSE=0.25%). In addition, strong predictive performance was reported for the lower calorific value of the gas (R^2=0.966), cold gas yield (R^2=0.915), and tar content (R^2=0.873). Model uncertainty was quantitatively assessed using bootstrap resampling (n=100), and 95% confidence intervals were generated for all outputs. Literature validation showed that the average absolute errors for CO and CO_2 remained below 1%. The developed XGBoost-based framework offers a computationally efficient tool that can quickly and accurately predict syngas composition in biomass gasification processes, suitable for use in sustainable bioenergy applications such as process optimization, techno-economic analysis, and gasifier design.

Keywords: Updraft gasifier; Syngas prediction; XGBoost; Machine learning; Thermodynamic modeling.

Impacts of Renewable Energy Systems on Urban Fire Safety

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Abstract

The development and widespread adoption of renewable energy sources provide significant conveniences and environmental benefits to daily life. New sustainable technologies such as solar energy systems, battery storage solutions, electric vehicle infrastructures, and charging stations offer substantial energy and environmental advantages in urban areas; however, they may also introduce new risks in terms of fire safety. In particular, the rapid energy transition in densely populated cities creates uncertainties in the integration processes with existing infrastructures and generates emerging fire-related risk types. To prevent and mitigate the impacts of potential fires caused by these systems, relevant legislation—especially fire and building regulations—must be updated in accordance with renewable energy technologies and their increasing complexity. In this regard, strengthening the regulatory framework, improving risk-based planning, adopting practical protective measures in engineering applications, enhancing emergency response capacity, and raising public awareness are of great importance for ensuring a safe and resilient energy transition aligned with the objectives of sustainable cities.The aim of this study is to comprehensively evaluate the impacts of renewable energy systems on urban fire safety. For this purpose, current scientific studies in the literature, international standards and regulations, as well as various case examples have been thoroughly examined. Additionally, how fire safety should be addressed within the framework of sustainable urban planning has been discussed as an important component of fire-resilient city strategies. The findings reveal that the transition to renewable energy contributes significantly to sustainability goals; however, the very rapid integration of these technologies into the urban fabric may occasionally lead to the safety aspect being overlooked. Therefore, in order to ensure long-term urban fire safety, the safety dimension must be addressed through a holistic approach during the planning, implementation, and operational phases of renewable energy technologies, and be effectively integrated into decision-making mechanisms and fire safety regulations.

Keywords: Urban fire safety; Renewable energy systems; Fire safety regulations.

Investigation of Chain Extender Effects on Recycled Polyamide 6.3 and Process Parameter Optimization

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Abstract

Polyamides are engineering thermoplastics that exhibit high mechanical strength, thermal stability, and wear resistance due to the presence of amide bonds in their main chains and the strong hydrogen interactions formed between these bonds. Although they are recyclable owing to their thermoplastic nature, repeated thermo-mechanical loads encountered during mechanical recycling processes lead to chain scission and a reduction in molecular weight. This structural degradation results in significant performance losses in the rheological, mechanical, and thermal properties of recycled polyamides. In the literature, the use of chain extender (CE) additives has been highlighted as an effective approach to mitigate these losses; such additives react with polyamide chain end groups, reorganize the chain architecture, and improve molecular-weight-dependent properties.

In this thesis, the reactive modification and optimization of recycled polyamide 6.3 (PA6.3) systems were investigated under different chain extender contents and processing temperatures (260, 270, and 280 °C). Virgin and recycled polyamide samples were prepared with varying additive ratios, and the resulting systems were evaluated using rheological, mechanical, thermal, and chemical characterization methods in a multidimensional manner. The results demonstrated that the recycling process led to an approximately 44–48% reduction in elongation at break and toughness. In contrast, optimization studies revealed that the combination of 2 wt.% CE and a processing temperature of 280 °C constituted the most successful modification condition, exceeding the performance of the original PA6.3 material in terms of maximum tensile strength and elongation at break. Overall, the integrated findings of this study quantitatively demonstrate that, beyond compensating for performance losses, the original material properties of recycled PA6.3 systems can be surpassed under appropriate modification conditions.

Keywords: Polyamide 6.3; Recycling; Chain extenders; Reactive extrusion; Rheology.

Energy and Exergy Analysis of Organic Rankine Cycles for Waste Heat Recovery in Heat Exchanger Networks

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Abstract

This study aims to optimally integrate Organic Rankine Cycle (ORC) into a Heat Exchanger Network (HEN) to increase amount of heat recovered and provide beneficial work output. ORC has the advantage of using organic fluids that has lower boiling temperature when compared to water, allowing them to be suitable for low temperature applications when compared to conventional Rankine Cycles. ORC is integrated into HEN as a bottoming cycle to provide heat recovery from below pinch temperature and reduce cold utility requirement of HEN superstructure while not increasing hot utility requirement of HEN cold streams. Producing work out of low temperature waste heat provides clean energy and reduces thermal pollution on the environment, therefore provides double benefit towards sustainability and optimal usage of system resources at expense of initial investment. Investment and operational costs are caused by additional heat transfer area of ORC evaporator and condenser while each ORC component also provides further cost and further complexity to the integrated superstructure. Energy and exergy analysis of various ORC schematics have been performed for different working fluids to point out advantages of each configuration for example problems. Comparisons with other studies have been presented while analyzing the exergy aspect to provide to the literature.

Keywords: Organic rankine cycle; Heat exchanger network; Waste heat recovery; Process optimization; Thermodynamic analysis.

Adaptive Droop-Controlled DC Micro Grid for Electric Vehicle Fast DC Charging with Photovoltaic Integration Under Partial Shading Conditions

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Abstract

The increasing penetration of high-power electric vehicle (EV) fast charging stations accelerates the demand for DC microgrid architecture, especially in applications that require high efficiency, flexible power sharing, and integration of renewable energy sources. This paper presents the modeling and control of a 120 kW DC microgrid-based EV charging system operating at an 800 V DC bus, integrating a grid-connected Vienna rectifier and a photovoltaic (PV) generation unit under partial shading conditions. The proposed system implements a 120 kW three-phase Vienna rectifier as a grid interface that regulates the DC bus voltage and supplies power to an EV charger operating in constant current and constant voltage charging modes. A PV source is interfaced to the DC microgrid through a DC-DC boost converter and is controlled as a power-injecting unit based on a maximum power point tracking algorithm. Partial shading impact simulation results are implemented on the PV system to introduce sudden and non-uniform variations in the available solar power to simulate practical scenarios. This paper introduces a droop control scheme that adapts to facilitate collaborative power sharing among the DC microgrid as well as DC bus voltage stability. The DC bus voltage regulation function, as part of the proposed control system, is performed by the Vienna rectifier, whereas the PV system supplies DC power to the DC grid as per the maximum power point tracking (MPPT) values without engaging with DC bus voltage control. This overcomes PV power reduction during tight DC bus voltage control and ensures proper utilization of the available PV output during EV charging applications. The overall DC microgrid with the Vienna rectifier, PV source, adaptive droop controller, and EV chargeable DC microgrid load is represented and simulated using a PLECS simulation platform. Simulation results verify stable DC bus voltage regulation, effective power sharing between grid and PV sources, and robust system performance under EV load transients and partial shading conditions. The presented architecture offers a practical and scalable solution for high-power DC EV charging stations with integrated renewable energy sources, which is well suited for future DC microgrid-based fast charging applications.

Keywords: DC microgrid; Fast DC EV charging; Adaptive droop control; Photovoltaic integration; Partial shading conditions.

Silicon Nanowire/Borophene Composite Gas Sensor for VOC Detection

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Abstract

Volatile organic compounds (VOCs) are chemicals that negatively affect indoor and outdoor air quality and can lead to serious health problems with long-term exposure. Formaldehyde, in particular, is known to pose significant risks to human health due to its carcinogenic effects, while cyclohexane is found in crude oil derivatives and cigarette smoke. Other types of VOCs, such as acetone, ethanol, chloroform, toluene, hexane, and isoprene, also have adverse effects on the respiratory system, nervous system, and liver. Reliable detection of these gases, even at low concentrations, is of great importance. Among the materials used in gas detection processes, silicon nanowires (Si nanowires) offer significant advantages due to their high surface-to-volume ratio, enabling effective adsorption of gas molecules onto the surface. The accumulation of charge throughout the volume of Si nanowires allows for rapid gas detection and a shorter sensor response time. However, to overcome the disadvantages of traditional metal-oxide semiconductor sensors, such as high operating temperature and limited selectivity, borophene, a two-dimensional material, stands out in the literature as a promising alternative with its strong surface activity and high electronic properties. In this study, it is predicted that a Si nanowire/borophene composite structure, created by modifying borophene with silicon nanowires, will provide higher charge transfer compared to Si nanowire-based structures and consequently improve VOC detection performance. In this composite structure, electron and hole migration occurs due to the p-n heterojunction formed between n-type Si nanowires and p-type borophene, leading to the expansion of the depletion region and a decrease in the conductivity of the sensing layer. Ultimately, the aim is to increase the sensitivity and detection stability of the sensor with the resulting structure. The sensor will primarily measure formaldehyde, a carcinogen or potentially carcinogenic chemical found in human breath, and cyclohexane, found in crude oil and cigarette smoke, as well as acetone, ethanol, chloroform, toluene, hexane, and isoprene gases. It is anticipated that the sensors produced will achieve detection limits at ppb levels at room temperature and response and recovery times within seconds.

Keywords: Urban fire safety; Renewable energy systems; Fire safety regulations.

Development of a Modular Test System for Gas Sensor Performance Analysis

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Abstract

Gas sensors may exhibit significant variations in performance parameters such as sensitivity, accuracy, response time, and long-term stability when exposed to different gas types and concentration levels. Therefore, evaluating sensor performance under repeatable and observable laboratory conditions is of great importance for both academic research and industrial applications. In this study, a modular, user-friendly, and low-cost gas sensing test system has been developed to investigate the detection performance of various gas sensors under different gas concentration conditions. The test system includes a sealed test chamber in which sensors can be exposed to predefined gas concentrations. During the testing process, ambient temperature and humidity values are continuously monitored to assess the influence of environmental conditions on sensor performance. This approach enables the evaluation of gas sensor sensitivity to environmental variations. After each measurement cycle, residual gas accumulated inside the test chamber is removed using a fan-based ventilation mechanism. This process helps restore the test environment to conditions close to the initial state for subsequent measurements. The performance analyses conducted using the developed system are critically important for a wide range of applications, including gas leak detection in smart building systems, monitoring of toxic and flammable gases in occupational safety applications, environmental pollution monitoring, and greenhouse gas monitoring in agricultural environments. In particular, the accuracy and reliability of gas sensors in industrial and agricultural sectors play a decisive role in ensuring human safety and improving operational efficiency. The modular and low-cost gas sensing test system developed within the scope of this project provides a domestic infrastructure suitable for educational and R&D purposes in universities, research centers, and test laboratories. The proposed system aims to contribute to the development of local gas sensing technologies by offering an alternative to imported test equipment.

This study was supported by the TÜBİTAK 2209-A University Students Research Projects Support Program.

Keywords: Gas Sensor; Sensor performance evaluation; Temperature and humidity monitoring; Modular design

Fabrication of CZTS Thin-Film Sensing Layers on Gold Electrodes Using Dip-Coating Technique

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Abstract

Recent advancements in nanoelectronic technologies have played a critical role in the development of modern sensor systems, enabling significant improvements in miniaturization, performance, and system integration. In particular, Micro-Electro-Mechanical Systems (MEMS) technology has become a fundamental platform for sensor technologies by integrating mechanical and electrical components at the microscale. MEMS-based sensors offer notable advantages, including reduced device size, lower production cost, enhanced sensitivity, and improved reliability. Furthermore, the reduced influence of volume-dependent effects such as inertia at the microscale enables the development of sensing systems with faster response times and more stable operation. These features have made MEMS-based gas sensors promising solutions for a wide range of applications requiring compact and efficient sensing platforms. The need for effective gas detection has become increasingly important in industrial, environmental, and public safety applications. In this context, there is a growing demand for sensing materials that are capable of operating at room temperature while providing low cost and reliable performance. Among various semiconductor materials, Cu_2ZnSnS_4 (CZTS) has attracted considerable attention due to its low toxicity, earth-abundant elemental composition, and favorable electrical and chemical properties. These characteristics make CZTS a promising candidate for gas sensor applications, particularly within MEMS-based sensor architectures. This study focuses on the initial stages of the fabrication process of a CZTS thin-film sensing layer designed for MEMS-based gas sensor applications. Within the scope of this preliminary work, a CZTS solution was synthesized using the sol–gel method, and the prepared solution was deposited onto pre-fabricated gold (Au) electrodes via the dip-coating technique. The surface homogeneity and integrity of the deposited CZTS layer were examined in order to evaluate its suitability as an active sensing layer for gas sensor applications. This preliminary study provides a fundamental framework for future investigations, including structural and morphological characterization as well as gas sensing performance analyses of CZTS-based sensors.

Keywords: Gas sensor; CZTS; Sol-gel; Dip-coating; Thin film.

Category Theory and Sustainability in Mathematics

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Abstract

Sustainability is increasingly recognized not merely as a problem of resource optimization but as a question of long term structural continuity under transformation. Rather than focusing solely on equilibrium states or quantitative efficiency, contemporary sustainability research emphasizes the preservation of system integrity under change. Category theory, with its focus on relationships, compositionality, and structural invariants, provides a natural mathematical framework for analyzing such systems. In this study, we propose a categorical perspective on sustainability in mathematics and complex systems by modeling subsystems as objects and transformation processes as morphisms within appropriate categorical structures. Within this framework, sustainability is characterized as the preservation of compositional coherence under functors and natural transformations, while structural breakdown corresponds to the loss of categorical consistency. To further capture multi level interactions and control mechanisms inherent in sustainable systems, we incorporate the theory of crossed modules as an algebraic refinement of the categorical model. Crossed modules enable the representation of local transformation processes together with global regulatory structures, encoding compatibility conditions between internal dynamics and external control. By interpreting sustainable resource networks through crossed module structures, structural stability can be analyzed in terms of homotopy invariant properties rather than numerical equilibria. This perspective allows sustainability to be understood as resilience under admissible deformations, where essential structural relations are preserved despite perturbations. Additionally, categorical concepts such as limits, colimits, and monoidal structures are interpreted as mathematical counterparts of stability, growth, integration, and circular resource dynamics. The proposed approach offers a unifying and structurally rigorous foundation for sustainability, bridging category theory, crossed module theory, and sustainability science. It highlights the role of advanced algebraic structures as powerful tools not only for modeling sustainable systems, but also for ensuring conceptual sustainability within mathematics itself.

Keywords: Sustainability; Category theory; Crossed modules; Complex systems; Algebraic modeling.

Interactive Gamified Learning in Primary Education

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Abstract

Teaching can be defined as the process of delivering knowledge in line with a specific objective, whereas education refers to the individual's ability to internalize this knowledge by transforming it into practice, thereby making it permanent and improvable. One of the fundamental problems of the current education system is the inability to concretize theoretical knowledge and relate it to real-life situations, which prevents students from applying raw information in practice. Due to this deficiency, students often fail to transform knowledge into lasting skills; instead, information becomes a temporary and nonfunctional form of memorization that is quickly forgotten once immediate needs are met. The main objective of this project is to concretize abstract theoretical knowledge through the use of digital games. The proposed approach involves embedding course content into real-life scenarios presented within game environments. In order to maintain student engagement and motivation, level-based progression systems and various reward mechanisms are integrated into the games. Furthermore, the system is designed in accordance with the spiral learning model. When previously learned topics begin to fade, reminder-based mini tasks are activated within the game, enabling learners to revisit and reinforce prior knowledge. In this way, learning is not limited to repetition; instead, knowledge is continuously expanded and strengthened. Upon completion of the project, the expected outcome is that students will be able to comprehend theoretical concepts and effectively apply them in daily life, ultimately becoming individuals who are not merely memorizing information, but who can solve problems and further develop the knowledge they acquire.

Keywords: Sustainability; Gamified learning; Educational technology; Digital learning; Interactive learning environments.

Data-Driven Analysis and Bibliometric Review of Sustainable Diet Approaches

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Abstract

The concept of a sustainable diet is defined as a multidimensional dietary approach that aims, beyond individual health outcomes, to reduce environmental impacts, ensure efficient use of natural resources, and strengthen the long-term resilience of food systems. In the literature, sustainable diets are classified according to criteria such as environmental impact (carbon and water footprints), nutritional adequacy, socio-economic affordability and accessibility, and cultural appropriateness. Within this framework, plant-forward, Mediterranean-style, flexitarian, and local or seasonal dietary patterns have become prominent. In this study, the theoretical foundation of the sustainable diet concept is outlined in light of the recent literature, research trends in the field are assessed through bibliometric analysis, and food consumption patterns are analyzed using a data-driven approach. The bibliometric analysis indicates that, in recent years, the sustainable diet literature has increasingly concentrated on themes such as climate change, life cycle assessment (LCA), plant-based eating, the Mediterranean diet, and public health policies. These trends suggest that sustainable diet research is evolving toward a more interdisciplinary structure and that the interaction between nutrition science and environmental sustainability is becoming increasingly stronger. In the data analysis component of the study, the nutrient profiles of foods were examined using the USDA FoodData Central "Foundation Foods" dataset (n = 316). Energy density (kcal/100 g) was evaluated, and protein and dietary fiber densities per 100 kcal were calculated. The findings indicate that vegetables, fruits, whole grains, and legumes form the core of sustainable dietary patterns in terms of nutrient density. The analysis was interpreted together with Eurostat food supply and consumption data, showing that plant-forward dietary tendencies are gradually increasing at the European scale. In contrast, foods with high sodium and saturated fat contents were found to be concentrated in specific product groups, suggesting that processed food consumption represents a critical constraint for achieving sustainable diet goals.

Keywords: Sustainable diet; Diet classification; Bibliometric analysis; Mediterranean diet; Public health; Artificial intelligence.

Bibliometric Analysis of Inefficiencies in Digital Twin-Based Smart Factory Management

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Abstract

This study aims to examine the role of digital twin technology in management processes in smart factories using bibliometric analysis methods and to classify the systemic inefficiencies reported in the literature. With the Industry 4.0 paradigm, digital twins have become a critical tool in the monitoring, simulation, predictive maintenance, and development of decision support mechanisms for production systems. However, technical, organisational, and operational problems encountered during implementation limit the performance of digital twin-based systems.Within the scope of the study, publications obtained from selected academic databases were evaluated using bibliometric analysis techniques. The publications were analysed in terms of distribution by year, co-occurrence networks of keywords, and topic clusters. Based on the results obtained, the prominent problem areas in digital twin applications were clustered under themes such as data integration, sensor infrastructure, model accuracy, human factor, and organisational resistance. These themes were classified using a fishbone (Ishikawa) diagram to enable a more systematic presentation of cause-and-effect relationships. The fishbone diagram is widely used in the literature for quality management in smart factories, process improvement, analysis of production losses, and identification of root causes of problems arising from digital transformation. In this context, the study provides a comprehensive reference for future decision support and improvement models by presenting the factors leading to inefficiency in digital twin applications within a methodological framework.The findings reveal that not only technological competence but also data management strategies and organisational alignment are critical in digital twin-based smart factory management.

Keywords: Digital twin; Smart factories; Bibliometric analysis; Fishbone diagram; Industry 4.0.

A Next-Generation Firefighting Drone for Emergency Response Operations

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Abstract

Firefighting operations are often conducted in hazardous, hard-to-access environments that require rapid and effective intervention. In such conditions, direct human involvement may pose significant risks to firefighter safety, particularly in enclosed spaces, high-rise structures, or areas exposed to extreme heat and toxic gases. This study presents the design and development of a firefighting drone intended to support fire brigades during fire suppression operations. The primary objectives of the proposed system are to reduce initial response time, minimize operational risks in the field, and enhance the overall safety of firefighting personnel. The developed drone is designed to rapidly access high-risk or inaccessible areas and provide effective support during the early stages of fire intervention. The mechanical structure of the drone has been designed with an emphasis on lightweight construction and structural durability. Carbon fiber–reinforced arms combined with a compact airframe improve payload capacity while maintaining flight stability and maneuverability. The propulsion system consists of high-torque brushless direct current motors coupled with electronic speed controllers, ensuring sufficient thrust and reliable performance under varying load conditions. Power distribution is managed through a dedicated power distribution board to ensure safe and efficient operation of all onboard components. During firefighting operations, the water spraying mechanism can cause instantaneous shifts in the drone's center of gravity, leading to potential instability during flight. To address this challenge, a secondary inertial measurement unit (IMU) has been integrated into the system. The use of dual IMU sensors enables more accurate detection of tilt and orientation changes, allowing real-time motor speed adjustments to maintain flight balance and stability under dynamic payload conditions. In addition, the drone communicates with a ground control station via a telemetry link, enabling real-time monitoring of critical flight parameters such as battery status, attitude, velocity, and altitude. This communication infrastructure allows operators to continuously observe system performance and make informed control decisions during operation. The results demonstrate that the proposed firefighting drone provides a safe, reliable, and effective support platform, offering significant potential to enhance operational efficiency and safety in firefighting scenarios.

Keywords: Firefighting drone; Unmanned aerial vehicle; Flight stabilization; Inertial measurement unit; Emergency response.

The Use of Deep Learning Algorithms in Industry: A Bibliometric Evaluation

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Abstract

The acceleration of the digital transformation process has made the effective analysis of large volumes of complex data generated by industrial systems a critical necessity. In this context, deep learning algorithms have begun to be widely used within the scope of Industry 4.0 thanks to their multi-layered structures and high representational capabilities. This study aims to examine the areas of application and development trends of deep learning algorithms in industrial applications using bibliometric analysis methods. Academic publications from 2000 to 2024 containing the keywords "deep learning" and "industry" in the Scopus database were analyzed within the scope of the research. The historical development of the literature, publication trends, and prominent concepts were visualized using VOSviewer software; the studies were classified under thematic headings such as production automation, quality control, predictive maintenance, and autonomous systems. The findings reveal a significant increase in publications on deep learning, particularly after 2015, and highlight the prominence of models such as convolutional neural networks (CNN), LSTM, and GRU in industrial applications. In conclusion, this study demonstrates that deep learning strengthens industrial decision-making processes, increases production efficiency, and offers the potential to reduce costs; it provides a literature-based framework for future applied studies.

Keywords: Deep learning; Industry 4.0; Artificial Intelligence, Automation; Machine learning.

AI-Based Predictive Modeling of Tensile Behavior in PDMS, PVC, and PU Polymers

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Abstract

In this study, the tensile behavior of PDMS, PVC, and PU polymers was numerically analyzed using ANSYS Fluent, and the obtained results were evaluated using artificial intelligence–based predictive models. Tensile analyses were carried out for specimens with thicknesses of 2, 4, 6, 8, 10, and 12 mm under applied loads ranging from 10 to 50 kN. As a result of the numerical analyses, mechanical outputs such as total deformation, maximum equivalent elastic stress, equivalent stress, and stress intensity were obtained. These outputs were predicted using Poly2 + Ridge, Random Forest, and Extra Trees machine learning models. Model performances were evaluated using the R-value metric, and prediction accuracies exceeding 90% were achieved for all models. The findings demonstrate that AI-assisted predictive approaches are effective tools for rapidly and reliably estimating the mechanical behavior of polymer materials.Furthermore, the integration of numerical simulation results with machine learning models enhances the interpretability and robustness of mechanical behavior predictions. Overall, the proposed approach contributes to the development of data-driven methodologies for polymer material analysis and supports their potential use in future simulation-based and intelligent engineering studies.

Keywords: PDMS; PVC; PU; Machine learning; ANSYS Fluent; Random Forest.

An Examination of Preschool Teacher Competencies Across Different Regions of the World

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Abstract

The aim of this study is to comparatively examine preschool teacher competencies implemented in different geographical regions of the world and to identify their similarities and differences. Within this scope, preschool teacher competencies determined by authorized institutions in countries from various continents were included in the research. The study systematically analyzed the preschool teacher competencies of Australia in the Southern Hemisphere; the U.S. states of California, South Carolina, and Massachusetts in the Americas; countries in Southeast Asia; as well as the United Kingdom and Türkiye in Europe. The analyses revealed that the main themes of teacher competencies in the examined countries largely overlap; however, the sub-competencies are structured differently according to each country's cultural context, social characteristics, and educational priorities. The identified main competency themes aim to strengthen teachers' professional capacities in line with the requirements of the contemporary era, with the ultimate goal of ensuring quality education. They also emphasize that teachers should effectively utilize their developmental knowledge to address children's individual differences and developmental needs. Australia identified its core areas as facilitating student learning, assessing student learning outcomes, participating in professional learning, engaging with curriculum policies and program initiatives in an outcome-based environment, and establishing partnerships with the school community. California's core areas include child growth and development, learning environments and curriculum, positive relationships and guidance, family and community engagement, health, safety, and nutrition, professionalism, professional development and leadership, and administration and management. South Carolina outlined child development, curriculum, health, safety, and nutrition, guidance, and professional development as its core areas. Massachusetts emphasized understanding the growth and development of children and youth, interaction and guidance with children and youth, partnerships with families and communities, health, safety, and nutrition, learning environments and programs, curriculum planning and development, and professionalism and leadership. Southeast Asia identified content knowledge, learning environment, participation and collaboration, and professional development as its core areas. The United Kingdom established its core areas as setting high expectations that inspire, moti-

vate, and challenge children; promoting children's progress and positive outcomes; providing knowledge to understand children's early learning and development; planning education and care with consideration for all children's needs; conducting accurate and effective assessment; safeguarding and promoting children's welfare while providing a safe learning environment; and fulfilling professional responsibilities. Türkiye defined its core areas as developmental domains, communication with families, family involvement and education, assessment, communication, creativity and aesthetics, collaboration with school and community, and ensuring professional development. Furthermore, the study revealed that approaches regarding how teachers develop and maintain these competencies vary across countries

Keywords: Education; Early childhood education; Preschool teacher competencies.

Development of a Current Model for the Türkiye Reference Energy System System

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Abstract

At the global scale, energy systems are undergoing a rapid transformation driven by climate change mitigation efforts, energy supply security concerns, and sustainable development goals. Effective planning of this transformation requires comprehensive and quantitative analyses of national energy structures through integrated modeling approaches. In this study, an up-to-date Reference Energy System (RES) model for Türkiye is currently under development to support the assessment of the country's existing energy infrastructure and its prospective energy transition pathways.The proposed model is being structured to represent the entire energy chain, from primary energy resources to final energy consumption. Major sectors, including electricity generation, industry, transportation, and buildings, are considered separately. Fossil fuels, renewable energy sources, and emerging energy technologies are being systematically incorporated into the model framework. Through the reference energy system approach, the aim is to comprehensively represent Türkiye's energy supply–demand balance, resource allocation, and sectoral energy consumption structure. In the ongoing model development process, a base year is being defined using the most recent available statistical data, and the framework is being prepared for long-term energy system projections. In addition to the reference scenario, alternative scenarios based on different policy and technology assumptions are planned to be constructed. These scenarios are intended to enable comparative analyses of energy demand trends, renewable energy penetration, and carbon emission trajectories.The preliminary structure of the developed model highlights the potential of reference energy system modeling as a robust analytical tool for examining Türkiye's energy transition. Once completed, the model is expected to provide a quantitative decision-support framework for strategic energy planning and policy development, supporting evaluations of national energy policies, sustainability targets, and long-term decarbonization strategies.

Keywords: Reference energy system; Energy system modeling; Energy transition; Renewable energy; Carbon emissions.

Investigation of the Effects of Different Grain Refiners on the Microstructure and Mechanical Properties of Etial-171 Alloy

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Abstract

In recent years, due to their advantages such as low density, high corrosion resistance and low carbon footprint resulting from their recyclability, aluminium alloys have increasingly replaced materials such as cast iron and steel in automotive, aerospace and defence industries. Accordingly, the development of aluminium based casting alloys and improvement of their performance have become an important research area both academically and industrially. In this context, the Al Si Cu Mg based Etial 171 AlSi10Mg alloy stands out as a heat treatable aluminium casting alloy that exhibits high mechanical performance in parts with complex geometries. Owing to its high tensile strength, ductility, thermal resistance and machinability, Etial 171 is widely used in critical automotive components. The properties expected from this alloy under service conditions include high fatigue strength and a microstructure that is as homogeneous and fine grained as possible. Grain refiner additions used to improve the microstructure and mechanical properties promote nucleation during solidification, leading to reduced grain size and improved service performance. In this study, the effects of grain refiner type on the microstructure, solidification behavior and mechanical properties of the AlSi10Mg alloy were investigated. An Al 5Ti 1B master alloy rod and a grain refinement tablet type grain refiner were employed. Cooling curve and derivative analyses showed that Al Ti B containing additions promoted aluminium nucleation at higher temperatures with more pronounced peaks, indicating enhanced heterogeneous nucleation. Tablet added samples exhibited higher nucleation density, resulting in a significantly finer grain structure. This refinement was directly reflected in the mechanical properties. Compared to the unrefined alloy, the Al 5Ti 1B addition provided moderate strength improvement while achieving the highest ductility. The tablet added samples reached the highest strength and hardness levels, however their elongation decreased due to increased porosity associated with a higher density index. In addition to mechanical improvements, the results indicate important environmental benefits. The lightweight nature of aluminium alloys sup-

ports vehicle weight reduction, increasing driving range in electric vehicles and improving fuel efficiency in conventional vehicles. Furthermore, enhanced mechanical properties achieved through grain refinement enable wider replacement of heavier materials with aluminium components, contributing to reduced carbon footprint and lower emissions in transportation applicationsrevealed that approaches regarding how teachers develop and maintain these competencies vary across countries

Keywords: Aluminium; Etial-171; Grain refiners; Microstructure; Mechanical properties, Casting.

Development of Cu-Sn Coatings Using Waste Copper Cable Scraps

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Abstract

Copper cables are components used in various industrial fields such as transportation, construction, communication, and consumer goods. It is reported that 70,000 tons of copper cable waste are dumped in landfills every year. This leads to the waste of copper resources and a local environmental burden. Impure scraps need to undergo smelting and electrolysis before it can be used again in order to produce new copper products. This increases the processing cost. However, it has been reported that recycling copper requires only 10-15% of the energy needed to extract copper from ore. CO_2 emissions can be reduced by 65% using copper scrap. However, the ability to directly convert copper scrap into an industrial product would reduce all these cost steps. This study questions the production of electrolytic plating bath directly from waste metal scrap. It focuses on developing environmentally friendly electrolyte compositions to create Cu-Sn coatings from waste copper cables. The primary goal is to reintroduce cable waste into the industry, bypassing traditional recycling processes and directly generating Cu-Sn alloy coatings. The reason for investigating tin as an alloying element is that it is the most common element in secondary copper waste and the superior performance of copper-tin coatings in various engineering fields. Methanesulfonic acid supported electrolyte is researched for an environmentally friendly electrolytic bath formulation owing to its unique properties; good biodegradability, low toxicity, excellent metal salt solubility, high conductivity, and stability. A two-electrode system was employed for electrodeposition. Coating properties depending on electrolyte composition and current densities were researched by SEM, EDS and XRD analysis in order to study morphology, compositional, and phase analysis. It was observed that using HEDTA as a complexing agent along with an organic brightener resulted in smoother and more homogeneous coatings. Increasing the tin content in the electrolyte to four times that of copper increased the coating content from approximately 24% Sn to 84% Sn at a current density of 0.05 A/cm². When the current density was increased to 0.1 A/cm², a Sn content of 71% was obtained. In other words, with the same electrolyte, increasing the current density increases the Cu content. XRD analysis showed that in the sample containing approximately 24 wt% Sn, Cu_6Sn_5 and Cu_3Sn phase peaks were dominant, while in the sample containing 84% Sn, peaks belonging to the β-Sn phase were detected along with these phases.

Keywords: Copper-Tin alloy; Electrodeposition; Reuse; Methansulfonic acid; Green electrodeposition.

Inclusivity in Sustainable Development: Focusing on Preschool Children

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Abstract

Sustainable development, when addressed through its environmental, social, and economic dimensions, represents a multidimensional learning and life practice that should be established during early childhood. This study aims to examine sustainability-oriented research conducted in early childhood education and to explore the extent to which preschool-aged children are inclusively involved in sustainable development processes. The reviewed studies predominantly focus on key concepts such as sustainability, environmental education, environmental awareness, ecological footprint, the 7R model, and teacher and parent awareness. The findings indicate that the preschool period is a critical stage for the development of sustainable attitudes and behaviors, and that teachers' pedagogical content knowledge and parents' role-modeling behaviors play a decisive role in fostering children's sustainability competencies. In addition, instructional approaches such as play-based learning, arts-based activities, children's literature, and emerging technologies, including augmented reality, are identified as effective tools in sustainability education. The reviewed evidence also highlights the importance of integrating sustainability more explicitly and systematically into early childhood curricula. In conclusion, addressing sustainable development in early childhood education through an inclusive, holistic, and multi-stakeholder approach that actively involves children, teachers, and families is essential for promoting long-term sustainable awareness and behavioral change

Keywords: Sustainable development; Early childhood education; Environmental sustainability.

Integrating Renewable Energy and Sustainable Materials in Urban Housing Design for Semi-Arid Regions

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Abstract

Urbanization and climate change are creating increasing pressure on cities, particularly in semi-arid regions, where extreme temperatures and limited water resources pose significant challenges to sustainable development. Housing, as one of the largest consumers of energy in urban environments, plays a critical role in addressing these challenges. This study investigates the integration of renewable energy systems and sustainable construction materials in urban housing, aiming to reduce energy consumption, improve thermal comfort, and support the objectives of energy transition. A multidisciplinary approach combining architecture, urban planning, and materials science was employed. Passive design strategies, including building orientation, natural ventilation, and shading devices, were integrated with active renewable technologies such as photovoltaic panels and solar water heating systems. Locally sourced, eco-friendly materials were selected based on thermal performance, durability, and environmental impact. Simulation tools were used to model building energy performance under the local semi-arid climate, analyzing energy savings, indoor comfort, and environmental benefits. Results indicate that the combination of sustainable materials and renewable energy solutions can significantly reduce building energy demand, lower carbon emissions, and enhance occupant comfort throughout seasonal variations. Furthermore, adopting such strategies contributes to the resilience and long-term sustainability of urban settlements while demonstrating the feasibility of interdisciplinary approaches in housing design. The study provides practical insights for architects, urban planners, and policymakers seeking to implement sustainable urban development practices in semi-arid regions and similar climates. This research highlights the importance of integrating energy-efficient design, renewable energy, and sustainable materials to promote urban sustainability, offering a scalable framework for future housing projects aligned with global energy transition goals.

Keywords: Renewable energy; Sustainable materials; Energy transition; Semi-arid climate, Urban housing.

Evaluation of Türkiye's Energy System in Line with Energy Transition and Sustainability Targets

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Abstract

At the global scale, energy systems are undergoing a rapid transformation driven by the need to combat climate change, ensure energy supply security, and achieve sustainable development goals. This transformation requires a comprehensive evaluation of existing energy structures not only from a technological perspective, but also by considering economic, environmental, and policy dimensions. In this context, türkiye has identified energy transition as a strategic priority due to its increasing energy demand, high import dependency, and rising greenhouse gas emissions. This study evaluates türkiye's current energy system within the framework of energy transition and sustainability targets. The main objective of the study is to present a holistic assessment of türkiye's energy supply and demand structure, the distribution of energy resources, and the potential of renewable energy sources. To this end, national and international literature, energy policies, and existing strategic documents are reviewed in order to analyze the current status of türkiye's energy transition process.The study emphasizes that the evaluation of energy systems through quantitative and model-based approaches plays a critical role in the development of sustainable energy policies. Achieving türkiye's energy transition targets requires the assessment of the existing energy system through up-to-date, consistent, and integrated models. In this respect, the study provides a conceptual framework for future research on türkiye's energy system and aims to contribute to policy-oriented and modeling-based studies related to the energy transition process.

Keywords: Energy transition; Sustainability; Türkiye energy system; Energy policies; Energy systems analysis.

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