ACADEMY OF SCIENCES OF ALBANIA

International Scientific Symposium

RENEWABLE ENERGY, SUSTAINABLE SOURCES AND TECHNOLOGIES (RENETECH 2025)

February 7, 2024

PROCEEDINGS BOOK

International Scientific Symposium:

RENEWABLE ENERGY, SUSTAINABLE SOURCES AND TECHNOLOGIES
(RENETECH 2025)

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PROCEEDINGS BOOK

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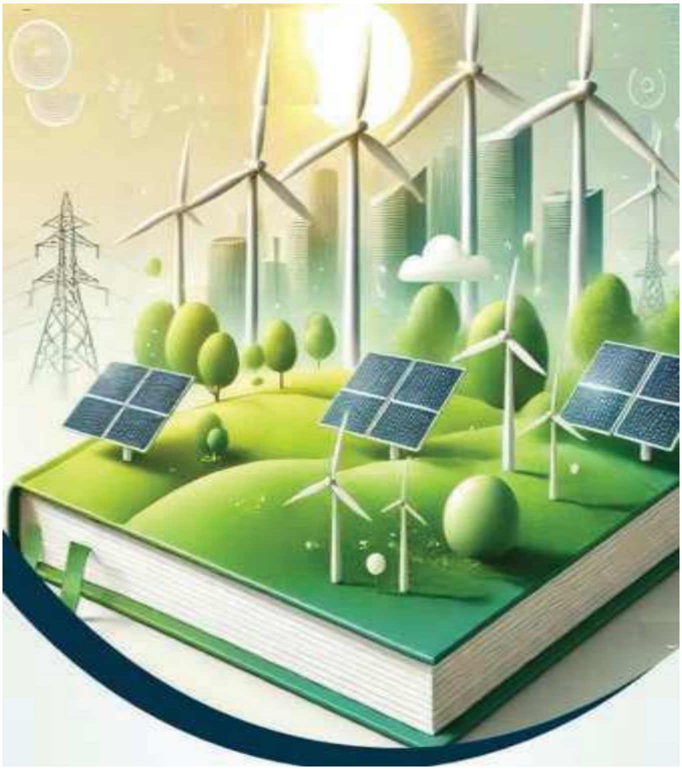
Tiranë, 2025

RENEWABLE ENERGY SOURCES SYMPOSIUM PLATFORM



RENEWABLE ENERGY, SUSTAINABLE RESOURCES AND TECHNOLOGIES
SUSTAINABLE ENERGY AND ALTERNATIVE FUELS FROM THE USE OF RENEWABLE ENERGY SOURCES
(Held on February 7, 2025)

Overview of the Scientific Platform for the Symposium on Renewable Energy Sources

Objectives

- *Promote knowledge sharing*: Facilitate discussions on the latest advances in renewable energy technologies and applications.
- *Fostering collaboration*: Encouraging partnerships between academia,

industry and government sectors.
- *Highlight Innovations*: We present the latest research and developments in renewable energy sources.

Structure of the Symposium

1. Elements of the conference

We organize sessions around specific topics to cover a wide spectrum of topics within renewable energy:
- Energy storage systems: Innovations in battery technologies and energy management.
- Advances in inverters and converters for the integration of renewable resources.
- Grid Integration: Strategies for integrating renewable resources into existing energy networks.
- *Sustainability Practices*: Best practices for sustainable energy use and environmental protection.
- Emerging technologies: Discussions on digital twins, smart grids and applications of Artificial Intelligence in energy systems.

2. Keynote speakers

We will invite renowned experts in the field to provide insights on current trends and future directions. Potential speakers may include:
- *Researchers from the main universities of the country and abroad*
- *Industry leaders from leading renewable energy companies.*
- *Policymakers involved in energy regulation and sustainability initiatives.*

3. Engagements in the preparation process and symposium panels

Interactive workshops and panel discussions will be included to actively engage participants:
- Workshop: Practical sessions focusing on practical applications of renewable technologies.
- Panels: Panels of experts discussing challenges and opportunities in the renewable energy sector.

4. Networking opportunities

Informal networking spaces will be created to foster connections between participants:
- Networking sessions: Specific times will be set for participants to meet and discuss possible collaborations.
- Exhibition space: Companies are allowed to showcase their innovations

and services related to renewable energy.

Publication opportunities
Participants will be encouraged to submit their research for publication in reputable journals. We collaborate with journals that focus on renewable energy research, such as:
• International Journal of Renewable Energy Research (IJRER) etc.

Logistics
1. Choosing a Symposium room that is accessible and equipped with the necessary equipment, such as audio-visual equipment, on-line communication, etc.
2. Registration process
An online registration system will be implemented that allows participants to easily register for the symposium, submit abstracts (and possibly pay a fee).
3. Media
Drafting a marketing plan to promote the symposium through various channels:
• Social media campaigns targeting relevant audiences.
• Email materials to academic institutions and industry professionals.

Conclusion
By creating a structured platform that emphasizes knowledge sharing, collaboration and innovation, the Renewable Energy Symposium can significantly contribute to the advancement of research and development in this critical area. Engaging speakers, interactive sessions and numerous networking opportunities will ensure a successful event that meets the needs of all attendees.

Symposium reference topics (including but not limited to)

Section I: Power Engineering and Renewable Energies
Feeding the grid from renewable energy sources, Biofuels as a sustainable solution: Waste Reduction,
Smart use of renewable energy sources;
Our planet's resources are limited and recycling is more important than ever;
Green hydrogen infrastructure: Recycling of end-of-life fuel and electrolysis cells;

How recycling of spent fuel and electrolysis cells can contribute to a sustainable hydrogen infrastructure;
Energy Interconnection, Integrated Energy System
Energy storage technologies and equipment (use efficiency in industry, construction, etc.) Energy Systems and Automation

Section II: Clean and renewable energy
Alternative renewable and industrial energy sources Renewable energy saving technology
New renewable energy applications
New Renewable Energy Materials and Equipment Photovoltaic Systems and Solar Energy Engineering Effective use of Renewable Energy
Wind Energy Systems Biomass Energy Systems Solutions for energy recovery

Section III: Intelligent Computing and Applications for Sustainable Energy and Environment
Advanced intelligent theories and algorithms for advanced searches for renewable energy sources
Theory and algorithms of modeling, monitoring and intelligent control of renewable energy production processes
Intelligent computing, modeling, optimization and control in the use of clean and renewable energy sources
Intelligent modeling, simulation and environmental control such as climate change, water treatment and waste management etc.
From the use of artificial intelligence to optimize packaging recycling, to the critical role of industrial recycling, to innovative projects in battery recycling, our case studies and partnerships show how the latest technologies and processes are helping to maximize value of waste and protect our environment;
Case Study: Artificial Intelligence in experimental laboratories UPT, UT etc. Everyone talks about AI, but we show how it can be applied in the lab. This case study shows how a polymer processor successfully uses AI for quality control of recycled materials.

ROUND TABLE WITH THE MAIN ACTORS:
Details for the content of the concrete cases of the study in the references of the Symposium:
a) On the recycling of lithium-ion batteries (LIBs). The focus is on analyzing the state of charge to efficiently recover valuable materials and significantly improve the sustainability of battery technology.

b) Success story: Use of simultaneous thermal analyzers to convert solid waste into energy materials;
c) To convert solid waste into recyclable materials of higher value. Accurate analysis enables the optimization of waste treatment processes, resulting in the effective use of resources and the recovery of valuable materials.
d) How to identify and evaluate the different compositions of plastic in the recycling stream
e) Identification and quantification of different recycling cycles.

The individual components of a mixture can be precisely separated and identified, significantly improving the analysis and optimization of recycling processes.

ORGANIZATIONAL
COMMITTEE

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- Prof. Dr. Nevton Kodhelaj
- Prof. as. Dr. Lorenc Malka
- Prof. Dr. Petrit Zorba
- Prof. Dr. Ilirjana Boci
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14. Prof. Dr. Elmaz Shehu
15. Prof. Dr. Spiro Drushku

OPENING SPEECH OF THE SYMPOSIUM:
Academician Ilirjan Malollari
Invited participants (Italy, Kosovo, North Macedonia, Serbia, Montenegro etc.)
Persons expected to participate in the Symposium on renewable energy and national strategy and priorities:

- Government officials from the Ministry of Infrastructure and Energy, Ministry of Environment, and other relevant ministries and agencies. (AKBN etc.)
- Representatives from the private sector, including renewable energy developers, investors and producers.
- Representatives from non-governmental organizations (NGOs) working on renewable energy and climate change issues.
- Academic experts in renewable energy and energy policy.
- Experts from the University of Tirana (URTI), Faculty of Agriculture and Environment, Agricultural University of Tirana, Polytechnic University of Tirana, National Energy Authority, Undergraduate and postgraduate engineering students.
- Representatives of AKKSHI. etc.

In addition, journalists, members of the media and the general public are also invited to participate in the Symposium.

The Symposium is a timely and important event, since Albania is at a critical moment in its development. The country is facing a number of challenges, including energy security, climate change and economic development. Renewable energy can play a key role in addressing these challenges and building a more sustainable and prosperous future for Albania. It will serve to discuss the challenges and opportunities for the development of the sector. By bringing together experts from the government, the private sector and NGOs, the forum will provide a platform for dialogue and cooperation. This is essential for the development of a comprehensive and effective national strategy for renewable energy.

The motivation of the Symposium on Renewable Energy, National Strategy and Priorities is to raise awareness of the importance of renewable energy for the future of Albania. Albania has significant potential for the development of renewable energy, including solar, wind, hydropower and biomass. However, the country is currently highly dependent on imported fossil fuels, which makes it vulnerable to energy price shocks and climate change.

The challenges and opportunities for the development of the renewable energy sector in Albania will be discussed. The Symposium brings together experts, representatives from the government, the private sector and NGOs to discuss the main challenges and opportunities for the development of the renewable energy sector in Albania. These challenges include financing, regulatory barriers and public awareness. The Symposium will also explore the potential benefits of renewable energy development, such as job creation, economic growth and environmental protection.

The Symposium will develop recommendations for a national renewable energy strategy that will outline the government's goals and objectives for the sector, as well as the steps to be taken to achieve these goals. The development policy will be developed in consultation with stakeholders from all sectors and will be consistent with Albania's national development goals and international commitments.

The expected outcomes of the Symposium will be comprehensive in relation to renewable energy and the national strategy and priorities:

- recommendations for the improvement and effectiveness of the national renewable energy strategy, developed in consultation with stakeholders from all sectors.
- A better understanding of the challenges and opportunities for the development of the renewable energy sector in Albania.
- Increased awareness of the importance of renewable energy for the future of Albania.
- Activation of a network of experts and stakeholders who are committed to the development of the renewable energy sector in Albania.
- Stimulation of investments in the renewable energy sector.
- Creation of jobs and economic growth. Reducing Albania's dependence on imported fossil fuels and improving its energy security.
- Reduction of greenhouse gas emissions and mitigation of climate change.

The products of the Symposium will be:

- Drafting of a Declaration with recommendations for legislative and law enforcement bodies for the establishment of a national certification system, which can be implemented for the first time in Albanian scientific institutions.
- Discussion on ensuring financial support and state control for the implementation by scientific institutes in Albania of the energy transition system as a scientific, applied, organizational and political process.

I wish the symposium a successful development of its proceedings!

ACADEMY OF SCIENCES OF ALBANIA

INTERNATIONAL SIMPOSIUM

Renewable Energy, Resources and Sustainable Technologies

RENETECH2025

**Under the care of Acad. Skënder Gjinushi,
President of Academy of Sciences of Albania**

Parallel Session: Solid waste from the food industry for bioenergy

February 7, 2025

Academy of Sciences of Albania

P R O G R A M

8:30–9:30	**REGISTRATION**
9:30–10:00	**PLENARY SESSION** – (Aleks *Buda* Hall) **Chaired by: Acad. Ilirjan Malollari, Acad. Neki Frashëri** • Greeting Speech from President of the ASA: **Acad. Skënder Gjinushi** • Other Greetings from the authorities

(*Aleks Buda* Hall) Online
https://us02web.zoom.us/j/83345931406?pwd=F4mWM42Ottcm1HXwP2ai8htiTlGUJG.1
Meeting ID: 833 4593 1406, Passcode: 015091

SESSION I: Clean and Renewable Energies (*Aleks Buda Hall*)

Session Chair: **Acad. Fetah Podvorica, Prof. Dr. Marko Dalla Rosa**

TIME	PRESENTATION TITLE	AUTHORS
10:00-10:15	Applications For Bioenergy Production From Industrial Waste And Alternative Renewable Energy Systems For Sustainable Development	Acad. Ilirjan Malollari
10:15-10:30	Environmental Issues and Energy in National Security	Acad. Besnik Baraj
10:30–10:45	The Dimension of Renewable Energy in the Framework of the National Climate and Energy Plan 2030	Dr. Gjergji Simaku
10:45-11:00	Hydrogen as an Energy Vector	Fetah I. Podvorica, Fejzullah Krasniqi
11.00-11.15	Renewable Energy roles in the Food Ecosystem Circular Economy. Selected case studies	Prof. Dr. Marko Dalla Rosa
11.15:11.30	Nuclear Energy Part of Clean Energy Transition	Fatos Ylli, Fatos Klosi, Kostandin Dollani, Floran Vila
11:30-11:45	**COFFEE BREAK**	
Time	**PRESENTATION TITLE**	**AUTORET**
11.45-12:00	Photovoltaic Energy in Albania: Between Theory and Reality Towards a Sustainable Future	Prof. Dr. Petrit Zorba, Dr. Nike Shamku
12:00-12:15	Evaluation of the Potential of Nickel Hyperaccumulator Plants for Nickel and Energy Production	Prof. Dr. Aida Bani
12:15-12:30	Challenges of wind integration in lowland- areas	Lorenc Malka, Alban Kuriqi, Jakub Jurasz, Helena Ramos and Partizan Malkaj
12:30-12:45	The Challenges and Opportunities of Interconnected Transmission Systems in the Context of the Green Transition	R. Bualoti, M. Çelo, A.Gjukaj, E.Voshtina

12:45-13:00	Kinetic Modeling of Catalytic Pyrolysis of Biomass in a Semi-Batch Reactor	Slavcho Aleksovski, Igor Aleksovski, Karmina Miteva, J. Stanojevıc, L. Stanojevıc, A. Milenković, I. Malollari
13:00-13:15	Analysis of A Pump-Turbine Energy Storage System to Increase the Level of Renewable Energy	Driada Mitrushi, Irma Berdufi, Valbona Muda, Joan Jani
13:15-13:30	Applications of Catalysts for Waste Plastic Conversion to Fuel	Karmina Miteva, Slavcho Aleksovski, Gordana Bogoeva-Gaceva
13:30-13:45	Decentralization of the Grid and Role of Energy Community in Albania	Lorenc Gordani, PhD

13:45-14:30	**LUNCH COCTAIL**	

(*Aleks Buda* Hall)
https://us02web.zoom.us/j/83345931406?pwd=F4mWM42Ottcm1HXwP2ai8htiTlGUJG.1
Meeting ID: 833 4593 1406, Passcode: 015091

SESSION II: Applications for Sustainable Energy and the Environment
(Academy of Sciences, *Aleks Buda* Hall)

Session Chair: Acad. Rajmonda Bualoti, Prof. Dr. Petrit Zorba

Time	PRESENTATION TITLE	AUTORET
14:30 -14:45	The use of vegetative/plant biomass as an important element of renewable energy.	Hajri Haska, Eneida Haska, Edlir Haska, Olsi Miraçi
14:45-15:00	The Possibility of Biodiesel Production from used Cooking Oil in Kosovo	Sami Makolli, Laura Nushi, Violeta Lajqi (Makolli), Ilirjan Malollari
15:00-15:15	The Challenges Of A Strategy For The Effective Utilization Of Renewable Resources, Including The Alternation Of Hybrid Models Of Energy Production.	MSc. Ing Kristi Thodhorjani, MSc.Ing. Igli Reci
15:15-15:30	Kosova Atlas for Renewable Energy - Solar Radiation and Wind	Dr.(C) Gazmir Çela, Prof.Dr. Petrit Zorba
15:30-15:45	Application of Differential Evolution Algorithms in Hydropower Optimization: A Case Study on Ulza Hydropower Plant	Monika Gjetaj, Enkela Karroçi
15:45-16:00	Short-Term Load Forecasting: Case study the Albanian Power System	Viktor. Rrotani, R. Bualoti, M. Çelo, B. Lesi
16:00-16:15	$DeNO_x$ Catalyst An Efficient Way To Minimize The Environmental Impacts Of The Fossil Energies Combusted In Diesel Engines	B. Karroci, E. Noçka
16:15-16:30	Application of The Decline Curve Analysis in Calculation of The Decline Rate For The Gorisht-Kocul Oil Field In Albania	Lusjen Ismaili
16.30-16:45	Study of the physicochemical aspects of formation damage and the action of polymers during oil field processing	Lorina Malollari, Drilona Sauli
16:45-17:00	Transforming Abandoned Oil Wells into Geothermal Heat Sources: A Case Study in Patos-Marinza	E. Karamani, K.Vlashi and O. Gropa
17:00-17:15	Advancements in Drilling Technology for BHE Wells in Albania: Innovations And Challenges	O. Gropa, E. Karamani, K.Vlashi
17:15-17:30	Maximizing Efficiency: Advanced Techniques for Enhancing Geothermal Well Performance	Kejsid Vlashi, Ortenca Gropa, Erison Karamani
17:30-17:45	Economic analysis of wind integration for TEC Vlore sh.a's energy system: A HOMER Pro simulation	M. Halili, V. Muda, D. Mitrushi, V. Veshaj
17:45	Meeting of the Kosovo and Albania Working Groups for the Energy Project (Energy Strategy)	The working groups from the two countries Kosovo-Albania
	Closing of the Symposium	

(*Aleks Buda* Hall) Online participating on the following link:
https://us02web.zoom.us/j/83345931406?pwd=F4mWM42Ottcm1HXwP2ai8htiTlGUJG.1
Meeting ID: 833 4593 1406, Passcode: 015091

WORKSHOP FOR PKKZH PROJECT
Academy of Sciences (UT, UK, UGJ, UBT)

7 February 2025
Academic Book Hall, Academy of Sciences

PARALEL SESSION: SOLID WASTE FROM THE FOOD INDUSTRY FOR BIOENERGY

Chaired by: Acad. Ilirjan Malollari, Prof. Luljeta Pinguli

Time	PRESENTATION TITLE	AUTHORS
10:30-10:45	Specific Processing of Spent Beer Grain in Beer Production Industry or Their Revalorization	Prof. Luljeta Pinguli (UT), Ilirjan Malollari, Redi Buzo, Terkida Prifti, Dr. Fatjon Hoxha, Jonilda Llupa
10.45-11.00	Solid Waste Discharged from the Beer Industry in Albania, their Management and Valorization	Dr. Redi Buzo (UK), Ilirjan Malollari, Luljeta Pinguli, Terkida Prifti, Fatjon Hoxha, Jonida Llupa
11.00-11.15	Management Insights in Albania	Dr. Fatjon Hoxha (UBT), Dr. Redi Buzo (UK), Ilirjan Malollari, Luljeta Pinguli, Terkida Prifti, Jonida Llupa
11.15-11.30	Use non-thermal pre-treatments to improve functional compounds recovery from food industry side streams as brewers' spent grains and seafood processing by-products	M. Dalla Rosa
11:30-11:45	COFEE BREAK	
11:45-12:00	Proteins in malt, wort, beer and solid waste generated by a brewery	Dr. Terkida Prifti (UT), Redi Buzo, Ilirjan Malollari, Luljeta Pinguli, Fatjon Hoxha, Jonida Llupa
12:00-12:15	Evaluation of Brewery Waste: Strategies and Recommendations for Effective Monitoring and Control	PhD. Jonilda Llupa (UGJ), Ilirjan Malollari, Luljeta Pinguli, Dr. Redi Buzo (UK), Terkida Prifti, Fatjon Hoxha
12:15-12:30	Leveraging Innovation and Circular Economy for Agro-Industrial Resilience: The role of integrated regional policies and the Emilia-Romagna	Dr. Lorenzo Ciapetti
12:30-12:45	Questions, Comments and Discussions from attendees	Working Group
12:45-13:15	Conclusions and Recommendations	Acad. Ilirjan Malollari

(Akademic Book) Online participating on the following link:
https://us02web.zoom.us/j/85715284853?pwd=FM5qPNSA2Q48W64ZsMYOzu3ZeKyNxf.1
Meeting ID: 857 1528 4853 Passcode: 219242

International Scientific Symposium:

RENEWABLE ENERGY, SUSTAINABLE SOURCES AND TECHNOLOGIES
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PROCEEDINGS BOOK

USE NON-THERMAL PRE-TREATMENTS TO IMPROVE FUNCTIONAL COMPOUNDS RECOVERY FROM FOOD INDUSTRY SIDE STREAMS AS BREWERS' SPENT GRAINS AND SEAFOOD PROCESSING BY-PRODUCTS

M. Dalla Rosa
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ABSTRACT

It is well known that the Biorefinery processes are dedicated to the transformation of biomass for the production of compounds, materials and energy and are to date largely fueled by organic fractions from dedicated crops or by biomasses from agri-food industry side streams. However, their full economic sustainability is still a challenge. On the other hands, in the framework of the Circular Bioeconomy, the use of waste matrices as feed and food can help limit the costs of biorefineries. This strategy may represent an opportunity for the food ecosystem in a region like Emilia Romagna, where there are rich sources in organic residues from strategic sectors such as agriculture, livestock, fisheries and aquaculture. Brewers' spent grain (BSG) is the most abundant by-product obtained from beer production and it contains some bioactive compounds such as phenolic compounds. Therefore, the valorization of BSG is important to recovery these compounds and reused them as functional ingredients in food industry. On the other hand seafood by-products contain several valuable components such as proteins, lipids, carotenoids and chitin.
When extracted and isolated, these valuable compounds are characterized by bioactive capacities such as anti-microbial, antioxidant, and anti-cancer, and that could be used as nutraceutical ingredients or additives in food, pharmaceutical, and cosmetic industries. In both cases, to improve recovery, of the functional compounds form the by-products, various modern non-thermal processes and in particular pulsed electric field (PEF) has been used as extraction pre-treatment.
Keywords: Sustainability, Circular Bioeconomy, functional compounds recovery, seafood, Brewers' spent grain

APPLICATIONS FOR BIOENERGY PRODUCTION FROM INDUSTRIAL WASTES AND ALTERNATIVE RENEWABLE ENERGY SYSTEMS FOR SUSTAINABLE DEVELOPMENT

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[3]Department of Biology and Chemistry, Fan S. Noli University of Korça, Albania

ABSTRACT

This paper investigates the potential of utilizing industrial biomass waste as a sustainable energy source for the future. It analyzes the bioenergy production cycle, biomass availability, and global energy landscape. The research highlights the escalating demand for energy, the transition from traditional fossil fuels to renewable biomass, and the increasing global bioenergy production. It explores the opportunity for industrial biomass waste to serve as a viable, sustainable energy source moving forward. By delving into the bioenergy production cycle, biomass availability, and the existing energy landscape, the paper aims to understand the topic comprehensively.

The introduction emphasizes the necessity for alternative and sustainable energy sources to meet the rising energy demand. This demand is driven by industrialization, urbanization, and population growth. The shift from fossil fuels to renewable biomass is warranted. This paper emphasizes the shift from conventional fossil fuels to renewable biomass energy. This shift is crucial for reducing greenhouse gas emissions and mitigating climate change. Biomass energy is a cleaner and more sustainable option, as it is derived from organic matter that absorbs carbon dioxide during photosynthesis. So, there is an indispensable need to increase bioenergy production.

Keywords: *bioenergy, industrial waste, alternative renewable energy, sustainable development*

INTRODUCTION

The primary types of biomass waste utilised in Albania for energy production include forest waste, Albania's primary energy source for heating, primarily firewood, shrubs, and waste generated from forestry operations. Urban Waste: Another significant source of biomass energy in Albania is urban waste, which encompasses municipal solid, industrial, and agricultural waste.

The calorific value of urban waste typically ranges from 10 to 17 MJ/kg. Agricultural Residues: such as straw and other pressed stubble, are estimated to have a potential energy production capacity of around 2300 GWh per year. Biomass from Forestry and Agriculture: Biomass derived from forestry and agriculture, including energy crops like grasses and short-rotation trees, is recognised as an essential renewable energy source in Albania. Waste from the Food Industry: waste generated from the food industry, including residues from agriculture and food processing, is also harnessed for energy production [1-5].

Biomass waste streams are used in various energy applications, including heat generation, electricity production, and biofuel production. Global bioenergy production is steadily increasing and is fueled by technological advancements, supportive government policies, and a growing demand for sustainable energy solutions [6-8]. In Albania, agricultural waste is transformed into energy through several methods, including: *Anaerobic Digestion*: This biological process involves microorganisms breaking down organic matter without oxygen, resulting in biogas, a mixture of methane and carbon dioxide. Biogas can be harnessed to generate electricity and heat or as a transportation fuel. *Combustion*: Direct burning of agricultural waste in incinerators produces heat and electricity. This method is prevalent in small-scale, farm-level energy production scenarios. *Gasification*: This process entails the partial oxidation of biomass at high temperatures to generate synthesis gas (syngas), which can be employed for electricity generation or the production of biofuels. *Pyrolysis* is a thermal decomposition technique that converts biomass into bio-oils, biochar, and syngas. These byproducts can serve as fuels, chemicals, or mediums for energy storage. *Biodiesel Production*: Through transesterification reactions with vegetable oils or animal fats, agricultural waste can be transformed into biodiesel, providing a renewable alternative to fossil fuels. These processes effectively convert agricultural waste into diverse forms of energy, including electricity, heat, biofuels, and various chemicals [9-12].

Biomass Waste as a Sustainable Energy Source

This study investigates various biomass materials types and sources, encompassing agricultural, forestry, and industrial waste. It delineates the advantages of utilizing biomass waste for energy production, such as minimizing environmental impact and fostering a circular economy.

This section of the paper examines the role of biomass waste as a sustainable energy source, highlighting the diverse types and sources of biomass materials. The benefits of harnessing biomass waste for energy generation are particularly underscored, including:

Environmental Impact Reduction: Biomass waste can significantly mitigate environmental challenges by diverting waste from landfills and lowering greenhouse gas emissions [13-15].

Circular Economy: By converting biomass waste into energy, we promote a circular economy that minimizes waste and generates a sustainable energy source [16-20].

Renewable Energy Source: Biomass is a renewable energy source because it can be regenerated through natural processes, making it a viable alternative to fossil fuels [21].

Carbon Neutrality: Biomass energy is considered carbon neutral since the carbon released during combustion is approximately equal to the amount absorbed during the biomass's growth, contributing minimally to net greenhouse gas emissions.

Job Creation and Local Economic Support: The biomass industry has the potential to create jobs and bolster local economies by utilizing regionally sourced biomass and encouraging local economic development [22-25].

Energy Security: Biomass energy enhances energy security by diversifying the energy mix and decreasing reliance on imported energy.

Versatility: Biomass can be transformed into various forms of energy, including solid biomass, liquid biofuels, biogas, and biochemicals, showcasing its versatility as an energy source.

So, the paper emphasizes the significance of biomass waste as a sustainable energy solution, illustrating its potential to reduce environmental impacts, enhance the circular economy, and deliver a dependable renewable energy source. Nowadays, the focus is on industrial biomass waste. The paper specifically focuses on industrial biomass waste as a potential energy source. This type of waste includes materials from various industries such as agriculture, forestry, and manufacturing. Using these waste materials, the paper aims to reduce waste disposal costs and promote a circular economy [26].

As seen, integrated production systems and multi-functional land uses are essential. These can provide food, animal feed, and biomass for energy and other valuable products. Additionally, it notes the role of bioenergy in the broader bioeconomy and its potential to contribute to sustainable energy systems [27-28].

Bioenergy Conversion Technologies

The paper reviews biomass conversion technologies, including mechanical, thermal, and biochemical processes. These technologies, such as direct combustion, pyrolysis, gasification, fermentation, and transesterification, can transform biomass waste into useful energy products, heat, and electricity.
The bioenergy conversion technologies discussed in the paper include:
Thermochemical Conversion: Combustion: Burning biomass in the air to produce heat, mechanical power, or electricity. Pyrolysis: Thermal decomposition of biomass without oxygen to produce bio-oil, biochar, and syngas. Gasification: Biomass conversion into a mixture of carbon monoxide, hydrogen, and methane. Liquefaction: Conversion of biomass into a liquid fuel.
Biochemical Conversion: Biogas Production: Microbial fermentation of biomass to produce biogas, a mixture of methane and carbon dioxide. Fermentation: Microbial fermentation of biomass to produce ethanol, butanol, and other biofuels [29].
Mechanical Extraction: Esterification is the chemical conversion of biomass into biodiesel. Currently, attention is directed towards industrial biomass waste, which is highlighted in this paper as a promising energy source. This category of waste encompasses materials generated by various sectors, including agriculture, forestry, and manufacturing. By utilizing these waste materials, the paper seeks to lower waste disposal costs while fostering a circular economy.
The paper emphasizes the significance of integrated production systems and multi-functional land uses, which can yield food, animal feed, and biomass for energy, alongside other valuable products. Furthermore, it underscores the role of bioenergy within the broader bioeconomy and its potential contribution to sustainable energy frameworks [30].

MATERIALS AND METHODS

The primary challenge facing society is: What are the main obstacles in utilizing industrial biomass waste for energy production? Based on research findings, the key challenges identified include: *Availability and Accessibility of Biomass Waste*: Biomass waste is frequently scattered and unevenly distributed, complicating efforts to source and collect it in adequate quantities. Seasonal fluctuations in biomass availability can also lead to inconsistencies in supply. Additionally, logistical difficulties in transporting biomass waste over long distances may drive up costs. *Variability in Composition and Quality:* Industrial biomass waste exhibits significant composition, moisture content, and energy density variability, complicating

the conversion process. This inconsistency in biomass quality can lead to operational challenges and inefficiencies in energy conversion technologies. *Technical Barriers*: Effective pretreatment technologies are essential to prevent biodegradation and preserve the heating value of biomass waste, thereby increasing production costs. Furthermore, the lack of standardization and inadequate specialized equipment for biomass conversion can impede the development of efficient energy systems. The industry faces challenges due to an immature supply chain and limited experience integrating biomass waste into energy production processes [31].
Economic Challenges: The high upfront investment and operating costs associated with biomass waste-to-energy technologies pose significant barriers. Additionally, securing long-term, reliable, cost-effective contracts for biomass waste supply remains difficult. The industry's perceived risks and low profitability further limit financing opportunities and investor interest.
Policy and Regulatory Barriers: There are no explicit government policies and incentives to promote the utilization of industrial biomass waste for energy production. Regulatory challenges related to waste management and disposal may also obstruct the adoption of waste-to-energy solutions. *Environmental and Social Impacts*: Biomass plantations can have potential negative environmental consequences, such as soil nutrient depletion, aesthetic degradation, and biodiversity loss. Social challenges may arise in rural areas where energy farms are situated, including land use conflicts, increased traffic, and the demand for additional services. Addressing these challenges through technological advancements, policy support, and collaboration among stakeholders will be critical for unlocking the full potential of industrial biomass waste as a sustainable energy source.
Let us consider the economic barriers associated with utilizing industrial biomass waste for energy production. *Composition Variability*: The chemical makeup of biomass waste, including cellulose, hemicellulose, lignin, and ash levels, can vary significantly based on the feedstock type, growing conditions, and preprocessing methods. This variability in composition influences the efficiency and yields of downstream conversion processes such as fermentation, pyrolysis, and combustion. For instance, a higher ash content in herbaceous biomass can lead to reduced pyrolysis oil yields compared to woody biomass. *Moisture Content Variability*: Biomass moisture content can fluctuate greatly due to environmental conditions and storage practices. Elevated moisture levels can adversely affect handling, feeding, and conversion efficiency. Potential solutions include selecting feedstocks with favourable drying characteristics, implementing best management practices for harvesting and storage, and enhancing preprocessing technologies.

Physical Property Variability: Particle size, shape, and density can differ significantly in biomass waste, impacting handling, feeding, and conversion processes. Inconsistent particle morphology can decrease plant efficiencies by as much as 50%. To address this, it is necessary to develop preprocessing technologies that ensure consistent bulk solid properties and to engineer more robust handling systems. *Seasonal and Geographic Variability*: Biomass yield and composition can significantly vary across different seasons and geographic regions, influenced by climate, soil conditions, and agricultural practices. This spatial and temporal variability can affect biomass supply's reliability and cost-effectiveness, potentially jeopardising bioenergy projects' economic feasibility.

Blending and Formulation: Combining and blending various biomass waste streams can help alleviate the negative impacts of this variability on conversion processes. Thoughtful feedstock selection and formulation can enhance the overall quality of biomass. However, the inherent variability in biomass waste composition, physical properties, and availability presents considerable challenges for efficient and cost-effective energy production. To commercialise biomass-to-energy systems successfully, it is essential to address these sources of variability through technological, operational, and supply chain optimization strategies.

These barriers and challenges highlight the complexity and multifaceted nature of bioenergy implementation. Addressing these barriers is crucial for successfully deploying bioenergy technologies and achieving sustainable energy goals.

Bioenergy supports sustainable development goals, such as reducing greenhouse gas emissions, by promoting circular economy principles and fostering local economic growth. This paper highlights successful case studies from around the world that demonstrate bioenergy projects' environmental, social, and economic benefits.

The role of bioenergy in sustainable development is multifaceted and crucial for achieving a low-carbon energy economy. Bioenergy can contribute to sustainable development by:

Reducing Greenhouse Gas Emissions: Bioenergy can replace fossil fuels in energy production, reducing greenhouse gas emissions and mitigating climate change.

Promoting Sustainable Land Use: Sustainable forest management and agricultural practices can ensure that biomass is sourced from sustainably managed forests and agricultural lands, reducing environmental impacts.

Enhancing Energy Security: Bioenergy can improve energy security by reducing dependence on imported energy sources and enhancing local energy production.
Supporting Economic Development: Bioenergy can create jobs and stimulate local economies by utilizing locally sourced biomass and promoting regional economic development and Challenges. The research highlights the barriers and challenges associated with utilizing biomass waste for energy production. These challenges encompass technical, economic, and regulatory factors that must be addressed to realize this renewable energy source's potential fully.

Barriers and Challenges

The research also discusses the barriers and challenges associated with the utilization of biomass waste for energy production. These include technical, economic, and regulatory factors that need to be addressed to fully unlock the potential of this renewable energy source.
The barriers and challenges to bioenergy implementation include:
Technological Barriers

- ✓ *High Capital Investment*: Large-scale production of lignocellulosic biofuels requires significant capital investment in biorefineries.
- ✓ *Low Technological Readiness*: New bioenergy technologies, such as biomass-based aviation fuels and biomass for high-temperature industrial processes, are still under development.
- ✓ *Lack of Infrastructure:* Bioenergy infrastructure, such as on-site biomass storage and natural gas grids for biomethane, is limited.

These barriers and challenges highlight the complexity and multifaceted nature of bioenergy implementation. Addressing these barriers is crucial for the successful deployment of bioenergy technologies and the achievement of sustainable energy goals.

Sustainable Development and Bioenergy

The paper examines the role of bioenergy in supporting sustainable development goals, such as reducing greenhouse gas emissions, promoting circular economy principles, and fostering local economic growth. It highlights successful case studies from around the world that demonstrate the environmental, social, and economic benefits of bioenergy projects.
The role of bioenergy in sustainable development is multifaceted and crucial for achieving a low-carbon energy economy. Bioenergy can contribute to sustainable development by:

- *Reducing Greenhouse Gas Emissions*: Bioenergy can replace fossil fuels in energy production, thereby reducing greenhouse gas emissions and mitigating climate change.
- *Promoting Sustainable Land Use*: Sustainable forest management and agricultural practices can ensure that biomass is sourced from sustainably managed forests and agricultural lands, reducing environmental impacts.
- *Enhancing Energy Security*: Bioenergy can improve energy security by reducing dependence on imported energy sources and enhancing local energy production.
- *Supporting Economic Development*: Bioenergy can create jobs and stimulate local economies by utilizing locally sourced biomass and promoting regional economic development.
- *Improving Energy Access*: Bioenergy can provide reliable and affordable energy access to remote and underserved communities, enhancing energy access and reducing energy poverty.
- *Mitigating Environmental Impacts*: Bioenergy can reduce environmental impacts by utilizing waste streams and organic residues, decreasing pollution, and promoting sustainable land use practices.
- *Supporting Climate Change Mitigation*: Bioenergy can contribute to climate change mitigation by reducing fossil fuel use and promoting sustainable land use practices.
- *Enhancing Energy Efficiency*: Bioenergy can improve energy efficiency by utilizing waste heat and promoting energy-efficient technologies.
- *Supporting Sustainable Agriculture*: Bioenergy can support sustainable agriculture by promoting sustainable agricultural practices and reducing the environmental impacts of agriculture.
- *Enhancing Energy Security*: Bioenergy can enhance energy security by reducing dependence on imported energy sources and promoting local energy production.
- These benefits highlight the critical role bioenergy plays in achieving sustainable development goals and mitigating climate change.

How can Albania balance its support for different renewable energy sources?

Albania can balance its support for different renewable energy sources through a multi-faceted approach that addresses regulatory, infrastructural, and financial challenges while promoting public engagement. Here are key strategies to achieve this balance:

1. *Diversified Policy Framework*

Equitable Support Mechanisms: Implement policies that provide equal incentives for solar, wind, biomass, and geothermal energy. This could include revising feed-in tariffs (FiTs) and auction schemes to ensure they are attractive for all types of renewable projects.
Streamlined Licensing Processes: Simplify the administrative procedures for obtaining permits and licenses for various renewable energy projects. This would reduce investor uncertainty and encourage more diverse energy developments.

2. *Investment in Infrastructure*
Grid Modernization: Invest in upgrading the electricity grid to accommodate a mix of renewable sources. This includes enhancing grid stability and integrating energy storage solutions to manage solar and wind energy variability.
Land Use Planning: Address land use conflicts by designating priority zones for renewable energy development. This can facilitate the implementation of large-scale solar and wind projects while minimizing environmental impact.

3. *Public and Private Sector Engagement*
Community Involvement: Foster community engagement and public awareness campaigns to educate citizens about the benefits of renewable energy diversification. Informed communities are more likely to support local projects, increasing acceptance and participation.
Private Sector Collaboration: Encourage partnerships between the government and private sector stakeholders to leverage investment in diverse renewable technologies. This collaboration can bring the expertise and funding necessary to expand the renewable energy landscape.

4. *Research and Development*
Innovative Technologies: Promote research into emerging renewable technologies such as green hydrogen production from solar and wind power. This could open new avenues for energy use in hard-to-abate sectors, enhancing overall energy security.
Feasibility Studies: Conduct comprehensive feasibility studies on various renewable sources to identify the most promising options based on local conditions, such as solar radiation levels and wind patterns.

5. *Long-term Strategic Planning*
Integrated Energy Planning: Develop a national energy strategy that outlines clear targets for each renewable source, ensuring that all forms of energy are considered in future planning efforts.
Monitoring and Evaluation: Establish mechanisms for ongoing monitoring of renewable energy projects' performance, allowing for adaptive management of policies and practices based on real-world outcomes.
By implementing these strategies, Albania can effectively balance its support for various renewable energy sources, enhancing its energy security while contributing

to sustainable development goals. This balanced approach will not only help diversify the energy mix but also position Albania as a leader in renewable energy within the Balkan region.

CONCLUSIONS

In summary, this paper highlights the significant potential of industrial biomass waste as a sustainable energy source for the future. Bioenergy can significantly contribute to the global transition towards a more sustainable and decarbonised energy system by addressing various technical, economic, and regulatory challenges while leveraging innovative applications.
Albania is currently navigating a complex energy landscape characterised by a heavy reliance on hydropower, ongoing challenges in energy diversification, and a gradual shift towards renewable energy sources. The following are key aspects of the situation in Albania:
Energy Dependency and Infrastructure; Hydropower Dominance: Albania generates approximately 99.6% of its electricity from hydropower, making it one of the few countries globally with a high dependency on a single renewable source. While this reliance facilitates decarbonization, it also renders the country vulnerable to climate variability and water scarcity, which could affect energy production by 2040.
Energy Imports: Despite its hydropower capacity, Albania frequently imports electricity due to fluctuations in hydropower generation. The nation has faced challenges with an outdated energy infrastructure, resulting in significant electricity losses, estimated at around 21% in early 2023.

Renewable Energy Initiatives
Commitments to Renewables: Under the Energy Community Treaty, Albania committed to increasing the share of renewable energy to 38% of its gross final energy consumption by 2020, a target it has exceeded with a reported 45%. Recent developments include the commissioning of a 140 MW solar power plant and plans for further solar and wind projects supported by EU funding.
Future Goals: As part of its National Energy and Climate Plan, Albania aims to achieve a 54.4% integration of renewable energy into its final energy consumption by 2030. This includes expanding investments in wind and solar power generation to diversify its energy sources. Based on the information provided, here are the key conclusions regarding the role of bioenergy and modern applications in sustainable development:

Bioenergy as a Sustainable Energy Source: Biomass waste, including agricultural, forestry, and industrial waste, can be a viable and sustainable energy source. Utilizing biomass waste for energy production can reduce environmental impacts, promote the circular economy, and provide a renewable energy source.

Economic Benefits of Bioenergy: Biomass waste used for energy production can offer various economic benefits, such as job creation, reduced energy costs, support for local economies, and enhanced energy security.

Bioenergy Conversion Technologies: The paper explores a range of bioenergy conversion technologies, including thermochemical, biochemical, and mechanical extraction methods. Advancements in these technologies are crucial for improving the efficiency and scalability of bioenergy production.

Barriers and Challenges: Implementing bioenergy faces various barriers and challenges, including technological, policy, supply chain, environmental, social, financial, and regulatory issues. Addressing these barriers is essential for the successful deployment of bioenergy technologies.

Role of IT Applications: IT applications can significantly enhance bioenergy production by optimizing biomass sourcing, supply chain logistics, energy conversion processes, carbon pricing and emissions management, feedstock diversification, research and development, public awareness, policy and regulation, economic analysis, and data analytics.

Contribution to Sustainable Development: Bioenergy can contribute to sustainable development by reducing greenhouse gas emissions, promoting sustainable land use, enhancing energy security, supporting economic growth, improving energy access, mitigating environmental impacts, supporting climate change mitigation, enhancing energy efficiency, supporting sustainable agriculture, and improving energy security.

Finally, the strategic integration of bioenergy is pivotal for achieving sustainable development goals and facilitating the transition to a low-carbon energy economy

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THE RENEWABLE ENERGY DIMENSION IN THE NATIONAL CLIMATE AND ENERGY PLAN

By Dr. Eng. Gjergji Simaku

ABSTRACT

This paper presents a thorough quantitative and qualitative analysis of the share of Renewable Energy Sources (RES) in the National Climate and Energy Plan (NCEP) until 2030. It also analyses the energy demand and optimal scenarios, as well as the environmental costs and benefits associated with the recommended Policies and Measures (PaM) for achieving the RES target and contributing to the decarbonisation of the energy sector in Albania. The paper begins by identifying the energy need to estimate the sector's production in 2030 and determine the extent of decarbonisation. This information is then used to analyse the PaM in the optimistic scenario, with supporting measures for the costs and benefits of RES diversification regarding energy efficiency (EE) achievements to target the 2030 goal.

In addition to the specific environmental benefits due to the increase in RES production, their consumption in Albania is more critical. In this context, co-benefits were assessed to understand their dimension and impact on decision-making regarding energy security in decarbonising this sector. Finally, RES supply curves in the electricity generation sector and beyond were developed to show photovoltaic plants' priority in the national energy balance. Due to the consolidation of energy security in Albania, decision-makers' behaviour has changed and should change even more in the future. Energy consumption in the residential sector remains a challenge that has the potential to contribute to and mitigate the production and/or transfer of carbon through energy. However, if advanced PaMs are applied, renewable energy, the cost-effectiveness of measures, and CO2 emissions trading remain unknown European realities in Albania.

Keywords: Decarbonization. Photovoltaics. Policies and Measures. Renewable Energy Sources. RES Consumption. RES Production. Climate and Energy Plan. Security of Supply. Cost-benefit, CO2 Emissions.

INTRODUCTION

The implementation of National Climate Policies is essential in addressing environmental challenges and promoting sustainable practices in the energy sector. These policies prioritize the reduction of greenhouse gas emissions (GHG), the promotion of renewable energy sources (RES) and the increase

of energy efficiency (EE), thus mitigating the impacts of climate change through the decarbonization dimension. The National Energy and Climate Plan (NECP 2020-2030) is an obligation for the Government with the aim of identifying concrete measures for the implementation of climate policies.
Currently, the NECP has been revised after the 2021 version (DCM 872/2021). This version had foreseen Policies and Measures (PaM) until 2030 which, if implemented, would enable the achievement of national climate objectives in accordance with the Paris Agreement (COP[1]21). The agreement was accompanied by the ratification of the NDC document[2] in 2016 to reduce cumulative CO2 emissions by -11.5% according to the 2030 emissions scenario. At the end of 2021 at the Glasgow COP26 conference, Albania presented an even more advanced proposal for reducing cumulative emissions by -20.9% based on 2016. This qualitative change has to do with the way the calculations were made in the NDC document. The article attempts to make a scientific analysis to calculate these previously immature decision-making at the technical level.
In the 2024 NECP, PaMs are part of the five dimensions of the energy/climate relationship: (i) energy security; (ii) internal energy market; (iii) energy efficiency; (iv) decarbonisation; and (v) research, innovation and competition. The five dimensions of the Energy Union together underpin the decarbonisation of the energy sector, and each addresses a key aspect of energy policy and infrastructure. In short, decarbonisation aims to establish a low-carbon energy system in all sectors of the economy, with a particular focus on supporting clean energy technologies and reducing carbon emissions. Without a doubt, in the last three decades, renewable energy is today not only a reality, but also a positive perception in the entire policy-making debate in Albania.

NECP 2025, Decarbonization and RES

Despite the "perception" that Albania is a country that produces 100% electricity from RES, the challenge of decarbonization is the object of the NECP. This means that the expansion and integration of Renewable Energy Sources (RES) and the implementation of mechanisms such as carbon pricing or emissions trading systems to stimulate the reduction of Greenhouse Gas (GHG) emissions in our country, are the two variables of decarbonization.

[1]The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21 - 21st Conference of Parties) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016 when it was ratified by the UNFCCC.

[2]NDC – National Determined Contribution. (National Targeted Contribution for GHG emissions)

Given the debate in the energy sector, there is no doubt that the expansion of the RES sector reduces the effect of GHGs and this through global climate agreements. These agreements for Albania come in the form of national RES and CO2 reduction targets. These two components are objects of legal monitoring and deserve a quantitative analysis necessary to understand where we are and where decisions on the expansion of RES are taking us. What are the main reasons?

First, are the strategic objectives in the decarbonization dimension which include the implementation of the revised national targets for greenhouse gas (GHG) emissions. The questions that arise are: how much CO_2 has been emitted into the atmosphere from Albanian land with the base year 2016? What about the base year 1990? How much is projected to be emitted by 2030 and 2050? Where does the analysis of the 4 national communications of GHG inventories for the energy sector lead? How much should they be reduced in the cumulative scenario of 2030? What about 2050? Which sectors are the largest contributors to carbon emissions? These questions are often unresolved and not analyzed or monitored.

Secondly, the regional and European energy market risks the development of RES in Albania. Green electricity market, too! All this because, the production of energy from RES in Albania risks being traded more expensively in the region and in Europe. Therefore, it is necessary to conduct a quantitative and qualitative analysis to find the way to achieve the objective of 54.6% renewable energy in the national energy consumption balance in 2030. For this, the analysis of the dimension of decarbonization through RES is quite necessary.

Thirdly, The Renewable Energy Sources dimension demonstrates Albania's commitment towards ensuring a reliable, affordable and sustainable energy supply through the diversification of energy sources.

Quantitative analysis of energy production and consumption from renewable sources

National balance

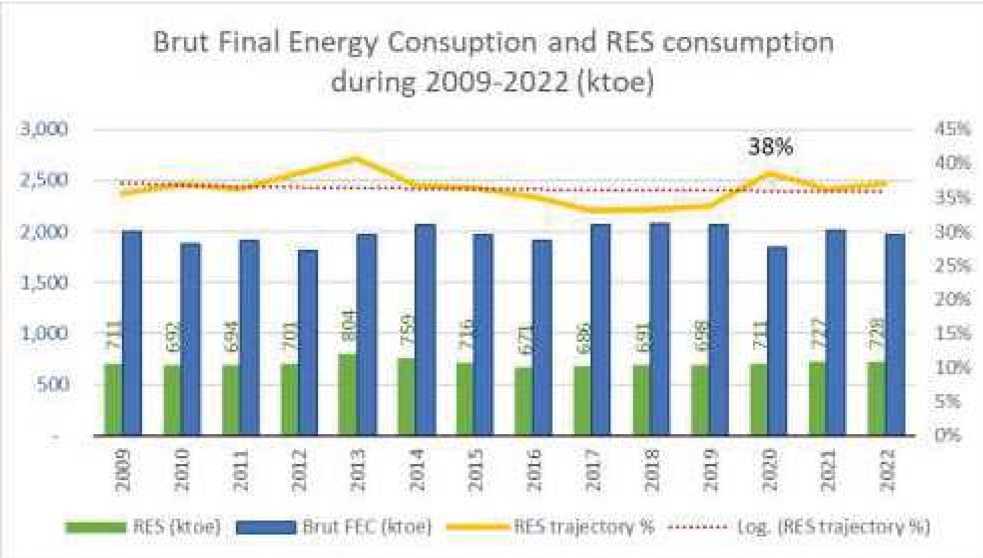
From the national balance data from 2010 to 2022, the Final Consumption of Energy Resources[3], consumption from RES[4], BRE-n/f[5]and RES[6], the total energy consumption from RES as well as the share of RES in percentage to the GFCF in the last 13 years is according to the table below.

[3]EUFC
[4]RES in the electricity sector
[5]RES in heating and cooling
[6]RES in the transport sector

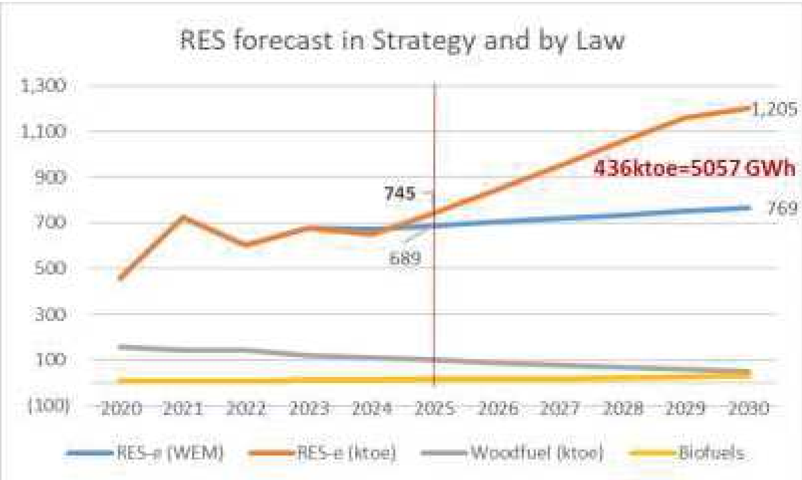
ktoe/year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BRE-electricity	507	487	486	495	593	561	507	474	515	523	532	543	573	573
BRE-heating	204	205	208	206	203	193	204	190	165	159	157	160	146	145
BRE-transport	-	-	-	-	8.1	5	5.2	6.6	6.1	8.7	9.45	8.4	8.4	10.15
BRE-Total	711	692	694	701	804	759	716	671	686	691	698	711	727	728
Brut FEC	1997	1879	1913	1817	1971	2070	1967	1912	2070	2082	2067	1845	2007	1964
RES %	36%	37%	36%	39%	41%	37%	36%	35%	33%	33%	34%	39%	36%	37%

Source: National Balance Reports (2009-2022), AKBN http://www.akbn.gov.al/bilanci-energjetik

As we can see in the graph, the 38% target for 2020 only occurred that year and varies between 41 and 33%. FEC is almost constant at 2000 ktoe.



In the National Energy Strategy 2018-2030 (NES), the forecasts for the increase in energy consumption were made based on the increase in GDP. The forecasts have never been confirmed. Albania continues to remain at the average level of 2000 ktoe of brut FEC from 2009 to the last year. Meanwhile, GDP has increased from 12 billion USD in 2009 to 23 billion USD in 2023. This growth of approximately 4% per year of GDP did not stimulate an economy with high energy consumption.



Conclusion: This discrepancy between NECPand the calculations derived from the acts and annual reports of the electricity system operators is very obvious. To correctly implement the RES law, about 14 TWh of electricity from RES is needed in 2030. Meanwhile, NECP foresees 8.9 TWh, an amount that is realistically possible. The remaining 5.1 TWh (the annual production of KESH) is an amount that should be addressed in other sectors where energy is consumed. The objective of 54.4% of the RES share can be achieved in 2050.

RES status and quantitative forecasts

Albania is implementing a RES diversification strategy to increase investments in non-hydro power generation projects. As a result of falling technology costs and the country's considerable renewable energy potential, the number of independent power producers is increasing year by year, which is an important step towards security of supply.

At the end of 2022, there were 48 MW of installed solar photovoltaic plants. During 2023, 12 plants with an installed capacity of 26 MW entered the production phase, of which 7 MW are hydro and 19 MW from photovoltaic plants. The electricity production realized by the plants that entered production during 2023 accounts for about 0.4% of the total domestic electricity production for this year. In 2024, 12 companies with 2MWp each were licensed and about 228MWp of plants were awarded to 4 companies for the free market. Earlier in 2024, two auctions were organized for 222 MW for wind energy and 300 MW for photovoltaic (PV). Production is expected to increase by 115ktoe or 6% of the annual energy balance.

The year 2025 began with the Prime Minister's statement that 196 MWp of PV modules have been installed on the roofs of businesses for self-production during 2020-2024, a development that reduced the demand for electricity by about 12% over the last three years. Total electricity consumption for 2023 results in a value of 7.875 TWh, which is almost the same as the consumption value of 2022. Electricity consumption for 2023 compared to 2021, which also represents the maximum consumption, results in a decrease of 0.54 TWh. However, dependence on energy imports accounts for 20-30% of energy demand and ensuring security of energy supply remains a challenge. Self-producers have provided approximately 255 TWh or 22 ktoe and are not taken into account in the ERE annual report because they are not dispatched.

The total net domestic electricity generation achieved for 2023 is 8,796 TWh, entirely produced from renewable sources with hydro and solar PV. The total consumption achieved for 2023 results in 7,875 TWh, almost the same values as the consumption achieved during 2022.

Quantitative estimates of RES consumption.

According to Law 24/2023 "On the Promotion of RES", the mandatory trajectory of the share of RES in relation to the GFCF is foreseen, which is 54.4%.[7]for 2030. NECPprovides the quantitative calculation for the

[7]Article 6, paragraph 1 “The share of energy from renewable sources in gross final energy consumption in 2030 shall be 54.4%.”

development of RES through two scenarios, namely the scenario with existing measures (WEM) and the one with additional measures (WAM).
According to the quantitative analysis of PKEK, the percentage of RES in TPES[8]for the period 2020-2030 should go from 34%, which is currently, to 54.4% in 2030 following the WAM RE (RE-e) scenario that takes into account only domestic electricity demand. In its analysis, this plan predicts that this amount of RES-e for 2030 could reach 39.6% of the share of renewable energies in the amount of TEFC[9] (FEC). In other words 39.6% or 895 ktoe[10]are 10.4 TWh the amount that Albania is expected to consume in 2030. This conclusion for 2030 is "contradicted" by the electricity consumption forecasts analyzed to date by ERE and OST, which are 8.9 TWh (769 ktoe).
The graphs above are derived from calculations with official data and show that the percentage of RES together that should be consumed in the Albanian territory is 1287 ktoe and the RES share is 1025 ktoe (about 14TWh) adding here the forecasts for woodfuel 50 ktoe and biofuels with 32 ktoe.

Is woodfuel a Renewable Energy Source?
In the World Bank study for the Western Balkans[11], Albania has a long history of using woodfuel for heating. After 1990 and until today, this consumption fell significantly due to deforestation, which led the Government to impose a moratorium on forest logging in 2016. The study shows that forest rehabilitation is almost impossible in the next 50 years
According to the national balance for the years 1990-2023, the consumption of woodfuel for heating has decreased significantly, from 208 to 123 ktoe. In terms of heat for heating, their volume has decreased from 2.4 TWh_{th}[12] at 1.4 TWh_{th}.
The decline in woodfuel consumption will continue for three reasons: (i) in Albania, woodfuel is being used only in a few districts such as Korça, Dibra, Kuksi and heat pumps are apparently replacing wood heating; this phenomenon is becoming more apparent every year. (ii) The forests used for woodfuel are not only far from populated areas but also expensive due to control over them and transportation. (iii) The burning of woodfuel is turning

[8]TPES - Total primary energy supply
[9]TEFC - Total Energy Final Consumption (TEFC)
[10]Table 33 page 262 of the draft for public consultation of the 2020-2030 PKEK
[11]Biomass-Based Heating in the Western Balkans 2017
https://documents1.worldbank.org/curated/en/135831542022333083/pdf/Biomass-Based-Heating-in-the-Western-Balkans-A-Roadmap-for-Sustainable-Development.pdf
[12]1ktoe=11.63 MWh. For firewood for heating, the index “th” means “thermal”.

into pollution due to the released GHGs that are no longer absorbed by the forests.

Conclusion: Woodfuel is a renewable energy source, as long as forests are managed sustainably by compensating for the cutting of trees by planting new ones, forests should recover faster than they are consumed. This is not the case in Albania.

It has been found that 1 kg of wood contains about 450 to 500 g of carbon. This means that 1 kg of wood releases about 1.65 to 1.80 kg of CO2. Thus, the forest acts as a carbon sink (carbon killer)[13]Similarly, burning 1 kg of wood should generate 1.65 to 1.80 kg of CO2.

Biofuels

In the Philippines, the 2006 law No. 9367, known worldwide as the “Biofuels Act” was enacted to regulate the production, blending, storage, handling, transportation, distribution, use and sale of biofuels, biodiesel and biofuel feedstocks. In Albania, through the continuous push by EnC[14] a relevant draft law was introduced in 2016 and still remains so.

The law provides for the mandatory use of biofuels in the fuel mix, as follows: Starting from 2020, the minimum annual amount of biofuels and other renewable fuels for transport on the market will not be less than 10% of the amount consumed by transport in 2018 and 2019; the level of biofuels produced from waste, non-food cellulosic materials and resulting non-waste cellulosic materials will be half the target level set for other biofuels.

In Albania, biofuels began production in 2008 in accordance with law no. 9876 dated 14.02.2008 as a novelty for the Albanian hydrocarbon processing industry, when the first Bio-refinery in Albania was built in Porto Romano – Durrës. This plant, owned by the Green Fuel company, has a production capacity of 120,000 tons per year.

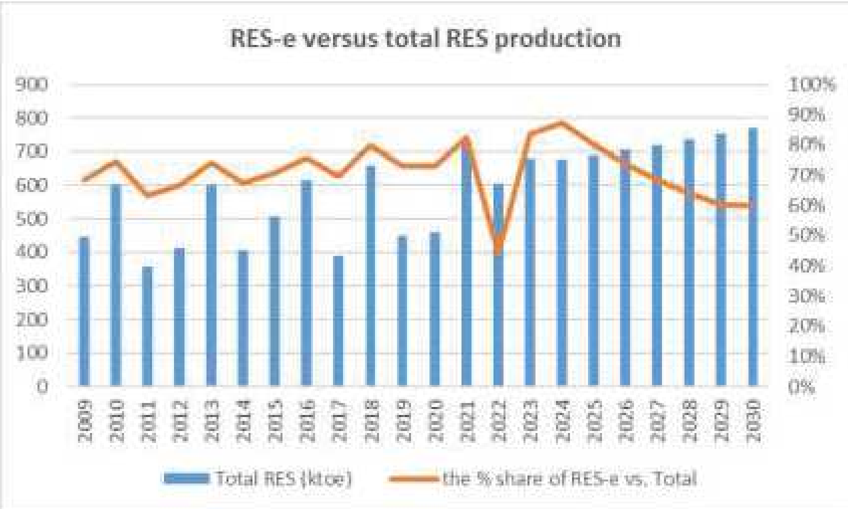
The basic products of this plant are “Biodiesel” (blended diesel - a mixture of organic matter of plant origin - vegetable oil) and Bioethanol (gasoline mixed with organic matter, produced by the fermentation of sugar-rich products - sugar cane, sugar beet, etc.). However, Albanian and EU legislation also recognizes as combustible biofuels for transport Biogas, Biomethanol, Bio-ETBE (Ethyl-Tertiary-Butyl-Ether), Bio-MTBE (Methyl-Tertiary-Butyl-Ether), Synthetic Biofuel, etc.

[13]https://www.quora.com/Is-wood-a-renewable-or-non-renewable-source-of-energy.

[14]EnC – Energy Community in Vienna where Albania is a contracting party since its establishment in Thessaloniki in 2006

Within the framework of the NDC for the reduction of greenhouse gases in the Transport sector, the law aims to promote the contribution to the fulfillment of commitments for gas emissions resulting from the consumption of hydrocarbons in this sector. For Albania, Transport is the largest contributor of CO2 in road transport and is estimated to be 740 -850 ktoe per year with an increasing trend of GHGs which, even in the size of the country, significantly affect climate change.

Conclusion: RES in Albania are dominated by electricity production at 80-85% in recent years. Biofuels and wood biomass account for about 15%. Renewable energy due to heating/cooling from heat pumps is not yet calculated and is potentially high.

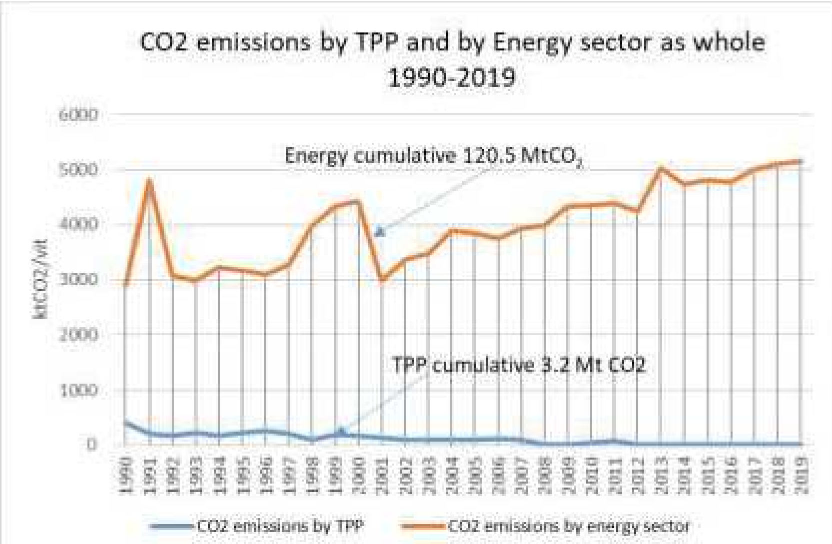


Carbon emissions from energy and thermal power plants in Albania after 1990.

Regarding the beginnings of electricity production, in 1923 the first Diesel group was installed in Tirana, which was followed by installations of other groups in the main cities of the country. In 1951 the first TPP in Tirana.[15]. In 1957, the National Electric Power System was created, which had in its portfolio 60 MW of installed generating power and about 200 km of 110/35 kV voltage line. In 1980, the 60MW Czech turbine was installed in Fier, which marks the end of the era of TPPs before the '90s. We inherited from the totalitarian regime an installed power of 1684 MW, of which 1446 MW with

[15]Source: Albanian Electric Power Corporation

HPPs, 194 MW with HPPs and 14MW small HPPs. Thus, seven HPPs with a power of 194 MW used coal, fuel oil, gas or solar as raw materials.
With the sudden increase in electricity consumption due to the lack of fuels in general and the decline of industries in particular, in the early 1990s, production by TPPs fell drastically. TPPs in the country began to stop production, starting with the Vlora TPP in 1991 and ending with the Fier TPP in 1993.
Regarding carbon emissions, in the literature[16]At least 1228 grams of CO_2 is predicted for every kWh of electricity produced for coal-fired power plants for efficiencies lower than 50%. This assumption is made to roughly estimate that carbon emissions from power plants in the years 1990-2019 are at the level as in the table below where it can be seen that for this period the cumulative CO_2 emissions in the energy sector in general are a total of 120.5 compared to 3.2 Mt CO2 contribution from power plants.



Source: First Communication[17], second[18], third[19]and fourth[20]national GHG inventory in Albania.

As can be seen in the graph, the TPPs in the country began to stop production starting from the TPP of Vlora in 1991 to the last one of Fier, which produced at a very high cost and in extremely depreciated conditions until 2007. The

[16]UBA 2019 - Emissionsbilanz erneuerbarer Energieträger 2018
[17] https://unfccc.int/sites/default/files/resource/albnc1.pdf
[18] https://unfccc.int/sites/default/files/resource/albnc2_0.pdf
[19]https://unfccc.int/sites/default/files/resource/Albania%20NC3_13%20October%202016_0.pdf
[20]https://unfccc.int/sites/default/files/resource/Fourth%20National%20Communication%20of%20Albania%20to%20the%20UNFCCC_EN.pdf

stoppage of production of these power plants came as a result of their extreme depreciation. Thermal power plants in Albania (although with a production cost several times higher than hydro production) have served and can serve in terms of security of supply, for load balancing and often to allow a more efficient use of hydropower. Also in our country before 1990 we have a history of combined heat and power production from small TPPs that served mainly industrial processes, such as the one in Tirana in '51, 1x2.5 and 1x2.4 MW which stopped in 1994, Cërrik '56 with 2x3.5 and 1x1.5 MW stopped in 1992, Vlorë '56 with 2x1.5MW stopped in 1991, Kuçovë '41, '54' and '60 with 1x3.6 and 1x2MW stopped in 1992, Korçë '71 with 6MW stopped in 2000, Maliq '51, '60 and '83 with 1x4 and 2x1.5MW, as well as in Fier '60 and '80 with 2x12, 3x25 and 1x60MW that stopped in 2007.
After a period of almost 30 years when no new thermal power plant was built, in 2007 the approved project led to the construction of a new TPP in Vlora with an installed capacity of 97 MW fuelled by oil. This project was put into operation at the end of 2011 and, following a defect in the cooling system, is currently under conservation.
Thermal power plants in Albania continue to attract the attention of the Government even today. This energy policy is being promoted in a period when, throughout Europe, there is talk of an “energy transition” and when Albania has approved COP21 by law. However, before the crisis due to the Russian invasion of Ukraine, the “energy transition” in most European countries meant “face out” of energy production with TPPs that use fossil resources lignite (hard coal). The year 2024 has proven to be the first year when this European energy policy has been fully implemented. The share of electricity produced by coal-fired TPPs in the EU-27 decreased to 20% in 2018. In 2020, 166 coal-fired TPPs with a total capacity of 112 GW were decommissioned in 18 EU countries. However, coal remains a key fuel in the European energy mix. The transition to cleaner forms of energy and innovative technologies, such as carbon capture and storage, are being used today to meet the EU's commitment to reduce CO2 emissions by at least 55% by 2030. The EU is committed to becoming the world's first climate-neutral bloc by 2050.
The Paris Agreement advanced the ambition for Climate with meetings of member countries in the coming years[21]and the use of natural gas as a fuel to replace power generation with the “face down” theory has become part of the decarbonization of the electricity generation sector in Europe. In the

[21]COP22 – Marrakesh 2016; COP23 - Bonn 2017; COP24 – Katowice 2018; COP25 – Madrid 2019; COP26 – Glasgow; COP27 – Sharm El-sheikh; COP28 – Dubai; COP29 – Baku.

framework of COP26, at the end of 2021, Albania appeared in Glasgow with the ambition to reduce GHG even further (-20.9%).
During the years 2021-2024, in addition to the 97MW Vlora TPP built in 2011, within the framework of the development of TPPs in Albania, there are two Government decisions. The first, through the Council of Ministers No. 757/2021, the floating TPP with HFO fuel was approved.[22]90MW located in the Gulf of Vlora. The decision authorized KESH sh.a. to temporarily (1-2 years) lease additional thermal generating assets, which can be easily connected to the Albanian Power Transmission Network. The TPP is currently on standby and partially in operation as it operates in case of emergencies.
The second decision concerns DCM 785/2024 "On the approval of the construction of the Thermal Power Plant and auxiliary works, which is not a concession object, located in Roskovec, Fier district, by the company "Fier Thermoelectric", sha"[23]This TPP is planned to be of the 170MW CCGT type and is intended to be connected to the TAP project's Natural Gas pipeline.
In 2007, the construction of the Vlora Combined Cycle Power Plant (CCGT) with a capacity of about 97 MW was approved. The aim was to increase production capacity and create an alternative energy source that would create "independence" from the conditions. This plant was planned to operate with a combined cycle using oil or gas as fuel.

Conclusions and recommendations

This paper contrasts two important components of energy production: RES and CO2 that comes from electricity production and beyond.
The results of the analysis show that the necessary amount of energy production and consumption from renewable sources to meet energy demand is the first and necessary indicator to achieve the 54.5% renewable share target in the EU. Given the current status of RES developments in the last 5 years (2021-2025), we can conclude that the dimension of renewable energy towards the decarbonization of the sector is:
1. The amount of RES for the domestic market currently:
RES-E
a. HEC/HECV = 683 ktoe (constant average 2020-'30)
b. Solar PV, 70 MWp Karavasta /0.12TWh/10 ktoe
c. Distributed solar PV 196MWp/0.25TWh/22 ktoe

[22]Heavy Fuel Oil
[23]published in the Official Gazette FZ-2024-216, page 24872

d. Solar Vau Dejës 5.5MWp/0.07TWh/0.6 ktoe
e. Solar PV 19x2MWp/0.808TWh/70 ktoe
RES Wood biomass 103 ktoe
BRE transport biofuels 73 ktoe

Total 960/2365 = 40.5% RES in 2025
The GHG effect[24] =4.57 Mt CO2eq/year

The amount of RES that are for the domestic market is forecasted:
f. Solar PV 70 MWp Spitalla/0.13TWh/10 ktoe
g. Solar PV 300 MWp hybrid/0.5TWh/43 ktoe
h. Solar PV 50 MWp EU/0.75TWh/6.5 ktoe
i. Wind 333 MW/0.97 TWh/83 ktoe
RES Wood biomass 103 ktoe
BRE transport biofuels 73 ktoe

Total 1019.5/2365 = 43% RES in 2028
The GHG effect = 5.2 Mt CO_2eq/year

2. The amount of RES for the free market provided by the Ministry of Energy:
a. PV100MWp Karavasta+Hospital/0.15TWh/13 ktoe
b. PV 603 MWp approved/0.9 TWh/77.8 ktoe
c. PV 293 MWp preliminary approval/0.44 TWh/38.0 ktoe
d. WP 1950 MW under approval/2.9 TWh/251 ktoe

Total free market on RES it predicts 2946MW or 4.39TWh which is about 380 ktoe.
Assuming that this amount would be spent within the Albanian territory (not on the free market), in 2030 Albania would meet around 1400 ktoe and reach 52.8% of the RES share in the brut FEC. This amount would decarbonize by +1.9 Mt CO2eq/year. The amount of 7.1 Mt CO2eq/year is equal to 6% of cumulative GHG. From 1990 to 2019 the amount of emissions from energy is in the amount of 120 Mt CO2eq.

RECOMMENDATION It is worth technically and formally reviewing RES and CO2 reduction as two components of national targets or Goals.
Gj.S. 04.02.2025

[24]Compared to natural gas CCGT plant (411gCO2eq/kWh)

KINETIC MODELING OF CATALYTIC PYROLYSIS OF BIOMASS IN A SEMI-BATCH REACTOR

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ABSTRACT

The constant increase in energy demand, as well as the introduction of new standards for the use of non-polluting energy, motivated investors to invest in renewable energy sources. Biomass is an abundant source of renewable energy. The establishment of biomass refineries can significantly contribute to the search for economical and sustainable energy solutions. Pyrolysis is a thermochemical process that transforms organic materials from biomass into valuable products, usually in the presence of a catalyst and in an oxygen-free environment. During the process, the obtained products are solid residues, liquid, and gaseous fuels. Bio-oil, a significant product of pyrolysis, has the potential to serve as a partial substitute for traditional petroleum fuels or as a precursor for chemical synthesis. Additionally, bio-char produced during pyrolysis has various applications, including use as a domestic solid fuel, activated carbon, additive, and fertilizer. The generated biogas can be utilize as a fuel source.

In this study, the fast pyrolysis of biomass, Oak wood chips, was investigated. Pyrolysis was performed in an inert atmosphere, in presence of nitrogen, in a semi-batch reactor with Al_2O_3 and natural opalized silicate - tuff as catalysts. The ratios of biomass, Al_2O_3, and tuff as catalysts and the obtained bio-oil were 1:0.25:0.75 and 1:0.75:0.25, and 50.48% and 52.59%, respectively. The bio-oil produced is a viscous liquid that varies in color from dark to light brown and possesses a smoky odor. The influence of type and amount of catalyst on the kinetics of the process and the amount of obtained products were investigated. Adequate mathematical models were used to describe the kinetics of obtaining bio-oil.

Keywords: pyrolysis, biomass, catalysts, bio-oil, modelling

1. INTRODUCTION

With the progress of industrial development, the need for energy has also increased in the last few decades. The limited use of fossil fuels due to their negative environmental consequences and limited resources has created a need to research new alternative fuels, derived from renewable energy sources, which can serve as a partial or complete replacement for fossil fuels. The utilization of renewable energy sources contributes to a decrease in the emission of greenhouse gases and particulate matter in the atmosphere. Biomass, although it possesses a lower calorific value in comparison to fossil fuels, remains one of the most prevalent energy sources. Typically, the utilization of biomass is limited to combustion, generated energy primarily employed for residential heating. The primary biomass consist of cellulose, which accounts for approximately 50% by weight on a dry basis, hemicellulose, comprising around 25% by weight on a dry basis, and lignin, also representing about 25% by weight on a dry basis [1]. Pyrolysis is a thermo-chemical process that transforms solid and liquid materials into fuels suitable for diesel engines, boilers, and gas turbines. In recent years, there has been significant interest in utilizing waste biomass as a feedstock for the production of liquid bio-oil. During the pyrolysis of biomass, the valuable products, such as liquid (bio-oil), solid (bio-char) and gas (syngas), were produced [2-4]. The yield and composition of the products obtained during the pyrolysis process depends on the type of materials, process conditions and the type of catalysts. Also, the quality of the resulting bio-oil is influenced by the conditions under which the process is conducted, as well as subsequent upgrading methods. Enhancing the quality and stability of bio-oil is essential due to its high acidity, moisture content, and elevated levels of oxygen. Furthermore, for the commercial utilization of bio-oil, particularly in terms of storage and transportation, thorough characterization is required [5-8].
Kinetic modeling of biomass pyrolysis involves understanding and predicting biomass decomposition processes with time and temperature. Typically, modeling the kinetics of biomass pyrolysis is followed by determination of kinetic parameters from the rate constants, such as activation energy and frequency factor. In this way, the reaction mechanism for the pyrolysis process is determined [9-12]. Until now, in a literature can be found modeling the kinetics of thermal pyrolysis of the large macromolecules that make up the biomass (lignin, hemicellulose and cellulose) and there are still no integrated researches on the kinetics of the whole biomass in the presence of catalysts [13-16].

In this paper the integrated kinetics of catalytic pyrolysis of waste biomass (Oak wood chips) are studied. Modeling of the kinetics was conducted by simple empirically mathematical models. The effects of the type and composition of catalysts was investigated to maximize the yield of obtained bio-oil.

2. EXPERIMENTAL

Materials and methods

The kinetics analysis of the pyrolysis process was carried out in a semi-batch reactor, with a volume of 0.4 x 10^{-3} m³ and an inner diameter of 5 x 10^{-2} m. Oak wood chips were conducted on pyrolysis in an oxygen-free environment and presence of catalysts, Figure 1 and Figure 2. Bio-oil was collected at three separators with constant temperatures (T_1=70°C, T_2=T_3=0°C), then measured, filtered and analyzed. The fast pyrolysis reaction was conducted in the presence of commercial Al_2O_3 from BASF (contains 92.7% Al_2O_3, Figure 3) and natural opalized silicate - tuff (comprising 94.51% SiO_2, Figure 4) as catalysts. The heating rate and temperature within the reactor are 10°C min^{-1} and 650°C, respectively; Process conditions were regulated and optimized through a PID controller, specifically the Unitronics V 570, Figure 5. Nitrogen, serving as the carrier inert gas, was utilized at a flow rate ranging from 50 to 100 x 10^{-3} m^3 h^{-1}.

Figure 1. Laboratory equipment for pyrolysis

Figure 2. Oak wood chips

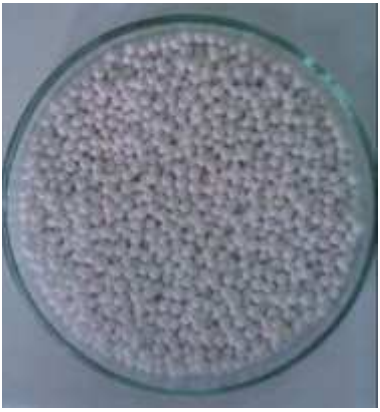

Figure 3. Granulate Al_2O_3

Figure 4. Natural opalized silicate tuff

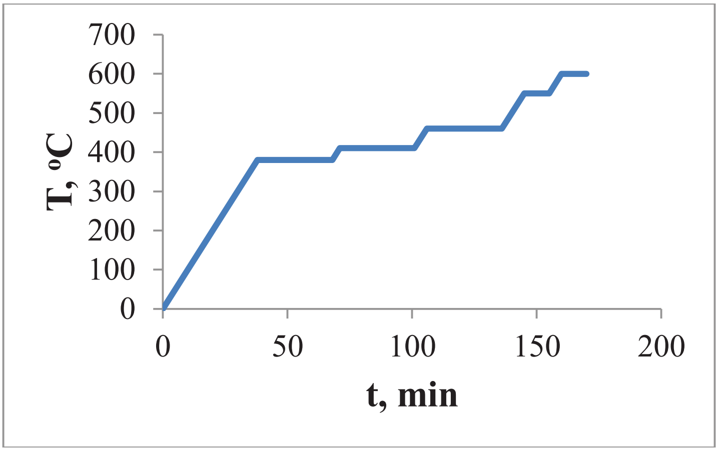

Figure 5. Operating mode of the PID controller for the process of pyrolysis of Oak wood chips, T – temperature, °C; t – time, min

The reactor is filled with 30-40 g of biomass and catalyst alternately, forming a packed layer of biomass and catalyst. Then, the reactor is closed and connected to three thermostatic separators placed in series, where condensation of the evaporated part of the biomass and its fractionation was performed. The inert gas supply is connecting to the reactor and heating is started. The choice for the heating rate of the reactor, according to which the experimental tests are carried out, was made from previously performed experiments and according to literature data [17-19].

3. RESULTS AND DISCUSSION

Kinetics analysis

The kinetics of the pyrolysis process and the influence of the ratio of biomass and type of catalysts on the yield of obtained bio-oil were investigated, Figure 6. The onset of pyrolysis of wood chips starts at 370 °C, with the first drops of condensate consisting mainly of water and a little bio-oil appearing already at 250 °C. The pyrolysis process takes place intensively from 370-410 °C, and then decreases to 530 °C. The pyrolysis ends up to 550 °C and the continuation of the pyrolysis performed at a temperature of 600 °C does not change the amount of obtained bio-oil. The collected bio-oil has a yellow to light brown color and a pleasant smell of smoke, Figure 7. Obtained bio-char (carbon black) was dark black in color and irregular in shape, Figure 8. The yield of collected bio-oil with the reaction time was analyzed under different catalysts compositions. The combination of commercial obtained Al_2O_3 and natural opalized silicate - tuff showed excellent results on increasing the reaction rate and the amount of obtained bio-oil. From the performed experiments and the obtained results, it can be concluded that the use of Al_2O_3 as a catalyst in a larger amount significantly contributes to obtaining a higher yield of bio-oil. Experimental investigations show that the kinetic curves are composed of two long linear parts and one short exponential, transitional part.

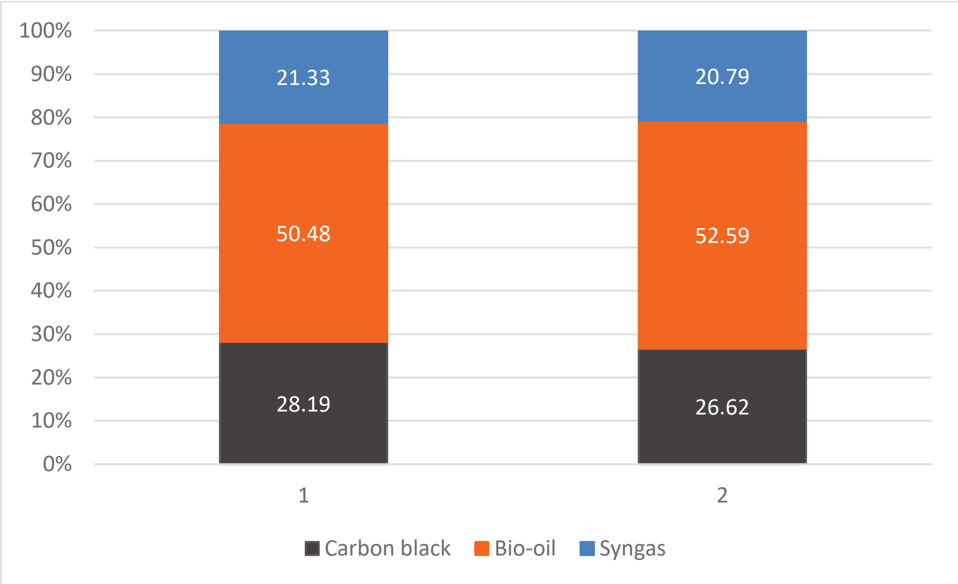

Figure 6. Overall pyrolysis product yield (bio-oil, syngas and bio-char);
Experiment 1. Biomass: Al_2O_3:Tuff = 1:0.25:0.75,
Experiment 2. Biomass: Al_2O_3:Tuff = 1:0.75:0.25

Figure 7. Bio-oil

Figure 8. Bio-char

Modeling kinetics of obtained bio-oil

Biomass has a complex chemical structure with a variable composition, a different biomass material, which affects the kinetics of the chemical reactions that occur during the pyrolysis process. As a result, in the literature, different ways of modeling the kinetics are encountered with different assumptions and conditions depending on the type of material, the pyrolysis conditions and the catalysts used. During the pyrolysis of biomass, products are simultaneously obtained in gas, liquid and solid phase. When describing the dynamics of the process mathematically, it is necessary to take into account all the reactions that occur during pyrolysis. To solve these problems, two approaches are possible: using phenomenological models [20, 21] and solving the complex process by applying empirical models. The mathematical description of the dynamics of the waste oak chips pyrolysis process is performed by applying empirical models. Choosing the model was made according to the shape of the pyrolysis curves, bio-oil opposite time and temperature, which define biomass decomposition. The kinetics of the biomass pyrolysis can be effectively modeled using multi-parameter empirical models. It can be present by two linear parts: the first when the reaction rate is kinetically controlled and the second when the reaction is diffusion limited. The estimation of the empirical constants that are part of the applied models is done by applying the method of fitting the experimental data to the model data. The kinetics of the biomass pyrolysis process and obtaining bio-oil are shown on Figure 9 to Figure 11. The amount of syngas produced was calculated from the material balance. The mean square deviation was taken as a measure of the accuracy of the model, and the Solver tool from the computer program Excel, Microsoft Office 2016 was used to calculate the model parameters, Table 1. Empirical models have shown good applicability in modeling the dynamics of the pyrolysis process and obtaining bio-fuel. Empirical models are simple, easy to use, and can describe the biomass pyrolysis process and liquid fuel production with high accuracy. Some of these empirical models are shown below:

Model 1:

$$Y = \frac{a}{\left[1 + \exp\left(b + c * t\right)\right]} + d$$

Where:

Y - total amount of bio-oil

a, b, c and d are model parameters

t - pyrolysis time

Model 2:

$$\frac{Y}{Y_\infty} = 1 - \left[k_1 \exp(-k_2 * t) + k_3 \exp(-k_4 * t)\right]$$

Where:

Y_∞ - bio-oil obtained at infinite time k_1, k_2, k_3, and k_4 are model parameters

Model 3:

First period:

$$Y = k_1 * t \text{ for } Y \leq Y_1$$

Second period:

$$Y = Y_1 + k_2 * (t - t_1) \text{ for } Y > Y_1$$

$$t_1 = Y_1 / k_1$$

Where:

Y_1 – bio-oil obtained in the first, fast period of pyrolysis

k_1, k_2 are model parameters

y_1 – intersection of the two curves of the first and second period of pyrolysis, $y_1 = Y_1/m$; m – amount of biomass

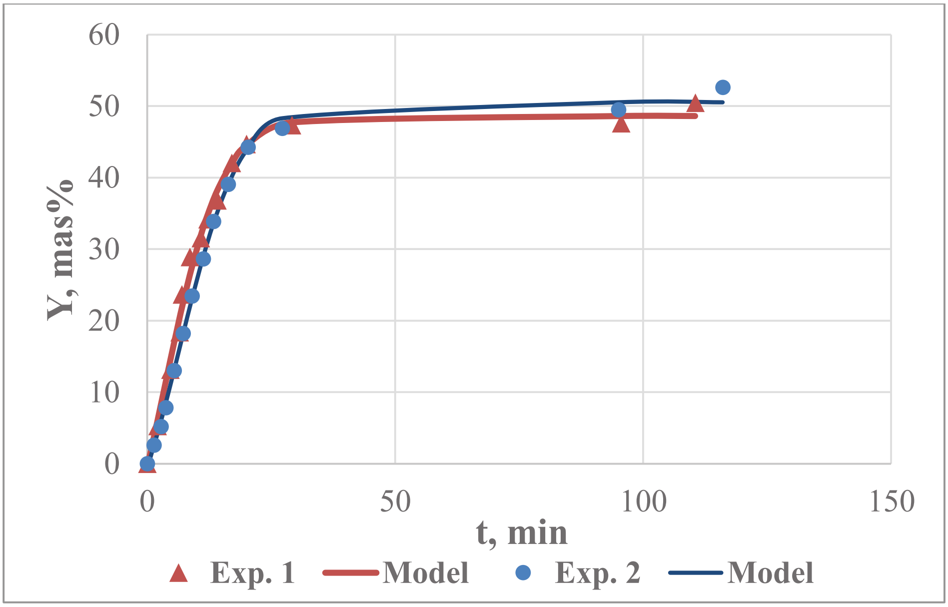

Figure 9. Experimental and model curves, Model 1

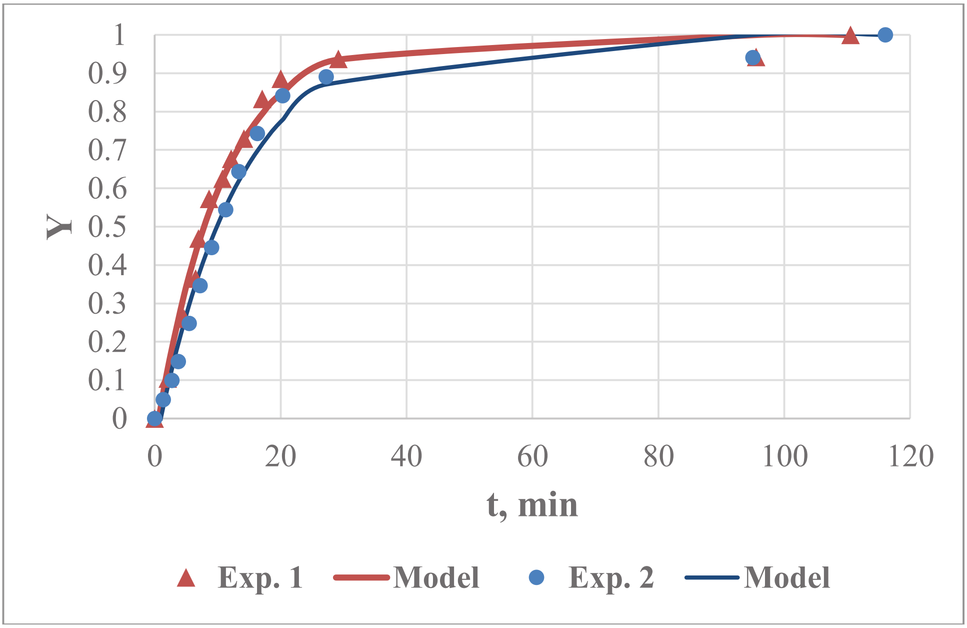

Figure 10. Experimental and model curves, Model 2

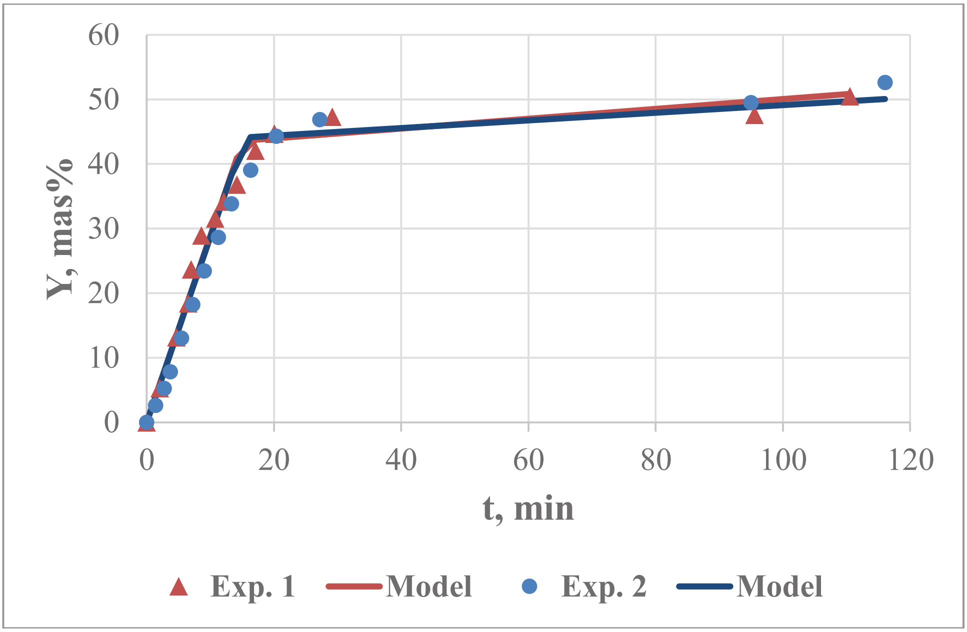

Figure 11. Experimental and model curves, Model 3

Table 1. Estemated model parameters

No.	*Model 1*				
	a	***b***	***c***	***d***	***R***
Exp.1	-75.8580	-0.6104	0.1730	48.6090	0.9966
Exp.2	-68.1962	-1.0963	0.1646	50.5533	0.9990
No.	*Model 2*				
	k_1	k_2	k_3	k_4	***R***
Exp.1	0.9003	0.0961	0.1594	0.0961	0.9923
Exp.2	0.9163	0.0778	0.1500	0.0778	0.9925
No.	*Model 3*				
	k_1	k_2	y_1		***R***
Exp.1	2.8910	0.0761	43.5867		0.9913
Exp.2	2.8764	0.0590	44.1216		0.9925

R –coefficient of correlation

4. CONCLUSSION

The pyrolysis process is represented by the overall reaction rate for the three products obtained focusing on bio-oil production, with no additional data on the structure and composition of the material required. The kinetics of the pyrolysis process of waste Oak cheeps was investigated by monitoring the amount of collected bio-oil in certain time intervals with pre-optimized process conditions and in the presence of catalysts. Mathematical modeling of the kinetics was provided with simple empirical models. Three types of empirical models are discussed in this paper. The kinetic models successfully fitted the experimental data, predicting the yield of bio-oil, obtained from the catalytic pyrolysis of Oak wood chips (high correlation coefficients, P>0.99). Pyrolysis curves can be approximated by two linear functions, the first dominated by kinetically controlled reactions and the second where diffusion is the limiting factor. By using aluminum oxide and opalyzed silicate - tuff as catalysts in an equivalent ratio with biomass, a high percentage of biomass conversion to bio-oil is achieved (more than 50%). The larger amount of aluminum oxide than opalyzed silicate as a catalyst has very little effect on increasing the amount of bio-oil obtained.

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APPLICATIONS OF CATALYSTS FOR WASTE PLASTIC CONVERSION TO FUEL

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ABSTRACT

Plastic waste is non-biodegradable and more voluminous than other waste types. Recycling waste plastics is an important issue to overcome environmental problems. Eco-friendly cracking technologies such as pyrolysis are promising techniques for transforming solid plastic wastes into usable products, such as fuels or high-value feedstock for the chemical industry.

This study investigated the catalytic pyrolysis of a waste plastic mixture of high-density polyethylene (HDPE) and polypropylene (PP) to obtain liquid fuel. Two synthetic catalysts, ZSM-5 and Al_2O_3, were employed in experiments of plastic waste conversion to fuel. The pyrolysis reaction in the semi-batch reactor at a constant heating rate of 10°C min^{-1} was performed. The 60g of waste plastic was heated to 550°C, and liquid fuel yield dependence was evaluated over time and temperature. The intensive formation of liquid product was obtained between 390ºC – 410ºC for the ZSM-5 catalyst. There is a shifting of liquid fuel formation to a higher temperature range of 420ºC – 440ºC when an Al_2O_3catalyst was used. The amount of the obtained condensed products was more than 85% for the Al_2O_3 catalyst, but the ZSM-5 catalyst gave a lower liquid fuel yield in the range of 46-58 wt%. The nature of the ZSM-5 catalyst is responsible for lower liquid fuel yield formation. During the pyrolysis, the fractionations were performed and two or more different fractions were obtained. All obtained fuels with higher concentrations of catalyst have an intensive color, unlike those obtained with less catalyst.

Key words: pyrolysis, polyolefin, catalysts, liquid products, yield

INTRODUCTION

The growth in the economy, population, and rapid urbanization caused a great increase in energy demand worldwide [1]. Fossil fuels supply around 80% of global energy consumption but also increase greenhouse gases and CO_2 emissions, causing climate change [2]. A high demand for nonrenewable fossil fuels leads to a continuous decrease in their reserves. Alternative energy reserves are needed because of the depletion of fossil fuels. On the other hand, the huge amount of plastic waste is steadily increasing. Manufactured from petroleum products, plastics comprise organic molecules with long-chained hydrocarbons that rapidly gained broad acceptance due to their unique properties [3]. The non-degradable nature of plastic, its low cost, easy availability, and short service life create an enormous quantity of municipal waste. According to a scenario of some experts, global plastic waste production can increase from 240 Mt/y in 2016 to 430 Mt/y in 2040 [4]. Plastic waste needs more space in landfills because it is bulkier than organic waste, and its disposal is more expensive and inappropriate [5]. Incineration is also undesirable since, based on the type of plastic, burning plastic waste increases emissions of dust, dioxins, sulfur, nitrogen oxides, and other toxins [6,7]. Innovative methods, other sustainable solutions, and more for recycling plastic waste have been investigated. Numerous studies have been carried out to obtain energy and raw materials from waste plastic recycling [8,9]. To support the circular economy of plastics, about 28 companies worldwide have created or are in the process of creating thermal-chemical recycling solutions [10]. Techniques for the conversion of plastic waste into liquid fuel through a breakdown of polymers into their monomers include Pyrolysis, Hydrogenation, Gasification, and Thermal cracking [11]. Pyrolysis is a technique used in tertiary recycling, serving as a process that transforms low-value polymers into gaseous and liquid hydrocarbons, which can be either thermal or catalytic [12]. This process is not costly, as plastic waste is degraded in an inert atmosphere at high temperatures (400–600°C) [13]. Experimental results indicate that the final composition of products heavily depends on the purity and type of polymer(s), temperature, and residence time; thus, optimizing these variables results in a good balance between cost and product value [14]. Thermal pyrolysis requires high temperatures, which usually results in products with low final quality [15]. Improving can be performed by the addition of catalysts, which reduce the reaction temperature and time. Obtained hydrocarbon products have a higher added value, such as fuel oils and petrochemicals [16]. The most used catalysts for the catalytic degradation of polymers are zeolite, alumina, silica-alumina, FCC, reforming catalysts, etc. [17]. The different catalytic activity depends on the type of catalysts and their acid sites. The textural properties, such as particle size, specific surface area, and pore volume, also affect the catalytic process's performance. Large polyolefin molecules' entrance to the solids' active catalytic internal spaces, and it is regulated by these properties [18,19]. Typical catalysts used for polyolefin catalytic cracking, like HDPE and PP in numerous studies are acid-porous solids, such as amorphous silica-alumina, zeolites, and ordered mesoporous materials [20,21]. Excellent hydrogen transferability is a characteristic of the zeolite molecular sieve catalyst. Therefore, this study aims to use the very effective catalyst ZSM-5 for the catalytic pyrolysis of waste mixes of HDPE and PP. Also, another effective familiar pyrolytic synthetic catalyst, Al_2O_3, was used. A comparison of the catalytic activity of these synthetic catalysts was performed. The influence of reaction temperature and time of reaction on liquid yield product formation was evaluated. Emphasis will be given to the optimization of process parameters for the high conversion of waste plastic to liquid products.

2. EXPERIMENTAL

2.1. Materials

The polymer used in this work is a waste mixture of high-density polyethylene and polypropylene as raw materials. The samples were re-granulated by manufacturers. The polymer mixture pellets have a maximum particle size of 5-6 mm. Two synthetic catalysts, Al_2O_3 and ZSM-5, were used. The purchased pelletized Al_2O_3 catalyst (5 mm) has a specific surface area of 400 m²/g. The specific surface area of employed zeolite ZSM-5 in the experiments was 425 m²/g.

2.2 Experimental Setup

Each experiment involving the decomposition of waste polyolefin mixtures with different catalysts was conducted in a 400 mL stainless steel batch reactor (Figure 1). The reactor's temperature was controlled and kept at a constant heating rate of 10°C/min using a PID (Unitronics V570) temperature controller.

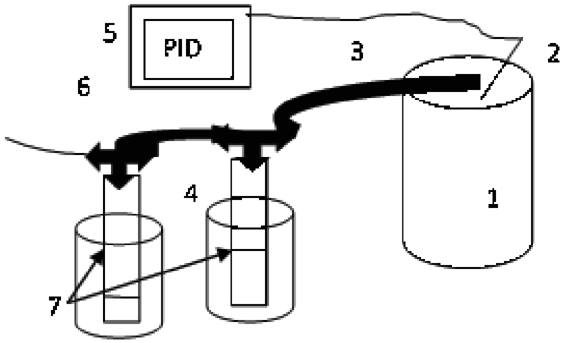


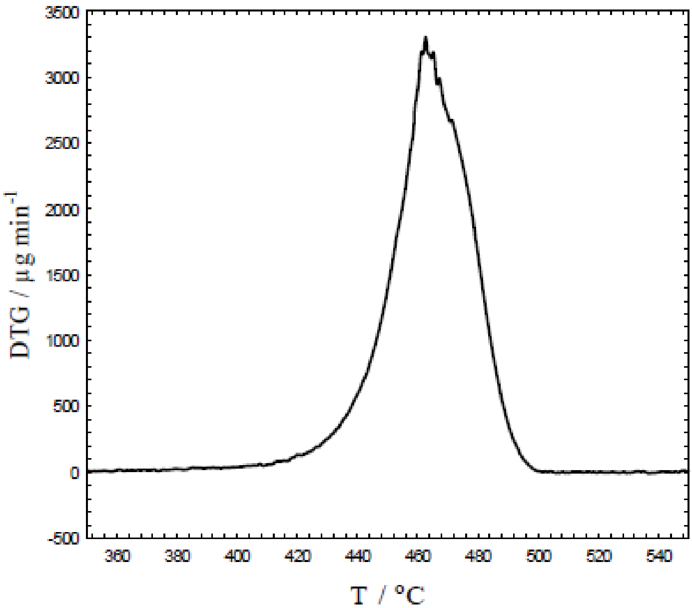
Figure 1 Schematic flow diagram of the semi-batch reactor and the separation system: 1. Reactor, 2. Thermo-couple, 3. Effluent pipe, 4. Water cooler, 5. PID Controller, 6. Exhaust for gases, 7. Condenser-separator

The batch reactor was charged with 60 g of a raw waste mix of HDPE/PP. The amounts of synthetic catalysts were 10 wt%. The sample and the catalyst were mixed before the reactor was charged. To enhance heat transfer through the plastic sample, metal particles (M) were also added to the reactor and mixed with the catalyst and raw material. A deep pipe that extended into the reactor was used to collect the reactor's exhaust gases. The other side of the pipe was connected to a water condenser separator to condense the liquid products.

The first separator was maintained hot to prevent wax formation by immediate condensation, while the second separator was cold to condense low-boiling-point hydrocarbons. The cracking experiments were carried out under dynamic conditions using a 10°C/min heating rate and different retention times on a previously set temperature program. The condensed liquid products were formed in the condenser at a temperature over 380°C.

3. RESULTS AND DISCUSSION

The experiments were conducted under consistent conditions: reaction temperature, reaction time, and heating rate. The reaction time for both experiments was 14,460 seconds, with a heating rate of 1 °C min^{-1}. To improve polyolefin cracking and achieve a higher yield of valuable liquid products, several retention periods were conducted at varying temperatures. This indicates that a sufficiently long retention time within a cracking temperature range facilitates the breakdown of large plastic polymer molecules into smaller hydrocarbon molecules, ranging from C5 to C16 (the range of petroleum fuels, diesel, and gasoline). The PID controller was set to achieve a higher liquid yield by retaining previously optimized temperatures. Several temperatures for retention were chosen according to the previously made TGA experiments. According to Figure 1, the DTG curve consists of a series of peaks representing the different stages of degradation. Since the thermal degradation of polyolefins is a single stage, the resulting DTG curve is single-peaked. The degradation maximum of the waste mixture is represented by the peak maximum. The area of the peaks is proportional to the amount of mass loss for each stage separately. Figure 1 shows the DTG curve from which the maximum degradation rate was determined, which occurs at the inflection point at T_{max} = 463 °C.



DTG curve of waste polyolefin mixture of HDPE/PP

According to this finding, a series of temperatures (380°C, 410°C, 460°C, 500°C, 550°C) were chosen as retention temperatures. The retention duration on fixed temperatures was adjusted for a waste polyolefin mix consisting of long chain molecules, to have enough time for cracking and form liquid products with low-weight molecules. A long enough retention time on a cracking temperature, lower than 450ºC, provides a higher liquid yield. Operating conditions (temperature, reaction time) as well as the type and amount of used catalysts strongly depend on the variation of liquid product yield.

The literature confirms that two synthetic catalysts, ZSM-5 and Al_2O_3, have different characteristics. These two catalysts convert the waste polyolefin

HDPE/PP mixture, producing various pyrolytic liquid products that yield distinct temperatures and reaction times. This claim can be understood by analyzing the following tables. The first experimental data presented in Table 1 shows the dependence of temperature and the produced volume of liquid pyrolytic product (liquid fuel).

Table 1. Reaction temperature – liquid pyrolytic product yield dependence

Al_2O_3 catalyst		ZSM-5 catalyst	
T °C	ml	T °C	ml
408	1	380	1
419	3	391	3
434	7	396	7
441	11	407	11
447	15	419	15
453	19	421	19
458	23	425	23
459	24	447	24
460	26	452	26
461	28	465	28
462	30	473	30
466	32	510	30
468	36		
469	40		
471	44		
471	48		
472	51		
476	55		
493	59		
497	6		
504	65		
510	69		

It is obvious that at the beginning, at 380°C ZSM-5 catalyst produces the pyrolytic liquid fuel at almost 30°C lower temperature. Temperature increases lead to larger deviations and high-temperature differences. This trend lasted until 24 ml of liquid product was collected, Table 1 (yellow cells). This time the temperature difference between the two catalytic reactions rapidly decreases at 12 °C; its value for Al_2O_3 is 459 °C, and for ZSM-5 it is 447 °C (yellow cells). An interesting fact about the ZSM-5 catalyst is that a higher increase in temperature is required for the collection of only 1 ml. Under the yellow cells in Table 1, the temperature differences between the two catalytic reactions decrease and almost equalize until the grey cells. Formation of a liquid product increases enormously for the Al_2O_3 catalyst until the end of the reaction, the red cells. At the end of pyrolysis, liquid fuel produced over Al_2O_3 catalyst doubles comparatively with ZSM-5 catalyst-produced fuel. The influence of operating temperature and the reaction time for the liquid pyrolysis product of waste plastic is evident; therefore a proper choice of PID program is very important. The results of this dependence of catalytic degradation which include liquid products yield expressed through collected volume are summarized in Table 2.

Table 2. Reaction time – liquid pyrolytic product yield dependence

Al_2O_3 catalyst		ZSM-5 catalyst	
t [s]	ml	t [s]	ml
6250	1	4180	1
6350	3	4980	3
8340	7	6015	7
8604	11	6775	11
8710	15	7910	15
8990	19	8430	19
9104	23	8602	23
9260	26	8880	26
9410	30	10760	30
9720	36	14460	34
10 060	40		
10 375	44		
10 710	48		
11 075	51		
11 625	55		
12 175	59		
13 350	65		
14460	69		

The experimental data presented in Table 2 have a similar trend as the results in Table 1. Initially, it is obvious that at the beginning, at 4180 seconds, the ZSM-5 catalyst starts producing liquid fuel. This catalyst needs a significantly shorter reaction time of around 2000 seconds for the conversion of waste polyolefins mixture and producing liquid fuel. This trend remains almost constant until 8 000 seconds pass and a collecting 15 ml liquid fuel. It is

shown with yellow row cells in Table 2. Below the yellow cells, up to the grey cells, the reaction time difference and formation of liquid product decrease significantly in only about 500 seconds. Synthetic ZSM-5 catalyst for a total reaction time of 14,460 seconds yields only 34 ml of liquid fuel, which is lower than double, as in 69 ml of liquid fuel produced over Al_2O_3 catalyst. Table 2 illustrates this with red cells.
The obtained results correspond with the literature because the ZSM-5 catalyst favors the production of gas products due to its large specific surface area and numerous active sites on the external surface, which increases its activity and degradation of large molecules to gaseous products.
Some physical properties of the produced liquid fuels, derived from waste plastic mixture, were determined and presented in Table 3. The density and viscosity are determinate according European standard test methods (EN), and American standard test methods ASTM [22].

Table 3. Physical properties of the produced liquid fuels

Catalysts	Y[(m/m) %]	Viscosity at 40°C [mm^2 s^{-1}]	Density at 20°C [mm^2 s^{-1}]	Index of refraction
ZSM-5	45.55	0. 4883	0. 7963	1.4622
Al_2O_3	87.57	0.7822	0.7681	1.4393

Obtained values for the ZSM-5 catalyst correspond to liquid fuel with a high content of heavier hydrocarbons, which represents the kerosene fraction, but the Al_2O_3 catalyst produces a liquid fuel that corresponds to the gasoline fraction.

CONCLUSIONS

Catalytic pyrolysis with synthetic catalysts ZSM-5 and Al_2O_3 is a promising technique for the thermochemical cracking of polyolefins in municipal plastic waste and the production of fuels. Batch pyrolysis and the proper PID temperature program seem to be very promising for the production of sustainable liquid fuel and appropriate conversion of plastic waste. The different natures of ZSM-5 and Al_2O_3 catalysts are responsible for different product types and yields. Anyway, two catalysts have successfully converted waste plastic into fuel. The influence of operating temperature and the reaction time for the liquid pyrolysis product of waste plastic is evident. The optimal temperature range for the pyrolysis experiment over Al_2O_3 was between 410 and 490°C. Zeolite ZSM-5 catalysts have an ideal lower optimum temperature range, and according to the obtained experimental data, it was to be between 390 and 450°C. In comparison to the produced liquid fuel yield by ZSM-5, the liquid fuel yield obtained over Al_2O_3 catalysts doubles at the end of pyrolysis. Zeolite catalyst ZSM-5 favors the production of gas products due to its large specific surface area and numerous active sites on the external surface. According to the obtained physical properties, the ZSM-5 catalyst produces liquid fuel with a high content of heavier hydrocarbons, which correspond to the kerosene fraction. The second catalyst, Al_2O_3, catalyst produces a liquid fuel in the gasoline range.

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NUCLEAR ENERGY PART OF CLEAN ENERGY TRANSITION

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ABSTRACT

The direction of the global transition to clean energy was agreed in the Paris Agreement, where the participant countries accepted to limit the increase in global average temperatures to below 2°C, relative to pre-industrial levels by reduction of greenhouse gas emissions. With around two thirds of the world's electricity coming from burning fossil fuels, to reach these climate goals by 2050 will require at least 80% of electricity to be shifted to low carbon sources.

Nuclear power is the second-largest source of low carbon energy used today to produce electricity following hydropower and is practically renewable based in large uranium reserves. Nuclear power (2024) accounts for around 9.6% of the world's electricity, and nuclear power plants (NPP) can operate at full capacity almost without interruption, regardless of weather conditions. This contrasts with renewable energy sources, such as solar and wind, which are weather-dependent and require back-up power during their output gaps.

The IAEA has analyzed the nuclear energy option for Albania, where it is emphasized that Albania has expressed interest in building a nuclear power plant (NPP) for a period not earlier than 2028. With new developing NPP design, its capacity can be based on Small Modular Reactors (SMR). The nuclear energy option should be carefully and professionally examined by specialized agencies and interest groups, and this option should be performed in the context of positive developments and cooperation between the Balkan countries. Nuclear reactors – the process by which nuclear energy is used to generate electricity – now with technological developments will support the clean energy transition in the future.

Key words: *Clean energy, nuclear energy, climate change, low carbon sources*

I. INTRODUCTION

1. Overview of nuclear power

In September 2015, the United Nations adopted the post-2015 development agenda, which aims to develop a 2030 agenda for people, planet and well-being, with ***a new set of sustainable development goals***, including energy as a cornerstone of this agenda. Energy is considered a prerequisite for sustainable economic growth and well-being, with a direct impact on health, education and employment. Furthermore, if the aim is to avoid the catastrophic consequences of global warming and climate change, energy must be produced sustainably and used as rationally as possible.

Nuclear power represents the largest non-hydro power generation source with low carbon emissions into the atmosphere and is therefore classified ***as a clean energy source for sustainable energy development***. Nuclear power is economically competitive with all other forms of electricity generation. In 2024, about 9.6% of the world's electricity was produced by nuclear power plants. Fossil fuels, including coal, natural gas, oil and others, together provide 61% of global electricity production (2023).

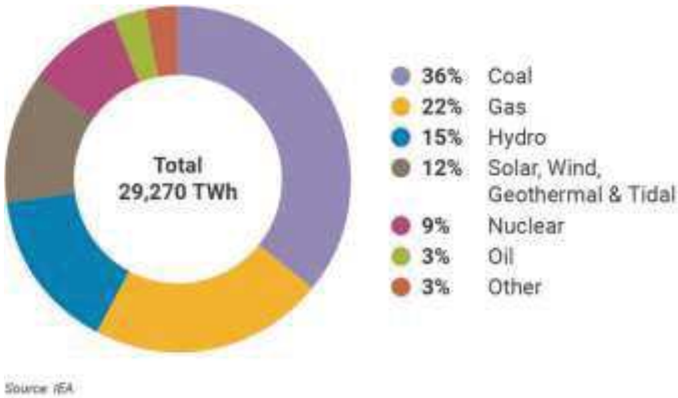

Figure 1. World electricity production by source 2022

According to the International Energy Agency - IEA, nuclear power plants have produced in 2023 and 2024, respectively 2,742 TWh and 2,843 TWh. The IEA predicts that in 2025 the total production of nuclear power will reach about 2,900 TWh, which accounts for about 10 % of the total production of electricity.

To meet the growing energy needs of developing countries and emerging markets, alongside traditional and renewable sources, there is a need to develop nuclear energy as a basic source for the sustainability of electric grids, both through large-scale reactors (Pressurized Water Reactor - PWR and Boiling Water Reactor - BWR) and through Small Modular Reactors - SMR with a generating capacity of 100-300 MW. The need for the development of new innovative Generation IV reactors has been identified in the Global Nuclear Energy Partnership (GNEP), where one of the main elements of this initiative is the compatibility between the electrical grid and the power of the reactors, as a necessary requirement to enable the expansion of the use of nuclear electricity.

2. Clean energy transition

The clean energy transition means shifting energy production away from sources that release a lot of greenhouse gases, such as fossil fuels, to those that release little to no greenhouse gases. ***Nuclear power, hydropower, wind and solar are some of these clean sources***.

The direction of the global transition to clean energy was agreed in the Paris Agreement (COP21 – 2015), where the central aim is to limit the increase in global average temperatures ***to well below 2°C*** relative to pre-industrial levels by encouraging the use of low carbon energy sources to reduce greenhouse gas emissions.

With around two thirds of the world's electricity (2020) still coming from burning fossil fuels, reaching these climate goals by 2050 will require ***at least 80% of electricity to be shifted to low carbon sources***, according to the International Energy Agency - IEA.

Greenhouse gases (carbon dioxide, methane, water vapor, nitrous oxide and fluorinated gases) in the Earth's atmosphere trap heat and radiate it back to Earth, causing the planet's average temperature to go up. Although some greenhouse gases come from natural sources, most come from anthropogenic activities. Globally, the primary sources of greenhouse gas emissions are electricity and heat (31%), agriculture (11%), transportation (15%), forestry (6%) and manufacturing (12%). Energy production of all type's accounts for 72% of all emissions.

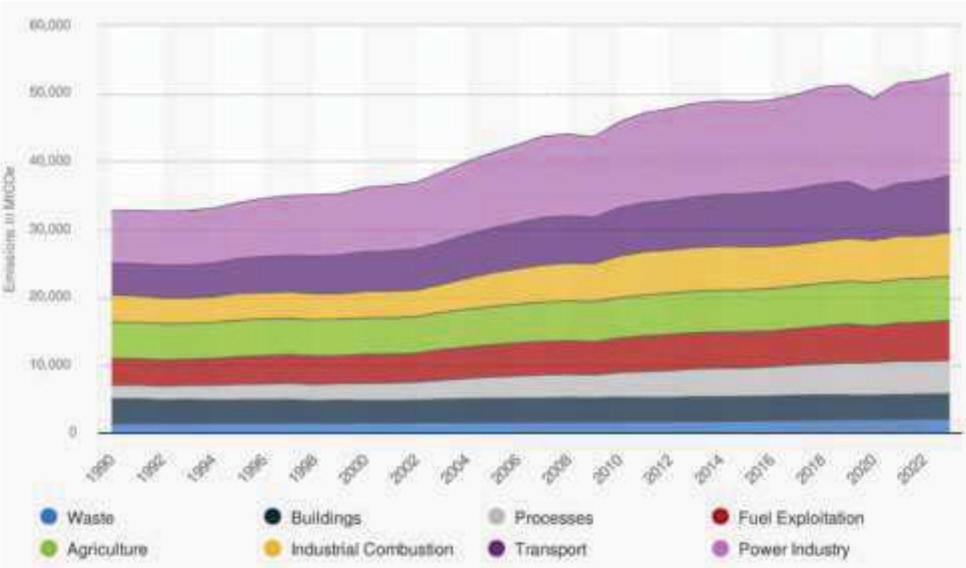

Figure 2. Annual greenhouse gas (GHG) emissions worldwide from 1990 to 2023, by sector (in million metric tons of carbon dioxide equivalent)

Global warming is causing environmental changes or climate change, such as more extreme weather, erratic rainfall, drought and unpredictable season changes. With the current fast progress of global warming, climate change and its effects are expected to become more extreme in the coming years.

3. Nuclear power & clean energy transition

Nuclear power is the second-largest source of low carbon energy used today to produce electricity, following hydropower. During operation, nuclear power plants produce almost no greenhouse gas emissions. Nuclear power accounts for around 9.6 % of the world's electricity (2024) and for around one third of global low carbon electricity. Currently, there are 417 reactors in operation in 31 countries and 62 reactors under construction in 15 countries, including 3 countries that are building their first nuclear reactors plants (Bangladesh, Egypt and Turkey).

About 30 countries are considering, planning or starting nuclear power programmes, and a further 20 countries have at some point expressed an interest. In Europe, Albania, Serbia, Croatia, Norway, Poland, Estonia, Latvia, Lithuania, Ireland had expressed their intentions in the future.

Nuclear power plants can provide a continuous and reliable supply of energy and this is in contrast to variable renewable energy sources, such as solar and

wind, which require back-up power during their output gaps, such as when the sunsets or the wind stops blowing.
A growth globally in population and living standards is driving an increase in energy consumption worldwide. Currently, the main sources for global electrical energy generation comes from thermal power, followed by hydro-electric plants, nuclear power plants with remaining energy being produced from biomass, geothermal, wind, solar and marine energy.
Almost all reports from governments and organizations (IEA - 2022) considered nuclear power as required to create a sustainable future energy system and concluded that achieving net-zero targets globally will be significantly harder and more expensive without nuclear energy.

- Global mitigation scenarios show more nuclear electricity is needed to limit global warming to 1.5°C or 2°C. IPCC & IEA highlight an important role for nuclear energy — in combination with other low carbon energy sources —compatible with the goals of the Paris Agreement.
- Nuclear heat and hydrogen production can play an additional role reducing emissions in non-electric applications. This additional mitigation potential of nuclear energy may not be fully reflected in current energy transition analysis and scenario pathways.
- Unlocking and accelerating investment is critical for rapid deployment of nuclear energy. Nuclear energy has a proven track record of rapid deployment, including in recent projects, which is critical for urgently and economically decarbonizing the global energy system.

4. Development of nuclear technology

In the early 1950s, the aim of using nuclear energy for peaceful purposes under the slogan "***Atoms for Peace***" accelerated the development of nuclear reactor technology and nuclear power plants. The great efforts of scientists and technicians since the 1950s led to the realization and continuous improvement of the cooling system, automatic operation control, reactor core geometry, effective nuclear fuels etc., applied in several models based on natural and enriched uranium, as well as the use of heavy water, light water, and various gases as coolants.
Meanwhile, comprehensive and continuous improvements have created the opportunity to enter the market of Generation III+ reactors, the most prominent examples of which are: EPR-1600 (Framatome ANP), APR-1400 and AP-1000 (Westinghouse), ABWR-1300 (GE-Hitachi-Toshiba), CANDU-9 and ACR-1000 (AECL), AES-2006 and VVER-1200

(Gidropress), etc. Reactors of this generation have standardized designs, long operating period (about 60 years), passive safety system, simpler and safer operation and management, low probability of reactor core meltdown, high efficiency of nuclear material burning and consequently reduction of radioactive waste, etc.
With the inauguration of the Generation IV International Forum (GIF) and other international initiatives, six future nuclear reactor systems were selected, which will be studied, designed and experimented based on extensive scientific and technological cooperation between the participating countries.
Today's technological developments in nuclear reactors are oriented i) towards the design and construction of advanced reactors, mainly medium and small reactors; ii) towards non-electrical applications, such as hydrogen production; desalination of seawater through the energy of power reactors; and iii) towards advanced reactors.
One of the fundamental elements in the development of a nuclear program is the nuclear fuel cycle, which currently relies on the element Uranium (U), but due to the almost complete exploitation of mineral reserves of this element, in the coming decades will be very urgent and important the exploitation of Thorium (Th).

5. Small Modular Reactors

To meet the growing energy needs of developing countries, in addition to large-scale reactors, have led to the development and implementation of Small Modular Reactor – SMR. Small-scale reactors are a logical solution for small countries or those countries that have a limited electricity grid capacity. Small reactors are attractive because of their qualities such as: simple structures, improved safety and limited financial resources. However, these reactors are not considered less economical than large reactors, due to the accepted axiom of economies of scale.
Small modular reactors are manufactured and transported immediately to the selected site, where they are installed, significantly reducing capital investments and construction time. The relatively small power of SMR reactors makes them very preferred for small-capacity power grids and for remote areas where there is no developed power grid and alternative energy sources, and on the other hand these systems have a high flexibility in energy production depending on demand.
The Advanced SMR are set to come online by 2030, marking a shift towards flexible, localized power generation that can support energy-intensive

operations like AI data centers. The SMR technology also allows for faster deployment and lower construction costs compared to conventional reactors, making nuclear energy more accessible and scalable in the upcoming nuclear energy landscape.

II. Economic analysis of nuclear power

Estimating the relative costs of new nuclear power plants using different technologies is a complex task and the conclusions depend largely on their location. Coal is, and will likely remain, economically attractive in different countries as China, the United States and Australia with abundant and easily exploitable domestic resources as long as greenhouse gas emissions remain cost-free. Gas also remains a competitor for power supply in many countries, particularly in combined-cycle power plants.

Although nuclear power plants are expensive to build, the costs of commissioning and maintaining them are low. In many countries, nuclear power competes with fossil fuels for power generation. Its operating costs also include the costs of waste management and decommissioning. When the social, health and environmental costs of fossil fuels are considered, the economics of nuclear power are highly competitive.

1. Estimating the nuclear energy costs

The economic analysis of nuclear power involves several aspects.

Capital costs include the costs of selecting and preparing the site for the plant, constructing, manufacturing, commissioning or rating, and financing a nuclear power plant. For comparison of different generation technologies, capital costs should be expressed in terms of the generating capacity of the plant (e.g. as USD/kiloWatt). The calculation of capital costs may include or exclude financing costs. When financing costs are included, then capital costs vary in proportion to the duration of construction and commissioning of the plant using the interest rate or financing method as an indicator. The term "**investment cost**" is usually used for this. If financing costs are excluded from the calculation, capital costs are called "**overnight costs**", since the plant is assumed to be built "in one day".

Operating costs of the plant include fuel, operation and maintenance (O&M) costs, and a fund for the costs of decommissioning the plant, processing and storing spent fuel and radioactive waste. Operating costs can be divided into "fixed costs" that occur regardless of whether the nuclear power plant is generating electricity, and "variable costs" that vary with changes in production. These costs are usually expressed in terms of the price of a unit of electricity (e.g., cents-USD/kWh) to allow for a clear comparison with other electricity generation technologies. To calculate the operating cost of a power plant over its entire life (including the costs of decommissioning and the management of spent fuel and waste), we need to estimate the "**levelized cost**" at present value. It represents the price of electricity if the project breaks even.

External costs to society are costs that arise from operating a plant, which in the case of nuclear power are usually taken to be zero. They may include the costs of eliminating the consequences of a serious accident that exceeds the insurance limit and must in practice be covered by the government. The legislation and regulations governing nuclear power explicitly require the plant operator to set aside funds for the treatment of potential nuclear waste, which are considered internal costs. Fossil fuel electricity generation is not regulated in this way, and therefore thermal power plant operators do not yet consider the costs of greenhouse gas emissions or other gases and particulates released into the atmosphere as internal. Including these external costs in the calculation gives nuclear power a significant advantage over fossil fuel thermal power plants.

2. Energy and sustainable development

The realization of an energy system is based on the recognition of its interactions with sustainable development. A critical problem in sustainable energy management is the inclusion of all social costs in the price of energy and the aim of realizing large benefits for society as a whole.

Due to the complexity and diversity of energy systems around the world, there is no single solution to make them more sustainable, while simultaneously meeting today's social and economic obligations. Since no technology exists without its own risks, be they related to waste production or interaction with the environment, the role of each technology must be assessed in its entirety and from balanced perspectives. Although there is no consensus on the suitability of nuclear energy with sustainable development, nuclear technologies are currently considered by international agencies and specialized institutions as a preferred option for meeting growing needs.

The use and maintenance of nuclear capacities requires the implementation of strict technical security and safety measures as well as those against international terrorism and the illicit use of nuclear materials. The peaceful and safe use of nuclear technologies is continuously monitored and verified by the International Atomic Energy Agency and is supported by its nuclear safety system and action plan. Given the great number of the indicators examined, nuclear energy can be considered as a basic and safe source of energy that can play an important role in diversifying electricity sources and guaranteeing a more stable supply of electricity to the grid.

III. Cooperation in nuclear emery

1. International Cooperation in the field of nuclear energy

Cooperation in the field of nuclear energy in Europe and between Europe and other countries takes place at different levels. The European Atomic Energy Community (EURATOM) was established under one of the Treaties of Rome in 1958 to create a common market for the development and peaceful uses of atomic energy.

The Euratom Treaty provides a stable legal framework that encourages the growth and development of the nuclear industry, while improving the security of supply of nuclear fuel. It covers all civil nuclear activities in the European Union and aims to ensure a common market for nuclear materials, ensuring that these materials are not diverted from their original intended use or misused for other purposes.

In March 2013, twelve EU countries joined forces to promote the role of nuclear energy in the EU's energy mix. The countries that signed the agreement were the United Kingdom, Bulgaria, the Czech Republic, Finland, France, Hungary, Lithuania, the Netherlands, Poland, Romania, Slovakia and Spain. The joint statement underlines that they are "... committed to cooperating on security and to creating greater confidence for investors in low-carbon energy infrastructure projects". These countries pledged to promote the deployment of low-carbon technologies, including nuclear energy, renewable energy, and carbon capture and storage.

In November 2023 the European Parliament approved the Net Zero Industry Act (NZIA). The NZIA sets a target for Europe to produce 40% of its annual deployment needs in net-zero technologies by 2030 and to capture 25% of the global market value for these technologies. Included in the ten proposed technologies was "**advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle, small modular reactors, and related best-in-class fuels“.**

On 21 March 2024 world leaders from more than 30 countries and the European Union met at the inaugural Nuclear Energy Summit in Brussels. The summit continued to build global momentum for nuclear power in the clean energy transition, following the historic importance of nuclear energy at COP28 (Dubai, 2023) **with the inclusion of nuclear energy in the Global Stock take**. At the summit, high level representatives emphasized the

importance of using nuclear power to achieve energy security, climate goals and drive sustainable development. Increased financing, workforce development and more proactive support to nuclear newcomer countries were identified as key to long term success.
A bilateral scientific meeting (UK Royal Society and Académie des Sciences de France) on Sustainable Nuclear Science and Engineering was held on 18 – 19 July 2024. Government policy in the UK and France seeks to provide energy security for their citizens and economies whilst also protecting them from the worst impacts of global climate change. For this reason, nuclear fission, as a zero-carbon, "always on" power source is experiencing a much-welcome renaissance in both countries, combined with a positive trend in the public acceptance of nuclear energy.
France has 18 commercial nuclear power plants with a total of 56 PWR reactors, providing about 70% of electricity and UK has 5 nuclear power plants with a total of 8 AGRs and 1 PWR, providing about 15% of electricity.

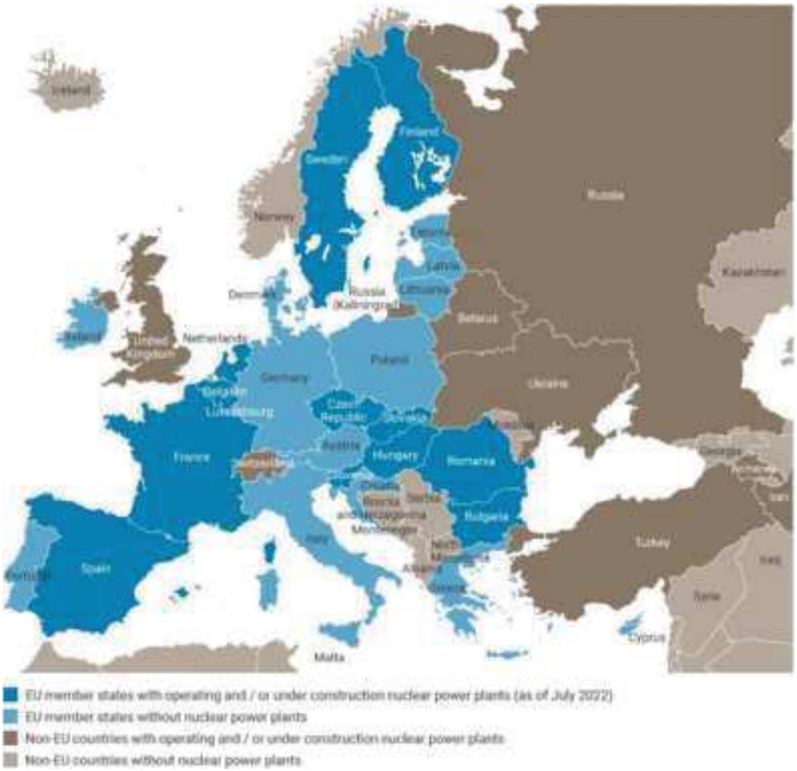

Figure 3. Operating and under constriction Nuclear Power Plant (July 2022) in Europe

Generation IV and III+ systems can provide much more than baseload electricity to the grid and have the potential to assist in the decarbonisation and to contribute beyond electricity as the generation of hydrogen as a carbon-free alternative fuel, the provision of district heat for housing, the production synthetic fuels, … and the provision of desalinated drinking water. From the above, it is evident that cooperation in the field of energy and the integration of electricity networks is developing rapidly, both within the EU and between the countries of Eastern and Western Europe.

2. The Nuclear Energy Program and Albania

The nuclear energy program that we propose foresees several complex activities spread over several years. Experience to date has shown that the time from the initial political decision of the Government on nuclear energy to the start of the first nuclear power plant is at least 10 to 15 years. Albanian institutions have addressed the possibility of using nuclear energy in our country in various materials, and for more than 10 years they have professionally analyzed the nuclear option with the assistance of international and European agencies in this field. Initially, the National Agency for Natural Resources (AKBN) and now for several years the National Nuclear Agency (AKOB) have increased the intensity of these researches and in 2014 the Report of the study carried out with the IAEA "**Analysis of electricity supply options for Albania until 2040**" was published and which was updated in 2023. This Report assesses electricity supply strategies, including the development of a nuclear energy program, which should be subject to a political decision regarding the production and use of nuclear energy and its regional dimensions. The Report notes that overall energy demand is expected to increase by 2.5 times between 2010 and 2040, with an average growth rate of 3.2% per year. The conclusions of this report emphasize that the nuclear option offers a sustainable cost of energy generation and low greenhouse gas emissions. The nuclear option requires a large initial investment and infrastructure preparation. The development of a nuclear energy program is an option of interest from a regional point of view due to the size of the plant itself (in relation to the Albanian economy and energy system). The preparation, and then the launch of the implementation of the Nuclear Energy Program, requires expertise and assistance at the national and international levels. At the national level, it is necessary to engage all human and technical resources located in research institutions - domestic and abroad, draft and approve the legal framework, establish regulatory structures and launch undergraduate and postgraduate programs for the preparation of young

Albanian specialists in various disciplines, directly or indirectly related to the establishment and operation of a nuclear power plant. At the international level, it is necessary to engage the specialized structures of the International Atomic Energy Agency and the European nuclear energy agencies.

IV. Conclusions

- Nuclear energy is economically competitive with all other forms of electricity generation, except where low-cost fossil fuels are available.
- The cost of nuclear fuel constitutes only a small part of the overall cost of generating electricity in nuclear power plants, while capital costs are higher than those of coal and gas power plants.
- Nuclear energy, which enables the production of electricity through advanced technologies, constitutes an incentive for significant capital and long-term investments, while simultaneously achieving a secure and sustainable energy supply.
- Nuclear energy is considered a clean energy source, without carbon and greenhouse gas emissions.
- Radiation from the nuclear fuel cycle, including the operation of a nuclear power plant, as well as interim and permanent radioactive waste disposal, are considered insignificant by specialized international agencies.
- The nuclear energy option In Albania should be carefully and professionally examined by specialized agencies and interest groups, and the nuclear option should be realized
    - in the context of positive political, economic and technological developments in the Balkan countries or
    - in the context of the of PPP investments in Small Modular Reactor technology.

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ENVIRONMENTAL ISSUES AND ENERGY IN NATIONAL SECURITY

Acad. Besnik Baraj

ABSTRACT

Unlike previous decades, national security has taken on a much broader meaning. Now, it is not only related to military capabilities, but also to other factors, where the environment occupies an important place. Environmental security includes factors such as water, soil, vegetation, fauna, climate, energy, air quality, etc., which ultimately support our entire economy and consequently our political and social stability. Climate change scenarios show that Albania is one of the countries that will be significantly affected by drought and reduced rainfall. In circumstances where the current energy sources in our country are 98% hydro, we are lagging behind compared to our neighbors in diversifying energy sources, with a focus on environmentally friendly ones. Erosion phenomena, damage to forests, flora and fauna are causing imbalances in the phenomena of floods, soil erosion, sustainable conservation of water resources, the extinction of many living things, etc.
Also, the problems of air pollution from the burning of fossil fuels are showing that there is a very close correlation between pollution and the increase in a number of dangerous diseases, such as cardiovascular diseases, cancer, hemorrhages, dangerous viruses, including Covid - 19, etc.
Although political rhetoric often has terminological inflation in dealing with environmental aspects, it has done very little in implementing legislation, increasing monitoring capacities, publishing reliable data, transparency and informing the public. The lack of involvement of scientific capacities in recognizing the problem, informing and providing alternatives for solutions shows that in practice policymakers do not have the right approach. This is shown by the extremely modest investments in science, monitoring capacities, the introduction of new technologies in the energy system, the rehabilitation of hot spots, waste management, cleaning of cities, etc. For Albanian society, significant investment in environmental issues and the inclusion of intellectual capacities in the economic and social development of the country to increase development efficiency and, consequently, national security remains a challenge.

Keywords: National security, energy, environment, climate change, politics

PHOTOVOLTAIC ENERGY IN ALBANIA:

BETWEEN THEORY AND REALITY TOWARDS A SUSTAINABLE FUTURE

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ABSTRACT

In this presentation, the impacts of climate change on the potential of solar radiation on photovoltaic systems and their performance will be highlighted. Also in the context of the possible scenarios of the expected ongoing of the climate in the territory of our country, taking into account the technological developments, a special point is devoted to the analysis of the increase in the possibility of extreme weather events; which, regardless of the reason of their origin, affect not only the safety of photovoltaic systems, but also the reduction of performance and the yield of their work. Undoubtedly, a special attention is given to the presentation of new forms of electricity storage, such as the gravitational one. Despite the developments and trends to support the widest implementation of energy production from renewable sources in accordance with EU directives, in this presentation it is highlighted and suggested who should have priority to be included in the production of electricity from photovoltaic systems and who should have the systems for converting solar energy into thermal energy for the purpose of heating water. Also, it is proposed which areas should have priority for such implementation, taking into account also technical consideration, which are conditioned by the electricity transmission system of the country.
Keywords: Renewable Energy, Solar Radiation, Photovoltaic Systems, Gravitational Energy, Albania

1. INTRODUCTION

Renewable energies are an important component for ensuring a more sustainable energy system and meeting the energy needs of the country's economy. Albania is among those countries that have quite good potential for utilizing this natural energy source, particularly in terms of solar radiation. However, it should be noted that the implementation of technologies for converting solar energy into electrical or thermal energy requires consideration of several other elements. These relate to both the utilization of spaces within the country's territory and the types of technologies, as well as the interrelated impacts arising from this implementation on the environment and climate of the respective areas, without neglecting the capabilities and capacity that the national electricity transmission system can handle over time and space in certain areas of the country.

2. MATERIALS AND METHODS

The analysis is based on the utilization of information from both meteorological stations in Albania, conducted in accordance with WMO standards, as well as satellite data and information from international professional platforms. These sources provide data on cloud cover, solar radiation, air temperature and other meteorological elements necessary for the study. The data primarily refer to the periods of the reference norms 1991-2020 and 1961-1990, as well as the last four years 2021-2024. They have been processed and analyzed according to technical and scientific criteria and methodologies of WMO.

3. RESULTS AND DISCUSSION

3.1 Solar Radiation

Regarding the assessment of solar radiation, it should be noted that due to a lower level of cloud cover on a continental scale including our country's territory, as illustrated in Figure 1; there is reported a negative anomaly of -10% to -20%.

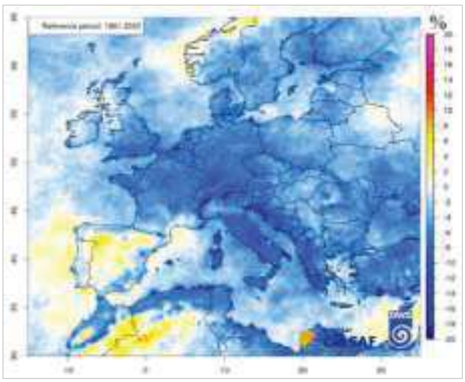

Figure 1. The anomaly of the cloud's coverage (in %) for the European continent for 1991-2020 according to EUMETSAT, etc.

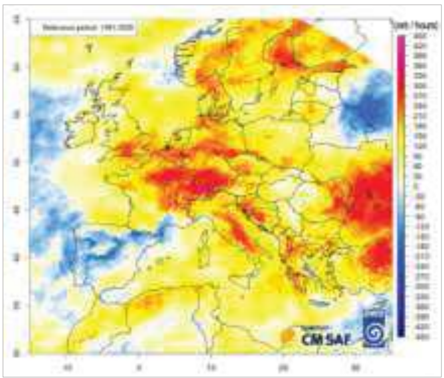

Figure 2. Anomaly of the sunshine index (hours of sunshine) for Europe for 1991-2020 according to EUMETSAT, etc.

This has resulted in an increase in the amount of solar radiation that reaches the Earth's surface, which has marked higher values compared to many years ago. In Figure 2 the data of sunshine presents for the territory of Albania a positive anomaly. that has reached +150 to +300 more hours of sunshine than the values of the reference period 1991-2020.

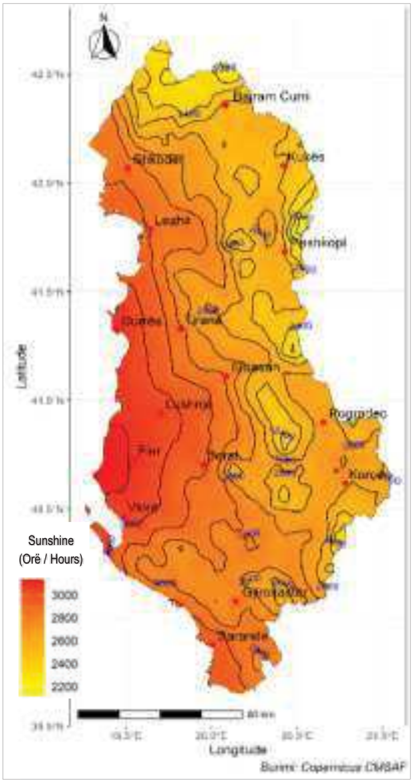

Figure 3. The sunshine values (in hours) for the year 2024 for Albania.

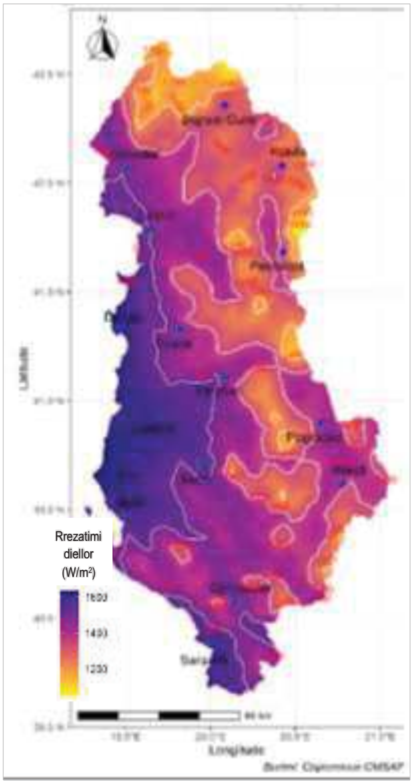

Figure 4. The global horizontal radiation for the year 2024 for Albania (in kWh/m^2).

Based on a number of studies conducted in the past regarding the climate of Albania, as well as those published periodically in the Monthly Climate Bulletin from 2017 to 2024, has seen noted an increase in the values of this indicator in recent years. The map shown in Figure 3 presents the data on sunshine hours for 2024 for Albania, according to the “ERA5” platform. The territory of Albania is distinguished by high values exceeding 3000 sunshine hours in the SW part of the Western Lowlands, down to relatively lower values in the NE part of the country, where up to 2400 sunshine hours per year are recorded. Another indicator presented in Figure 4 for Albania shows the annual values of global horizontal solar radiation in kWh/m^2 (in hours) for the year 2024.

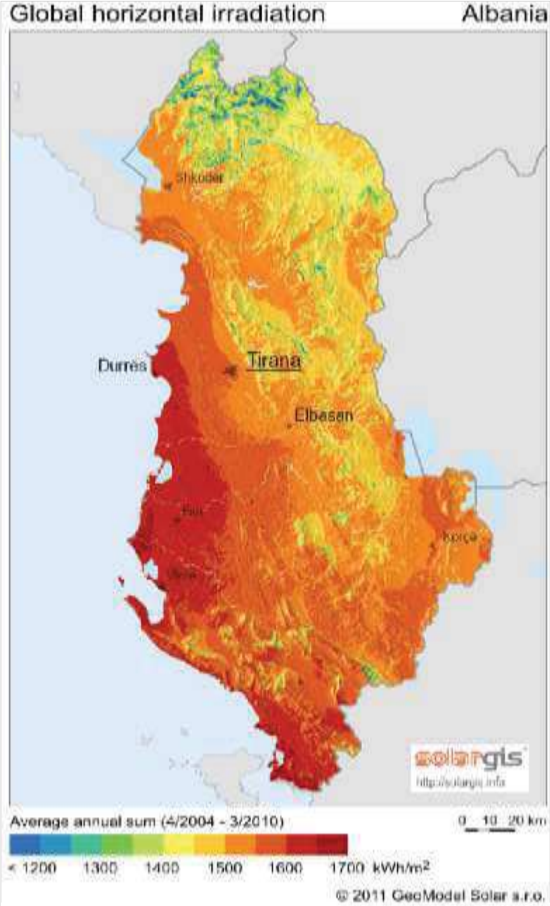

Figure 5. Long-term average of global horizontal irradiation for the period 2004 -2010 for Albania.

Meanwhile, in Figure 5, map of Albania shows the values of the global horizontal solar radiation indicator (in kWh/m²) for the period 2004-2010. From the perspective of climate change and its consequent impacts, it should be noted that regarding this indicator, our country has a positive impact, as an increase in the values of solar radiation reaching the Earth's surface will naturally translate into a greater amount of electricity generated by photovoltaic systems, as well as into a larger quantity of thermal energy converted by solar panels for water heating. Faced with this quite favorable situation, as trends indicate high values of solar radiation for the coming years, the utilization of solar energy and its conversion through photovoltaic systems for electricity production or for conversion into thermal energy, primarily for use in water heating, becomes more attractive. Therefore, the assessment of the photovoltaic power potential represented by this solar radiation is presented for Albania on the map given in Figure 6, referring to products realized with the support of the World Bank for various countries, including our own. The areas that stand out with higher values are the central and SE parts of the Western Lowlands as well as the Vurg field in the southern part of the country.

Figure 6. The photovoltaic power potential for Albania (in kWh/kWp) (reference period: 1994-2018).

The distribution of demands for energy resources, in this regard, is related with the demographic distribution of the population in Albania. Based on the recent census from 2024 shows that the majority of the population is concentrated in the Western Lowlands, and consequently, the demand for energy resources is higher. Moreover, this region has been visited by a large number of tourists throughout the year, especially during the warm season.

Now let us analyze how the trends of other meteorological elements appear in this context and what their expected impacts are on the production and security of photovoltaic systems.

3.2 Air temperatures

The anomalies data of the average, maximum, and minimum air temperatures for Albania from 2017 to 2023 indicate an upward trend characterized by an increase of +1.89°C above the norm, referencing the period from 1961 to 1990 for mean values. The most pronounced anomalies are observed for the maximum values, which, especially during the summer months, have deviations of up to +2.68°C and the minimum air temperature reached a +1.09°C anomaly on an annual scale.
Studies highlight that for each degree Celsius above the optimal temperature, the efficiency of a typical crystalline silicon PV cell can decrease by approximately 0.4% to 0.5%. This means that above 25°C, the ideal operating temperature, the cell's efficiency can drop by 10-12.5%. Furthermore, at an operating temperature of 56°C, the efficiency of solar panels decreases by 3.13%, while at 64°C, the efficiency reduction reaches 69%. To provide a more detailed view of air temperature trends at midday, data on average maximum temperatures for some meteorological stations in our country for July 2024 are presented in Figure 7.

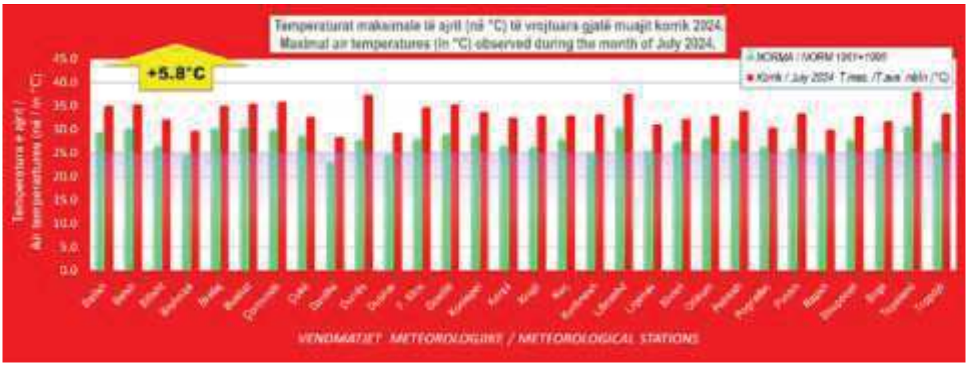

Figure 7. Values of mean maximal air temperatures for some meteorological stations of July 2024 for Albania.

This clearly shows values exceeding the threshold of 25.0°C and their respective anomalies compared to previous years. At the national level, the situation assessed over the past 8 years, from 2017 to 2024, is characterized by a pronounced anomaly in maximum air temperatures with a rising trend,

that for the months of June and July 2024, experienced deviations of +5.8°C at the country level [5]. Furthermore the absolute maximum air temperatures for several meteorological stations in Albania for July 2024, clearly showed high deviation from the 25°C threshold, reaching up to 41°C.
Assessments of the environmental temperature coefficient where the solar panel is located are important for modeling and predicting the performance of photovoltaic systems, which may operate under varying temperature conditions. If these situations begin to become critical, additional technological interventions will be necessary for cooling the solar panels, which undoubtedly incurs additional costs. So, it appears that the areas of the Western Lowlands of Albania faces a deteriorating trend, while the areas further inland and at higher altitudes, which previously had maximum average temperatures below the 25°C, are now closer to or slightly above this level. So, these areas appear to be more suitable for the installation of photovoltaic systems. However, it should be noted that these areas are experiencing depopulation and energy demands are becoming more limited.

3.3 Atmospheric precipitation

Another factor to be considered is the number of rainy days that for Albania in recent years show a decrease by approximately -11%. Undoubtedly, a lower rainy days number, implies a smaller chance of cleaning the dust deposited on panels during the intermediate periods between rainy days, which in turn affects the performance of solar panels. Regarding the performance of solar panels, are many studies on the relationship with air temperature trends, wind speed, snow, but as for precipitation and its effect, only in recent years have some studies been conducted, which collectively show the important role that atmospheric precipitation plays in cleaning solar panels from pollution [8]. According to some estimates, a build-up of pollutants, dust for 45 consecutive days, can reduce the efficiency of solar panels by up to 20% [11]. In humid areas, dust particles can form a sticky layer on the surface of panels. Such a thing would require, on the other hand, continuous maintenance and cleaning of their surfaces, naturally at the corresponding costs in these cases, to ensure their optimal operation.

3.3.1 Hail

In this assessment, it is impossible not to mention the increasing impact of extreme weather phenomena. According to specified studies in the Mediterranean countries, such as Italy, the phenomenon of hail is becoming more frequent compared to past years. In recent years, European researchers have suggested, "the risk of hail and the vulnerability of solar panels to it should be incorporated into risk models and climate adaptation strategies" [17]. The damage caused by hail not only can reduce the efficiency of the panels but, in certain cases, can cause cracks that may subsequently lead to fires. Referring to the technical standards of the International Electrotechnical Commission (IEC) [18], standard 61215 requires that solar panels produced by the industry must remain undamaged by hailstones up to 25 mm in diameter, striking at a speed of 23 m/second.

3.4 Wind

Wind is another meteorological element that presents significant interest for the operation of solar panels. It plays a special role in maintaining a certain temperature on the surface of the panels, especially in cases when high temperatures are recorded at midday, as it affects their cooling and maintains high performance. However, high wind speed values and phenomena such as "wind gusts" have also shown, in our country, for instance, in the case of photovoltaic panels installed over the water surface of Banja Lake, where serious damage and destruction of their structures were verified a few years ago. Therefore, projects for the installation of photovoltaic systems should analyze and consider the trends and characteristics of key indicators related to wind direction and speed, calculated for different safety levels [6].

3.5 Dust

The impact of Sahara dust is becoming a frequent phenomenon that penetrates under specific synoptic conditions into the Mediterranean countries. Sometime this impact often extends deeper into the continent. During the first 6 months of 2024, the presence of African dust from the Sahara was evidenced in several cases over the European continent. On February 15, 2024, the impact was felt mainly in the Iberian Peninsula initially, and later it extended to France, Germany, etc., affecting photovoltaic systems by a 30% efficiency drop [3]. Later, on April 23, 2024, the presence of Sahara dust was observed over our territory [4], as illustrated in the Figure 8. In the affected areas, the influence reached up to a 20% reduction in photovoltaic panel production. Later on dates of June 18-24, 2024, the presence of African dust again affected our territory [5].

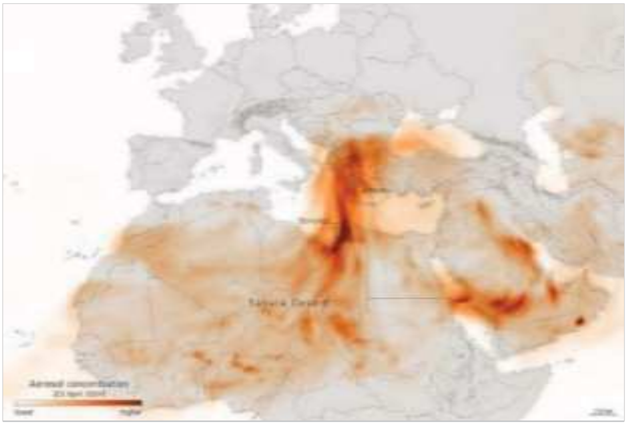

Figure 8. Aerosol concentration on April 23, 2024, due to the presence of dust originating from the Sahara.

3.6 Weather Modification

Alongside these phenomena, in recent years, atmospheric interventions and weather modifications have become increasingly frequent, which naturally also affects the deterioration of atmospheric transparency, creating greater difficulties for sunlight penetration close to the Earth's surface. Figure 9 shows an image of the sky where the phenomenon of "contrails" – condensation trails created during aircraft flight, regardless of their origin – invariably lead to atmospheric dimming and reduction of solar radiation. During the first six months of 2024, there were recorded 100,407 flights per day. It is also estimated that the combustion fuels in the atmosphere from aviation amount to a fuel load calculated at more than ≥10,000 kg/km²/year.

Figure 9.

3.7 Global warming

Studies have shown that in environments with large areas covered by solar panels; these influence the warming of the area due to the air masses above them, which during the day get warmer. It is estimated that during summer months at midday, temperatures above the surface of the panels can reach values of up to 65°C or more. Naturally, the air masses that are above these surfaces do not remain static after they warm up, but instead, they are displaced to nearby areas, affecting and transferring warmer air masses, consequently influencing the warming and modification of the microclimate in the surrounding areas, whether urban zones or agricultural surfaces. Estimates show that if 20% of the Sahara were covered with solar panels, there would be a local temperature increase in the desert by +1.5°C, according to relevant models. This warming would naturally spread throughout the globe via the atmosphere and ocean movements, raising the average global temperature by +0.16°C for 20% coverage and +0.39°C for 50% coverage [9]. That said, it should be kept in mind for the territory of our country that in areas where solar panels are intended to be installed, even a small effect will undoubtedly be verified in the local microclimate.

3.8 Agricultural Land

For our country, it should be noted that agricultural land is limited and must be preserved with special care. A layer of agricultural soil 1 mm thick takes about 500 years to form naturally. Therefore, since the installation of photovoltaic systems, in one form or another, occupies agricultural land and can affect its degradation, it would be advisable to select areas based on certain criteria. For example, in the Western Lowlands, saline lands that cannot be used for agricultural production could be suitable. Meanwhile, the experience of European countries in recent years has highlighted restrictive legal interventions, such as the legal decree in Italy in 2023, which limits farmers from occupying more than 10% of their farm's area with solar panels.

3.9 Fire Risk

The high temperatures recorded especially during midday in the summer season, on the surface of solar panels, is an important element that must be considered on favoring the fires. Regardless of the reasons, it should be known that a temperature of 60°C or 70°C on the surface of solar panels can initiate the self-ignition process of organic materials that might fall onto their surface and be moved by the wind afterward, such as leaves from nearby vegetation or biomass material carried by birds, etc. At meteorological station of Fier, values between 50°C and 60°C have been recorded at midday on land surface, which would certainly be significantly higher if measured on the surface of a solar panel. Under conditions of soil moisture absence and low relative humidity in the air, self-ignition of these residues can occur, and when there is a nearby-forested area, it can lead to larger fires. Meanwhile, it should be noted that the presence of various electrical circuits connecting the solar panels to the respective energy distribution system near the building or photovoltaic plant itself can, in certain cases and for various reasons, cause fires. Damage to the panels from weight or other impacts related to micro cracking can create hot spots, potentially causing fire risks over time.

3.10Technology

The right technology should be chosen regarding the water heating systems. Those used in our country as presented in Figure 10/(a) have been banned by law in some countries. The version (a) has the lowest energy conservation efficiency, because of energy losses resulting from long-wave radiation, when the water cools down during the night and loses the energy gathered during the day.

Figure 10. Various panels for converting solar energy into thermal energy for water heating.

Also it imposes an additional load on the roof and is also not aesthetically pleasant. The version (b) has better vertical layering of hot water inside and retains energy more effectively, being approximately 14% more efficient than version (a). Meanwhile, the type (c) has an efficiency coefficient up to 40% higher than that of (a), as the energy losses at night due to long-wave radiation are considerably less. Additionally, it do not impose any weight load on the roof and is aesthetically much better. This is suitable for both small buildings and multi-story structures, which can easily adapt and install this technology, ideally from the design phase. So, this type would have several advantages for the current situation in Albania. It would not impose extra load on the transmission system of electricity, and as well cannot be affected by the energy losses in the grid, as it is not related by this system. Additionally, it would help households since one-third of the energy bill for families goes towards heating water. This heating water system help during the period when demand is highest, not only from the population, but also from tourism.

3.11 Energy Transmission and Distribution System

The energy transmission system in Albania consists of lines with voltage levels of 110 kV, 150 kV, 220 kV, and 400 kV, along with the corresponding substations at these voltage levels and all the equipment whose functions include the transmission of electrical energy [13]. The connection of a series of solar panels, both individually and in grouped forms for small businesses or large-capacity photovoltaic systems, requires the fulfillment of several conditions and standards for the existing network to handle the said load. Regarding the 20 kV lines, it needs to be supplemented and have a denser distribution to capture and cover exactly that amount of energy transmitted by these small producers with photovoltaic panels. Otherwise, despite good intentions, technically, this becomes difficult and impossible.

Another issue is related to energy losses in the distribution network that although the recent improvements still requires adjustments to meet EU standards. When it comes to total losses in the transmission and distribution energy system, they are at levels of 3.48% for Austria, 2.60% for the Netherlands, and in the neighboring countries Kosovo is at 25.11% and North Macedonia at 10.35% [14]. For our country, this indicator, which used to be as high as 48% years ago, has now decreased to a level of 21% [16]; thus, a lot of work is still needed to improve this indicator as quickly as possible in the coming years. According to INSTAT 2023, "Network losses reached the value of 1.655 GWh in 2023, down from 1.658 GWh in 2022, marking a decrease of 0.2%. Transmission losses have increased by 10.1%, and their share in total network losses is 13.3%. Distribution losses account for a larger share, about 86.7% of the total network losses and in 2023 have decreased by 1.6% compared to 2022" [15].

3.12 Legislation

Still are needed improvement on the **legislative side** regarding renewable energies, where better detailing and completion of the subordinate acts is required. Other than limitation for the use of agricultural land should be clarified by low that this clean energy initially should be injectable for use in the distribution system to meet the country's needs, and only after these needs are fulfilled can be allowed for export.

3.13Storage of Produced Electrical Energy.

An essential element is not only the production of energy, but also its storage and utilization at times of demand. Nowadays, certain technologies, such as gravitational energy storage, are being applied in various countries like the USA, India, Morocco, etc. This involves raising certain weights to a height using energy produced from renewable sources like solar and wind and then, when energy is needed, these heavy masses are released, generating electricity through appropriate equipment. To ensure a specific height, alongside lifting them above the surface of the ground as presented in Figure 11, a practice of considerable interest is the utilization of disused mine galleries, which could be a good option for our country, especially for areas that may be are far way to the main transmission network of energy. This system is a new technology suitable for small-scale use, which requires minimal land use and does not use water for its operation.

Figure 11. Presentation of the gravitational energy storage system.

It has advantages in terms of installation, as it can be installed in buildings and off-grid. This new system has the potential for high storage density, discharge times on the order of minutes, a lifespan of 50 years, and efficiency of around 90%, which would optimize energy supply and utilization while increasing energy self-sufficiency. The ramp rate for this technology is as low as one millisecond, and the storage system can go from zero to 100% power in no more than 2.9 seconds. Similarly, this energy storage system is approximately 50% cheaper than battery storage technology.

3.14 Insurance Policies

Considering all of the above, the implementation and application of insurance policies by the respective companies is of primary importance to cover any potential risks from these extreme weather phenomena, which, in recent years, have shown an increasing trend.
Based on the above and the issues related to network loads, energy losses, etc., climate changes and their positive and negative impacts on the environment, as well as national development policies, it would be beneficial for the conditions in Albania to undergo a studied approach and to consider institutional scientific opinions primarily. This would lead to investments having the highest economic effectiveness for the country.

4. CONCLUSIONS AND RECOMANDATIONS

- Before investing in any renewable energy source, it is essential to invest in reducing the energy loss coefficient in the energy transmission and distribution system. With the current level of energy loss in Albania, it is needed to makes an economic analyses if investment in increasing electricity production through renewable energy systems by 1% or more, when in mean time facing high losses in the grid. Furthermore efforts should be made simultaneously to improve the infrastructure of the energy transmission and distribution network with the 20kV lines that serve to capture and inject into the system all these small energy producers.
- Secondly, if investments were to be made in this sector, the priority should be aimed specifically at the type of energy to be pursued through these renewable sources. Considering the aforementioned issues related to the network's ability to handle energy produced by photovoltaic systems and the losses in the grid, there should be an urgent focus on converting solar energy into thermal energy firstly.
- Thirdly, photovoltaic systems should be prioritized for installation in public buildings such as schools, kindergartens, hospitals, local and central government institutions, rehabilitation institutions, etc. Not only do they utilize a clean energy source, but they also have an impact on educating and informing the public about the importance of renewable energies. Furthermore, they contribute to fostering a new mentality regarding energy conservation.

- In the case of approval for the installation of photovoltaic systems for business needs with limited capacity, legal aspects that are applied in EU countries should be taken into consideration.
- **Meteorological monitoring** as presented in Figure 12 should be a priority when it comes to the approval and installation of photovoltaic systems primarily intended for electricity production for sale and not for self-consumption, similar to what has been approved for hydroelectric plants. The monitoring is necessary for the producers themselves to track the progress of electricity production, maintenance needs, possible technological improvements, etc., and to assess the various environmental impacts resulting from this installation.

Figure 12. Meteorological monitoring equipment near a solar system.

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EVALUATION OF THE POTENTIAL OF NICKEL HYPERACCUMULATOR PLANTS FOR NICKEL AND ENERGY PRODUCTION

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Agromining is an emerging technology aiming at recovering metals from soils using hyperaccumulator (HA) plants. This paper focuses on (i) the results of applying phytomining technology to recover nickel (Ni) and generate energy from agricultural ultramafic sites. *In Albania, Odontarrhena calchidica* can be cultivated across 11% of the country, with potential yields exceeding 150 kg of Ni per hectare. Ashing offers additional benefits, as the resulting ash acts as a bio-ore containing 15 % Ni, while the energy produced during the burning process can be recovered and utilized. Phytomining field plots have been operating since 2005 in Albanian mineralized regions and in sites contaminated by industrial activities in southeast of Albania. The experiments were designed to test the biomass production and potential nickel yield of *O. chalcidica* with organic fertilization regimes (chicken manure+ mineral fertilizer (NPK), We reached a biomass production 5.5-10.4 t ha^{-1} in three ultramafic regions and nickel yields from 71.5 to 164.32 kg ha^{-} . By considering, a household consumes around 800 to 1,000 kWh of electricity per month, or 9,600 to 12,000 kWh annually approximately 2-2.5 tons of plants per household would be necessary for heating and domestic hot water production only. Therefore, Albania has significant potential to expand biomass utilization from various sources.

THE POSSIBILITY OF BIODIESEL PRODUCTION FROM USED COOKING OIL IN KOSOVO

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ABSTRACT

In recent years, climate change has become a major global challenge. Alongside the increasing
demand for energy, driven by industrialization and population growth, it has significantly increased the need for sustainable energy sources. The production of biodiesel using recycled waste oils makes it a sustainable alternative with substantial environmental and economic benefits, offering a solution to these challenges.
This study examines the feasibility of producing biodiesel from waste oils generated in the gastronomy sector in Kosovo, using methanol and potassium hydroxide. Through laboratory analyses and interviews with employees in this sector, the study evaluates the market readiness and potential for implementing these practices. Additionally, it highlights the potential energy loss resulting from the failure to utilize waste oils as raw material for biodiesel production.
The research findings also reveal Kosovo's potential to convert waste oils into sustainable energy. It is recommended to establish a well-organized infrastructure for the collection and recycling of waste oils, raise public awareness about the benefits of biodiesel, and develop supportive policies that encourage the adoption of these practices. Implementing these measures could play a crucial role in reducing environmental impacts and advancing the development of a more sustainable energy sector in the country.

THE POSSIBILITY OF INTEGRATING ELECTRICITY THROUGH RENEWABLE SOURCES IN SAZANI ISLAND

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ABSTRACT

The purpose of this study is to integrate renewable energies for the electrification of an insular small area, Sazani Island, in complete lack of electricity. Sazani Island in south-west of Albania (40.502, 19.282), has been a former military base and has been isolated and unreachable for many decades. In the absence of electricity from conventional sources the possibility of integrating renewable sources is very promising due to favorable climatic conditions and the tourism development of the island will be easier and applicable in the future scenarios. Wind velocity hourly data (1981-2014) are adopted from Balkan Wind Atlas and solar data from PVGIS-SARAH solar radiation database. Non-linear model is used for wind energy output. Wind and solar shows a good complementary in seasonally basis. The levels of penetration of renewables will be discussed economically, the cost kW / euro are calculated for wind 0.039 euro/ kWh to 0037eur/ kWh and solar 0.064 euro/ kWh respectively. Complementarity between sources shows a week correlation coefficient 0.0014 for the summer season.
Keywords: Renewable energy, lack of electricity, small island, wind and solar complementary

1. INTRODUCTION

The insular system of Sazan Island

The largest island outside Albania, with a total area of 5.7 km^2, lies strategically between the Adriatic and Ionian seas, between the territorial waters of Albania and Italy. The island has long served as a military base. In 1975 the island was like a small republic. There lived an army of about 1500-2000 active soldiers and officers, equipped with heavy artillery shells, around the island sheltered in bunkers, with anti-aircraft artillery, navy, artillery, artillery, liaison, points signaling and other specialties. About 200 military families lived on the island. At that time the island was powered by a tunneled diesel -generating plant, three 250 kV, working in parallel. Also in the tunnel was the 04/6 kV transformer booth [1]. From there with the 6 kV airline the whole island was powered through five 6/04 kV cabins. The island was a remote area, totally isolated, and the problem was to reconstruct the entire distribution network. . All airlines had to remove, because firstly, the strong winds on the island always caused malfunctions and power outages, but they had to mask as well. They were replace with 6kv land-based cable lines in 1-1.5m deep ditches open with soldiers under the technical guidance of electrical specialists of the military construction company. A major problem remained the high consumption of fuels and lubricants as well as their transportation to the island, which cost the economy a great deal. Only one diesel generator consumed at that time 60 liters of diesel per hour. This fact severely limited the working hours on Sundays, including the part-time lighting of the island, 4 hours in the morning and 4-5 hours in the daytime. The shortage of 24 hours of energy caused problems for the military readiness and livelihood of the island. In 1981, underwater cables through a very ambitious project that successfully implemented for electrified the island. This project actually had no life expectancy in fact at that time. After 1991 the population decreased until all the families moved to the part of the continent. The island has a very limited number of inhabitants in the military base. Today the demand to visit this island is great but it actually offers nothing but a short visit to see a very attractive island. The main problem is electricity, the demand for electricity is expected to increase continuously, and significant increases can be attributed to rapid growth of tourist development in the area. In 2015 the government for the first time briefly allowed cruise ships from the Gulf of Vlora to land in Sazan and people could watch the hidden island and swim from its beaches. In 2016 the island was closed again from the government, but in April 2017, after the Ministry of Defense, Economy and Tourism reached an agreement, decided to reopen the island for tourist purposes from May to October [2]. Energy is the main factor of investments and tourism development of the island. In this contest will be necessary for development of sustainable strategies. The access to sustainable energy service for the area it will derive on the infrastructure of the islands. The other problem with electricity consumption is that only a minimum required for the months from May-October can be predicted, within a project scenario (projects scenarios are being proposed, that will be developed in the near future).

Sazani Island is the only habitable island that visited every year by a considerable number of tourists. Sazani has a great potential for the development of renewable energy, especially in the summer period when it is already allows populating by a large number of people, and as a result significantly increases energy consumption. The complementary way of energy peak is with diesel engines, whose consumption price is relatively high, further adding to the island's pollution. Integrating sun and wind sources in general would be the right solution but supplementing with simulations of accurate calculations of the energy situation depending on the approximate consumption on the island. Although the energy potential is considerable, the problems of accurately determining RES integration pose a challenge that needs to addressee by taking different scenarios in the relationship between RES sources, conventional sources such as electric motors and projected energy consumption.

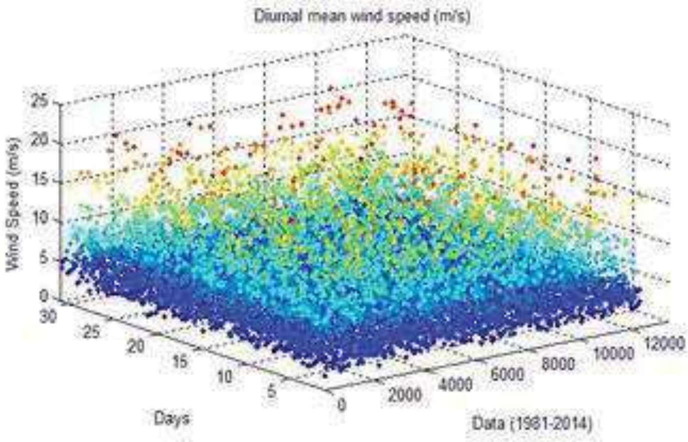
Due to the intermittency and time uncertainty of solar and wind sources it is necessary to connect to storage systems in order for the network demand to be secured, as well as to the voltage and frequency control systems, in many countries there is a limit for direct penetration into the electrical network. While for isolated areas in complete and without any connection to the electrical distribution network, the combination of these sources together supplies in an unlimited way. The success of these resources is limited to small-scale systems. While the possibility of replacing these energy sources with each other ensures the optimal fulfillment of electricity demand [3], [4]. The situation in general for isolated areas can clearly projected depending on the number of inhabitants, and the approximate forecast for consumption during the summer season, by integrating photovoltaic and wind systems together with energy storage systems. This complicated situation requires the simulation of a large amount of data that includes area-specific energy consumption data. Battery systems are the most commonly used in conjunction with the electrical frequency stabilization system. There is a lot of problem with providing electricity consumption data because they change significantly from year to year with the increase in the number of tourists in the summer period, and this consumption is almost negligible during other seasons, due to the emptying of the island. The more renewables are integrated, the lower the fuel consumption and dependence on their costs [5]. In this, paper with the aim of integrating solar and wind sources in this remote area is studied the wind and its parameters, as well as the availability of solar energy. In addition, the leveled energy cost calculated for the given scenario of the initial project of installing wind and solar systems. Then the temporary complementarity of these resources for the same location, because it is clear that we will have a decrease in the correlation coefficient even between the resources of the same type when the position of the sites changes [6], [7]. The combination of wind and sun sources (RES) in fact shows a variable dependence of complementarity especially between the seasons, the wind potential for example decreases significantly during the summer season and

increases during autumn and winter. One of the most widely used metrics is through data series correlation, which enables linear correlation between variables. The purpose of the correlation lies in the possibility of realizing energy efficient scenarios for this area [8],[9].
The objective of this paper is to integrate wind and solar sources in a remote area totally isolated from the power grid. The possibility of developing on the island of combined solar small wind systems on a small scale as a start, together with storage systems would be the ideal solution

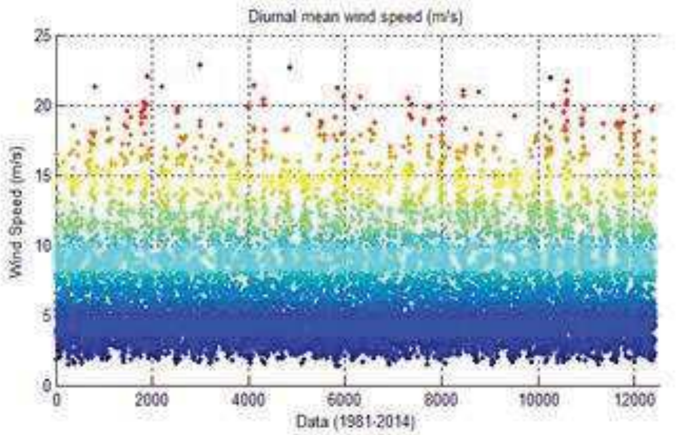
2. METHODOLOGY

2.1 Availability of solar and wind potential on the Islands

The purpose of wind and solar measurement in the islands was for weather forecasting in military station and therefore not a reliable one to consider it for energy studies. In fact, for various studies on the availability of solar and wind sources, data series can be obtains from terrestrial measurements, satellite measurements but also combinations between them and in other cases also from numerical models. In this study, a wind speed data are long-term wind speed data (for the period 1981–2014) based on Balkan Wind Atlas of Sazan Island, and has been considered and analyzed to evaluate the potential of wind energy [10]. There is a complete lack of data on electricity consumption during the summer by tourists on the island, in recent years, and lack of data on energy consumption in military systems throughout the year, and for the summer period during the management of simple tourist systems. The use of electricity within the necessity and in the absence of infrastructure for each period of the year on the island intensifies between the months of May-October; legally is allowed to enter the area, especially frequented in June-August. In this time interval, we have examined the wind potential and the potential of solar energy to reach the conclusion which of the sources is the most cost-effective. Wind speed data are for a period of 33 years based on the Balkan Wind Atlas. In the Fig.1 are plotted long-term data, the data are analyzed that the evaluation of wind energy potential is within the accuracy criteria. From the data for wind speed is estimated an average variable between 5.63 to 6.94 m / s, at an altitude of 50 m [11].



a)



b)

Figure 1. Thirty-four year daily, mean wind speeds at height 50 m on the ground in Sazani Island.

For the months of June and August, respectively with the period of attendance of the island by tourists, the wind speed is low and the potential of wind energy is not significant. In addition, variations in wind speed generally throughout the year imply a variable, non-stable wind energy output. An energy conservation system would be the solution, in combination with solar energy, could be a long-term project related to the sustainable development of the island's infrastructure development [12]. Ilustration of wind speed data at height 50m, for the period 1981-2015 presented in Fig.2. Monthly wind speed are calculated for the presentation.

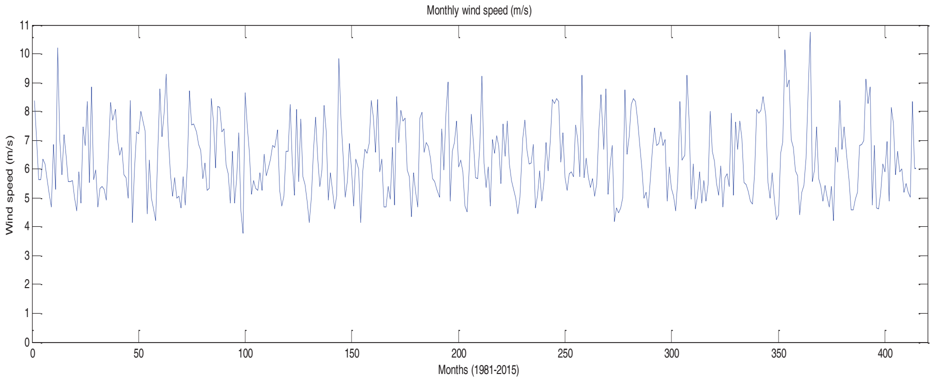
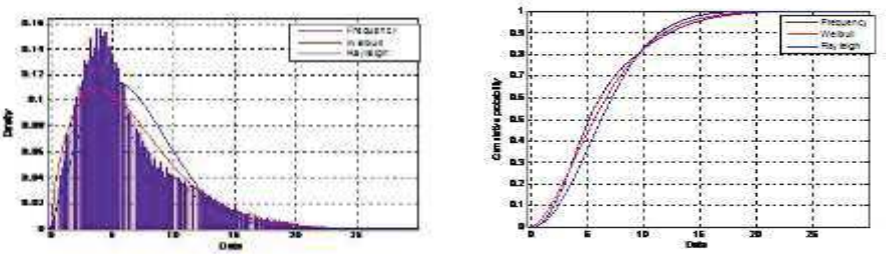


Figure 2, Variation of monthly mean wind speeds at height 50 m over the ground in Sazani Island.

Fig.3 shows from the statistical calculations the density function probability for Weibull and Rayleigh distribution.



a) b)

Figure 1. Statistical analysis for the data series. Probability and cumulative density function

Weibull scale (*c* m/s) and shape (*k*) parameters respectively 7.0734 m/s and 1.6221 for 34-years data for wind speed. Mean wind speed, predicted by Weibull and Rayleigh distribution 6.3341 m/s and 4.7201 m/s. Weibull statistical distribution from the measurements predict the mean wind speed profiles of the station quite adequately.

2.2. Wind energy model calculation

In this study, we consider small-scale application of wind system, in such a way as to compensate for the limited needs of energy consumption. Wind turbine specification summarizes the output power suitable for a small service building or residential building, price compared to other similar models, operation at speeds of 2.5m.s or 3.5m / s up to the limit of 25 m/s, efficiency of the wind turbine, dimensions such as weight or height are in consideration. Nonlinear model is used to calculate energy output of wind turbines [13]. Air density 1.225 kg/m^3 and the mean wind speed calculated from the the data is 6.30 m/s at 50 m height and the predicted mean wind speed 6.33 m/s. In addition, 225kW, 250kW (Vestas, Nordex and Wind World) wind turbine model was assessed for the site's wind characteristics.

Table 1: Characteristics of wind turbine models, and energy output per year from measurements

Wind Turbine Model	Cutt in/ off (m/s)	Rotor diameter (m)	Hub Heights (m)	Power (kW)	Capacity Factor	Energy Output kWh/m^2/ year	Energy Output kWh/ year
Vestas V27	3.5-25	31.5	standart	225	24	824	471788
Vestas V 29	3.5-25	31	Standart	225	26	780	515320
Nordex N 29	4-25	50	50	250	27	894	590592
Wind World 29.2	3.5-25	41	41.5	250	24	789	528323

For the annual energy output, the chosen wind turbine capacity factor, defined by the ratio of the actual power generated to the rated power output. Cost of the project including initial costs such as transportation, installation, grid integration, are 35% of turbine cost. Fixed Operation and Maintenance costs are assumed 50eur/kW/year. Lifetime of the system will be 20 years. Annual operation and maintenance costs plus the land rent come to 5% of the turbine cost. Cost of a construction project is around (higher than in non isolated areas 1800eur/kW). The simple economic analysis scenario gives LCOE ranging from 0.039 eur / kWh to 0037eur/ kWh. [14]

2.3. Solar energy model calculation

Grounds measurements high accuracy are related with high quality sensors regularly calibrated, and the data is a condition in energy measurements to be as long as 10 years.[15], [16] There are no meteorological stations installed in island for the purpose of accurate and reliable measurements, especially for calculating the energy obtained from these sources. Meteorological stations in Albania are limited and with equipment which are not evaluated for energy calculations but for meteorological purposes. This study use solar radiation database PVGIS-SARAH covering from 2005-2016, the data set has a high temporal (hourly, daily and monthly set of data). In the Fig.4 daily average Irradiance, for global, diffuse and direct respectively, month of June presented.

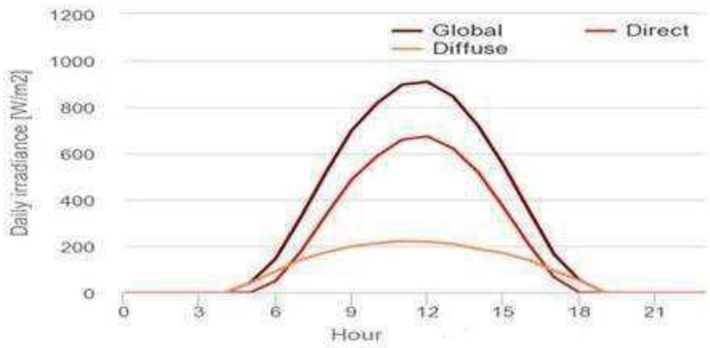


Figure 2: Daily average Irradiance for the month of June

For the energy production the model used:

$$\eta_{pv} = \eta_{ref}\left[1-\beta'\left(T_{cell}-T_{cell,ref}\right)+\gamma Log\left(\frac{G_{\beta}}{G_{\beta,ref}}\right)\right] \qquad (1)$$

T_{cell} is the temperature of the PV cell, η_{ref} is the efficiency of the module in standart condition. ($G_{\beta,ref}$=1000 W/m^2; $T_{cell,ref}$=25 ºC); γ and β' respectively are the coefficients of solar irradiance and temperature. Parameters for standard conditions ($T_{cell,ref}$ η_{ref}) Aand γ , β' are supplied by the producers of PV modules.
In the Fig.5, from PVGIS, monthly average energy for three types of PV systems presented, vertical axis, inclined axis and two axis.

Figure 5. Monthly average energy for tracking PV system.

The calculations for cost production of two PV systems, on/ of grid performed. The parameters to take in considerate are all the costs of PV systems, as the price of the systems, installation, and maintenance. In total these costs parameters together compared with the predicted PV energy production for the lifetime supposed of the system [17], [18].

For the calculation of PV cost is used "Levelized Cost of Energy" (LCOE) method [19]. In the calculation an initial loan used to pay the whole cost of the PV system and is repaid in fixed yearly installments until the end of the lifetime of the system. For the self-payment period in years some parameters are important, the price of electricity in the network, the investment of the systems and the predicted life of the system. For the PV system, for the efficiency of the inverter 97.5%, losses from DC system 5.5% and 1.5% from AC, availability 99%. Return on investment vary for different investors , there is also a difference based on location, investment cost, cost of capital and electricity tariff, annual percentage of O&M maintenance and services, cost of total capital 3%, discount rate 5 % and annual degradation of PV production 0.5% per year. LCOE is 0.064 Euro/ kWh

2.4. Wind and solar linear complementarity

The most promising and most feasible application for insular areas are solar-wind hybrid systems applications. Complementary of these sources can bring a reliable system with a significance economical efficiency that is strongly dependent to the variability of the wind and solar resources [20]. The impact on the energy balance of wind and solar is very important. In their combination, the intermediate compensation of these sources need to chosen so that the losses could be minimal within the selected scenarios. The problem that can cause the overcome of the two sources of energy can be reduced by integration optimally combination during periods. From the measurements, more solar radiation is available during summer period, wind is significant during winter period, and it shows a constant behavior in spring, as is shown in the Fig. 6.

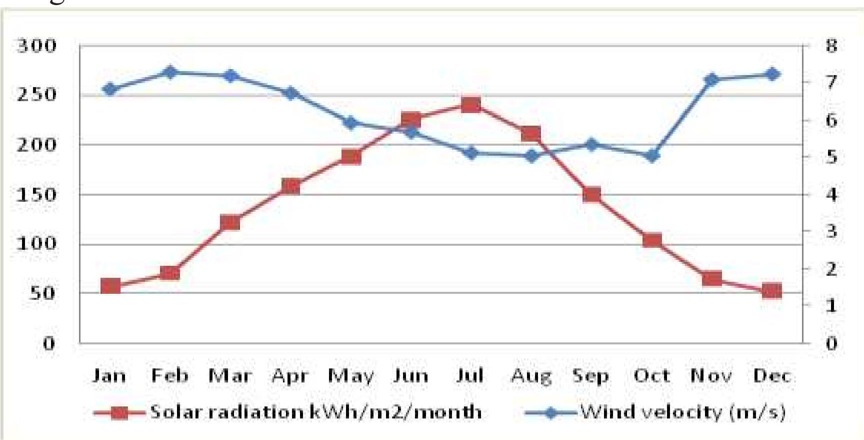


Figure 6: Monthly mean wind speed and solar irradiance

In the Fig,7 presented wind and solar energy during a period of a typical year for the island. Calculation are made respectively, for wind energy production evaluated from Pallabatzer model, and for solar energy production evaluated from Durich Model.

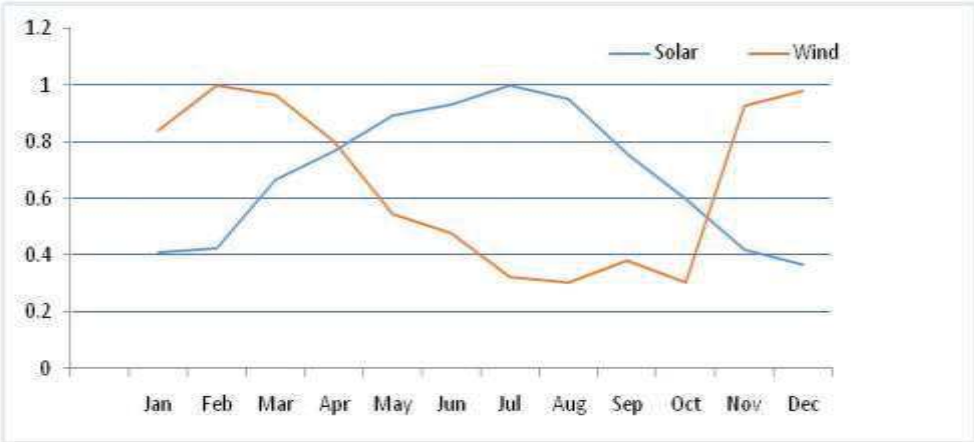


Figure 7: Availabilities energetic (solar and wind) for a typical year.

The operating thresholds for wind turbines do not vary with season, it is important to determine the wind velocity thresholds during the seasons to define “low” and “high” wind speeds using all data in the year. It is clear that the importance of wind speed and solar irradiance performance during the summer season, during the period June, July, August. We note that, as seen in Figure 5, there are very few high-windy days in the summer. Similarly, the winter high-winds correspond to summer low winds that can conclude in good proportion of the available windy days, or sunny days. In reality without a real scenario it is not possible to compare strictly the outputs from wind turbine and PV systems in different season. The aim is to present the situation of energy resources on the island and to be sure that the only reliable option is the integration of wind and solar resources. In the statistics the linear correlation between two sets of data is given by Pearson correlation coefficient [21].

$$R_{XY} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2}\sqrt{Y_i - \bar{Y})^2}} \qquad (2)$$

Where X and Y are the sets of data to be analyzed.

The long term data for solar radiation and wind velocities, temperatures are used in the calculation. In the Fig.8, the analysis performed by calculating the linear correlation coefficient between the two sets of data for the month of June.

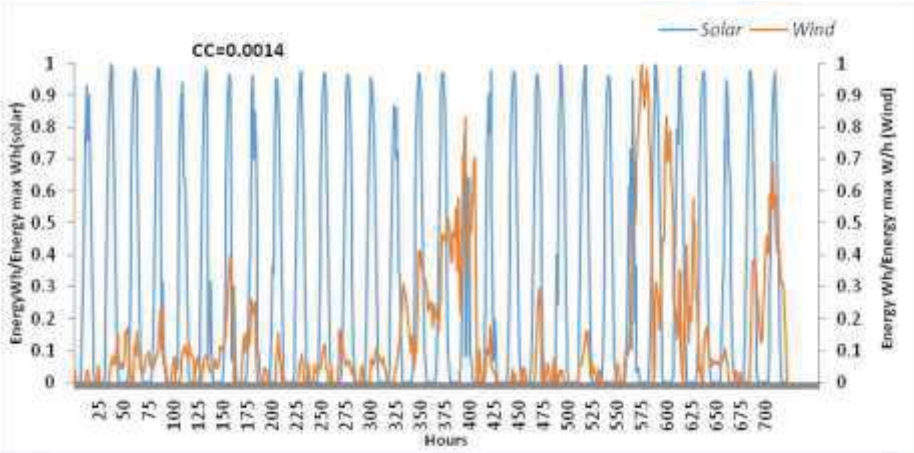


Figure 8: Correlation Solar and Wind in nominal energy values, for June

For the month of June the Correlation coefficient between solar and wind availabilities is very week CC=0.00136, for July is 0.165227, and for August the linear coefficient is 0.22134 which is a week correlation. Wind energy during these periods it shows not a good complementarity. The significant accumulated energy for wind is during other seasons. In the Fig.9 the analysis performed between the two sets of data for the month of July and August that corresponds the period when the islands is visited be the tourists.

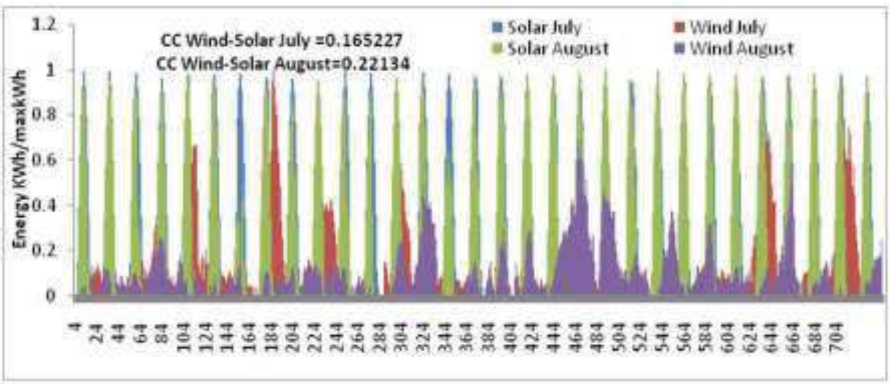


Figure 9: Solar and wind energy availability during the season of tourism, allowed in Sazani Island

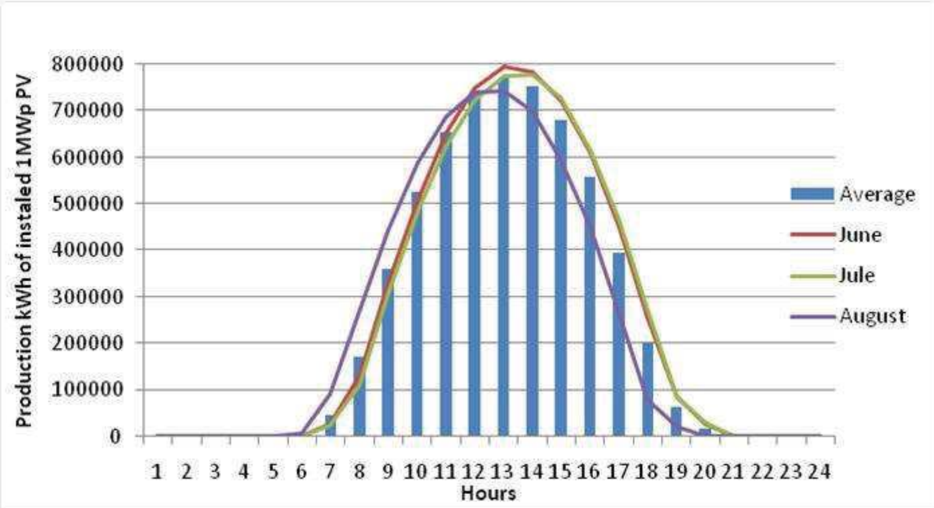


Figure 10: Daily average Solar Production for the period June, July and August

The correlation coefficient for the three months CC=0.0014, which is a week correlation as it is expected. For the correlation between June and July for solar availability, CC=0.930681, between July and August, CC=0.913605, and for June-August CC=0.766483. These values shows a strong positive correlation, and is illustrated in Fig.10

3. CONCLUSIONS AND DISCUSSIONS

In this study considered the possibility of development of the island of Sazan, focused more on the summer period when tourism development is possible and allowed. In the complete absence of electricity and connection to the central energy network on the island, diesel engines are in use for the minimum required energy. The island is in complete lack of energy. Due to the distance and high cost of interconnection from the ground, renewable resources are important to integrate on the island. The wind potential on the island is good and considerable especially during the winter season. For the summer season where the number of tourists on the island has increased a lot in recent years, the potential of solar energy is essential for use.
Several development plans with different scenarios are in process study government programs. It seems that the best option is to integrate wind and solar sources as efficiently as possible of the energy situation. For storage system first electrochemical batteries for the storage process and then it can be suggested other storage systems that are widely used on islands such as pumped hydro storage. The potentials of wind and solar energy evaluated,

focusing on the period of the summer season period that is legally allowed to enter in the island. By a simple economic scenario for wind energy, values of LCOE ranging from 0.039 Euro / kWh to 0037Euro/ kWh. For solar energy LCOE is 0.064 Euro/ kWh . Otherwise, in the development scenarios for the island, the possibility of overlapping resources is very necessary. In fact, the complementarity of the sun and wind as well as the energy storage system would be an optimal solution.
Complementarity for wind and solar sources seems to be very week during summer season, CC=0.0014, between solar availabilities between months as it is expected is very good. For the summer period, starting from June, it is clear that the integration of solar photovoltaic systems would be more efficient in economic terms. The anticorrelation between wind and solar power cannot produce a well-balanced energy supply for the summer season. Installation of wind turbines for use only during the summer period would not be economically viable, if the development of the island would allow its population in other seasons, hybrid wind, solar and storage systems would be the optimal solution. Hybrid system solar -battery or other storage system is a necessity, and electrical motors in addition to complete the energy peak. In the near future various scenarios are in study process out with the support of the government in such a way as to overcome the economic and financial barriers to the integration and installation of renewable resources in order to optimize the situation on the island.

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WIND INTEGRATION CHALLENGES IN LOW REGIONS.

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ABSTRACT

Albania's National Energy and Climate Plan (NECP) 2050 is a pivotal plinth aimed at steering the country towards a sustainable energy future setting out three primary objectives: increasing the contribution of renewable energy sources (RES) to 54.4% of total final energy consumption, reducing final national energy consumption by 8.4%, and cutting CO_2 emissions by 18.7%. Achieving these goals requires a proven and comprehensive approach that addresses energy production, consumption, and environmental impact, reshaping Albania's energy as whole system based on large-scale integration of RES. The country's geographical landscape, characterized by significant wind and solar potential, provides an excellent foundation for large-scale renewable energy projects. The successful execution of the NECP 2050 has the potential to revolutionize Albania's energy landscape by optimizing the entire energy system employing synergies across various sectors, leading to a greener and more sustainable future that hasn't been included in previous national strategies.
Keywords: Wind and Solar Energy, Sustainable and Clean energy; deep decarbonization anergy modelling tool.

1. INTRODUCTION

Albania's National Energy and Climate Plan (NECP) 2050 is a pivotal framework aimed at steering the country towards a sustainable energy future. This ambitious plan sets out three primary objectives: increasing the contribution of renewable energy sources (RES) to 54.4% of total final energy consumption, reducing final national energy consumption by 8.4%, and cutting CO_2 emissions by 18.7%. Achieving these goals requires a comprehensive approach that addresses energy production, consumption, and environmental impact, reshaping Albania's energy landscape for the better. Albania has a significant potential of renewable energy resources (RES) and generates around 100% of its electricity from intermittent energy sources (HPP), but that is not a good picture as the lack of wind power plants make our national energy system unstable and not diversified, therefore more R&D should be undertaken on other RES forms such as wind potential. In quiddity, wind and solar energy has the aptitude to acts as a stabilizing and optimizing force for a balanced hydro energy system and better manage of the Drin cascade, creating conditions for synergistic, stable and reliable implication, with effective costs and operates in pace with the environment .

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THE USE OF VEGETATIVE/PLANT BIOMASS AS AN IMPORTANT ELEMENT OF RENEWABLE ENERGY.

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ABSTRACT

An extraordinary increase in population in recent decades undoubtedly increases the demand for more products and services in the function of human society with ever higher demands to improve the quality of life. Undoubtedly, in this context, after food and shelter, the use of energy resources by populations in both rural and urban areas also occupy an important place. The energy sources produced and used have been different at different stages of social development. They have evolved from country to country and from time to time. However, in recent decades it has been noted that the use of several different energy sources as raw materials such as coal or oil by-products such as fuel oil, etc., has brought significant negative impacts on the environment. It should not be forgotten that apart from the sun, which humans used most naturally, the first resource that humanity used was wood, used in the simplest way through fire, mainly for heating and cooking. The use of vegetative biomass has gone through various stages and methods. Initially, it was used directly, such as firewood or plant waste, etc., then through various stoves, and then more sophisticated plants were built. Thus, from vegetative biomasses, biofuels began to be produced that are very friendly to the environment, or very modern power plants were built for the production of electricity. But we must not forget something very important: plants, trees, etc., have sequestered during their life cycle a considerable amount of CO_2, which they emit into the atmosphere during their combustion. Fortunately, vegetative biomasses are not finite, they are renewable. But, a smart and environmentally friendly use of these resources is needed. Therefore, for this ratio to be at least zero, we need to plant as much vegetation, forests or wood as we burn, to grow and sequester the same amount or more of the CO_2 that is released. Only in this way can we say that vegetation biomass is truly a renewable energy, but it also becomes environmentally friendly. In this context, many countries have begun to use methods and technology that produce clean, environmentally friendly energy from vegetative biomass, including wood biomass. We will address some of these important issues in our paper that we are presenting at this important scientific symposium.

Keywords: *renewable energy, vegetative biomass, environmentally friendly.*

INTRODUCTION

Undoubtedly, in this context, after food and shelter, the use of energy resources by populations in both rural and urban areas also occupy an important place. The energy sources produced and used have been different at different stages of social development. They have evolved from country to country and from time to time. However, in recent decades it has been noted that the use of several different energy sources as raw materials such as coal or oil by-products such as fuel oil, etc., has brought significant negative impacts on the environment. It should not be forgotten that apart from the sun, which humans used most naturally, the first resource that humanity used was wood, used in the simplest way through fire, mainly for heating and cooking. The use of vegetative biomass has gone through various stages and methods. Initially, it was used directly, such as firewood or plant waste, etc., then through various stoves, and then more sophisticated plants were built. Thus, from vegetative biomasses, biofuels began to be produced that are very friendly to the environment, or very modern power plants were built for the production of electricity. Grasses and short-rotation trees are used for biofuels, and agricultural residues are converted into biogas. [12].

Agricultural systems, but especially agroforestry systems in many countries, but also in our country, among others, are also a good source for providing vegetative biomass and especially woody biomass which can be used in the energy production industry based on biomass trees. By agroforestry we mean: agroforestry is a land use system in which both agricultural and forestry production are shared [6], and in more scientific definition based and to (ICRAF) as: agroforestry is a dynamic, ecologically based management system of natural resources that, through the integration of trees on farms and in the agricultural landscape, achieves and maintains diverse production to increase social, economic and environmental benefits for land users at all levels. [6].

But we must not forget something very important: plants, trees, etc., have sequestered during their life cycle a considerable amount of CO_2, which they emit into the atmosphere during their combustion. Fortunately, vegetative biomasses are not finite, they are renewable. But, a smart and environmentally friendly use of these resources is needed. Therefore, for this ratio to be at least zero, we need to plant as much vegetation, forests or wood as we burn, to grow and sequester the same amount or more of the CO_2 that is released. Only in this way can we say that vegetation biomass is truly a renewable energy, but it also becomes environmentally friendly. In this context, many countries have begun to use methods and technology that produce clean, environmentally friendly energy from vegetative biomass, including wood biomass. Bioenergy/renewable energy produced from organic materials - the conversion of complex organic carbohydrates into energy. Organic matter (often called biomass) can be used directly as fuel (to produce heat), or converted into liquid or gas (for transport) and for the production of electricity using a variety of technologies and plants depending on the field of use and the types of raw materials used. Importantly, bioenergy is defined as an energy source that is not only renewable but also "environmentally compatible," meaning that it is produced and used without additional obligations to the environment and its components, mainly to biodiversity, soil, air, water, etc. Renewable energies, which are also called "white" or ecological energies, include: water, solar, wind, geothermal, and biomass energy or bioenergy. [7]. We will address some of these important issues in our paper that we are presenting at this important scientific symposium.

MATERIAL AND METHODS

For the realization of this study, we are based on the collection, analysis and review of a large and voluminous scientific theoretical material, but also contemporary practical in relation to the uses of clean and renewable energies, and especially those with vegetative biomass, and mainly those that use wood biomass. Also, the methodology of this work consists of reviewing and analyzing geomorphological, climatic, land, socio-economic and demographic factors, etc., to determine the most suitable regions in our country. At the same time determining important attributes such as the selection of tree species that will be used for the production of wood biomass for energy production plants, that use vegetative biomass as raw material, the selection of the place where the plant will be built, the methods of planting trees, the methods and mechanisms used for cultural services realization for planted trees and up to the harvesting and transportation of the wood biomass produced. The recognition of EU legislation on energy production from vegetative biomass and the proposal for certified plants will be based on the methodology used.

RESULTS AND DISCUSSIONS

Man, since the beginning of human life, has had two main problems: shelter and food. Then came the fire that helped us a lot for heating and cooking, and wood was the first source of energy that was used directly with combustion...

but let's not forget steam engines, locomotives, steamers, etc. that in the beginning supplied large boilers that used steam, initially fueled by wood and then by coal. Wood is the largest energy producer worldwide, but some people wonder, is wood a renewable resource? In the 1800s it was the primary energy source in the US until 1885 when coal surpassed it. In the 1920s petroleum surpassed both wood and coal making wood the third largest energy provider. With this short history, it's safe to say that wood has been a primary energy source for a long time. One reason for this longevity is its renewable properties. [5].

Biomass originates from organic material from forestry and agriculture (such as trees and plants), from waste and residues of biological origin as well as the biodegradable fraction of waste. It can be used for heating, electricity generation, and the production of transport fuels. Increasing the use of biomass in the EU can help diversify Europe's energy supply, create growth and jobs and lower greenhouse gas emissions. Biomass for energy must be produced, processed and used in a sustainable and efficient way in order to optimize greenhouse gas emissions savings and maintain ecosystem services. Biomass for energy (bioenergy) continues to be the main source of renewable energy in the EU and accounted for about 59% of the renewable energy consumption in 2021, according to the 2023 E. Union bioenergy sustainability report.[2].

The world has a total forest area of 4.06 billion hectares (ha), which is 31 percent of the total land area. This area is equivalent to 0.52 ha per person1 – although forests are not distributed equally among the world's peoples or geographically. The tropical domain has the largest proportion of the world's forests (45 percent), followed by the boreal, temperate and subtropical domains. More than half (54 percent) of the world's forests is in only five countries–the Russian Federation, Brazil, Canada, the United States of America and China. [3]. But forests are distributed in different ways across the globe. Thus, about 64 countries in the world that together have a population of about 2 billion people have less than 0.1 ha per capita. The 10 richest countries in the world with forests today represent 2/3 or 66% of the total forest area in the world today, but 7 countries have no forests at all (Falkland Islands, Gibraltar, Holy See, Monaco, Nauru, South Georgia and South Sandwich Islands and Tokelau) and about 57 countries have less than 10% of their land area covered by forests. [7].

Global wood production is at record levels, at about 4 billion m3 per year. An estimated 2.04 billion m^3 of roundwood was harvested in 2022, which was similar to the volume in 2021. About 1.97 billion m^3 was harvested in 2022 for woodfuel, constituting just under half (49.4 percent) of the total wood harvest; the proportion was much higher in Africa, at 90 percent [4a].

There has been and still is a lot of debate and discussion about the use of vegetative biomass for energy, not only from civil society but also from scientific circles around the world. The use of woody biomass is indeed a renewable energy source, meaning that it is renewed by planting or natural regeneration, but in fact when energy is produced from plant and woody biomass, especially when this woody biomass is burned in the traditional way, but also in somewhat more modern ways such as briquettes and pellets, there are still considerable emissions of CO_2 into the atmosphere, and even residues such as smoke and soot that pollute the atmosphere and are never absorbed by the trees in the ground. Therefore, more scientific methods have recently emerged for the use of woody biomass by producing biogas or biofuels from them that are more usable in a more modern way and that are also more environmentally friendly because they do not emit greenhouse gases into the atmosphere at the same levels as when we use wood directly for combustion or in the form of briquettes or pellets.

It is undeniable that the main woody biomasses are derived from forests, primarily from their harvesting/exploitation, but also and from wood residues resulting from various activities and services in forests, such as clearings, thinning, etc. Forest bioenergy potentials can be converted into alternative biofuels. This process involves physical processes, thermochemical processes, chemical processes and biological processes. However, biophotolysis processes have gradually become widespread among conversion methods in recent years. Physical presses include grinding, drying, pelletizing and briquetting. The main thermochemical processes are combustion, pyrolysis (torrefaction, slow pyrolysis and fast pyrolysis), gasification and hydrothermal processes. Pyrolysis, gasification, fermentation and anaerobic digestion methods, which are among the biomass-to energy conversion technologies, are used to convert forest-derived biomass into energy[16].

Forestry residues, such as branches, twigs, leaves, and stumps, are generated as derivations of forestry activities, such as logging and thinning (Moskalik and Gendek, 2019). These residues can be used for various purposes such as bioenergy production, soil improvement, and animal feed. However, if not managed properly, forestry residues can cause environmental problems including soil degradation, erosion, and greenhouse gas emissions. Therefore, effective and sustainable operation of forestry residues is crucial for both environmental and economic reasons [16].

As a result, it is observed that the collected cutting residues from the fields that are sufficient in terms of benefit and cost is burned to generate electricity in electricity generation stations [16].

To build an impiant that produces electricity entirely with wood biomass, this can be best achieved through the creation of plantations planted with forest trees, although can use and wood biomass resulting from natural forests, or from agricultural systems or agroforestry systems, can also be used, so, Albania has significant biomass resources, including forest waste and agricultural residues [13]. But great care must be taken not to take everything from natural forests and damage and impoverish them, or create soil erosion phenomena, etc. according to the national forest and pasture inventory in Albania for 2021, forests cover approximately 46% of the country's total land area, amounting to 1,179,000 hectares. These forests contain a substantial volume of wood, totaling about 57.7 million cubic meters, with an average of 0.65 hectares per person [15]. In terms of land area per inhabitant, Albania ranks among the top countries in Europe. However, when assessing the quality of these forests, it's important to consider various indicators, such as annual growth per hectare and standing volume per hectare. These indicators reveal that the quality of Albania's forests is relatively low. It's worth noting that a significant portion of the forested land is classified as shrubs, which impacts the overall quality assessment. Forests dominated by beech, oak, and fir, but and many surfaces covered by shrubs, especially Mediterranean Machia. [7].[8] [10].[15]

The supply of primary energy sources for our country, for the year 2010, was in the values of 2105.55 ktoe. In the supply by source, for the year 2010, it is worth mentioning that hydrocarbons contributed with 1232.9 ktoe, or 58.71% of the total, electricity with 584.31 ktoe, or 27.82%, firewood with 213 ktoe, or 9.76%, and the rest consists of sources such as coal, natural gas and energy obtained from solar panels. [14] Biomass in our country is valued as an energy source and is closely related to firewood. In 2010, it turns out that 93% of the firewood used was consumed for heating and cooking and only 7% was used in other services. Biomass contributes through firewood to the country's energy balance with 7.76%. [14] In Albania, biomass, as an energy source, is used in its traditional form for heating and cooking, through firewood or other agricultural waste. According to preliminary estimates, biomass energy in our country is about 7 Mtoe, while biomass energy provided by agricultural waste is estimated at about 130 toe/year.[14].

The demand for biofuels in Albania is based on the biofuels target, set in the NPVBRE, which is around 95.53 ktoe for 2020 (108,000 tons per year). [17].

Figure 2. Wood biomass types: cord wood, wood chips, pellet /briquets **(Source: Web)**

For example, in the last decade, energy sources in EU countries have been highly multifarious where the use of biomass for energy production has undoubtedly played a primary role. Biomass for energy (bioenergy) continues to be the main source of renewable energy in the EU and accounted for about 59% of the renewable energy consumption in 2021… Germany EU's biggest producer of solid biomass 2021, and 21.1 Mtoe biomass consumed by EU's industry sector in 2021[2]. But and in the future, it is again predicted that wood biomass will continue to be used for energy production in EU countries, and of course also in countries aspiring to join the EU, including our country, as a major source of renewable energy. The revised Renewable Energy Directive establishes binding targets for the share of renewable energy in the transport sector, including maritime and aviation. By 2030, EU countries are required to either achieve a share of 29% of renewable energy in transport, to reduce the emissions intensity of transport fuels by 14.5%, as well as a combined sub-target for renewable hydrogen and advanced biofuels of 5.5%[2]

Organic matter or biomass used for the production of bioenergy can be of different types, but they are mainly: various urban waste of an organic nature accumulated in urban settlements, which eventually result in relatively large quantities in populated centers; various waste from agriculture or urban forestry such as grass, straw, cereals, seed waste, fruit, vegetables, waste wood from pruning of urban trees, etc.; waste resulting from forests and the wood and paper processing industry such as wood chips, twigs, leaves, chips, sawdust, etc.; waste resulting from animal breeding complexes such as food waste, manure, animal waste, etc. and even aquatic vegetation.[7].[9]. In the figure 1 above presented wood biomass types: cord wood, wood chips, pellet / briquettes, which are currently used and in our country.

However, in order to reduce the pressure on the environment and its components in the use of organic matter for bioenergy production, there has recently been talk of integrated bioenergy production systems, where the various complexes and systems are supplied with cultivated biomass, which can be cereals with high bioenergy potential or forest wood species with short production cycles and high amounts of biomass per unit of land and time. Wood for energy use may come from various sources, such as natural forests, forest plantations, trees outside forests, wood residues from forest harvesting and wood-processing industries, and other waste wood.

All wood comprises about 50 percent carbon, 44 percent oxygen and 6 percent hydrogen (when measured on an ash-free and moisture-free basis). The heating value of wood is greatly affected by its moisture content. "Green" (i.e. freshly cut) wood has a heating value of about 8.2 megajoules (MJ) per kilogram (kg), while air-dried wood (with a moisture content of 10–20 percent) has a heating value of about 16 MJ per kg (corresponding roughly to 0.382 kg oil equivalent, or 4.4 kWh). Oven-dried wood has a heating value of about 18 MJ per kg. In comparison, the energy required for household cooking (after accounting for the thermal efficiency of cooking stoves) in India has been estimated at about 7 MJ per household per day. [4b].

Wood may be used as fuel directly in its original form or after processing or transformation into charcoal, pellets, briquettes or chips, or into various products in liquid or gaseous forms. Such transformation is achieved through the use of devices ranging from the very simple (e.g. three-stone stoves and earth-pit charcoal kilns), to the more sophisticated (e.g. improved cookstoves), to the complex, such as large-scale wood-pellet plants, modern boilers, and advanced wood-fired electricity generation plants. In order to reduce the pressure on natural forests, it is best to create large plantations through afforestation with suitable wood species for this purpose, which obviously must first meet certain specific parameters, some of the most important of which can be considered: rapid growth, high biomass production per hectare and high calorific value.

Selection of tree species – The selection of species to be used in afforestation is very important and depends primarily on the soil and climatic conditions of the region where the planting will take place, as well as on the requirements that particular plants have for soil and climatic factors, but also of course on the purpose and wood assortments that we want to produce. There are a number of criteria that we take into consideration when selecting the tree species to be used for planting in a given area. But we must not forget that the selection of species has its own specificities when these species are used in traditional forestry, in agroforestry or in urban forestry, and undoubtedly in artificial forest plantations. [6]. [8]. [9]. [10]. The geographical position of our country as well as the soil and climatic conditions favor the installation and growth of a considerable amount of vegetation in general and more specifically of tree species and shrubs. The country is characterized by a high diversity of ecosystems, habitats, and species. In Albania, 3,200 taxa of higher plants [1], which accounts for about 30% of Europe's flora, totaling around11,000 species. [12] They must have a series of very important characteristics that mainly consist of: fast-growing species, short rotation, low-cost seedling production, low service and irrigation requirements, high calorific value with fresh and dry biomass, resistance to diseases and pests, mechanized planting, cultural services and harvesting, etc., without forgetting, of course, adaptation to the soil and climatic conditions of the place chosen for this purpose. Near such requirements are several species such as: *plane, poplar, acacia, willow* (seedlings of these species are produced from cut pieces, called as pencil), *Pseudotsuga* a type of conifer with very fast growth, *Paulownia*-which indeed presents good characteristics for fast growth and biomass production, but there is recent evidence that it impoverishes and damages the soil structure. Thus, yellow willow has been widely used in England in recent years for biomass production for energy production plants.

Selection of location: As we mentioned above, years ago, the Albanian government established a working group to conduct a study on the establishment of a plant in our country to produce energy with wood biomass, of which the corresponding author of these rows was a member. Different territories in our country were analyzed, and precisely regions in the Fier-Lushje districts were studied, taking into account large territories of over 1500 ha with continuity between them, accessibility by highway, good positioning in populated regions, high soil fertility, good geomorphological and climatic conditions, and the presence of water sources.

Biomass harvesting: positioning the plant impant in the center of the plantation with a minimum radius for internal transport from the cutting sites to the plant for energy production from woody biomass not more as 20-30 km. So, mechanized logging and transportation operations have been shown to reduce labor costs and increase productivity in Turkish forestry.[16]. Gülci et al. (2023) based and on the studies of Acar et al. (2018) they underline that mechanization of work operations in the technological process of forest harvesting/exploitation in industrial forest stands, modern forestry machinery such as harvester, feller-buncher, and skidder have been used for activities such as tree felling, extraction, and skidding in Turkey, something that undoubtedly applies to our country, and undoubtedly also to the harvesting of woody biomass in artificial plantations with trees planted for the purpose of producing energy from woody biomass. A view of the mechanized harvesting of plants tree is shown in Figure 2 below. It is quite important that the means chosen for harvesting wood and the methods used are designed to not cause significant negative impacts on the environment, and for such operations, a preliminary assessment of the environmental impacts of harvesting wood is also carried out, impacts that appear most on the land, landscape, waters, air, etc. [11].

Figure 2. Harvesting biomass in mechanized way (Source: Web)

As everywhere, our country has great potential for bioenergy production, which must be put to use as efficiently as possible to alleviate the lack of energy in our country, the use and recycling of organic waste in various sectors, the use of uncultivated lands, higher employment, etc.
Bioenergy has been defined as a renewable energy source that belongs to the future for its clean and ecological nature, as an environmentally friendly energy. For practical implementations, which has begun in Europe and beyond, first of all, we need to get to know the current practices and implementations from our colleagues in other countries and then a complete feasibility study regarding practical implementations in a certain territory of our country.
So, for example, if we want to build a thermoelectric power plant that works with cultivated biomass (to reduce the pressure on the BD) with a power of 15MW, we must consider:
In 2003-2006 period, our government, in collaboration with several specialized European and Italian institutions, set up a working group with scientists from several different fields, part of which was and the corresponding author of these rows (H.Haska), and studied the possibility of

building a thermal power plant for electricity production that would run 100% on wood biomass.
Several regions were studied, where we finally focused on Lushnje–Fier region. More specifically, for example, if we want to build a thermoelectric power plant that runs on cultivated biomass (to reduce the pressure on BD in natural forest) with a power of 15MW, we must take into consideration the following parameters:
-100% of the cultivated biomass is needed
-in a year, about 150,000 tons of biomass with a power of more than 2500kCal/kg are needed
-by preferring some trees with fast growth and short production cycle, we note that in a fertile terrain we can get about 30-50 tons of biomass with a humidity of about 50% and a fuel power of 2000-2100 kCal/kg
-to reach the figure of 150,000 tons per year (and with a fuel power of about 2500 kCal/Kg, at least 3500-4500 ha of land are needed.
-the plant must be built in a central core where the transportation radius is not more than 30 km.
-it is necessary that planting, cultural services application, harvesting and transportation be mechanized to reduce the costs of production costs biomass per unit.
-The price is considered acceptable when spending about 15-18 Euros per ton with a power of 2500 kCal/kg
-planting of plants, seedlings should be done in November -February, taking into account the fact that growth occurs in the March-November periods.

It is definitely necessary to see as a concrete possibility the construction of these plants in the plain areas with fertile soils, rainfall, sunny days and high temperatures. This possibility can be seen in the districts of Fier, Lushnje, Durrës, Peqin, Kavajë, Vlore, etc. up to Tirana, Elbasan, Kruje, etc Also some river valleys where there is no flooding can be very well used and mechanization can be introduced, reservoirs and watersheds can be built, etc.
It is necessary for the investitors of the plant to have state-owned land of about 1000-1500 ha with a lease term of at least 20 years to have it as a core in supplying the plant. The rest should be tried to be secured with contracts with individuals for 20 years, either to provide the land or to take over the production of biomass according to the criteria and technologies that the financier of the plant will provide.
Regarding the species that should be used for biomass production, this should be considered more carefully because, for example, poplar species and especially hybrids have fast growth and high biomass production per hectare,

but have very low calorific value compared to other wood species. Once again, it should be noted that with 50% moisture, biomass has a low calorific value, perhaps using a quantity of dry wood with a higher calorific value in shifts can help the plant's performance.
There is also a problem in securing labor, especially in terms of biomass production, because in many areas young people have emigrated and left the land unworked. Of course, mechanization is needed, but we also need people to work both in the field of biomass production and in the energy production plant.

CONCLUSIONS

- Population growth has increased the requests for more resources to improve the quality of life. In this context, the demand for energy resources has increased.
- The use of traditional energy sources such as coal and oil with their derivatives in recent decades has brought problems to the environment and beyond.
- In recent decades, the use of renewable energies has begun to be supported, but they also include clean and environmentally friendly energies such as water, sun, wind.
- Thus, energies produced from plant biomass, in addition to those such as water, sun, wind, etc., have begun to be used on a large scale.
- Also, renewable energy from vegetative biomass has begun to be used with great success, by building modern plants that do not emit high levels of pollution into the environment.
- When we use plant biomass for energy production, we always keep in mind the fact that we must plant and cultivate plantations in such a way that at least the rate of CO2 release when it is burned is less than the rate that the plants we cultivate sequester.
- Plants or equipment used for energy production from woody biomass must be certified as not having any impact on the environment, especially with regard to the emission of greenhouse gases or pollutants.
- The major concerns about the large-scale modern use of wood energy include production sustainability in the context of land-use change and the impact on food impacts of large-scale commercial logging for industrial use on the environmental services of forests and possible biodiversity losses due to habitat change. The large-scale industrial use of wood energy has multiple socioeconomic and environmental impacts at the landscape

and even larger scales and its sustainability warrants careful consideration [4b].

- To limit/minimize the traditional use of woody biomass through direct combustion, especially for heating and cooking.
- The production of various forms of biofuels and biodiesel from woody biomass has increased their quality and have limited environmental pollution to high levels.
- There is a considerable forest wealth in the world that can be used for bioenergy, but we must be very careful not to damage the forests when we extract significant amounts of biomass from them.
- Also, in Albania we have potential for the use of plant biomass, specifically wood biomass, for bioenergy production
- When building plants for energy production from plant biomass, it is best to create plantations with fast-growing trees with short rotations in order to reduce pressure on natural forests.
- Such plants that produce energy with wood biomass can be implemented quite well in different regions of Albania, always under contemporary European and wider consultancy.

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GEOTHERMAL RESOURCES ARE THERMAL ENERGY RESERVOIRS IN ELBASAN AREA FOR ALTERNATIVE USES.

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ABSTRACT

With the increase in the world population and technological developments, the demand for energy is increasing. Alternative energies are a promising proposition among many, and the use of geothermal energy in many countries is on the rise. Albania represents a country with a real potential of low-enthalpy geothermal energy, still insufficiently exploited, which can be used to improve the country's energy balance, as well as for profitable economic purposes. Until now, thermal waters were used only for therapeutic purposes in various diseases. In Albania there are known sources and wells of low-enthalpy thermal waters, the temperatures of some of them are almost at the upper limits of low enthalpy. 60°C. Among them, the Elbasan Thermal Springs, with a thermo-mineral water flow rate of 15-18 l/s and a temperature of 55-65oC, have a potential of 2760 kW to be installed. This is an area with thermal mineral waters known since ancient times for the very good therapeutic properties of the waters. The economic solution to the heating problem in Albania is a task of the day, very important, especially with the conditions of widespread and alternative use of electricity in our country where the main source is the energy of hydroelectric power plants. One of the suitable alternative routes is the use of geothermal energy. In Albania, there is an explosion in the construction of multi-storey multi-storey buildings. They are still designed for heating with oil or gas boilers, as well as with air conditioners. In all buildings of state institutions, heating and cooling are done with air conditioners, hospitals, dormitories, hotels, etc. are heated with oil or natural gas boilers. The introduction of heating and cooling systems with the help of renewable energy sources, including that of the Earth's heat, should begin to be implemented. To open this new direction of using geothermal energy, which is renewable and environmentally friendly energy, in this concept project we propose to apply it in Llinxhat, Elbasan, in an indicative pilot project, for heating and cooling a building.
Keywords: geothermal energy, geothermal gradient, hybridized sistems, low-enthalpy, thermal sources.

THE CHALLENGES OF A STRATEGY FOR THE EFFECTIVE UTILIZATION OF RENEWABLE RESOURCES, INCLUDING THE ALTERNATION OF HYBRID MODELS OF ENERGY PRODUCTION.

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ABSTRACT

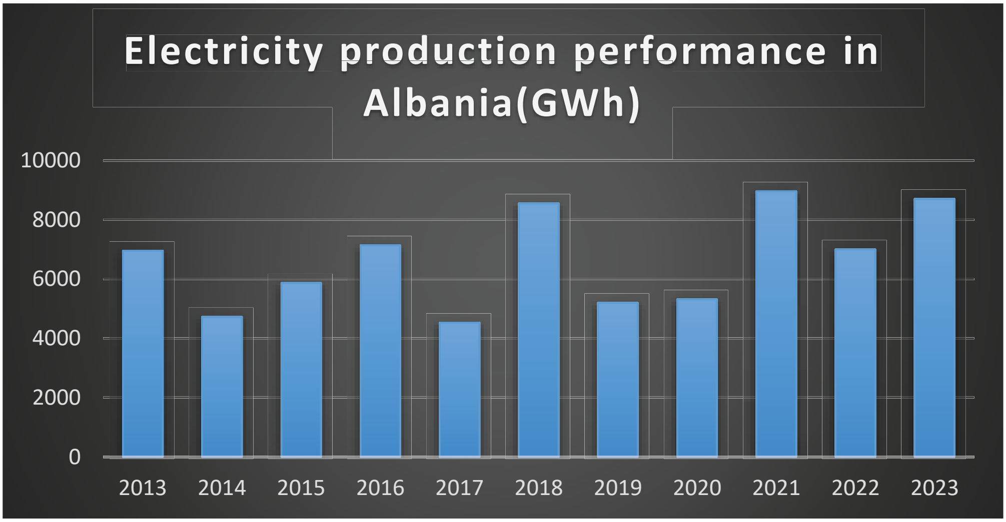
The construction of hydropower plants in Albania has brought stability to the country's electricity supply, but on the other hand, it has had an impact on the ecosystem, water resource management, and the increasing demand for water, which is also influenced by global warming. The National Energy Strategy 2018-2030 has as one of its main objectives the target of renewable energy to reach 42% of total consumption by 2030. Is this achievable? From an analysis of the last 10 years of electricity production in our country from 2013-2018, we së that there is only one source of energy: water. In 2019, photovoltaic plants contributed for the first time to electricity production with 0.4%, and in 2023, this contribution rose to 0.9%.This paper will compare hydropower plants and photovoltaic parks in terms of energy efficiency within the country's territory. The methodology for this study is based on the analysis of the production from state/private/concession hydropower plants and that of photovoltaic parks. Additionally, a technical analysis will be conducted on the required surface area for construction, capacity, and working hours.
The paper concludes that while hydropower plants remain the most stable source of energy in Albania, photovoltaic parks offer a complementary pathway to diversify energy production. A hybrid strategy combining these technologies is recommended to accelerate the country’s transition towards an independent and sustainable energy system.
Key words: hydropower, solar energy, renewable sources, electricity

1. INTRODUCTION

Albania is located in the western Balkans and has access to the Adriatic and Ionian Seas. Our country is rich in water resources. All the rivers in the country have an average annual discharge of 1308 m^3/sec, which corresponds to an annual volume of about 41.25 km^3. The main river network of Albania includes the rivers of Drin, Buna, Mati, Ishmi, Erzeni, Shkumbini, Devolli, Osumi, Semani, Vjosa, Drino, and Bistrica. The hydrographic network of Albania is characterized by high values of several parameters, such as flow coefficient and flow modulus, which are represented by very large values. The country's water resources, especially rivers, are a very important potential for the socio-economic development of the country, but especially for hydroelectric power production. Our country has secured and continues to secure the production of electric energy and water resources, and since 2019, it has also started the production of photovoltaic power plants. This fact makes our country one of the few in Europe with 100% renewable energy production. The main hydroelectric plants of our country are state-owned: Koman, Fierza, and Vau Dejes, alongside private HECs, and later hydroelectric plants under concession, a new policy initiated in our country since 2010. The national energy strategy, one of its main objectives until 2030, is to increase the contribution of primary energy resources to total primary energy supply to the level of 52.5% by 2030, as well as the target for renewable energy to reach 42% of total consumption by 2030. The Albanian power system is dominated by hydroelectric plants, representing 95% of them in the country, with an installed capacity totaling 2,493 MW. The country has a 98 MW thermal power plant using fossil fuels, which represents 4% of the total installed capacity, but it has not been put into use since its construction in 2011 due to a defect in its cooling system.

Albania is a net importer of energy. Net energy imports are directly linked to annual rainfall, considering that the electricity sector is entirely dependent on the production of hydroelectric plants. An additional contributor to energy imports is the country's growing demand for oil products, which are needed for the transport sector. Although Albania is the largest producer and exporter of oil in Southeastern Europe, most of the oil extracted in Albania is exported as crude, unrefined oil. As such, the country imports all of its refined oil products to meet its transport energy demand. This paper focuses specifically on renewable energy as the key element for improving life and achieving sustainable development—development that meets present needs without compromising the future. Climate change, the construction of over 200 hydroelectric plants in our country, and the population growth that has led to the expansion of water systems, are all factors that affect the annual production of electricity and the need for diversification of energy sources.

Sustainable energy development strategies usually involve three major technological changes: energy conservation on the demand side, improvements in energy production efficiency, and the substitution of fossil fuels with various renewable energy sources. Consequently, large-scale renewable energy implementation plans should include strategies for integrating renewable resources into coherent energy systems influenced by energy savings and efficiency measures. Renewable energy is at the forefront of the sustainable energy transition, ready to mitigate greenhouse gas emissions and stimulate economic growth. Solar, wind, geothermal, and hydroelectric power are gaining global attention as nations seek cleaner, more environmentally friendly energy alternatives.The advantages extend beyond emission reduction, including the creation of new jobs, independence from fossil fuels (in the transport sector), and reduced energy costs. Meanwhile, there is also new technological and innovative development in the form of hybrid energy systems, which combine multiple types of energy production and/or storage or use two or more types of fuel to power a generator.

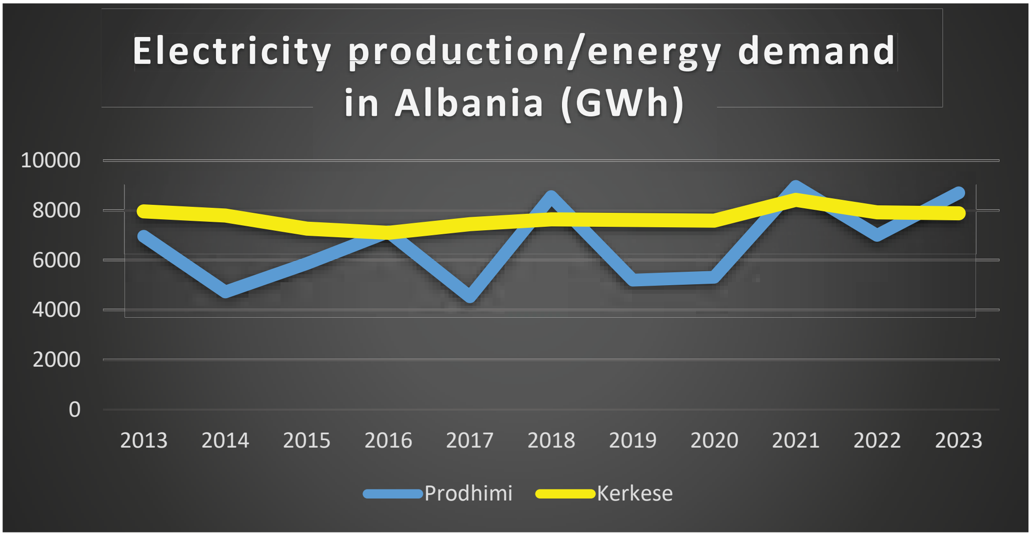


2. MATERIALS AND METHODS

The data that will be used for this paper are those regarding electricity production over the years from hydroelectric plants and photovoltaic parks, along with coordinates for the geographical distribution of these renewable energy installations in Albania. The method used in this paper is the analysis of electricity production and the LCOE analysis. This method is useful when it comes to understanding how our country can achieve the objectives of the National Energy Strategy, to understand whether the energy demand is met solely by our country, and to optimize the use of renewable resources.

3. RESULTS AND DISCUSSION

In the analysis of electricity production during the period 2013-2023, compared with the electricity demand of our country, it is clear that in 11 years, only in 3 of them was the energy demand met by the country's resources, specifically in 2018, 2021, and 2022.



If we also look at the number of hydroelectric plants built during these years, and those that have received approval for construction, we see a lack of sustainability and instability in the rainfall patterns of our country. If we quickly review the hydroelectric plants, both concession-based and not, we note that 562 hydroelectric plants were supposed to be built by 2023, while only 189 hydroelectric plants have been constructed (including Ashta and Devolli, which sell on the open market). In 2020, out of the total number of hydroelectric plants, only 6 of them secured production according to the forecast in the contract. In 2021, 31 hydroelectric plants out of more than 160 built met the forecasted production in their contracts, while in 2022, only 22 hydroelectric plants exceeded production. As mentioned above, the diversification of energy sources led to the construction of the first photovoltaic park in the Republic of Albania in 2019.

Table 1: Energy production from solar parks.

Viti	Annual electricity production MWh	% of solar energy
2019	5206	0.40%
2020	5313	0.60%
2021	8962	0.44%
2022	7002	0.70%
2023	8795	0.90%

Currently, in our country, 23 photovoltaic parks have been built with a total capacity of 192 MW, 37 are under construction with a total capacity of 417 MW, and 13 are in process with a total capacity of 135 MW. Therefore, the total current PV capacity, if all are built by 2025, will be 744 MW. But what is the total production, and how does it compare to national production? Unlike hydroelectric plants, all contracts for PV have achieved the planned production in their respective contracts, for various climatic reasons, global warming, technological advancements, tracking systems, and in the future, the installation of batteries to store energy during periods with more working hours. In comparison to working hours, hydroelectric plants are more reliable as they ensure 24 hours of operation, but the instability of rainfall has put them in competition with photovoltaic parks. Below is the current map of photovoltaic parks in production/construction/in process.

A new practice that has recently been introduced in our country is the use of hybrid systems. In the context of energy, hybrid systems refer to groups that combine renewable energy sources (such as solar or wind) with traditional energy sources (hydroelectric plants). These systems are used to increase the system's efficiency and the optimal utilization of the required area. A new/innovative idea is the installation of solar photovoltaic systems on water bodies using floating technology. Energy production results from combining PV plant technology and floating technology. This technology makes use of the surface of the reservoir, increases energy production, does not require additional land area, and is environmentally friendly.

Studies show that the return on investment for a 1 MW floating photovoltaic system has a payback period of 5 years, based on calculations, and its lifespan extends to 25-30 years.

Return on investment = Total cost of floating plant / Total annual costs after PV implementation.

Albania has over 650 dams, which have a significant reservoir surface that can be used for floating photovoltaic parks. In Albania, we only have one such system on the Banja dam. The Floating Photovoltaic Plant of Banja is an innovative research and development project with an installed capacity of 2 MWp and a planned annual production of about 2.6 GWh. Another ambitious project is the floating park by KESH on the Vau Dejes dam. According to KESH, the capacity of this plant will be 12.97 MWp, and according to calculations, the planned production in the first year will reach 18,808 MWh, with an average production of 17,822 MWh/year throughout its lifespan. The plant is expected to start construction in March 2025 and be completed by November 2025.

If the addition of floating parks were to begin, it is important to ensure a reasonable increase in the installed capacity in the grid. Dams for water supply/agriculture/energy have reasonable storage capacity, making it possible to invest the necessary funds for floating park implementation. In a dam, the installation of floating photovoltaic parks would result in the reduction of water evaporation and an opportunity to increase the amount of available water for energy generation, depending on local conditions.

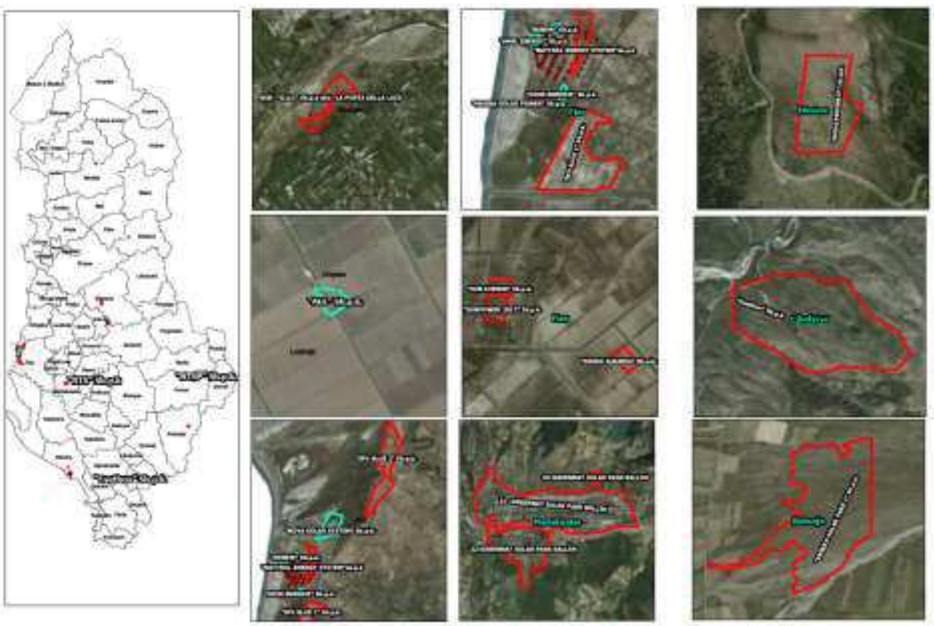
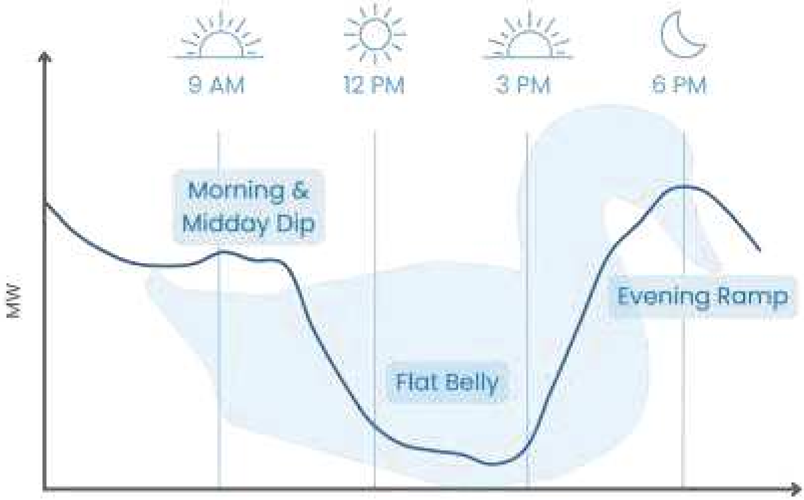


Figure 1: Geographical distribution of Photovoltaic Parks in the Republic of Albania.

Albania is making rapid progress in photovoltaic plant investments. The short time required for the construction of a photovoltaic plant, the ease of its construction, and the low costs of building and operating a photovoltaic plant make it quite attractive for investors. However, managing these plants and forecasting energy production presents new challenges in the energy market in Albania. These plants have higher energy production during the period from May to October, and their maximum production capacity is reached around noon. The increase in photovoltaic plant investments in recent years leads to a specific phenomenon during these months known as the "Duck Curve."



In the context of electricity, photovoltaic plants have become an increasingly important source of energy production. However, there are several significant challenges related to the integration and operation of these plants, which require careful attention and smart interventions to maintain the stability of the energy system.

• *Fluctuations in Energy Prices*
At midday, photovoltaic plants reach their maximum energy production due to the high intensity of solar radiation. This causes an increase in the energy supply on the market, driving the energy price to very low values, and in some cases, to negative values. This happens because the demand for energy is lower during this period, while photovoltaic plants continue to produce at full capacity. This phenomenon of negative prices is a challenge for producers, as they may have low profits or even losses during these periods.

• *Increased Demand and Its Impact on Energy Prices*
As production from photovoltaic plants begins to decline after midday, the demand for energy increases in the afternoon and at night. This balancing act between the decrease in production and the increase in demand causes the energy price to rise significantly, reaching high levels that can be several times higher than the average energy price for that day. Due to this fluctuation, energy producers from photovoltaic plants face difficulties in managing costs and profits.

• *Imbalance in Electricity Supply*
Another issue related to photovoltaic plants is the imbalance in energy supply. Actors who produce energy from photovoltaic sources prepare production forecasts for each hour of the day. However, to meet the demands of the European energy market, it will be necessary for these forecasts to be made for shorter intervals, such as 15-minute periods. This transition is a major challenge for photovoltaic plants, as energy production is highly dependent on unpredictable weather conditions, such as cloud cover over the plants. This causes forecasts to not always be accurate and leads to significant financial penalties for plant operators, who are forced to pay for production differences at very high imbalance prices, which can be up to 10 times higher than the average energy price.

• *Geographical Concentration of Photovoltaic Plants*
Another significant challenge is the concentration of investments in photovoltaic plants in a limited area of southern Albania, primarily in the Fier region. While this region has high potential for photovoltaic energy production, the variability of atmospheric conditions and the difficulty in accurately forecasting energy production cause issues with the stability of the energy transmission grid. For example, the passing of a cloud cover in a short period can affect energy production from most of the photovoltaic plants in the country, forcing operators to take urgent measures to maintain grid stability

4. CONCLUSIONS

Research on the integration of photovoltaic (PV) systems for a sustainable energy future for Albania has led to some significant findings. A priority is the importance of integrating photovoltaic systems with hydro-energy systems. We would like to emphasize the importance of a diverse strategy that combines the right policies, incentives, and modernization of the national electricity grid.

To reduce the impact of the "duck curve" phenomenon and minimize the costs associated with energy imbalances, it is recommended that photovoltaic plants invest in energy storage systems with batteries. This will allow them to store energy produced during midday, when energy prices are low, and sell it in the afternoon, when demand is higher and prices increase. This strategy will help stabilize revenues for producers and reduce energy imbalance costs, providing protection for their investments against daily price fluctuations.

Energy policy coordination, the promotion of transparent regulations, and the inclusion of the private sector will maximize the potential for integrating hybrid systems in Albania.

Engagement from the community and public awareness are essential; informed citizens are more likely to support and take responsibility for renewable projects, ensuring long-term success. Following the integration of hybrid systems and adapting plans based on real results, including experiences from neighboring countries, will significantly aid in achieving Albania's sustainable energy goals.

In conclusion, the integration of PV systems is not just an opportunity, but a strategic imperative for Albania's sustainable energy future. Albania can embark on a path toward energy independence, environmental sustainability, and long-term economic success by making solar energy a key component of its energy mix. By diversifying energy sources, implementing innovative technology in hybrid systems, and strengthening the electricity grid, considering that the use of energy storage batteries in central electricity networks does not justify itself due to high investment and maintenance costs. These are an acceptable alternative only for isolated objects or regions. Albania has the opportunity to create a more sustainable and resilient energy system, stimulating positive social and economic outcomes and fulfilling its climate commitments.

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KOSOVA ATLAS FOR RENEWABLE ENERGY - SOLAR RADIATION AND WIND

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ABSTRACT

This material will present maps produced by processing meteorological satellite information and various professional platforms such as CM SAF, as well as in accordance with WMO standards, offering users a high-resolution product. The maps will be presented for the Solar Radiation indicator (in W/m^2), for the expressed sun rays (in hours) for monthly values referring to the last 3-4 years 2021-2024. The methodology and available data will also enable a presentation for the last 30 years, referring to the 1991-2020 norm, insofar as the relevant institutions require such a thing, in order to have a more reliable assessment both in time and in space. Also, a lot of information will be presented about wind and its indicators, as an important source in the group of renewable energies. For this important meteorological element, maps of the average monthly wind speed at levels 50, 80 and 120 meters above the ground surface, estimated for a multi-year period in recent years, will be presented. In addition to the wind speed indicator, the values of the potential energy available (in W/m^2) for these levels offered by the wind in the territory of Kosova will also be given. Meanwhile, thanks to a logarithmic model for the vertical profile and the calculation of wind speed, more detailed information will be made available at an experimental level when observing such data, such as for meteorological stations or for the places where it is intended to be erected. a wind energy utilization plant. This will help in this way to make preliminary assessments of the feasibility or economic effectiveness that various projects in this field will have or present, as well as to orient more precisely in national development strategies in this renewable energy sector.
Keywords: Kosova, Renewable Energy, Solar Radiation, Wind Energy.

1.INTRODUCTION

Sunshine duration (SD) is a valuable climate parameter because it is directly or indirectly used in many studies and applications [5] Therefore, quantitative information about this key climate variable is required for many applications in regional climatology and environmental changes [4]. Renewable energy is an important factor in helping to increase energy production and create a more balanced energy system, especially in the context of meeting the demands of the economy and the population of the country, during a certain period of the year. In this type of framework for policymakers and the drafting of strategies in such an important sector of the country, it is very important to have maps of the total energy potential and meanwhile for the corresponding distribution that nature offers for both solar radiation and wind. Further, information is provided on how to estimate such an energy level for different locations, as well as a specific methodology, usable for interested users, which implies the establishment of a system for the production of solar or wind energy.

2. MATERIALS AND METHODS

Database of this study belongs to the satellite data of CM SAF, Eumetsat. This satellite database of NetCDF type through programming with R-Studio brought the analysis and visualization of the relevant maps. This methodology was used in the different scientific study or scientific journal like Monthly Climate Bulletin [2]. This work is focused on bringing users some practical information for the territory of Kosova for solar radiation (in W/m^2), the sun index estimated in sunny hours for each month and the wind speed at different levels above the earth's surface (in m/s). Of course, the estimates for the power in W/m2 are other results given by different maps and according to the time frame of months or years, for different levels above the earth's surface.

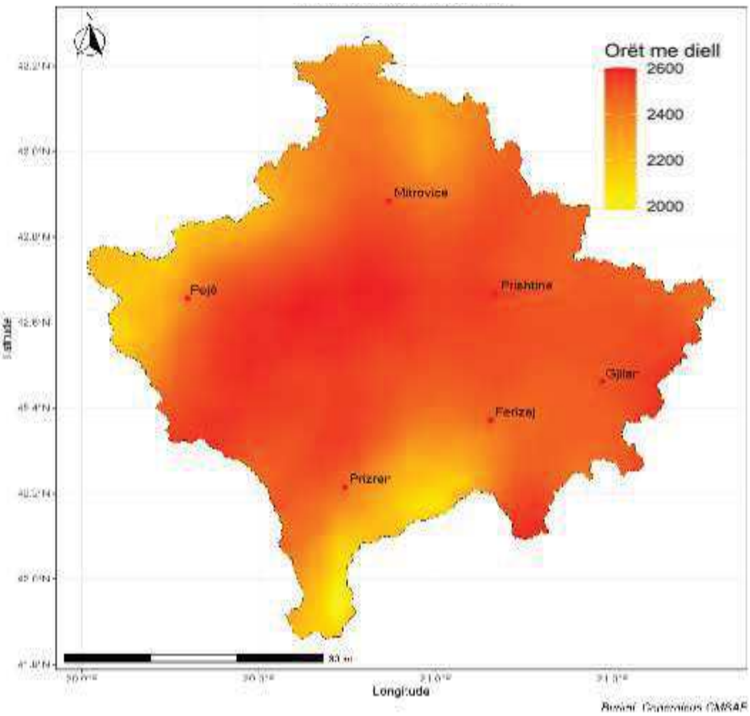
3. RESULTS AND DISCUSSION

3.1 Sunshine

Based to CM SAF-Eumetsat data for various meteorological information with a high resolution for the territory of Kosova area further elaborated the data of sunshine expressed in sunny hours and presented in specific maps not only for each month, but also for the different years. In figure, No.1 is presented the map for the year 2024, that clearly show some difference in the territory with value of sunny hour that decrease from 2600 at the low land surface of the country to 2000 for some near mountain areas, which manly are influenced by the topographic conditions.
As it was mentioned the product are result of some specific processing with the respective data and can be presented for each month, showing the differences and the ongoing of such climate index in time for various months and years. This type of product is processed for years 2021 – 2024 and are

available also for longer period of 30 years, but here on following figure No.3 is presented the index of sunny hours for each month for the Kosova Republic for only the last year 2024.

Figure 1. Sunshine duration (in sunny hours) for the year 2024 for Kosova Republic.



3.2 Solar radiation

Solar surface radiation expressed in W/m^2/year also provide an important information regarding the potential that the territory of Kosova present as a possibility to be used for generating electricity from photovoltaic systems.
On such context based to a product prepared and realized with high resolution for Kosova is presented on the figure No.2, related to the annual values as average of the period 1981-2012 [10].

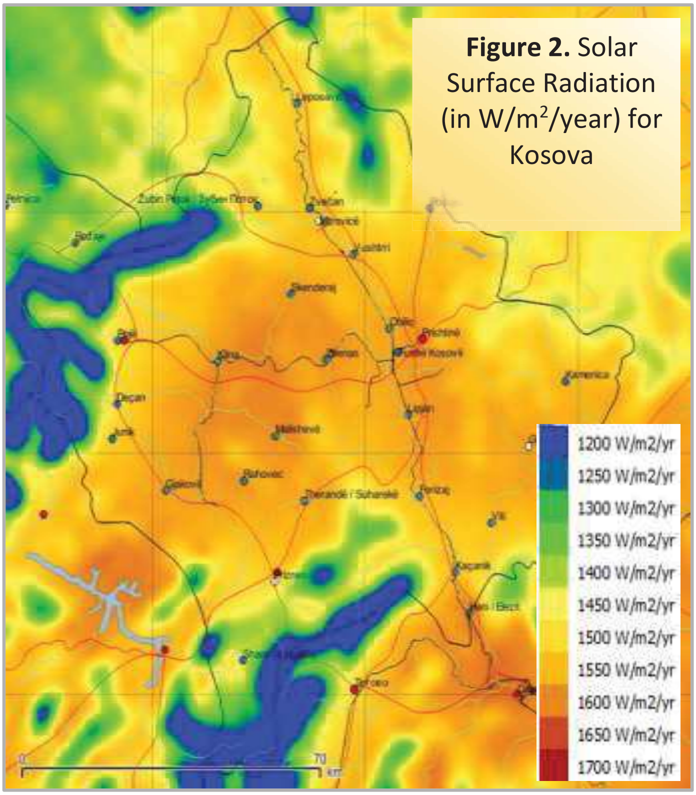


Figure 2. Solar Surface Radiation (in W/m²/year) for Kosova

This type of information is prepared for each month, where those categories of maps can help and facilitate the preliminary estimation, how his potential differ from one to another area and from winter months to the summer period.

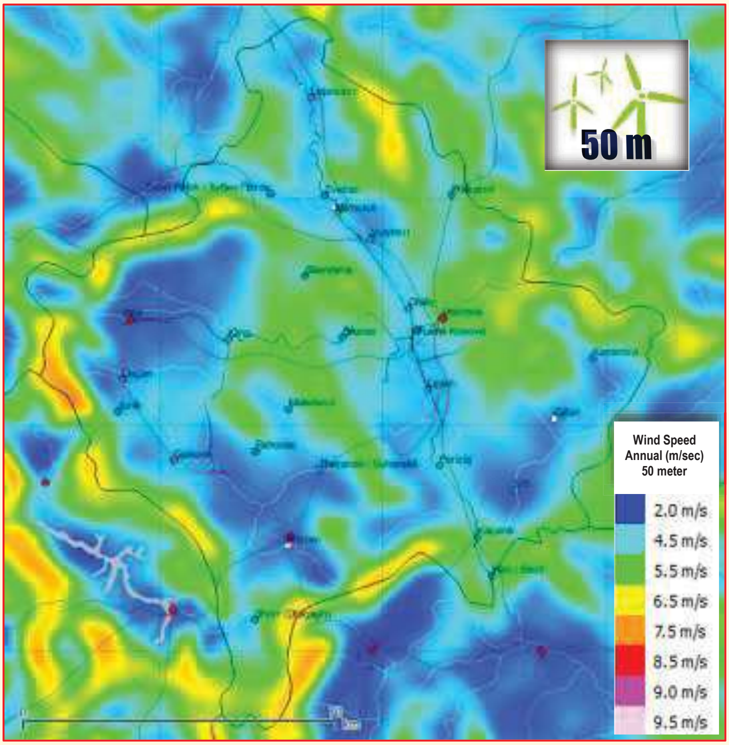


Figure 4. Wind Speed Annual values for Kosova at the level of 50 meters above land surface.

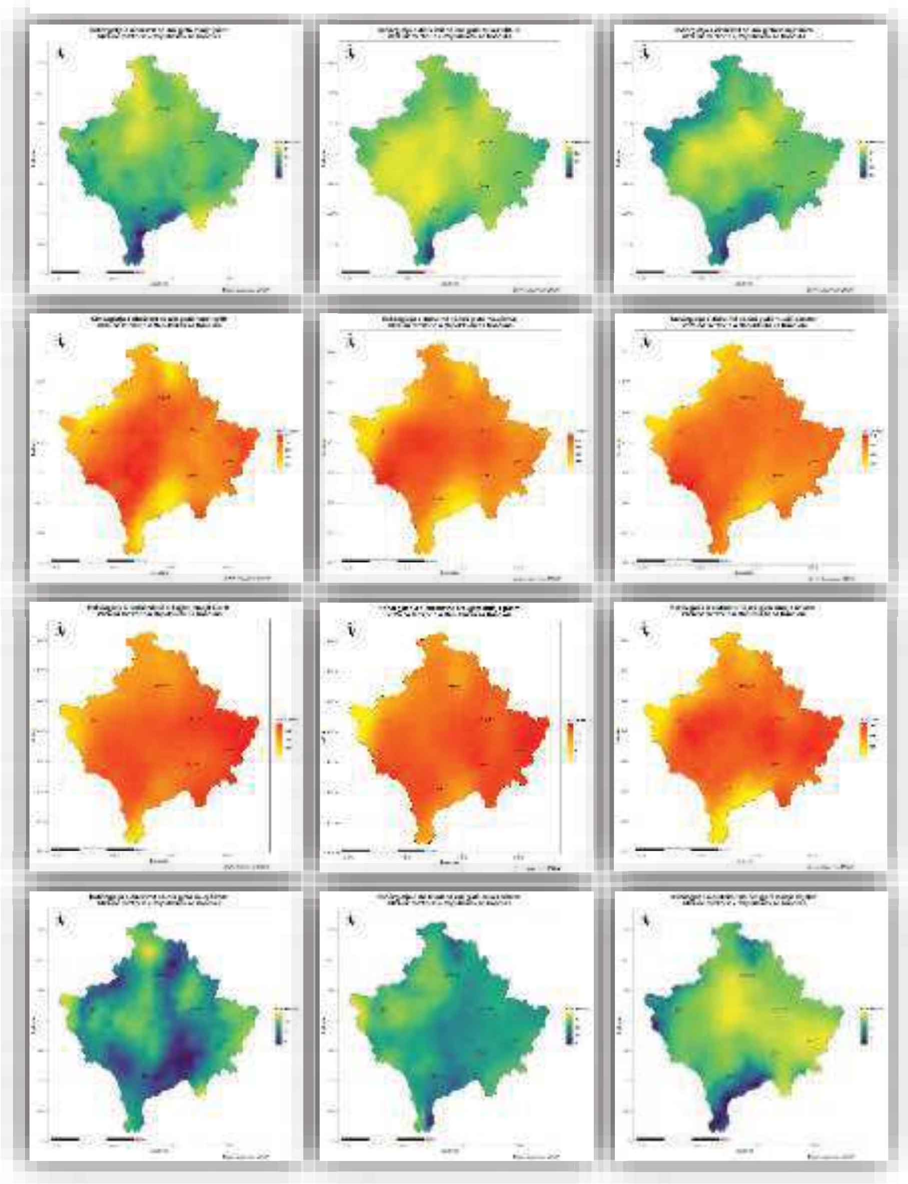
4.2 Wind

4.2.1 Wind Speed

The wind speed and direction normally are measured at the meteorological stations at the level of 10 meters above the land surface in conformity with technical criteria of WMO. Based to the data base of 8 meteorological stations of Kosova, referring to different directions of wind for the period 1961-1985, the evaluated speed is on the range of 2-3 m/s, except the stations of Kopaonik where are observed also value from 4 to 5.2 mm/sec [1]. However, as it is known around the word the wind energy is used at much higher level, than that of 10 meters.
Furthermore meteorological stations at the place when are projected to set up such wind plants are limited or probably do not exist. So, based to the international experience in this field generally are used the satellite information or those of different platform that provide data for vertical wind

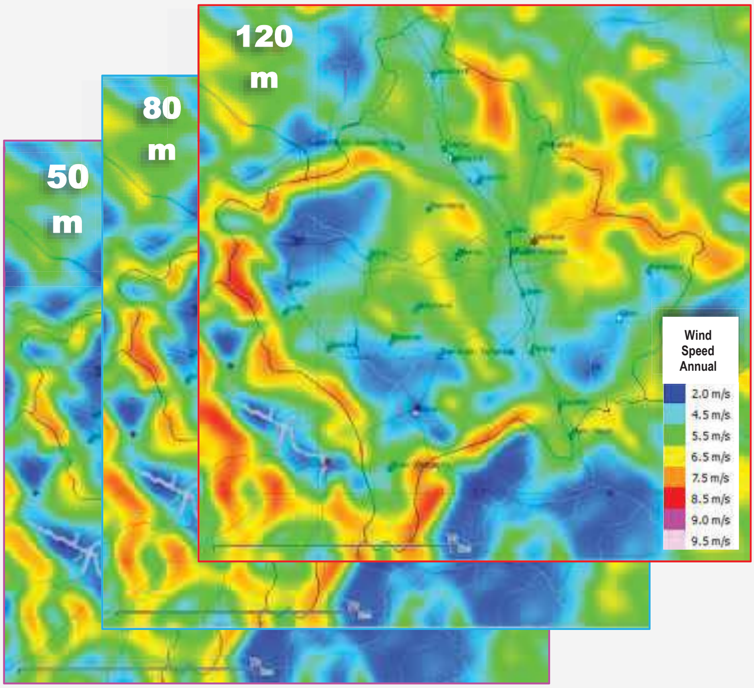
profile, which are carry out from the movement of air mass for specific locations and characterized with a relatively high spatial resolution.
In the figure No.4 is presented the map of Kosova with data about annual wind speed at the level of 50 meters above the land surface.

Figure 3. Monthly Sunshine duration (in sunny hours) for the year 2024 for Kosova.



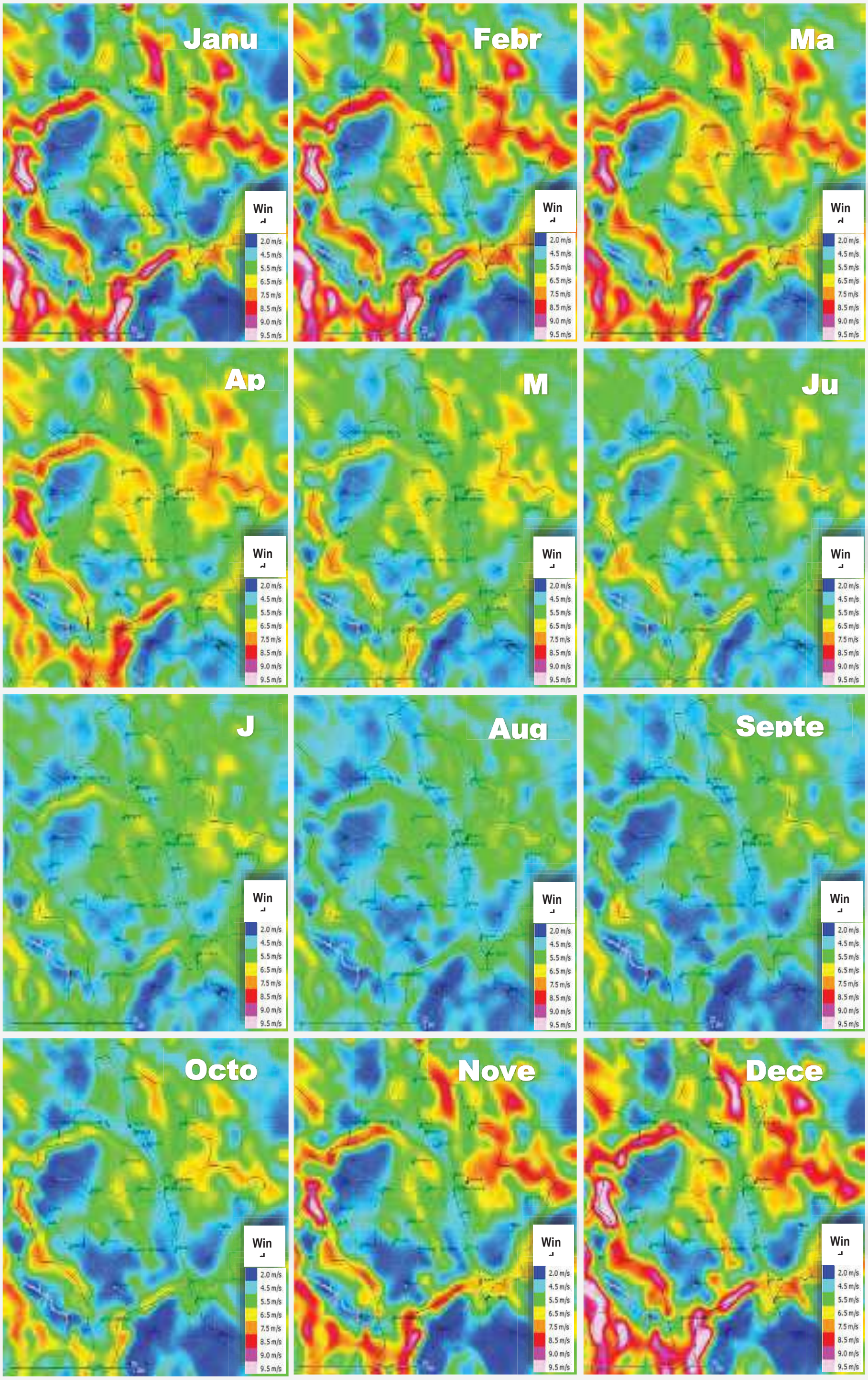
In mean time at the figure No.5 are presented the maps for wind speed in m/sec at the level of 50, 80 and 120 meter above land surface, which clearly shows an increase of wind speed by moving up over the land surface. This type of information is product of a platform done for some western Balkan country on 2014, by “Sander and Partner” company, part of an EU project, which can allow the users to get data with high resolution for any location of each country and for each month.

Figure 5. Wind Speed Annual values for Kosova at the level of 50, 80 and 120 meters above land surface.



Furthermore, for the recent year’s product processed and elaborated by our team provided by international platform like “CM SAF” etc., are published time by time at the Monthly Climate Bulletin of Albania. On such context like the maps for sunshine above presented for the year 2024, are provided at figure No.6 as well for the territory of Kosova the monthly mean values of wind speed (in m/s) for Kosova for the level of 120 meter above the land surface.

Figure 6. Monthly Wind Speed for Kosova at the level of 120 meters above land surface.



4.2.2 Wind Power

The wind power is evaluated for different levels above the land surface and by each month as well. For the annual values of the Wind power on figure, No.7 is presented for the territory of Kosova the distribution of the annual wind power values for the level of 120 meters above the land surface. As it can be noted the SW and NW part of the Kosova are more emphasized with high potential of wind, but as well, area on the NE have also potential to be used for such objective.

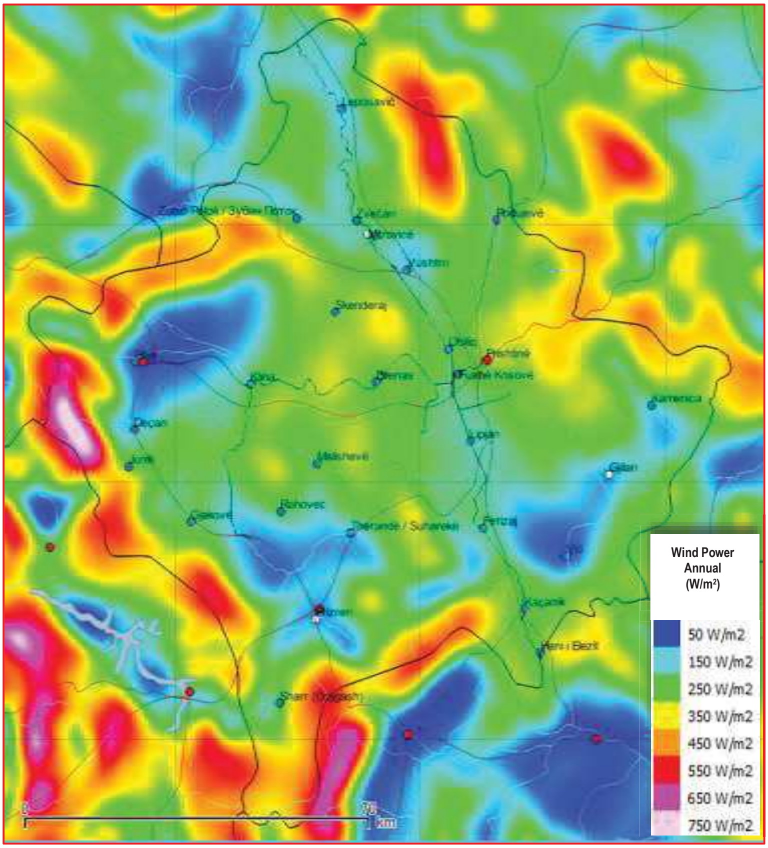


Figure 7. Wind Power Annual values for Kosova at the level of 120 meters above land surface.

Naturally, a more detailed information is provided by the monthly maps of wind power, estimated for the respective levels above surface of 50, 80 and 120 meters. In following map at the figure No.8 are selected and presented the respective maps for the wind power estimated for the January and July months for the level of 120 meter above the surface, which clearly show a large difference in variation of this type of potential between those 2 months.

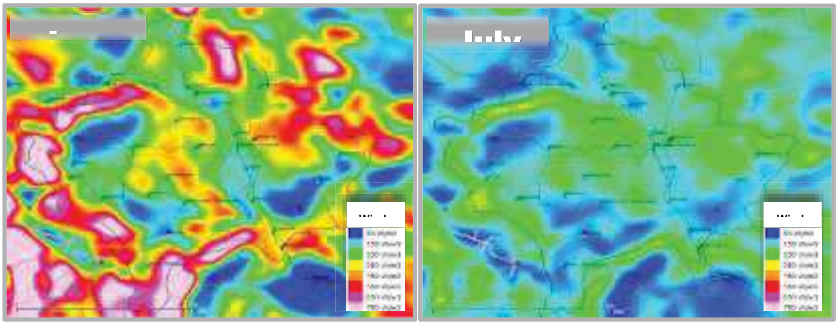


Figure 8. Wind Power values for Kosova at the level of 120 meters above land surface for the month of January and July.

4.2.3 Other meteorological important information

The wind power plant that use the wind speed to produce energy of course during the year are impacted also by other meteorological phenomena. One of them is also expressed by the icing surface duration, which is presented on the map of Figure No.9 for the territory of Kosova for the January month.

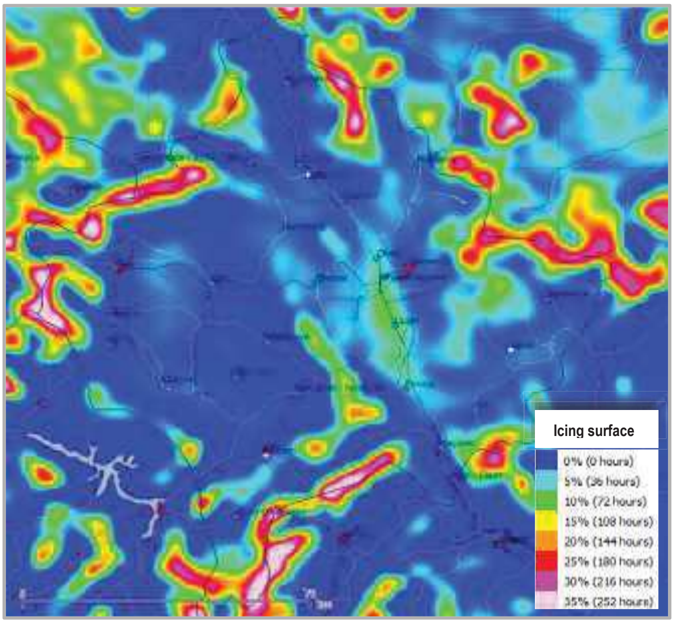


Figure 9. Icing surface – January values for Kosova in hours and in %.

4.2.3 Vertical wind profile

Based to the respective coefficient of roughness length that mainly depend from the orographic conditions of the area in following figure No.10 is presented a model for calculation of wind speed at different levels above the land surface [3], which help to better estimate the wind power for a certain level and area, when are available data of wind speed on 10 meters by meteorological station or experimental measurements.

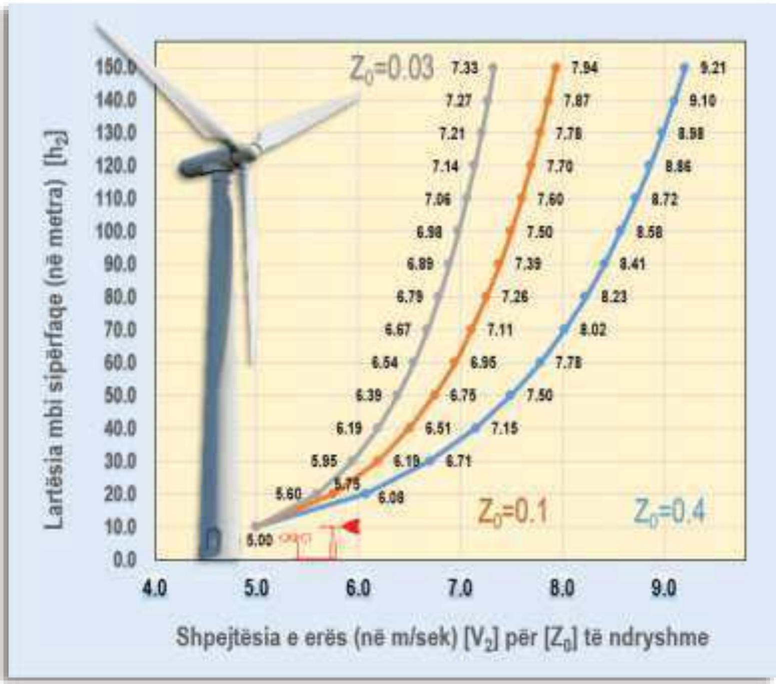


Figure 10. Wind speed V_2 change with elevation for roughness length Z_0=0.03, 0.1 & 0.4 and a base wind speed V_1 at 10 meters height of 5.0 m/sec.

4.2.4 The resolution of map

The level of resolution of the map provide quite detailed information specially for the areas that are near mountain, where in short distance are verified drastic change in the potential for any parameter, that of course can influence an impact the wind power plant. On that context an example is presented on the following map of figure No.11 for an area in Kosova, where the scale of the map go down from 70 km to 20 km and to 1 km and furthermore can be possible to get data even for few meter distance (one pixel 30 m). As can be seen on the map, they provide also the location of urban centers, or villages; so such information can serve for a better estimation about the situation not only in the context of renewable energy, but also for any environmental judgment.

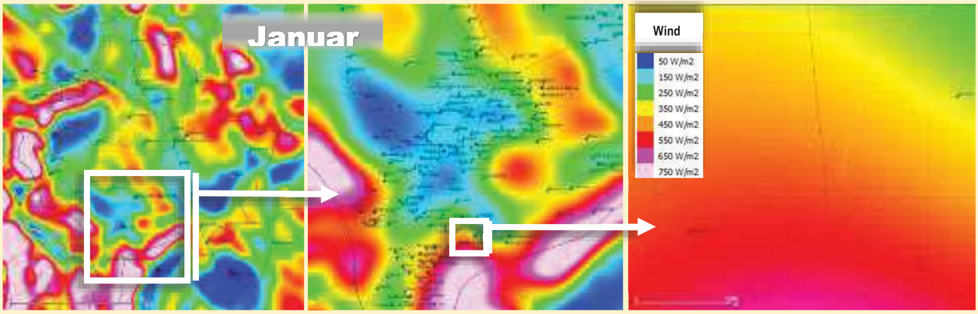


Figure 11. The maps shows the resolution for wind power for a selected area in Kosova at the level of 120 meters above land surface for the month of January.

5. CONCLUSIONS

- All these type of outputs can be presented in the format of an Atlas including maps of high resolution and into the appropriate print format used in such case. This atlas can serve as an important tool to preliminarily judge about the territorial distribution potentials that are presented by solar radiation and wind by nature of Kosova.
- Furthermore, information of high resolution and for specific areas can be provided by the authors to any requests for specific period during a year or for a multiannual period.
- The logarithmic vertical wind model composed by our team can be very useful in case that are available data from meteorological stations or from other experimental measurements source.

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STUDY OF THE PHYSICOCHEMICAL ASPECTS OF FORMATION DAMAGE AND THE ACTION OF POLYMERS DURING OIL FIELD PROCESSING

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ABSTRACT

Damage to productive formations mainly means damage to its porosity and permeability as a result of the action and interaction of external factors. Knowledge of the mechanism of damage to the productive layer helps in taking measures to prevent this damage and in eliminating the consequences of this damage. During the drilling process, contamination of the productive layer occurs as a result of the interaction of the washing fluids with the formations being drilled. The productive layer can also be contaminated during the cementing process, during the acquisition processes (especially during the physico-chemical processing of the layer), during perforation, as well as during the exploitation of the well. One of the main causes of contamination of the layers during their opening is the introduction of the dispersed medium (filtrate) and the dispersed phase of the washing fluid into the storage space of the productive formations. Damage to the formations is not always reversible and damage to the porous medium cannot be completely repaired. Therefore, it is better to prevent formation damage than to correct the consequences of damage. The presence of swelling clays in productive formations is one of the causes of formation damage. The swelling capacity of clays is related to their chemical and mineralogical composition. The high magnesium content is related to the high content of montmorillonite in the formations we study. High values of the SiO2/R2O3 ratio (where R2O3 is the amount of aluminum and iron oxides) also indicate a high content of montmorillonite in the formations and consequently the ability to swell and lose stability. The nature of other ions also affects their ability to adsorb. Of ions with equal valence, ions with a larger radius have the greatest adsorption capacity. The cause of this phenomenon consists in the high polarizability of these ions and their low hydration compared to ions with a smaller radius.

INTRODUCTION

The basic processes that cause damage to oil-bearing formations are: physicochemical, chemical, hydrodynamic, thermal, and mechanical. Liquid-

liquid incompatibility, for example, emulsions created between the filtrate of the oil-based washing fluid that penetrates the layer and the formation water. Also, rock-fluid incompatibility, for example, the contact of symmetric clays with swelling potential or deflocculated kaolinite clays that cause a decrease in the permeability of the formations near the well walls. Studies on formation damage are carried out to better understand these processes through laboratory and field testing, as well as to develop mathematical models by describing the basic mechanisms and processes. Also, they are carried out to optimize the prevention and / or reduction (reduction) of the possibility of formation damage, as well as the development of damage control strategies and preventive methods. These tasks can be accomplished through a model assisted by data analysis, case studies and extrapolation (approximation) and the determination of conditions that exceed the limiting conditions of the test. The challenges of studies on formation damage are related to the development of numerical schemes that solve the problem based on a model that describes a non-linear phenomenon, its modification (model) and its verification by experimental testing of different codes obtained from the porous medium.

Polymer injection in the Patos-Marinza Oilfield—Europe's largest onshore heavy oil reservoir—has led to notable improvements in oil recovery, especially during its earlier implementation phases.

Key Improvements Observed:

- Recovery Factor Increase: Polymer injection contributed to a 15–23% improvement in oil recovery rates. This enhancement was particularly effective in formations with high oil viscosity, such as the Driza and Goran zones.
- Reduced Water-Oil Mobility Ratio: By increasing the viscosity of injected water, polymers helped reduce the "fingering" effect, which occurs when water bypasses oil in the reservoir. This led to more uniform displacement of oil toward production wells.
- Enhanced Sweep Efficiency: The technique improved the ability to push oil through heterogeneous reservoir zones, especially in areas where conventional waterflooding had limited success.
- Field-Wide Impact: Polymer injection was part of a broader enhanced oil recovery (EOR) strategy that included horizontal drilling and diluent injection. Together, these methods helped reverse declining production trends in certain zones of the field.

However, it's worth noting that reservoir heterogeneity and high oil viscosity have posed challenges to sustaining these gains over time. As a result, newer methods like cyclic steam stimulation are being explored to complement polymer injection in deeper or more complex zones.

MATERIALS AND METHODS

Polymer injection is one of several Enhanced Oil Recovery (EOR) techniques, and it stands out for its **simplicity, cost-effectiveness**, and **efficiency in certain reservoir conditions**. Here's how it stacks up against other major EOR methods:

Polymer Injection

- *Mechanism*: Increases water viscosity to improve sweep efficiency and reduce water-oil mobility ratio.
- *Best for*: Medium to heavy oil reservoirs with high permeability and moderate temperatures.
- *Pros:*
  - Lower operational complexity than thermal or gas methods.
  - Cost-effective compared to other chemical EOR techniques.
  - Environmentally safer than gas injection.
- *Cons:*
  - Sensitive to salinity and temperature.
  - Less effective in very low-permeability or fractured reservoirs.

Thermal EOR (e.g., Steam Flooding, Cyclic Steam Stimulation)

- *Mechanism*: Uses heat to reduce oil viscosity and improve flow.
- *Best for:* Heavy oil reservoirs.
- *Pros*:
  - Highly effective in viscous oil recovery.
  - Proven success in fields like California’s Kern River.
- *Cons:*
  - High energy and water requirements.
  - Infrastructure-intensive and costly.
  - Not suitable for deep or thin reservoirs.

Gas Injection (CO_2, N_2, Natural Gas)

- *Mechanism*: Injected gas mixes with oil to reduce viscosity and increase pressure.
- *Best for:* Light oil reservoirs and deep formations.
- *Pros*:
  - Can significantly increase recovery factor.
  - CO_2 injection offers carbon sequestration benefits.
- *Cons:*
  - Requires high pressure and miscibility conditions.
  - Expensive and complex logistics.

Other Chemical EOR (e.g., Surfactant, Alkaline, ASP)

- *Mechanism*: Alters interfacial tension and wettability to mobilize trapped oil.
- *Best for*: Reservoirs with residual oil saturation.
  - *Pros*: Can achieve high incremental recovery; Tailored chemical blends for specific reservoir conditions.
  - *Cons:* High cost and chemical degradation risks; Complex formulation and compatibility issues.

RESULTS AND DISCUSSION

General Comparison

Method	Cost	Complexity	Recovery Boost	Best For
Polymer Injection	Moderate	Low	Moderate	Medium-heavy oil
Thermal EOR	High	High	High	Heavy oil
Gas Injection	High	High	High	Light oil, deep fields
Chemical EOR (ASP)	High	High	High	Residual oil zones

In fields like **Patos-Marinza**, polymer injection has proven especially useful due to its adaptability to **high-viscosity oil** and **cost constraints**, making it a practical choice over more energy-intensive methods like steam flooding.
Now let's explain some initial concepts:

What Is Polymer Injection?

Polymer injection involves adding **water-soluble polymers**—typically **polyacrylamide-based**—to the water used in secondary recovery. These polymers increase the viscosity of the injected water, making it more efficient at pushing oil toward production wells.

Step-by-Step Process

1. *Polymer Selection & Preparation*
   - Engineers choose polymers based on reservoir temperature, salinity, and oil viscosity.
   - The polymer is mixed with water at surface facilities to create a viscous solution.
2. *Injection into Reservoir*
   - The polymer solution is injected through existing water injection wells.
   - It flows into the reservoir, displacing oil toward production wells.
3. *Mobility Control*
   - The increased viscosity of the polymer solution reduces the **mobility ratio** (water/oil), preventing water from bypassing oil.
   - This leads to a **more uniform sweep** of the reservoir.

4. *Oil Displacement & Production*
   - As the polymer solution moves through the reservoir, it pushes trapped oil toward production wells.
   - The result is improved **volumetric sweep efficiency** and higher oil recovery.
5. *Monitoring & Optimization*
   - Operators monitor injection rates, polymer concentration, and reservoir response.
   - Adjustments are made to optimize performance and minimize polymer degradation.

Why It Works

- *Reduces Fingering*: In conventional waterflooding, water often takes the path of least resistance, bypassing oil. Polymer thickens the water, reducing this effect.
- *Improves Sweep Efficiency*: More oil is contacted and displaced.
- *Extends Field Life*: Especially useful in mature fields like Patos-Marinza, where conventional methods have plateaued.

Polymer Types Used

Polymer Type	**Characteristics**	**Suitability**
HPAM (Partially Hydrolyzed Polyacrylamide)	Most common, cost-effective	Moderate salinity & temperature
Xanthan Gum	Biopolymer, high viscosity	High salinity environments
Associative Polymers	Enhanced viscosity at low concentrations	Advanced applications

Polymer injection is often part of a broader EOR strategy and can be combined with surfactants or alkalis for even greater effect.

Polymer injection in the Patos-Marinza Oilfield—Europe's largest onshore heavy oil field—has delivered measurable improvements in oil recovery, particularly in the Driza and Goran formations, which contain highly viscous crude. Here are some of the real-world results observed from its application:

Recovery Factor Improvements

- 15–23% increase in recovery factor was achieved after polymer injection was implemented.
- This boost was especially notable in zones where conventional waterflooding had plateaued due to high oil viscosity and poor sweep efficiency.

Operational Enhancements

- Polymer flooding helped reduce the water-oil mobility ratio, improving the displacement of oil and minimizing water channeling.
- It led to more stable production rates and extended the productive life of several wells.

Field-Wide Impact

- Polymer injection was part of a broader EOR strategy that included horizontal drilling and diluent injection, which together helped increase output significantly after 2008.
- However, as the field matured, reservoir heterogeneity and formation energy decline began to limit polymer effectiveness, prompting the introduction of cyclic steam stimulation (CSS) in the southern Goran zone1.

Challenges & Limitations

- The effectiveness of polymer injection has been diminished in recent years due to increasing reservoir complexity and temperature/salinity constraints.
- Despite these challenges, polymer injection remains a cost-effective and environmentally safer alternative to more energy-intensive methods like steam flooding.

But, how these results compare with other EOR techniques used in the same field or help model the economics of polymer injection in similar reservoirs doing unpack both the **economic side** and the **technical behavior** of polymers in heavy oil recovery. These two aspects are tightly linked, especially in fields like Patos-Marinza where oil viscosity is high and operational efficiency is key.

Cost Implications of Polymer Injection

Polymer injection is considered one of the **most cost-effective EOR methods**, especially when compared to thermal or gas injection. Here's how the economics break down:

Key Cost Metrics

- Incremental Cost per Barrel: Polymer flooding typically adds \$3–\$6 per extra barrel of oil recovered.
- Utility Factor (UF): On average, 1.7 kg of polymer is needed per barrel of incremental oil, translating to ~80 tons of oil per ton of polymer injected.
- Capital Efficiency: Modular “plug-and-pump” systems allow for low upfront investment and flexible deployment, reducing infrastructure costs.

- Carbon Intensity Reduction: Polymer injection can cut CO_2 emissions by 3–6 times per barrel compared to waterflooding, due to reduced energy and water usage.

Cost Drivers

- Polymer type and concentration
- Reservoir temperature and salinity (affecting polymer stability)
- Surface facility upgrades (mixing, injection, and handling systems)
- Produced water treatment (to handle back-produced polymer)

Polymer Behavior in Heavy Oil Recovery

Heavy oil poses a challenge due to its high viscosity and low mobility. Polymers help overcome this by modifying the flow dynamics in the reservoir.

Mechanisms of Action

- Viscosity Control: Polymers increase the viscosity of injected water, improving the mobility ratio and preventing water from bypassing oil.
- Sweep Efficiency: Enhanced viscosity leads to more uniform displacement, contacting more oil and reducing fingering.
- Wettability Alteration: Amphiphilic polymers can shift reservoir rock from oil-wet to water-wet, improving oil displacement.
- Interfacial Tension Reduction: Advanced polymers like PAALB reduce oil–water interfacial tension to ultra-low levels, enabling spontaneous emulsification of heavy oil.

Real Performance Metrics

- Viscosity Reduction: PAALB polymer reduced heavy oil viscosity from 14,315 mPa·s to 201 mPa·s, a 98.6% reduction.
- Recovery Boost: In lab tests, PAALB increased recovery by 25.6% compared to traditional HPAM polymers.

Summary Table

Aspect	Polymer Injection Impact
Cost per barrel	$3–$6
Recovery factor increase	15–25%
Viscosity reduction	Up to 98% (with amphiphilic polymers)
CO_2 emissions	3–6× lower than waterflooding
Infrastructure	Modular, scalable, low capex
Best suited for	Medium to heavy oil, high-permeability reservoirs

Polymer injection is a smart choice when balancing technical feasibility, economic return, and environmental impact—especially in mature fields like Patos-Marinza.

CONCLUSSIONS

Conclusions on Polymer Injection in Patos-Marinza:

1. Effective Recovery Enhancement Polymer injection has led to a 15–23% increase in oil recovery, particularly in high-viscosity zones like Driza and Goran, where conventional waterflooding was less effective.
2. Cost-Efficient EOR Strategy With an incremental cost of $3–$6 per barrel, polymer flooding offers a low-cost alternative to thermal methods, making it economically viable for mature fields.
3. Environmental Advantage Compared to steam injection, polymer flooding has 3–6× lower carbon emissions per barrel, contributing to more sustainable field operations.
4. Technical Suitability for Heavy Oil Polymers improve sweep efficiency by increasing water viscosity and reducing mobility ratio, making them especially suitable for medium to heavy oil reservoirs.
5. Operational Flexibility Modular injection systems and adaptable polymer formulations allow for scalable deployment, even in complex reservoir conditions.
6. Limitations and Evolving Strategies Reservoir heterogeneity, salinity, and temperature can reduce polymer effectiveness over time, prompting the integration of cyclic steam stimulation and other hybrid EOR methods.

Polymer injection has proven to be a strategic, cost-effective, and environmentally favorable method for boosting oil recovery in Albania's largest oilfield. While not a silver bullet, it remains a cornerstone of enhanced recovery in viscous oil environments.

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SHORT-TERM LOAD FORECASTING IN THE ALBANIAN POWER SYSTEM

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ABSTRACT

Load forecasting is a fundamental process for planning periodic operations and facility expansions in the electricity sector. It is crucial for energy suppliers, TSOs, financial institutions, and other stakeholders involved in generation, transmission, distribution, and trade of electrical energy. The liberalization of energy markets has led to a major increase in the complexity of demand patterns, making it difficult to select the right forecasting model for a given power network. As energy supply and demand exhibit fluctuations, influenced by weather variations and other factors, electricity prices have surged, especially during peak load periods. Consequently, load forecasting is vital to ensure reliable energy services. Short-term load forecasts can help calculate load flows and make decisions to anticipate overloads, reduce equipment damage, and prevent blackouts. On the other hand, medium and long-term forecasting integrate historical load data, weather conditions, consumer demographics, economic trends, and sales data to support broader energy system planning and investment decisions. Two common approaches for medium and long-term forecasting are the end-use method and the econometric approach. In the short term, energy demand is primarily influenced by weather conditions, seasonal patterns (daily and weekly cycles, calendar holidays), and special events. The accuracy of load forecasting depends not only on the forecasting techniques but also on the accuracy of weather predictions. A wide range of mathematical methods and ideas have been used for load forecasting. Despite of that, none can be universally applied to all demand patterns. Methods such as artificial intelligence (e.g., neural networks, expert systems, and fuzzy logic), regression analysis, and grey prediction models are commonly used for short-term forecasting. Despite the diversity of methods addressed, many authors emphasize the necessity of developing and improving these techniques to achieve more accurate and applicable methods for energy companies. Meanwhile, they have no presence in load forecasting tools used by power companies. This study primarily aimed to identify a user-friendly tool for hourly peak load demand. The time series methods such as AR, MA, ARMA, ARIMA, and others are used to addresses short-term load forecasting. The forecasting is carried out with the help of MATLAB software. Real data obtained from a Substation 110/35/6 kV installed power of 15MVA for consumers (P, Q, I,

U, E_a, E_r, etc.) are used to illustrate the methodologies employed and the conclusions derived.
Keywords: Load Forecasting, Short-Term, Time Series, Regression, MATLAB

1. INTRODUCTION

Electric power is unique compared to material products, as it must be generated in real-time to match demand due to its inability to be stored. One of the primary goals of electric power companies is to ensure a stable and safe electricity supply, making Electric Power Load Forecasting (EPLF) critical for planning and operations. Accurate EPLF reduces costs, improves system reliability, and supports strategic decision-making. It is divided based on the forecasting horizon: short-term (up to a week), medium-term (up to a year), and long-term (beyond a year) [1].
Electricity demand patterns are influenced by various temporal, social, economic, and meteorological factors, leading to complex variations [2]. Environmental and social factors, including consumer behaviour, contribute to randomness in load patterns. The variability of electricity demand patterns has driven the advancement of sophisticated EPLF methods, which can be categorized into two main approaches: time series models, where demand is modelled based on past observed values, and causal models, where demand is modelled as a function of external variables. The literature presents a wide range of techniques, reflecting continuous efforts to enhance the accuracy of load forecasting. Typical examples of these models include ARIMA [3], [4] and ARIMA with exogenous variables (ARIMAX) [5], [6]. Machine learning techniques have also been used the recent years for predicting the electricity load, Artificial Neural Networks (ANN) [7], Support Vector Machines (SVM) [8].
This paper aims to identify the most accurate time-series forecasting technique for STLF, evaluating the model performance using AIC. It also identifies key factors influencing electricity demand, such as seasonal variations, industrial activity, and consumer behaviour, emphasizing the importance of adaptive forecasting models in power system management.
This paper is organized into five sections. The second section provides an overview of time-series techniques utilized in the case study. The third section presents the case study itself. The fourth section delves into a discussion of the results and conducts a comprehensive evaluation of the performance of these methods. Lastly, the fifth section presents the conclusions derived from the analysis.

2. MATERIALS AND METHODS

The time series prediction models are categorized into moving average, autoregressive, autoregressive moving average, and autoregressive integrated moving average models. In the autoregressive model (AR), forecasting is performed using previous data in which there is a linear regression relationship between the current data and the previous data. In the moving average (MA) model, the forecasting is performed from the white noise of previous data, where there is no linear regression relationship between current data and previous noise data. In the ARMA model, first, the AR parameters are estimated, and then MA is estimated based on the obtained AR parameters. The AR, MA, or ARMA models, discussed above, can only be used for stationary time series data. Therefore, the ARIMA models were proposed to include the case of non-stationarity as well. They have three types of parameters: the autoregressive parameters, the moving average parameters, and the number of differences applied.

2.1 Autoregressive (AR) Model

The main idea of autoregressive models is that the current value of the series, y_t, can be expressed as a linear combination of previous/past loads, then the Autoregressive (AR) model can be used to forecast future load values. The formula for the AR model is expressed as shown in Equations (1) and (2) [9].

$$y_t = k + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \ldots + \alpha_p y_{t-p} + \epsilon_t \quad (1)$$

$$y_t = k + \Sigma \alpha_i y_{t-i} + \epsilon_t \quad (2)$$

where y_t is the time series data, k is constant, $\alpha_1 \ldots \alpha_p$ are model parameters, and ϵ_t is random variable white noise. In terms of lag operator (T), AR (p) is given by Equation (3) [9].

$$\epsilon_t = (1 - \Sigma \alpha_i T_i)\, y_t \quad (3)$$

2.2 Moving Average (MA) Model

The moving average model that mimics the behaviour of the moving average process, is a linear regression model that regresses the current values against the white noise of one or more past values. The formulas for the moving average model are given in Equations (4) and (5) [9].

$$y_t = m + \in_t + \beta_1 \in_{t-1} + \beta_2 \in_{t-2} + \ldots + \beta_q \in_{t-q} \quad (4)$$

$$y_t = m + \in_t + \sum \beta_i \in_{t-i} \quad (5)$$

where m is the expectation of y_t, $\beta_1 \ldots \beta_q$ are model parameters. In terms of lag operator (T), MA (q) is given by Equation (6).

$$y_t = (1 + \sum \beta_i T_i) \in_t \quad (6)$$

2.3 Autoregressive Moving Average (ARMA) Model

The ARMA (p, q) models represent a combination of an autoregressive models AR (p) and a moving average models MA (q). In the ARMA models, the current value y_t is expressed linearly in terms of its past values and in terms of current and previous values of the noise. The formula used for the ARMA model is seen in Equation (7) [9].

$$y_t = k + \in_t + \sum \alpha_i y_{t-i} + \sum \beta_i \in_{t-i} \quad (7)$$

In terms of the lag operator, ARMA (p, q) is given by Equation (8).

$$y_t = (1 - \sum \alpha_i T_i) y_t = (1 + \sum \beta_i T_i) \in_t \quad (8)$$

2.4 Autoregressive Integrated Moving Average (ARIMA) Model

The ARIMA (p, q, d) model is similar to the ARMA model and can be expressed as seen in Equations (9) and (10). Here, d is the degree of differencing [9].

$$(1 - \sum \alpha_i T_i)\, yt = (1 + \sum \beta_i T_i) \in_t \quad (9)$$

$$(1 - \sum \alpha_i T_i)\,(1 - T)^d y_t = (1 + \sum \beta_i T_i) \in_t \quad (10)$$

2.5 Akaike Information Criterion (AIC)

Akaike Information Criterion (AIC) is a model selection tool. If a model is estimated on a particular data set (training set), AIC score gives an estimate of the model performance on a new, fresh data set (testing set), which is given by the formula (11) [9]:

$$AIC = -2loglikelihood + 2d \quad (11)$$

where and d is the total number of parameters.

3. CASE STUDY

Distribution system of Albania is organized into 11 distribution areas, with total consumption of 7.876 GWh [10]. The distribution of supply with electricity for 2022 is presented in Figure 1. Each region is responsible for its own load forecasting.

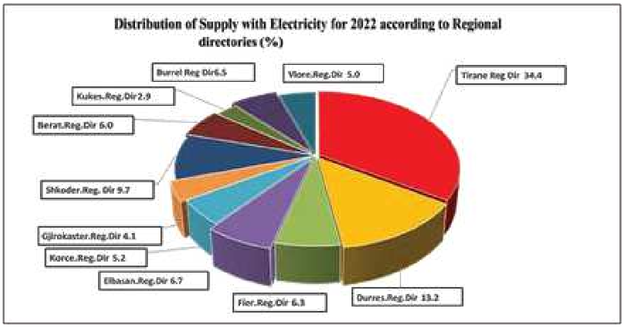
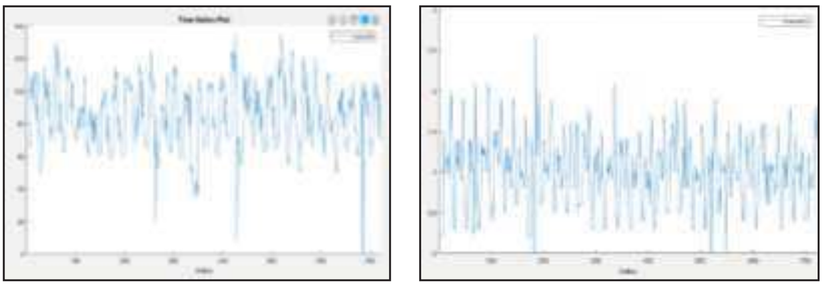
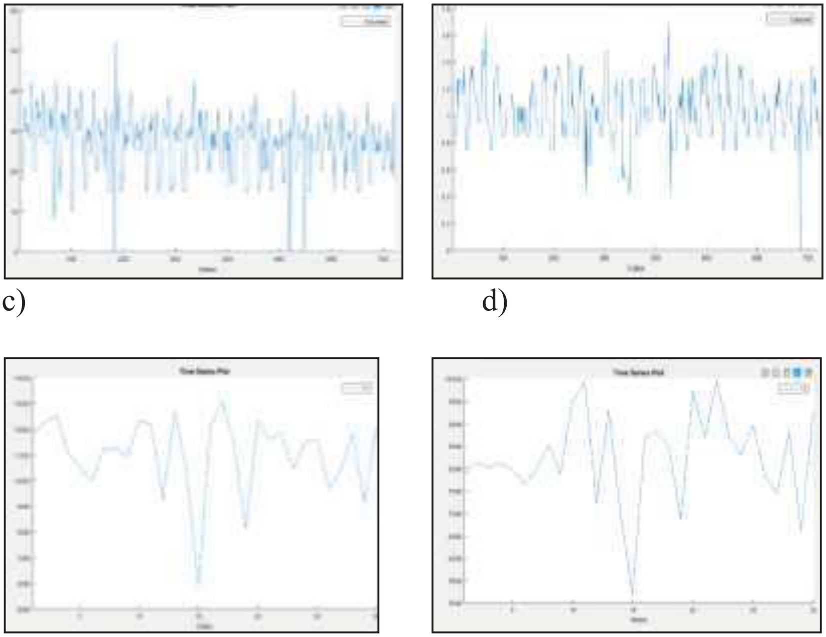


Figure 1. The distribution of supply of electricity for 2022 [10]

In this study, the calculations were conducted using real hourly data from the Rubik Substation, which has three voltage levels, 110/35/6 kV, six feeders 6 kV and an installed capacity of 15 MVA. The substation is equipped with modern measurement systems to collect data on active and reactive power, voltage levels, and current intensities across different feeders. These measurements are critical for monitoring system performance and conducting accurate load forecasting. Data is collected and structured daily, offering insights into trends and variations in energy consumption. Figure 2 illustrates the graphs of currents, active and reactive power in the Substation.



a) b)



c) d)

e) f)

Figure 2. Active power in 35 kV line a) Current in 6 kV line b) Current in 35 kV line c) Active Power in 6 kV feeder d) Active energy of Feeder 3 e) Reactive energy of Feeder 3 f)

Short-term load forecasting for the Rubik Substation was performed using time series methods, including AR, MA, ARMA, and ARIMA models. MATLAB was the primary tool for implementing these methods due to its advanced computational capabilities and visualization options.

4. RESULTS AND DISCUSSION

In the following, we have analyzed the forecasting of active and reactive energy for Feeder 3 using MATLAB and Excel through AR, MA, ARMA, and ARIMA methods.

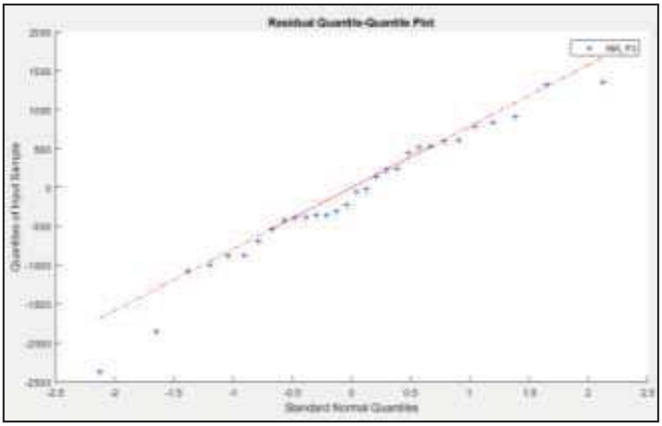
4.1 Autoregressive Model

The forecasting using the AR model will be made with an autoregressive order of 15 due to its better approximation to the model. In Fig. 3ab are illustrated the graphs of Model Fitting and residual plots.

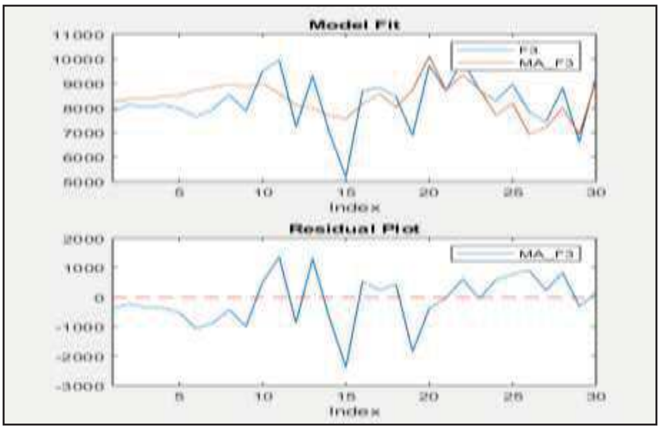
b)

4.2 Moving Average

The forecasting using the MA model will be made with an order of 15 due to its better approximation to the model. In Fig. 4ab are illustrated the graphs of Model Fitting and residual plots.

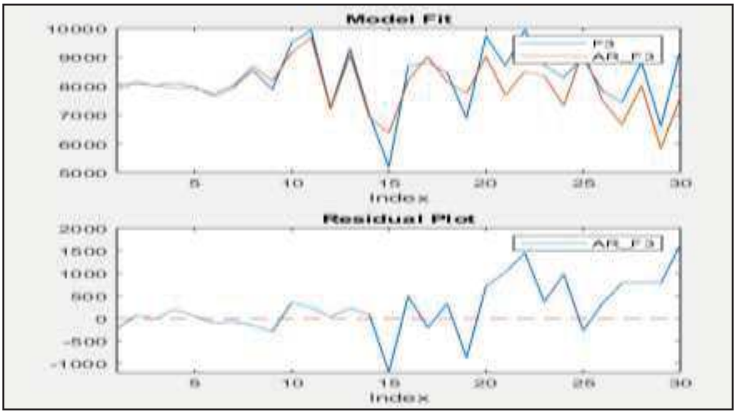


a)

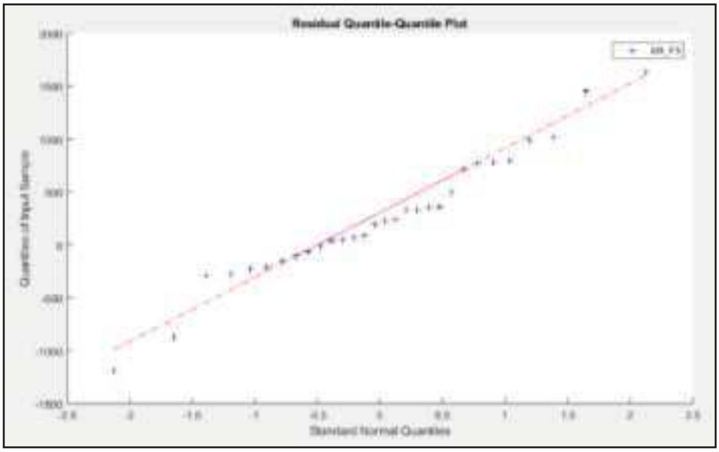


b)

Figure 3. Model fitting and residual plot a) Residual Quantile-Quantile plot



a)

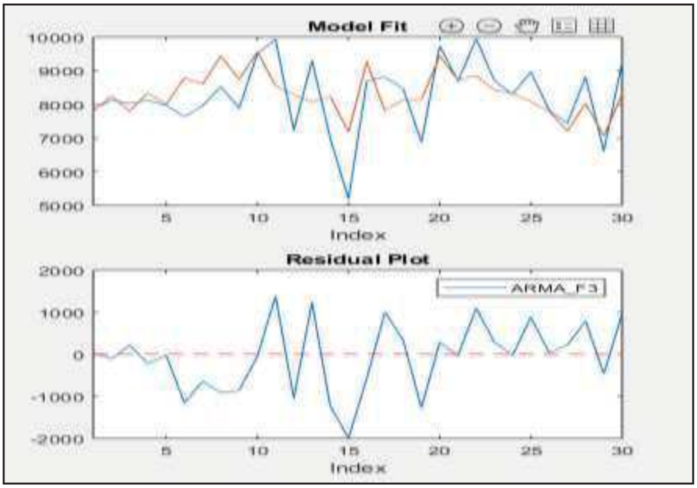


b)

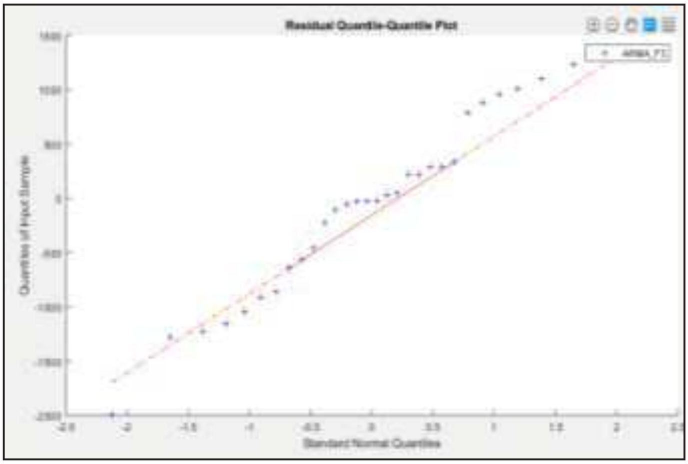
Figure 4. Model fitting and residual plot a) Residual Quantile-Quantile plot b)

4.3 ARMA Model

In the following forecasting, we will use the second case with parameters: Autoregressive order = 5 and Moving Average order = 5, as it provides higher accuracy. In Fig. 5ab are illustrated the graphs of Model Fitting and residual plots.



a)

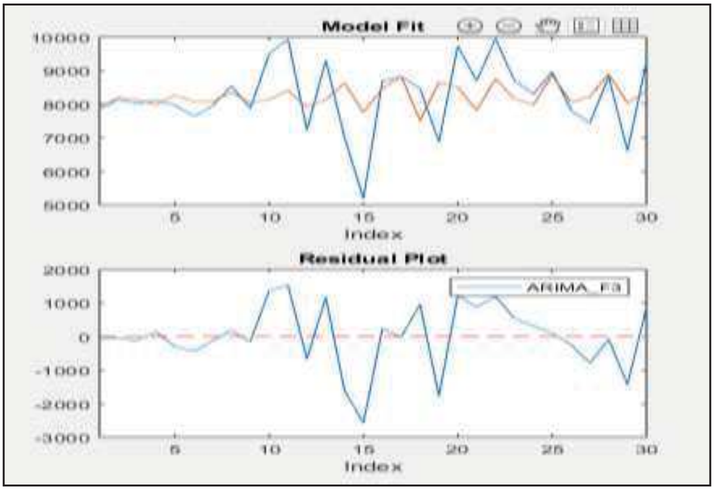


b)

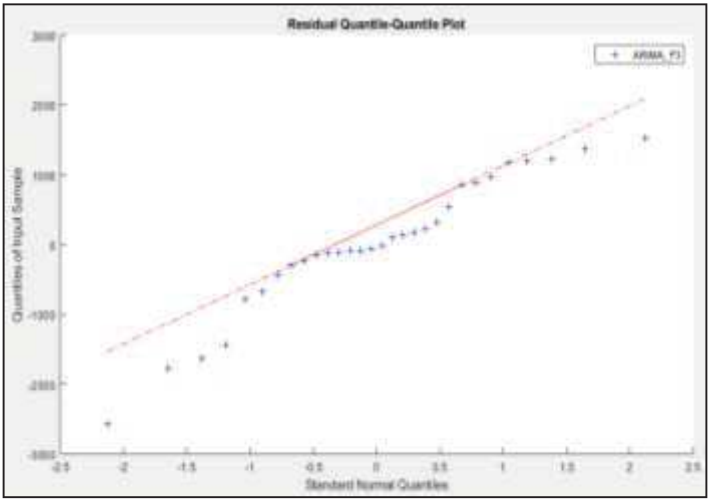
Figure 5. Model fitting and residual plot a) Residual Quantile-Quantile plot b)

4.4 ARIMA Model

In the following forecasting, we will use the second case with parameters: Autoregressive order = 3 and Moving Average order = 3, and degree of integration = 1, as it provides higher accuracy. In Fig. 6ab are illustrated the graphs of Model Fitting and residual plots.



a)



b)

Figure 6. Model fitting and residual plot a) Residual Quantile-Quantile plot b)

4.5 AIC

The results of Table 1 reveal that, the lowest value of the AIC index is for ARIMA model. This reduction signifies an enhancement in the performance of the applied method. This is because the ARIMA model is a combination of the AR and MA models, making it a more advanced and accurate model.

Table 1. AIC Index for the applied methods

	AIC
AR	540,17
MA	540,69
ARMA	532,91
ARIMA	531,24

5. CONCLUSIONS

This study used time-series models, including AR, MA, ARMA, and ARIMA to investigate short-term load forecasting for the Rubik Substation. The results showed that the ARIMA model provided the highest forecasting accuracy, as indicated by its lower AIC values compared to other methods, specifically 531,24. This confirms that ARIMA is a reliable approach for predicting short-term electricity demand, particularly in systems with fluctuating load patterns. The study also identified key factors influencing electricity demand at the Rubik Substation, including seasonal variations, industrial activity, and consumer behavior. These fluctuations emphasize the importance of adaptable forecasting models that can account for dynamic consumption patterns. Accurate short-term load forecasting is essential for optimizing energy generation, reducing operational costs, and ensuring power system stability. The findings suggest that integrating advanced statistical models, real-time data collection, and automation can significantly enhance forecasting accuracy. Future research could explore hybrid models that combine machine learning techniques with traditional statistical approaches to further improve predictive performance. By implementing the insights gained from this study, power system operators can make more informed decisions regarding energy distribution and infrastructure planning, ultimately leading to a more efficient and reliable power grid.

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DECENTRALIZATION OF THE GRID AND THE ROLE OF ENERGY COMMUNITY IN ALBANIA

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ABSTRACT

The trend for decentralized energy systems has gained significant momentum in recent years. This research discusses the role of energy communities in the decentralization of the electricity grid in Albania, analyzing the legal, financial, and socio-economic challenges they face. This research evaluates the Albanian regulatory framework and determines the major deficiencies that hamper the formation and functioning of energy communities. Furthermore, it examines various forms of organization, including cooperatives, public-private partnerships, and peer-to-peer trading, alongside financial instruments such as EU funding, carbon markets, and investments from the private sector. The study offers suggestions for policy improvements aimed at strengthening the legislative framework, streamlining administrative processes, and expanding funding opportunities to assist energy communities.
Keywords: *Decentralization, energy communities, renewable energy sources, energy cooperatives, financing mechanisms, Albania, European Union energy policy.*

1. INTRODUCTION

In recent years, energy communities have emerged as a key mechanism for integrating renewable energy sources and increasing consumer participation in the energy market. The European Union (EU) has strongly promoted energy communities as part of its energy transition strategy, particularly through the Renewable Energy Directive II (RED II), which establishes a legal framework for their recognition and operation (Hoxha et al., 2018; Klein et al., 2019).
In the context of Albania, the transition to a decentralized energy system is both a technical challenge and a socio-economic opportunity. Despite the potential benefits, the establishment of energy communities in Albania faces multiple regulatory, financial, and institutional challenges, including unclear

legal provisions, limited financial incentives, and low public awareness of the concept (Naeem & Ali, 2021; Hanif et al., 2020).
This study aims to analyze the role of energy communities in Albania's transition toward a decentralized energy system, focusing on three main objectives: Assessing the alignment of Albania's legislation with RED II and identifying legal gaps that hinder the establishment of energy communities; Evaluating available investment channels, including EU funds, carbon markets, and private-sector financing, to support energy communities; Exploring different organizational structures such as cooperatives, public-private partnerships (PPPs), and peer-to-peer trading systems, while considering international best practices.

2. Literature Review

The decentralization of energy systems and the formation of energy communities have been the subject of significant policy and academic interest, as they have been recognized as essential components of the global energy transition. The transition from centralized to decentralized energy production is viewed by many as a way to improve energy security, incorporate renewable energies, and boost local economic development (Chaplain & Verdeil, 2022; Pop et al., 2018). Energy communities are a key driver of such a transition; they are juridical entities that allow local actors to participate in the production, consumption, and control of renewable energy, thereby fostering citizen participation and energy democracy (Hoxha et al., 2018; Klein et al., 2019).

2.1. Theoretical and Regulatory Framework

Decentralization of energy has its roots in theories of distributed generation and prosumerism with an emphasis on the transformation of passive consumers of energy into active participants of energy production and trading. The concept is also in harmony with polycentric governance that advocates for the application of various decision-making centers in the energy market to enable localized, community-controlled energy resources (Chaplain & Verdeil, 2022; Lee et al., 2014). Besides, literature highlights the significance of digitalization and smart grid technologies in facilitating the uptake of decentralized energy systems, enabling sophisticated energy management along with P2P trading (Mezquita et al., 2019; Lüth et al., 2018).
At the regulatory level, the European Union (EU) has provided a robust legal framework for energy decentralization through the Renewable Energy

Directive II (RED II) and the Electricity Market Directive, which recognize and promote energy communities as a key instrument for achieving the EU's decarbonization goals (Hoxha et al., 2018; Plewnia & Guenther, 2020). RED II defines energy communities as legal entities that may engage in energy generation, distribution, supply, consumption, aggregation, and storage, emphasizing the principle of non-discrimination in market access (European Commission, 2019). Several EU member states, including Germany, Denmark, and the Netherlands, have successfully integrated energy communities into their national energy strategies, offering supportive legal frameworks and financial incentives (Klein et al., 2019; Mezquita et al., 2019).

In contrast, Albania's legal framework for energy communities remains underdeveloped. The 2015 Energy Law provides a general framework for renewable energy deployment but lacks explicit provisions for community energy models (Naeem & Ali, 2021; Hanif et al., 2020). Recent efforts have been made to align national policies with EU directives, but regulatory barriers such as licensing requirements, lack of clear market access rules, and insufficient financial incentives continue to hinder the development of energy communities in Albania (Vito et al., 2024; Sysoeva et al., 2023).

2.2. International Experiences and Comparison with Albania

The development of energy communities has been widely supported in the EU through policy instruments such as feed-in tariffs, net metering schemes, and capacity-building programs (Plewnia & Guenther, 2020; Lüth et al., 2018). In Germany, energy cooperatives have played a crucial role in the expansion of renewable energy, with more than 1,000 community-based energy projects established under the German Renewable Energy Act (EEG) (Klein et al., 2019). Similarly, Denmark has pioneered the community wind farm model, where local citizens own and manage wind energy projects, benefiting from financial incentives and preferential grid access (Mezquita et al., 2019).

Portugal has also demonstrated strong policy support for decentralized energy models, with the introduction of a legal framework for collective self-consumption and renewable energy communities that facilitates citizen participation in the energy transition (Teotia et al., 2020). In contrast, Albania lacks a dedicated policy framework for energy communities, resulting in limited citizen involvement in renewable energy projects and restricted access to financial instruments available in the EU (Vito et al., 2024; Cacaj, 2023).

Moreover, financial support mechanisms such as the European Regional Development Fund (ERDF) and Horizon Europe have been instrumental in financing energy community initiatives across the EU (Shakharova et al., 2023; Desfonteines et al., 2021). While Albania is eligible for various EU funding schemes, administrative bottlenecks and a lack of technical capacity have impeded effective access to these resources (Khan et al., 2022; Motamedi et al., 2021).

2.3. Identified Gaps in Literature and Contribution of this Study

Despite the extensive body of literature on energy decentralization, several key gaps remain, particularly concerning its implementation in developing energy markets such as Albania. Existing studies have primarily focused on EU member states, leaving limited empirical research on the adaptation of energy community models in candidate countries with different regulatory, financial, and socio-political conditions (Hoxhaj et al., 2022; Režný & Bureš, 2019).

Furthermore, while the role of energy communities in fostering energy democracy, social innovation, and grid resilience has been well documented, little attention has been given to the specific barriers and opportunities within Albania's legal and financial landscape (Naeem & Ali, 2021; Hanif et al., 2020). Additionally, while international research emphasizes the role of digitalization and blockchain-based P2P trading platforms in energy decentralization, these aspects remain largely unexplored in Albania's context (Mezquita et al., 2019; Lüth et al., 2018).

This study seeks to fill these gaps by:

1. **Assessing the regulatory barriers** to energy community development in Albania, comparing them with best practices in the EU.
2. **Analyzing financial mechanisms** that could support energy decentralization in Albania, with a focus on EU funds, carbon markets, and PPPs.
3. **Exploring implementation models** best suited to Albania's energy sector, drawing from international experiences.

3. Methodology/Approach

The current study follows a mixed-methods approach, employing qualitative and quantitative techniques to analyze the decentralization of the energy grid and the role of energy communities in Albania. The research approach is formulated to enable a comprehensive assessment of legal, financial, and institutional parameters powering the establishment of energy communities, combining comparative legal and financial analysis with empirical case studies on the EU scale.

3.1. Research Methodology

The research follows an exploratory and comparative research design. The exploratory part investigates existing regulation and financing structure for the decentralization of energy in Albania, revealing bottlenecks as well as potential areas of benefit. The comparative section examines EU member states' best practice experiences, in this research being Germany, Denmark, and Portugal, with the objective of distilling appropriate lessons for the Albanian context. By pursuing a series of diverse analytical strategies, the research provides policy-relevant findings with regard to informing the structured development of energy communities in Albania going forward.

3.2. Data Collection Strategy

The research employs a variety of secondary data sources, such as policy analysis, legislation, financial analysis, and case studies of the member states of the European Union, to analyze the investment climate and legislative environment for energy communities. The data collection is organized as follows:

3.2.1. Document Analysis and Literature Review

A literature review was conducted to assess the state of academic literature, policy documents, and legal frameworks on decentralized energy systems and community energy initiatives. Literature assessed included: EU legislative acts, i.e., the Renewable Energy Directive II (RED II); Albanian national energy policy and legislation, examining their alignment with EU directives; Global case studies of energy communities, addressing financial, legal, and social considerations.

3.2.2. Legal and Policy Analysis

A qualitative content analysis of the 2015 Albanian Energy Law and accompanying supporting regulations was conducted in order to determine to what extent the legal framework enables the development of energy communities. The analysis focused on: Regulatory convergence with EU RED II standards; Institutional roles for energy community management; Legal barriers related to market access, licensing, and grid connectivity.

3.2.3. Comparative Case Study Analysis

In order to comprehend the operation of energy communities under various regulatory and financial contexts, the research took three EU nations

(Germany, Denmark, and Portugal) as case studies. The nations were selected on the basis of: Regulatory and legislative incentives for energy communities; Financial subsidy mechanisms, i.e., European Union funding and national subsidies; Citizen participation level and governance institutions. These case studies serve as the benchmark by which to gauge Albania's energy transition, extracting best practices and areas of risk for replicating such models.

3.2.4. Financials and Investment Analysis

A comprehensive financial analysis was conducted to evaluate possible sources of funding and investment for Albanian energy communities. The analysis comprised: EU funding instruments such as the European Regional Development Fund (ERDF) and Horizon Europe; Carbon markets and green finance are potential sources of funds for decentralized energy projects; Public-private partnerships (PPPs) and innovative financial models, including crowdfunding and community investment funds.

3.3. Data Analysis Techniques

To enable a comprehensive and in-depth analysis, the study uses the following analysis methods:

3.3.1. Qualitative Analysis

Thematic analysis of policy documents, legal texts, and expert studies was conducted in the hope of identifying pending trends in energy decentralization. Data were clustered into thematic categories, such as: Legal gaps preventing the formation of energy communities; Economic barriers that discourage investment in decentralized energy systems; Institutional and social barriers on the scalability of community-based energy initiatives.

3.3.2. Comparative Analysis

A comparison table was prepared in order to compare easily Albania's financial and legal systems with some chosen EU nations. The comparison showed: Practices that may be used in the Albanian context; No policy support and tax incentives.

3.3.3. Quantitative Analysis

To evaluate the economic feasibility of energy communities in Albania, the research utilized economic modeling methods, such as: Return on Investment (ROI) and Payback Periods on de-centralized energy projects; Levelized Cost of Energy (LCOE) comparison between decentralized and centralized systems.

3.4. Reliability and Validation
To increase the validity of the results, the research employed data triangulation through cross-validation of data collected from various sources like: Government documents and policy briefs published by national and European Union authorities; Empirical case studies of EU member states; Financial information for EU-funded project and investment studies.

3. Current Situation and Issues in Albania

3.1. Institutional and Legal Gaps

Albania, with an interest in bringing its energy policies into alignment with EU standards, especially following the EU's endorsement of the Renewable Energy Directive II (RED II), is struggling to develop an extensive legal framework that would ease the implementation of energy communities. Yet, the current legal framework of Albania is not clear and specific, especially in relation to the energy communities' rights and obligations, which leaves no room for their development and success (Vito et al., 2024; Sysoeva et al., 2023).

One of the most significant legal gaps in the system of Albania is the lack of explicit rules on the functioning of energy communities. Although the Energy Law of 2015 sets a general outline for the growth of renewable energies, it lacks clear provisions regarding the formation, management, and operation modalities of the energy communities (Vito et al., 2024; Sysoeva et al., 2023). Such uncertainty has the potential to confuse potential stakeholders, such as local authorities, citizens, and investors, about the legal procedures and prerequisites necessary to establish and run energy communities.

EU member states, however, have made great progress in creating legal frameworks that are conducive to energy communities. Governments in Denmark and Germany, for example, have put in place clear legislation that enables the development of energy cooperatives and community-owned renewable energy initiatives. The success of such projects confirms the necessity of having a clear legal framework backing local involvement within energy markets, which further serves the energy transition in general (Hoxha et al., 2018).

In addition, the capacity of institutions to enact and enforce energy policy is another significant area where Albania lags behind. Effective governance structures are a prerequisite for the successful set-up and functioning of energy communities. In most of the EU states, specialized agencies or regulatory authorities exist to manage the enforcement of energy policy, providing energy communities with the requisite support and guidance (Vito et al., 2024; Sysoeva et al., 2023). In Albania, this deficiency could lead to insufficient coordination between different actors, such as government institutions, municipalities, and civil society organizations, which could also hinder the establishment of energy communities (Vito et al., 2024; Sysoeva et al., 2023).

The ambiguous rules and absence of clear guidelines for energy communities in Albania also pervade the area of financing and investment issues. Access to finance is of fundamental importance to the development of energy communities, as most projects call for considerable initial investment for infrastructure and technology installation. In the absence of clear regulatory frameworks, potential investors will not invest in community energy initiatives for fear of regulatory uncertainty and financial risk exposure (Vito et al., 2024; Sysoeva et al., 2023). In addition, the absence of special incentives or support schemes for energy communities can deepen these issues, since local initiatives may be unable to compete with more large-scale centralized energy initiatives (Vito et al., 2024; Sysoeva et al., 2023).

3.2. Business Models and Organizational Models for Energy Communities

The development of energy communities in Albania presents a novel chance to advance local energy resilience, foster the utilization of renewable energy sources, and support citizens' empowerment. Different organizational and business models can enable the formation and functioning of the communities, with each possessing distinct benefits and drawbacks. This section examines three prevalent structures for organizing energy communities: energy cooperatives, public-private partnerships, and peer-to-peer (P2P) trading platforms. Additionally, it examines cases from EU countries and discusses how these models are transferable to the Albanian context.

Energy cooperatives are a prevalent organizational structure for energy communities. Energy cooperatives usually consist of groups of individuals or institutions that join together to produce, manage, and consume energy collectively, mainly from renewable sources. The cooperative framework enables members to profit from energy generation, cost savings, and increased energy security. In a number of European Union nations, energy cooperatives have been successful in mobilizing local capital for renewable energy ventures, including wind farms and solar power installations, which has translated into greater energy independence and reduced carbon emissions (Klein et al., 2019).

In the Albanian situation, the cooperative model can be especially useful in rural communities where the access to centralized energy infrastructure is low. Through the establishment of energy cooperatives, the communities can collectively pool funds to invest in local renewable energy initiatives, thus improving their energy resilience while lessening their dependence on fossil fuels. To ensure successful implementation of this model, there is a need to develop a regulatory framework that enables and promotes the establishment of energy cooperatives. The framework must contain clear guidelines on governance, financial arrangements, and operational processes (Plewnia & Guenther, 2020).

Another viable model for structuring energy communities is public-private partnerships (PPPs). In this model, government authorities partner with private entities to design and deliver energy projects to local communities. PPPs can potentially draw on the experience and resources of private entities while safeguarding the precedence of public interests. The model has been used successfully in a number of European Union nations to drive renewable energy projects, enhance energy efficiency initiatives, and roll out smart grid technologies (Mitrea et al., 2024).

In Albania, PPPs can be important in enabling the growth of energy communities through access to finance, technical skills, and new technologies. For example, a collaboration between municipalities and private energy firms can result in community solar installations or microgrids serving the local population. The success of Public-Private Partnerships (PPPs) in Albania relies on having transparent procurement procedures, well-defined contractual agreements, and efficient stakeholder engagement (Zahraoui et al., 2024).

Peer-to-peer (P2P) exchanging stages speak to a transformative approach to vitality trade inside vitality communities. These stages empower people and organizations to exchange abundance vitality produced from renewable sources specifically with one another, bypassing conventional utility middle people. P2P exchanging can improve neighborhood vitality strength, decrease vitality costs, and advance the utilize of renewable vitality sources ("The Impact of the Number of Units on Peer-to-Peer Vitality Exchanging", 2023).

A few EU nations have effectively actualized P2P exchanging stages, permitting prosumers—individuals who both deliver and expend energy—to lock in in nearby vitality markets. For case, the Brooklyn Microgrid within the Joined together States has illustrated how P2P exchanging can engage neighborhood communities to oversee their vitality assets viably (Abidin & Yew, 2022). Within the Albanian setting, the execution of P2P exchanging stages seem encourage the trade of excess vitality produced by family units with sun oriented boards, subsequently advancing renewable vitality selection and upgrading vitality freedom.

To adjust P2P exchanging models to Albania, it is fundamental to address administrative and specialized challenges. This incorporates setting up clear legitimate systems for vitality exchanging, guaranteeing information protection and security, and creating the essential advanced framework to bolster P2P exchanges (Jogunola et al., 2022). Furthermore, open mindfulness campaigns will be significant to teach citizens almost the benefits of taking part in P2P vitality exchanging and to empower community engagement (Deepa et al., 2022).

The encounters of EU nations in setting up vitality communities give important bits of knowledge for Albania. In Germany, for occasion, vitality cooperatives have gotten to be a critical constrain within the renewable vitality segment, with thousands of nearby activities effectively creating and overseeing vitality (Klein et al., 2019). So also, Denmark's community wind ranches have empowered neighborhood inhabitants to require possession of vitality generation, driving to financial benefits and increased open acknowledgment of renewable energy activities (Mezquita et al., 2019).

Within the setting of P2P exchanging, the EnerPort extend in Ireland embodies how blockchain innovation can encourage vitality exchanging between microgrids, empowering nearby communities to oversee their vitality assets successfully (Teotia et al., 2020). These cases highlight the significance of steady administrative systems, community engagement, and inventive advances in cultivating fruitful vitality communities.

To successfully adjust these organizational and business models to the Albanian setting, a few contemplations must be taken under consideration. To begin with, the foundation of a clear lawful system that underpins vitality cooperatives, PPPs, and P2P exchanging is basic. This system ought to give rules on administration, financing, and operational procedures, ensuring that stakeholders understand their rights and responsibilities (Plewnia & Guenther, 2020).

Second, capacity-building initiatives will be crucial to equip local communities with the knowledge and skills required for meaningful participation in energy management and trading. Training sessions, workshops, and awareness campaigns can go a long way in raising awareness about the benefits of energy communities and encouraging active involvement (Lüth et al., 2018).

Finally, facilitation of cooperation between various stakeholders such as government agencies, municipalities, private firms, and community organizations will be critical to the successful development of energy communities in Albania. Through collaboration, these institutions are able to create an enabling framework that facilitates the advancement of renewable energy initiatives and develops local energy resilience (Gao et al., 2023).

4. Financial Aspects and Investment Mechanisms

4.1. The Role of Financial Institutions

Financial institutions' role in promoting energy communities is central in the development of decentralized energy systems, especially in countries like Albania, where this kind of projects has not yet reached maturity. Banks and other investment funds can offer the critical capital and financing tools for supporting the establishment and functioning of the energy communities. This section examines the role of financial institutions in assisting energy communities, evaluates EU financing experience, and considers the availability of current financial instruments that may encourage investment in renewable energy initiatives.

Banks and financial institutions constitute a critical component of energy community funding as they provide a range of financial instruments tailored to address the specific requirements of such ventures. These instruments comprise loans, grants, and equity investments designed in a specific way for renewable energy projects. Most of the countries of the European Union have seen the potential of energy communities in supporting energy transition objectives and have established special financial instruments for their promotion (Nikonova et al. 2019). Some banking institutions, for example, provide green loans at preferential interest rates to projects that fulfill certain conditions of sustainability, thereby promoting the implementation of renewable sources of energy (Khan et al., 2020).

In Albania, the involvement of local financial institutions in funding energy communities is crucial to break the initial capital constraints that tend to be a bottleneck in initiating such schemes. Nevertheless, the present situation demonstrates a lack of awareness and knowledge on the part of the financial institutions about the potential benefits of energy communities. Most banking institutions are still shy of investing in these ventures because of the risk and uncertainty associated with regulatory policies and prevailing market conditions (Baluk et al., 2024). To mitigate this obstacle, stakeholders must communicate with financial institutions, thereby bringing about more appreciation of the merits involved in investments in energy communities and the potential long-term returns from such an investment (Balcılar et al., 2023).

The experience of using EU funds for the development of energy communities is of significant importance for Albania. The European Union has created a variety of funding tools to support renewable energy activities and reinforce local energy initiatives. For instance, the European Regional Development Fund (ERDF) and the Cohesion Fund offer financial support to projects that increase energy efficiency and advance the use of renewable energy resources (Desfonteines et al., 2021). These funds have been instrumental in financing energy cooperatives, community solar programs, and other decentralized energy initiatives in EU member states (Shakharova et al., 2023).

Albania is able to utilize EU funding for the development of energy communities through coordinating national policies with EU objectives and making local projects eligible for funding. Coordination can involve developing clearly defined regulatory frameworks, promoting public awareness campaigns, as well as stakeholder collaboration (Khan et al., 2022). Additionally, Albania can benefit from technical assistance provided by EU bodies to build capacity in the local governments and community organizations to enable them to effectively access and use available funds (Motamedi et al., 2021).

In addition to the funds offered by the European Union, there are a number of financial tools aimed at supporting energy communities in Albania. These include public-private partnerships (PPPs), which can be used to increase investment in renewable energy projects by combining public assets with private sector expertise and capital (Vasyliev et al., 2019). Public-Private Partnerships (PPPs) have been used effectively in most European Union nations to foster the development of energy infrastructure; their application in Albania can help improve the sustainability of energy communities through the availability of alternative sources of funding (Rodiyah et al., 2018).

Besides, new financing models, like crowdfunding and community investment schemes, have the potential to enable local citizens to invest directly in renewable energy projects. Not only do these channels offer much-needed finance but also help promote higher levels of community participation and ownership, factors that are key to the long-term viability of energy communities (Yekimov & Nianko, 2021). Through awareness creation about these tools and their promotion, Albania can create a more supportive environment for energy community formation.

Although the use of financial institutions and European Union funds may have potential benefits in financing energy communities, numerous obstacles still exist. The absence of a well-defined regulatory framework and definitive guidelines for energy communities may discourage investment and cause confusion among financial institutions (Zapivakhin et al., 2018). Moreover, the low ability of local banks to evaluate and fund renewable energy initiatives is one of the most prominent obstacles to the development of energy communities in Albania (Liu & Chu, 2018).

In meeting these challenges, it is essential that the Albanian government prioritize the establishment of an overarching legal framework that clearly supports energy communities and provides clear guidelines in relation to financing mechanisms. This framework should include provisions for risk-sharing mechanisms, incentives to stimulate private sector investment, and provisions for activating the community (Hadi & Erzaij, 2019). Additionally, capacity-building programs that target the financial literacy of local banks and stakeholders engaged in energy communities can enable improved access to finance and foster sustainable investment approaches (Afieroho et al., 2023).

4.2. Potential Funding Channels

The financing of energy communities is crucial for their establishment and long-term sustainability, especially in the context of Albania's energy transition. Diversified funds, such as grants, European Union funds, carbon market mechanisms, and DSO and private investor support, can arrange the required finance to spur the creation of this kind of community. In this section, the prospective sources of funds and how they can be used to assist energy communities in Albania are examined.

Grant funding and European financing mechanisms are fundamental sources of support for energy communities, particularly in the early stages of project development. The European Union has established a number of funding programs aimed at supporting initiatives toward renewable energy and improving energy efficiency among member states and candidate countries. For example, the Horizon Europe program and the European Regional Development Fund (ERDF) allocate extensive financial resources to projects that support the sustainability objectives of the European Union (Winecoff & Graff, 2020; Zhu, 2023). The financial resources can be used to facilitate the formation of energy communities, such as expenditure on the development of infrastructure, deployment of technologies, and building capacity.

In Albania, the use of European financial resources has the potential to greatly increase the economic feasibility of energy community projects. Nonetheless, there are obstacles that range from administrative hurdles to limited awareness of the existing funding opportunities among local stakeholders. In order to break these obstacles, there is a need to educate and guide local communities on how to maneuver effectively through the process of applying for EU grants and funding (Alho, 2018; Liu, 2016). Additionally, establishing partnerships with existing organizations can help improve access to these financial resources.

Carbon market-based finance structures constitute another pathway to energy community financing. The carbon market allows for the trading of carbon credits, which can bring financial returns to greenhouse gas-reducing activities. Energy communities that spend money on renewable energy technology and energy efficiency improvements are rewarded with carbon credits, thus gaining access to more sources of revenue to finance the sustainability of their initiatives (Petlenko, 2024; Zhang et al., 2022).

In the context of Albania, integrating carbon market mechanisms into the financing strategies for energy communities can enhance their financial sustainability. By participating in carbon trading, energy communities can generate revenue that can be reinvested into further renewable energy projects or used to offset operational costs. However, for this approach to be effective, it is crucial to establish a robust regulatory framework that supports carbon trading and ensures transparency in the market (Rickman et al., 2022; Behrendt et al., 2019).

Distribution system operators (DSOs) and private investors play a vital role in the financing of energy communities. DSOs can provide technical support and infrastructure development, while private investors can offer capital and expertise to facilitate project implementation. Financial support mechanisms, such as public-private partnerships (PPPs), can enhance collaboration between public entities and private investors, enabling the development of energy community projects that benefit local residents (Napiórkowska-Baryła et al., 2022).

In Albania, fostering partnerships between DSOs, local governments, and private investors can create a supportive ecosystem for energy communities. By leveraging the resources and expertise of these stakeholders, energy communities can access the necessary financing to develop renewable energy projects and enhance local energy resilience. Additionally, establishing clear regulatory frameworks that outline the roles and responsibilities of DSOs and private investors can facilitate collaboration and ensure the successful implementation of energy community initiatives (Canassa & Costa, 2017; Scott, 2023).

5. Policy Recommendations and Future Projections

The effective deployment of energy communities in the Albanian energy system needs a cautious approach that eliminates legislative, procedural, and financial obstacles. In this section, policy suggestions aimed at enhancing Albanian legislation for the inclusion of energy communities, streamlining procedures for their operation and setup, and establishing additional funding channels and facilitation tools are defined.

In order to facilitate the creation of energy communities, Albania should reinforce its regulatory framework in compliance with EU directives, in particular the Renewable Energy Directive II (RED II). This involves putting in place clear definitions and legal recognition of energy communities, their rights, and their responsibilities. Albania's government should have draft legislation specifying the governance structure, operational procedures, and specifications for energy communities (Son et al. (2020)). These legislative actions would establish a robust framework for community-based projects and encourage local involvement in the production and consumption of energy.

Second, the regulatory framework must incorporate provisions that will facilitate the integration of energy communities into the national energy market. This encompasses the potential for energy communities to participate in energy trading, access to grid services, and involvement in demand response programs. By creating a favorable regulatory environment, Albania can enable local communities to own their energy assets and play a significant role in the country's energy transition (Plewnia & Guenther, 2020).

In addition to legislative improvement, there is a need for Albania to simplify the procedures for establishing and operating energy communities. Such bureaucratic processes are normally complex and could demotivate interested parties from participating in community energy initiatives. The simplification of such processes involves reducing administrative complexities, providing easy-to-follow guidelines, and preparing local authorities to support community projects (Mitrea et al., 2024).

One effective approach could be the establishment of a "one-stop-shop" for energy communities, where stakeholders can access information, resources, and support services in a centralized manner. This could include assistance with project planning, financing options, and regulatory compliance. By facilitating easier access to information and resources, Albania can encourage the formation of energy communities and enhance their operational efficiency (Jogunola et al., 2022).

Moreover, public awareness campaigns are essential to educate citizens about the benefits of energy communities and the processes involved in their establishment. Engaging local communities through workshops, informational sessions, and outreach programs can help demystify the concept of energy communities and encourage participation (Mochi et al., 2023).

Access to financing is a critical factor in the successful implementation of energy communities. Albania should explore various funding channels, including grants, European funds, and innovative financing mechanisms. The government can collaborate with international organizations and financial institutions to develop tailored funding programs that support community energy projects (Mazzola et al., 2020).

Additionally, Albania should consider establishing a dedicated fund for energy communities, which could provide low-interest loans, grants, and technical assistance to local initiatives. This fund could be financed through a combination of government resources, EU funds, and contributions from private investors. By creating a dedicated financing mechanism, Albania can enhance the financial viability of energy communities and encourage investment in renewable energy projects (Lüth et al., 2018).

Furthermore, integrating carbon market mechanisms into the financing strategies for energy communities can provide additional revenue streams. By participating in carbon trading, energy communities can generate income from their renewable energy projects, which can be reinvested into further initiatives (Gaybullaev et al., 2021). Establishing a robust regulatory framework for carbon trading will be essential to facilitate this process.

6. Conclusion

The roll-out of the electrical grid and the potential for energy communities in Albania is a tremendous opportunity for building energy security, advancing sustainable development, and strengthening local communities. This conclusion summarizes the key findings of the research, identifies the potential advantages associated with grid decentralization and energy communities, and considers opportunities for development in Albania.

The analysis indicates that the energy sector in Albania is at a juncture, with potential for substantial change via the decentralization of energy infrastructures. The study puts forward several main findings:

1. Regulatory Gaps: Albania's legal framework does not have specific rules addressing energy communities, making it difficult for them to be established and to operate. It is necessary to develop inclusive legislation that is aligned with EU directives, especially the Renewable Energy Directive II (RED II) (Son et al., 2020; Plewnia & Guenther, 2020).
2. Organizational Models: Several organizational models like energy cooperatives, public-private partnerships, and peer-to-peer trading platforms have been recognized as effective vehicles for the formation of energy communities. These models have the potential to increase local investment and involvement in renewable energy initiatives (Mitrea et al., 2024; Jogunola et al., 2022).
3. Financial Mechanisms: The availability of finances is still a major obstacle to energy communities in Albania. This research emphasizes the necessity for the establishment of new finance sources, such as grants, EU funds, and innovative financing models, to facilitate community energy initiatives (Mazzola et al., 2020).
4. Capacity Development: Capacity development activities to inform local populations of the advantages of energy communities and how they are formed are urgently needed. Stakeholder involvement through workshop sessions and outreach initiatives can lead to higher general participation (Mochi et al., 2023).

The decentralization of the grid and the empowerment of energy communities in Albania can have a range of benefits:

1. Increased Energy Security: Through the facilitation of local energy generation and consumption, energy communities can make energy systems less dependent on centralized systems, thereby improving energy security. This aspect is especially important for rural regions that might be deprived of access to conventional electricity (Atış et al., 2014).
2. Environmental Sustainability: Decentralized energy systems have the potential to increase the incorporation of renewable energy sources, thereby assisting in the decrease of greenhouse gas emissions and reinforcing Albania's resolve for climate change mitigation (Zhu, 2023; Jahanger et al., 2023).
3. Economic Development: The economic development at the local level can be enhanced in energy communities by offering jobs in renewable energy

fields and facilitating local investment. This enhances economic resilience and empowerment at the local level (Teplyshev et al., 2018).

4. Social Cohesion: Engaging local individuals in energy decision-making can be a means of establishing social cohesion and ownership of energy. This can lead to the public acceptance of renewable energy projects (Klepacki et al., 2021).

Looking ahead, it is possible to identify several directions for further development in Albania:

1. Legal Reforms: The Albanian government should focus on developing a comprehensive legal framework containing specific provisions in support of energy communities. The legal framework should include clear definitions, rights, and responsibilities for community energy initiatives (Son et al., 2020; Plewnia & Guenther, 2020).

2. Simplified Processes: It is crucial to simplify the processes of setting up and running energy communities. A "one-stop-shop" for energy communities has the potential to enhance information and resource availability, thereby facilitating stakeholder participation in community energy initiatives (Mitrea et al., 2024; Jogunola et al., 2022).

3. Innovative Financing Mechanisms: The establishment of new finance sources, including dedicated funds for energy communities and participation in the carbon markets, can increase the economic feasibility of community energy initiatives. Collaboration with international institutions and organizations may attract extra resources (Mazzola et al., 2020).

4. Capacity and Awareness Building: Continued capacity building efforts, along with public awareness campaigns, are needed to inform local communities of the advantages of energy communities and to solicit their active participation. Stakeholder involvement through workshops and outreach processes can be used to enhance participation (Mochi et al., 2023).

5. Stakeholder Collaboration: Collaboration among government agencies, regional authorities, private investors, and community groups needs to be promoted for effective installation of energy communities. These stakeholders, together, are more likely to create a conducive environment for community energy projects (Režný & Bureš, 2019).

Overall, the decentralization of the energy grid and the creation of energy communities in Albania provide an immense chance to enhance energy security, ensure sustainability, and enhance the status of local people. Through addressing the shortcomings in the regulations, making the process smoother, and providing new ways for funding, Albania can ensure the establishment of a proper atmosphere for energy community development.

The opportunities presented by such a shift are significant, and with appropriate policies and underlying frameworks established, Albania can set an example by creating a pathway towards a more sustainable and resilient energy future.

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APPLICATION OF DIFFERENTIAL EVOLUTION ALGORITHMS IN HYDROPOWER OPTIMIZATION: A CASE STUDY ON ULËZ HYDROPOWER PLANT

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ABSTRACT

The optimization of electricity production in hydroelectric plants is a critical task for maximizing efficiency, balancing environmental considerations, and meeting demand. This study focuses on the application of the Differential Evolution (DE) algorithm to optimize the electricity generation process of the Ulëz hydropower plant in Albania. The DE algorithm is a population-based optimization technique used to solve complex, multi-dimensional optimization problems. It was proposed by Storn and Price in 1995 and is particularly effective for continuous, non-linear, and non-differentiable objective functions.
The algorithm is used to determine the optimal water discharge schedule, turbine settings, and reservoir management while supporting to operational and environmental constraints. By utilizing concrete data, including water inflows, reservoir levels, and turbine efficiencies, the proposed DE-based optimization model demonstrates significant improvements in electricity production compared to traditional management strategies. The results highlight the potential of DE algorithms in addressing complex, multi-variable optimization challenges in renewable energy systems.
Keywords: differential evolution algorithm, turbine efficiencies, hydropower optimization, reservoir levels, water resource, renewable energy.

1. INTRODUCTION

Hydropower is one of the most reliable and widely utilized forms of renewable energy, playing a crucial role in global energy systems. The efficient operation of hydroelectric plants, such as the Ulëz Hydropower Plant in Albania, depends on effective management of water resources, turbine operation, and reservoir levels. However, achieving optimal performance involves balancing multiple objectives, such as maximizing electricity generation, maintaining ecological flow requirements, and adapting to seasonal variations in water availability.
Optimization algorithms have emerged as powerful tools for tackling these challenges. Among these, the Differential Evolution (DE) algorithm has gained recognition for its simplicity, robustness, and efficiency in solving non-linear, multi-dimensional problems. Unlike traditional gradient-based methods, DE does not require derivative information, making it well-suited for complex systems with

discontinuous or non-differentiable objective functions. This study explores the application of the DE algorithm to optimize the electricity production of the Ulëz Hydropower Plant.

By integrating real-world constraints, such as reservoir capacity, turbine efficiency, and ecological flow requirements, the proposed approach aims to identify the optimal operational parameters that maximize energy output. Using historical data on water inflows and reservoir levels, the model is tested and evaluated to demonstrate its effectiveness. The structure of this paper is as follows: Section 2 provides an overview of the Ulëz Hydropower Plant and its operational challenges. Section 3 details the methodology and implementation of the DE algorithm. Section 4 presents the results and discusses the findings. Finally, Section 5 concludes the study and outlines future research directions.

2. METHODOLOGY

2.1 Ulëz Hydropower Plant Overview

The Ulëz Hydropower Plant is located on the Mat River in Albania. It has a reservoir capacity of 240 million cubic meters, with a maximum length of 14.5 km and a width of 1.6 km. The plant has an installed capacity of 30 MW, consisting of four Francis-type turbines. The average annual electricity production is approximately 100 GWh. Key operational constraints include:

- Maximum and minimum reservoir levels: 128.5 m and 113 m, respectively.
- Maximum water discharge: 64 m^3/s.
- Average multi-year inflow: 44.5 m^3/s.
- Maximum and minimum hydraulic head: 54 m and 36 m, respectively.

2.2 Differential Evolution Algorithm

2.2.1 Energy Conversion Process

The potential energy possessed by water due to its position, during its descent with a head that varies depending on the reservoir level from 36 to 54 meters, is converted into kinetic or mechanical rotational energy by the Francis turbines. The turbine rotation enables the rotor's rotation, which is mechanically connected at a speed of $n = 333$ rpm. The rotor poles are connected to an excitation voltage that varies automatically between 20V DC and 90V DC, with a nominal excitation voltage of $U_{exi} = 42V$ DC.

As a result, a continuous electric field is generated from the rotor poles. This field rotates with the rotor, cutting through the stator windings, and consequently inducing an electromotive force (voltage) in these windings. Due to the rotor's construction, in the spaces between two poles, the electric field strength is zero, while at the middle of the pole, the electric field strength is at its maximum. For this reason, the electromotive force (voltage) induced in the stator winding is an alternating sinusoidal voltage. After synchronization with the grid through the generator switch, current is generated by increasing the water flow in the turbine via the opening and closing of the guide apparatus of the speed regulator.

2.2.2 Differential Evolution Algorithm

Differential Evolution (DE) is an evolutionary optimization algorithm that iteratively improves candidate solutions using mutation, crossover, and selection operations. DE is used for multidimensional real-valued functions but does not use the gradient of the problem being optimized, which means DE does not require the optimization problem to be differentiable, as is required by classic optimization methods such as gradient descent and quasi-newton methods

DE algorithm

```
begin
define problem dimension,  generate an initial population with a given size
calculate the fitness of the initial population.
initialize generation counter g ← 0
while termination criterion not satisfied do
    for each population in current generation do
        select three solutions at random.
        generate one offspring using the DE operators (mutation, crossover).
        if offspring is more fit than parent then
            the parent is replaced with offspring
        end
    end
    g ← g+1

end
```

Figure 1. The pseudo-codes of differential evolution (DE).

DE can therefore also be used on optimization problems that are not even continuous, are noisy, change over time, etc. In this study, DE is applied to maximize power output by optimizing water discharge and turbine settings while ensuring compliance with operational constraints.

Implementation of DE Algorithm: Maximizing power output: **$P=\eta\cdot\rho\cdot g\cdot Q\cdot H$**

Minimizing losses: **Loss=f(V,I,R)**

Ensuring generator efficiency: **ηgen=f(Uexi,n,T)** .The objective function for optimization is defined as:\[P = \eta \cdot \rho \cdot g \cdot Q \cdot H \] where:

- \(P \) = Power output (MW)
- \(\eta \) = Turbine efficiency (assumed 90%)
- \(\rho \) = Water density (1000 kg/m^3)
- \(g \) = Gravity (9.81 m/s^2)
- \(Q \) = Water discharge (m^3/s)

- \(H \) = Hydraulic head (m)

The optimization constraints include:

- \(10 \leq Q \leq 64 \) m³/s (operational range of turbines)
- \(36 \leq H \leq 54 \) m (variation in head levels)
- Power output \(P \leq 30 \) MW (installed capacity limit)

The DE algorithm is implemented with a population of 20 candidate solutions and a tolerance of 0.01 to ensure convergence.

```
#Python code1
import numpy as np
from scipy.optimize import differential_evolution
# Constants
eta = 0.88  # Efficiency (assumed)
rho = 1000  # Water density (kg/m³)
g = 9.81    # Gravity (m/s²)
# Constraints
Q_min, Q_max = 44.5, 64  # Water flow range (m³/s)
H_min, H_max = 36, 54    # Head range (m)
# Objective Function: Maximize power output
def power_output(x):
    Q, H = x  # Decision variables
    P = eta * rho * g * Q * H / 1e6  # Power in MW
    return -P  # Minimize negative power to maximize output
# DE Bounds
bounds = [(Q_min, Q_max), (H_min, H_max)]
# Run DE algorithm
result = differential_evolution(power_output, bounds, strategy='best1bin', mutation=0.7, recombination=0.8, popsize=20, maxiter=100)
# Optimized values
Q_opt, H_opt = result.x
P_max = -result.fun
print(f"Optimized Water Flow (Q): {Q_opt:.2f} m³/s")
print(f"Optimized Head (H): {H_opt:.2f} m")
print(f"Maximum Power Output: {P_max:.2f} MW")
```

Result: Optimized Water Flow (Q): 64.00 m³/s   Optimized Head (H): 54.00 m
Maximum Power Output: 29.83 MW

Interpretation: Water Flow (Q): The optimal flow rate is 64 m³/s, which is the maximum allowed flow rate This suggests that the power output increases with flow rate, and the system should operate at the highest possible flow rate within the constraints. Head (H): The optimal head is 54 meters, which is the maximum allowed head.This indicates that the power output also increases with head, and the system should operate at the highest possible head within the constraints. Power Output (P): The maximum power output achievable under these conditions is 29.67 MW.

```
#Python code2
import numpy as np
from scipy.optimize import differential_evolution

# Constants (hypothetical values for HEC Ulëz)
rho = 1000  # Water density (kg/m^3)
g = 9.81   # Gravitational acceleration (m/s^2)
H = 50     # Effective head (m)
eta_turbine = 0.90  # Turbine efficiency
eta_generator = 0.95  # Generator efficiency

# Objective function: Maximize power output while minimizing losses
def objective(params):
    Q, Uexi = params  # Water flow rate (m^3/s) and excitation voltage (V)

    # Ensure valid values
    if Q <= 0 or Uexi <= 0:
        return float('inf')  # Penalize invalid solutions

    # Power generated formula: P = eta * rho * g * Q * H
    P = eta_turbine * eta_generator * rho * g * Q * H  # Power in Watts

    # Loss function (simplified: higher Uexi increases losses)
    losses = (Uexi ** 2) * 0.0001  # Example loss function

    # We maximize power by minimizing -P + losses
    return -P + losses

# Constraints: Water flow and excitation voltage limits
bounds = [(5, 100),   # Water flow rate (Q) in m^3/s
          (200, 400)] # Excitation voltage (Uexi) in V

# Run Differential Evolution
result = differential_evolution(objective, bounds, strategy='best1bin', maxiter=1000,
tol=1e-6)

# Check optimization success
if result.success:
    optimal_Q, optimal_Uexi = result.x
    optimal_power = -result.fun  # Since we minimized -P, take negative
    print(f"Optimal Water Flow Rate (Q): {optimal_Q:.2f} m^3/s")
    print(f"Optimal Excitation Voltage (Uexi): {optimal_Uexi:.2f} V")
```

```
    print(f"Maximized Power Output: {optimal_power/1e6:.2f} MW")
else:
    print("Optimization failed to converge.")
```

Result: Optimal Water Flow Rate (Q): 100.00 m^3/s Optimal Excitation Voltage (Uexi): 240.03 V Maximized Power Output: 41.94 MW

Interpretation: Water Flow (Q): The optimal flow rate is 100 m^3/s, which is the maximum allowed flow rate. Optimal Excitation Voltage (Uexi): The optimal head is 240.03V. Power Output (P): The maximum power output achievable under these conditions is 41.4 MW.

4. RESULTS AND DISCUSSION

The optimization process was conducted using real-world inflow data and operational constraints. The key findings include: Optimized Water Discharge - The DE algorithm identified the optimal water flow that maximizes electricity generation while maintaining sustainable reservoir levels. Turbine Efficiency Gains - Adjustments to turbine settings led to improved efficiency and reduced water wastage. Seasonal Adaptations - The model demonstrated effective adaptation to seasonal variations in water availability, ensuring consistent power output.

The results show that using the DE algorithm improves energy production efficiency compared to traditional rule-based methods. The optimized model ensures better utilization of water resources, increasing electricity generation while reducing environmental impact.

5. CONCLUSION AND FUTURE WORK

This study demonstrated the successful application of the Differential Evolution algorithm in optimizing the electricity production of the Ulëz Hydropower Plant. The findings highlight the potential of DE-based optimization to enhance efficiency, sustainability, and adaptability in hydropower management. Future research can explore: - Integration of real-time sensor data for adaptive optimization. - Hybrid approaches combining DE with machine learning techniques. The implementation of such optimization frameworks can contribute significantly to improving renewable energy generation and sustainable water resource management.

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DeNO$_X$ catalyst an efficient way to minimize the environmental impacts of the fossil energies combusted in diesel engines

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ABSTRACT

The purification of nitrogen oxides (NOx) is an important challenge for environmental protection and meeting industrial pollution standards. The GE-MITSUI-BF system, an advanced NOx reduction technology, combines process efficiency with the use of optimized chemical reagents to ensure high performance under the most demanding conditions. This system integrates an NDRI gas analyzer for continuous monitoring of gas compositions and to guarantee accuracy in measuring NOx emissions during and after the cleaning process. The NDRI analyzer provides real-time data, facilitating process optimization and reducing energy consumption. The results show that the combination of GE-MITSUI-BF technology and the NDRI analyzer is an effective approach to significantly reduce NOx emissions, contributing to air quality improvement and environmental protection. This method promises to be a sustainable and applicable solution in various industries.
Keywords:NO$_x$, emissions, reaction, catalyst, analyxer, reduction

Introduction to the Experiment:
The purpose of this experiment is to become familiar with the "Selective Catalytic Reduction" (SCR) of NO$_x$ using ammonia (NH_3) and to study the activity of the catalyst (activated carbon).
Typically, NO$_x$ is found in high concentrations in the flue gases from combustible fuels, for example:

- Natural gas (25–160 ppm)
- Liquid fuels (100–600 ppm)
- Coal (150–1000 ppm)

During the combustion of fossil fuels and biomass, mainly NO (95%) is produced, along with NO_2, which together are referred to as NO$_x$. There are three types of NO$_x$:

- **Thermal NO$_x$:** formed from the reaction of atmospheric oxygen and nitrogen at high temperatures
- **Fuel NO$_x$:** formed during the combustion of organic compounds that contain nitrogen

- **Prompt NO_x:** formed during the combustion of reaction products of organic compounds with atmospheric nitrogen

SCR with ammonia is the process of reducing NO_x using atmospheric nitrogen and water vapor via the reactions:

- $4NO + 4NH_3 + O_2 = 4N_2 + 6H_2O$
- $4NO_2 + 4NH_3 + O_2 = 3N_2 + 6H_2O$

The parallel reactions that have a negative effect on SCR are:

- $2SO_2 + O_2 = SO_3$
- $4NH_3 + 5O_2 = 4NO + 6H_2O$
- $4NH_3 + 3O_2 = 2N_2 + 6H_2O$
- $2NH_3 + 2O_2 = N_2O + 3H_2O$

Due to these reactions, the process conditions must be optimized to achieve greater efficiency.

The system used is GE-Mitsui-BF

Catalyst Specifications:

Specific surface area [m^2/g]: 150–200

Mechanical strength (%): 95

SO_2 adsorption capacity [mg SO_2/g]: 60–120

NO_x dispersion efficiency (%): 80–85

Experimental Set-Up:

- Several gas holders as required
- A current controller
- A reactor placed inside a furnace connected to a temperature programmer
- A gas outlet from the reactor leading directly to a scrubber containing 30% phosphoric acid (for ammonia absorption)
- A dryer with silica gel (for water vapor adsorption)
- A converter of NO_2 to NO_x
- A gas analyzer
- Calibration cylinders

Experiment Development:

- The total flow must be = 100 mL/min, with the following concentrations: $C_{(NO)}$ = 800 ppm, $C_{(NH_3)}$ = 800 ppm, CO_2 = 5%
- Preparation of the catalyst: 200 g
- Calcination of the catalyst under a He flow for 30 minutes at 300 °C
- Conducting the SCR reaction at temperatures between 140 and 300 °C, each temperature maintained for 30 minutes

Catalysts: The activated carbon was oxidized in 65% HNO_3 for 2 hours, and modified with 5 wt% of Cu(II) (AC/Cu). The initial conditions are indicated at the first stage of the experiment development at the specified total flow.

Temp (°C)	NO (ppm)	CO_2 (ppm)	N_2O (ppm)
140	97	83	71
180	90	109	96
220	50	219	122
260	40	299	152
300	42	313	189

Summary and Conclusion of the Experiment:

Selective Catalytic Reduction (SCR) is a method to convert nitrogen oxides, also referred to as NO_x, into diatomic nitrogen (N_2) and water (H_2O) with the help of a catalyst. In our case, the reducing agent is ammonia, which is added to the smoke or exhaust gas stream and reacts on a catalyst. As the reaction proceeds to completion, nitrogen (N_2) and carbon dioxide (CO_2) are produced (in the case of using urea).

The reduction reaction of NO_x occurs as the gases pass through the catalyst bed. Before entering the catalyst bed, ammonia is injected and mixed with the gases. The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is:

- $4NO + 4NH_3 + O_2 = 4N_2 + 6H_2O$
- $4NO_2 + 4NH_3 + O_2 = 3N_2 + 6H_2O$

The ideal reaction has an optimal temperature range between 630 and 720 K (357 and 447 °C), but it can operate down to 500 K (227 °C) with a longer residence time. The minimum effective temperature depends on the type of fuel, gas components, and the geometry of the catalyst.

Other possible reducing agents include cyanuric acid and ammonium sulfate. Although SCR is very effective at high temperatures, it is impractical to heat large volumes of air for NO_x removal. Consequently, other technologies have been used at ambient temperatures. Since most NO_x emissions are related to vehicle exhaust, on-road air pollution reduction technologies are employed to combat NO_x emissions. Current technologies have very little effect on reducing NO_x on roads. These include walls coated with photocatalytic titanium dioxide (TiO_2) and roadside installations that utilize soil microorganisms to fix NO_x into nitrate (NO_3^-).

Activated carbon fiber units (AC) can also be used along roadsides to adsorb NO_x and oxidize these compounds into NO_3^-. The AC fibers have a pore structure uniformly distributed on their surface, which facilitates this uptake.

The mechanism consists of two steps:

1. Adsorption of NO_x
2. Oxidation of NO_x to NO_3^- ions; for example: $2NO + O_2 \rightarrow 2NO_2$, followed by $NO_2 + O_3 \rightarrow NO_3^- + O_2$

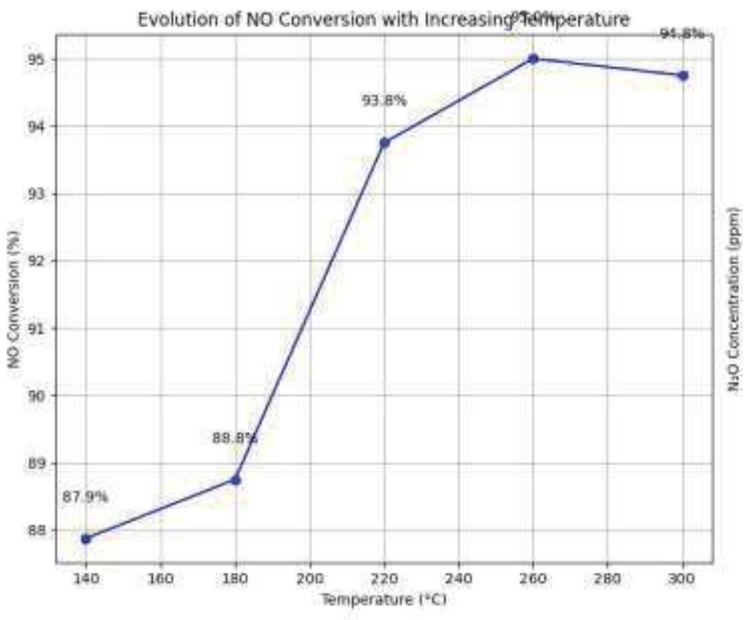
This is part of a regeneration cycle, where the vapor passes through the AC fiber units to remove HNO_3 from the surface. From the equations above, it is clear that NO must first be oxidized to NO_2 before being adsorbed onto the AC surface.

Activated carbons as catalysts have been used to selectively remove NO_x from simulated flue gas at temperatures between 25 and 125 °C. The processing conditions and the physical/chemical characteristics of the carbon that affect the adsorption, retention, and release of NO_x were investigated.

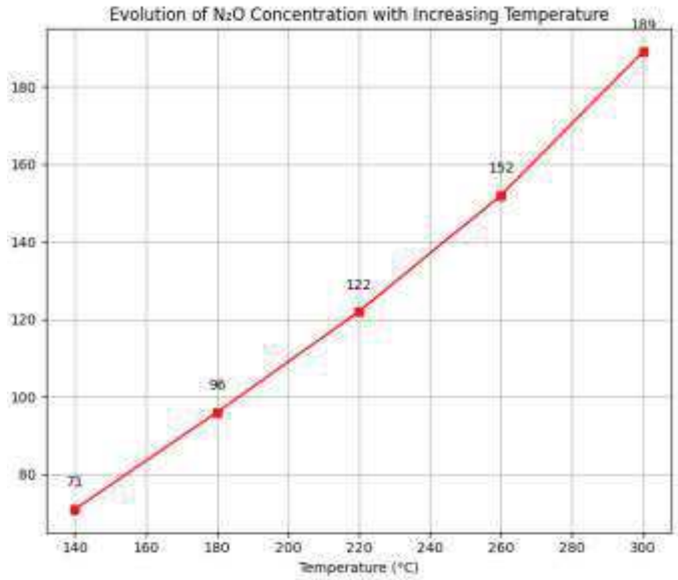
Oxygen as a co-reactant was necessary to maximize the conversion of NO to NO_2 and the condensation of NO_2 within the carbon pores. A mechanism for converting NO to NO_2 is presented and discussed in relation to previous studies. A process for the selective removal of NO_x and its concentration as NO_2 in an alternative process stream is described. The cleaned NO_2 stream can be used for the production of chemicals.

RESULTS:

- **Evolution of NO Conversion with Increasing Temperature**



- **Evolution of N_2O Concentration with Increasing Temperature**



In conclusion, from the experiment we deduced that for maximal conversion of NO to the lowest concentration of N_2O, the optimal process temperature would be around 260 °C. The conversion does not stabilize at higher temperatures, and the concentration of N_2O steadily increases; therefore, performing the process at higher temperatures would not be efficient. The catalyst used indeed fulfilled its function. At the proper temperature, 95% of NO was converted with very little N_2O present.

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MAXIMIZING EFFICIENCY: ADVANCED TECHNIQUES FOR ENHANCING GEOTHERMAL WELL PERFORMANCE

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ABSTRACT

As the global demand for sustainable and renewable energy sources grows, geothermal energy has emerged as a reliable and efficient solution. However, maximizing the efficiency of geothermal wells remains a critical challenge for operators and engineers. The performance of a geothermal well depends on various factors, including reservoir characteristics, drilling techniques, wellbore integrity, and heat extraction methods.

Optimization strategies focus on enhancing energy output, reducing operational costs, and prolonging the lifespan of geothermal wells. Advancements in well design, reservoir management, and real-time monitoring technologies have significantly improved performance, allowing for better energy recovery and increased sustainability.

This article explores advanced techniques for optimizing geothermal wells, from innovative drilling methods and improved thermal management to digital monitoring and maintenance strategies. By implementing these techniques, geothermal operators can boost efficiency, minimize downtime, and maximize the return on investment in geothermal energy projects.

1. Introduction

2. Well stimulation methods

The drilling of a geothermal well has similar characteristics as oil and gas wells. For this reason, methods used to drill oil and gas well can be implemented for geothermal. In many cases, oil and gas wells have contact with water-bearing zones that have the potential for geothermal energy exploitation.

One of the main challenges for geothermal wells is improving energy transfer from the reservoir to the surface. This issue is closely related to the physical properties of the reservoir, such as permeability. Similar to the oil industry, where increasing permeability enhances oil production, in this case increasing

permeability would improve the amount of energy transferred from the reservoir to the geothermal well.
Most commonly used methods that optimize the value of reservoir permeability are acid injection and hydraulic fracturing, which will be discussed below.

2.1 Hydraulic Fracturing

Hydraulic fracturing is a technique used to enhance the flow of the fluid from low-permeability reservoirs by creating fractures in the rock. This method increases permeability, allowing fluids to move more freely to the wellbore.
The process begins with well drilling, where a vertical or horizontal well is drilled, cased, and cemented to reach the target rock formation. Once the well is prepared, perforation is performed using explosive charges to create small holes in the casing, allowing direct access to the reservoir.
Next, fracturing fluid injection takes place, where a high-pressure mixture of water, sand (proppant), and chemicals is pumped into the well to create fractures in the rock. As pressure increases, fracture occurs, extending the cracks and allowing the proppant to keep them open, which significantly improves permeability.
Finally, during flowback, the pressure is reduced, allowing the injected fluid to return to the surface while the reservoir fluid flow freely through the fractures into the wellbore.

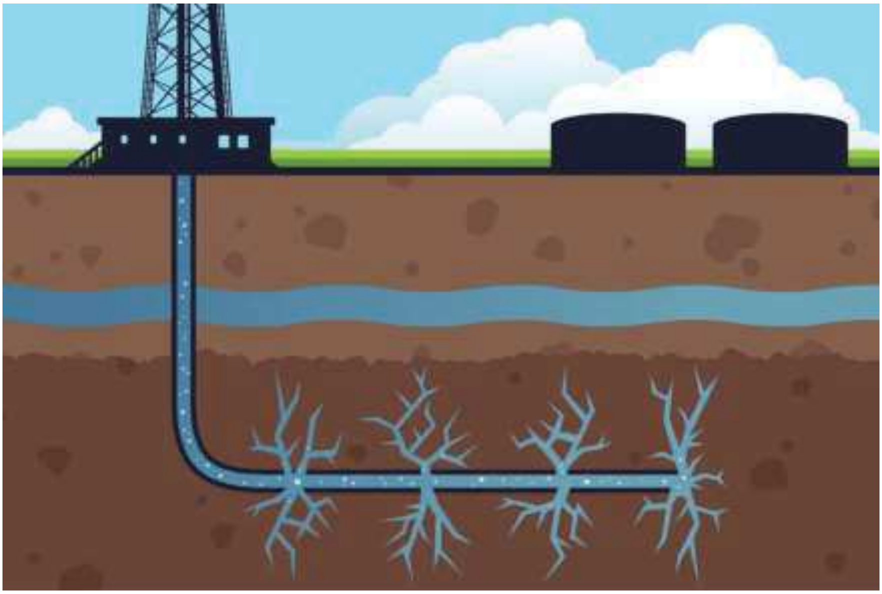


Figure 3 Hydraulic Fracturing

There exist some hydraulic stimulating methods that increase the permeability of the rock **(Reinicke, Rybacki et al. 2010),** namely:

1. Hydraulic Proppant Fracturing – A method that uses a viscous gel for hydraulic fracturing with a high concentration of proppant, creating multiple short fractures in the rock formation. After the process is completed, the well remains shut for some time, and the created fractures are kept open by the proppant element.
2. Water Fractuing - Uses water with a low concentration of proppant to carry out the hydraulic fracturing process. With this method, long and narrow fractures are created. As a result, the communication rate between the reservoir and the bottom of the well is increased. Chemical elements are added to reduce the friction force with the rock.
3. Hybrid Fracturing- Hybrid fracturing is a method that, as the name suggests, combines two of the previously mentioned techniques. This method combines the use of gel and water to perform the hydraulic fracturing process. It leverages the advantages of both methods and ensures the proppant is introduced deeper into the created fracture.

A significant amount of experimental work is required to determine the effectiveness of hydraulic fracture stimulation in geothermal engineering systems. This involves creating multiple fractures and optimizing the extraction of geothermal energy for its conversion into an alternative energy source. Refering literature related to Enhanced Geothermal Systems (EGS) in the US at the Fenton Hill (Duchane and Brown 1995), California (Rose, Sheridan et al. 2005), and at Soultz-sous-Forets, France (Baria, Baumgärtner).

2.2 Acid Fracturing

Acid fracturing is a well stimulation technique commonly used in carbonate formations, but its application in sandstone geothermal reservoirs presents unique challenges. Unlike carbonate rocks, which readily dissolve in acid, sandstones require specialized acid blends and techniques to effectively enhance permeability and improve heat extraction efficiency.

In geothermal sandstone reservoirs, factors such as formation damage, clay expansion, and mineral buildup can decrease permeability, restricting fluid movement and reducing heat extraction efficiency. When properly implemented, acid fracturing can dissolve obstructive minerals and improve reservoir connectivity. However, conventional hydrochloric acid (HCl) is ineffective for sandstone, as it may cause undesirable side effects like silica precipitation.

The acid injection process in geothermal rock formations is carried out in three steps **(Malate 2003)**:

1. Pre Flush - Hydrochloric acid (HCl) with a typical concentration of 5–15% is injected to dissolve carbonate minerals within the formation. This process helps prevent these minerals from reacting with the hydrofluoric acid (HF) in the main flush, which could otherwise produce insoluble calcium and magnesium fluorides.
2. Main Flush - The main flush consists of a blend of hydrochloric acid (HCl) and hydrofluoric acid (HF), commonly referred to as "mud acid." In geothermal well stimulation, a typical formulation includes 10% HCl and 5% HF. Hydrochloric acid is particularly useful for breaking down limestone and dolomite, while hydrofluoric acid effectively dissolves siliceous minerals like clays, feldspar, and silica sands.
3. Post Flush - Its purpose is to push the main-flush acid deeper into the formation and reduce precipitation near the wellbore. In oil well stimulation, weak HCl, ammonium chloride, diesel (for oil wells), and nitrogen (for gas wells) are often used. However, in geothermal well stimulation, fresh water is commonly used as the over-flush.

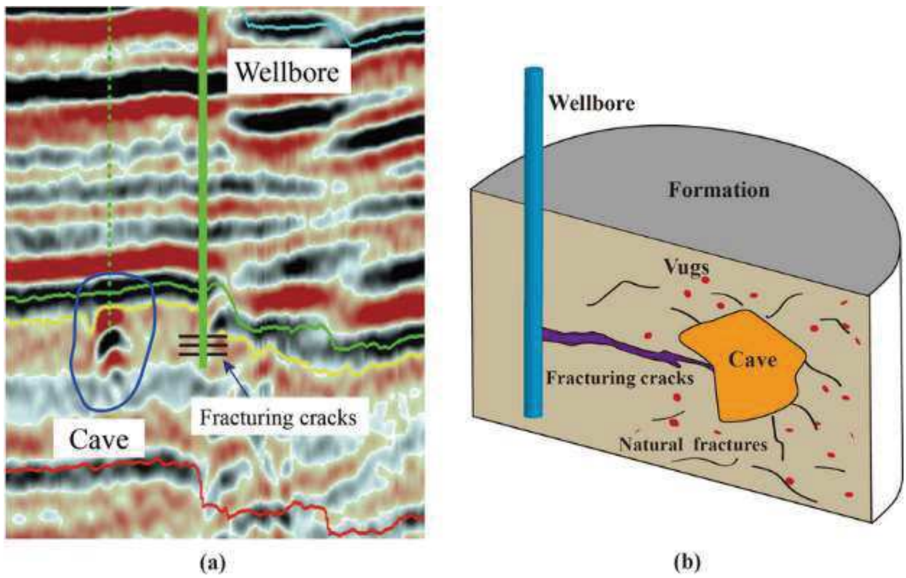


Figure 4 Acid Fracturing

The process removes formation damage by clearing both drilling-induced and natural permeability restrictions. It enhances heat transfer efficiency by improving fluid flow, which in turn increases geothermal production.

Additionally, it prevents clay swelling through specialized acid blends that mitigate clay particle migration and swelling. Lastly, it restores natural fractures by helping dissolve fines and cementing material, reopening existing flow paths.

3.RESULTS AND DISCUSSION

3.1 The Potential Application of Hydraulic Fracturing in the Patos-Marinza Oil Field.

Geothermal power plants utilize steam energy to drive the turbine for electricity production. The system typically consists of an injection well and a production well. The injection well reinjects the condensate into the reservoir, where it absorbs the Earth's heat. As the fluid heats up, it returns to the surface through the production well in the form of steam, which then drives the turbine to generate electricity.

This method can be implemented in the Patos-Marinza oil field. The Patos field area was discovered in 1928. Production began in 1939 and development generally progressed from shallow areas in the south to the oil/water contacts in the north. Around 2,550 vertical and over 435 horizontal wells have been drilled.

The reservoir zones are multiple stacked sands of Upper Miocene (Messinian) Age that were deposited as shallow marine deltas and bar sands. The deepest formations of interest are the Bubullima and Marinza, which contain lighter oil, and are present in the northern part of the development area. Overlying them, the Driza formation contains heavy oil, and holds the majority of the reserves. It is present throughout the field. Above the Driza lies the Gorani formation which is present over most of the field. The Lower Gorani (G5 and G6 sands) produce heavy oil in the northern part of the field, whereas the Upper and Middle Gorani sands are productive in the southern region of the field.

The Patos-Marinza field is a monocline, dipping at 8 - 13° to the northwest. The formations outcrop in the south and exceed 1800 m in depth in the north. A north-trending thrust fault forms the eastern boundary of the field. Within the field, the trapping mechanism varies somewhat from sand to sand but is essentially the oil/water contact in the northwest, faults to the east and west, and stratigraphic pinch-outs and faults to the south.

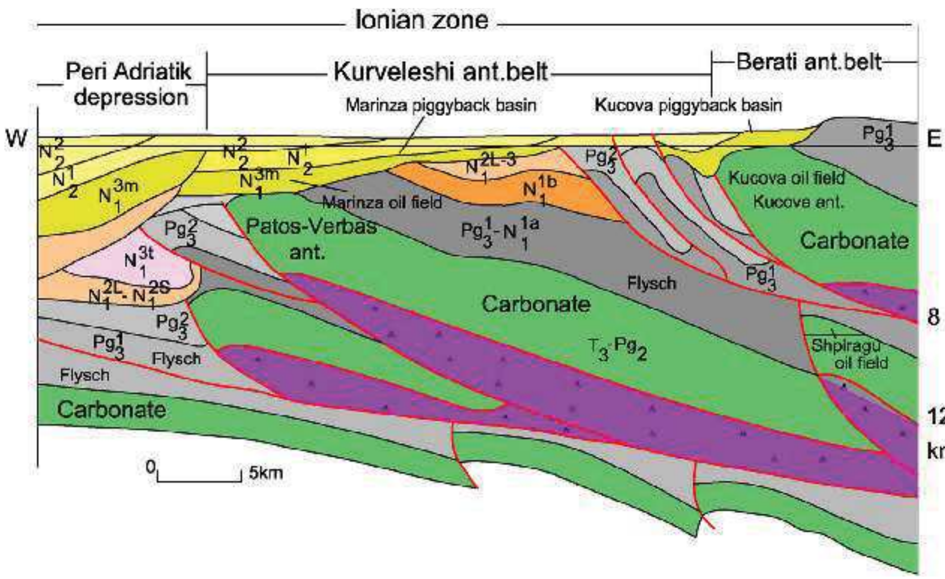
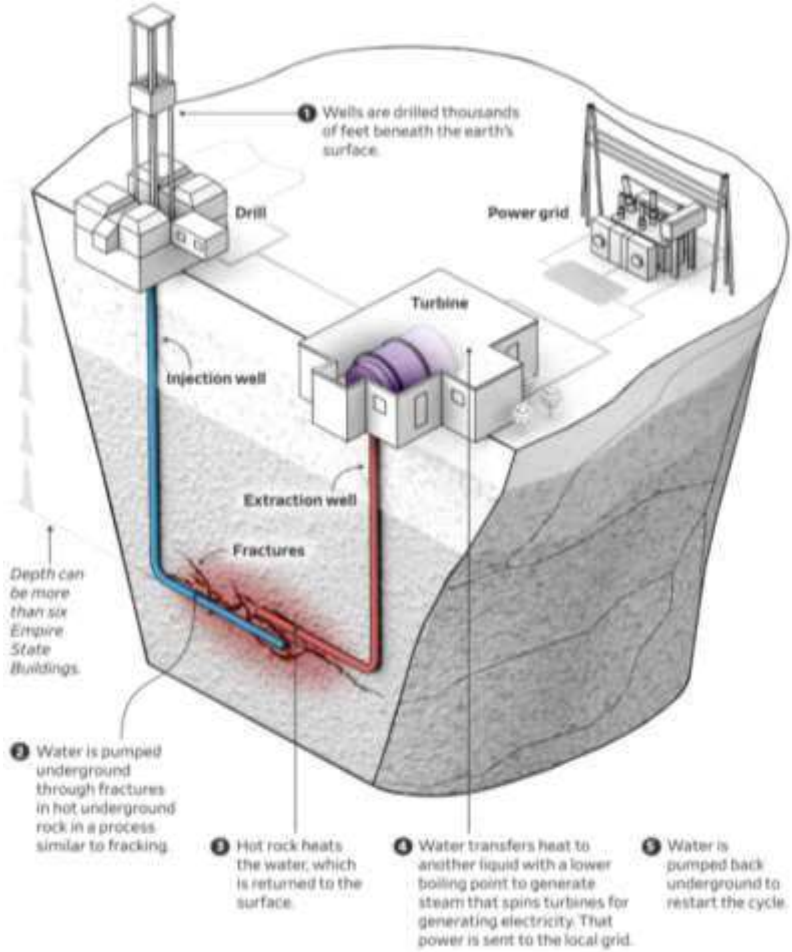


Figure 5 Geological cross-section in Patos-Marinza oil field area

In the Patos-Marinza oil field, polymer injection is applied as a method to enhance oil recovery. This process involves injecting polymer into injection wells to increase reservoir pressure. These wells communicate within the reservoir, leading to an increase in the amount of oil extracted from production wells. In this oil field, steam injection has recently been applied as a method to increase the oil recovery factor. This method helps enhance the reservoir's energy.

Over time, some production wells in this field became economically unviable, and as a result, they have been abandoned. These abandoned production and injection wells can be used for geothermal energy applications. Some wells in the Driza formation, being among the first to be put into production, serve as a concrete example of applying this method.

In these oil fields, hydraulic fracturing and acid injection methods have been applied to enhance the reservoir's permeability. These methods have been implemented in injection wells, and the results have been optimistic, with injection rates increasing significantly.



3.2 Experimental Enhanced Geothermal Systems EGS sites

The following section highlights several projects where acid injection and hydraulic fracturing methods have been applied. One notable example is the Cooper Basin project in Australia. In a well drilled within these geological formations at a depth of 4 km, the bottom-hole temperature reached 250°C. These geological formations are composed of radiogenic granites and uranium-rich rocks **(Meixner et al. 2000).**

In these formations, the hydraulic fracturing method was applied, with a total of 706,293.33 cubic feet of water injected at a depth of 13,943.57 feet. The flow rate increased from 126 GPM to 380 GPM. In the initial stages, the wellhead pressure was maintained between 4,500 PSI and 5,070 PSI. During the hydraulic fracturing process, approximately 10,500 seismic events with a magnitude greater than 0.8 were recorded at the surface (**Kumano et al. 2005; Soma et al. 2004**).

Table 1. Enhanced Geothermal Systems(EGS) projects for commercial purpose.

Project	Location	Year	Reservoir rock type	Well depth (m)	Reservoir temperature (ºC)	Stimulation method	Reference
Neustadt-Glewe	Germany	1984	Sandstone	2320	99	Hydraulic Fracturing	Schaefer and Heinig (2011)
Bruchsal	Germany	1983	Bunter Sand-stone	1874–2542	123	Hydraulic Fracturing	Schaefer and Heinig (2011)
Altheim	Austria	1989	Limestone	2165-2306	106	Acidizing	Tester et al. (2006)
Berlin	El Salvador	2001	Volcanic Rock	2000-2380	183	Hydraulic Fracturing	Portier et al. (2007)
Unterhac hing	Germany	2004	Limestone	3350–3580	123	Acid fractur-ing	Schaefer and Heinig (2011)
Paralana	Australia	2005	Meta-sediments, granite	4003	171	Hydraulic stimulation	Tester et al. (2006)
Insheim	Germany	2007	Sandstone and Granite	3600-3800	165	Hydraulic stimulation	Portier et al. (2007)
Cooper Basin	Australia	2003	Granite	4421	242–278	Hydraulic stimulation	Tester et al. (2006)

4. Conclusions

Enhancing the permeability of geothermal reservoirs is fundamental to maximizing energy transfer efficiency. Techniques originally developed for the oil and gas sector, such as hydraulic fracturing and acid injection, have proven to be highly effective in geothermal well stimulation. By improving fluid flow within the reservoir, these methods significantly boost the extraction and conversion of geothermal energy into usable power. Utilizing abandoned oil wells for geothermal applications, combined with the use of advanced stimulation techniques, presents a valuable opportunity to boost global geothermal energy production. This approach not only maximizes existing infrastructure but also supports the transition toward sustainable and renewable energy solutions.In Patos-Marinza oil field, the application of hydraulic fracturing and acid injection has successfully enhanced injection rates, demonstrating a significant improvement in reservoir permeability. The presence of abandoned wells in the area offers a promising opportunity for geothermal energy development, with the potential to repurpose the field into a valuable geothermal resource.

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APPLICATION OF THE DECLINE CURVE ANALYSIS IN CALCULATION OF THE DECLINE RATE FOR THE GORISHT-KOCUL OIL FIELD IN ALBANIA.

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ABSTRACT

Oil and gas reserves that are stored in the porous media of the geological formation can be considered a closed system known as a single hydraulically & hydro-dynamically connected system. Over the lifetime of a given oilfield it is expected that exploitation goes through several stages. To optimize this process is important to have as much knowledge as possible about these complex systems, for a more detailed analysis of production and its forecast. In this paper, the decline analysis method is elaborated, specifically in the determination of the Production Decline Rate by analyzing each formula that corresponds to each of the decline types as Exponential, Harmonic and Hyperbolic one.
Based on data and information provided such as annual oil extraction, average daily oil per well, cumulative oil, the number of wells in use for the period of six years (from 2009 until 2015) for the Gorisht-Kocul oil field, the practical implementation of the decline analysis was made, making possible the building of the corresponding Cartesian and semi-logarithmic curves, the determination of the decline rate, including the nominal decline calculated by the method of least squares, as well as the effective decline rate for every year. From the determination of these values, it was continued with the calculation of the predicted theoretical rate with two methods for the nine-year period, then the comparison of the values with the real rate and the graphic compatibility.
Keywords: Decline Curve, Oil Field, Well, Producing Life, Decline Rate, Reservoir.

1. Introduction

The fluids flow that occurs in underground oil and gas bearing reservoir is influenced by its shape. Regardless of the irregular shapes of reservoir boundaries, their rigorous mathematical description is nearly possible using the numerical simulators. However, for ease in the various calculations used during well testing, the geometry of fluid flow can be classified into three forms; radial flow, linear flow and spherical flow [1,2]. The very fine voids and channels which together make up the space where the liquid moves in the oil-bearing rock form a tangled network spread in a different way and with cross-sections that vary according to the geometric shape [3,4]. Therefore, starting from the practical meaning of the word, by agreement, we will call the movement of fluids in porous media and fractures filtration [5,6]. In reservoir engineering, the flow and type of fluids that progress in porous media, the hydrodynamic parameters and the filtration stages impacting the production led to pressure drop [7]. These parameters are the key to the practical solutions of numerous subjects that are faced during the exploitation of oil fields [8]. With the utilization of the pay zone and the extraction of the fluid to the surface, the pressure will start to decline, and this pressure drop affects not only the physical-chemical changes of the fluid but also the behavior of the reservoir [9]. Depending on the stage and regime of exploitation by applying the analysis of production decline curves and determining its type for the reservoir taken into consideration, specifically the Gorisht-Kocul oil field, the decline rate is determined and then the forecast of future production.

2. Methodology.

Starting from the “curvature” in the production-rate-versus-time, Arps (1945) proposed that curve can be expressed mathematically by a member of the hyperbolic family of equations. Arps recognized the following three types of rate-decline behavior [1,2,4]:

- Exponential Decline
- Harmonic Decline
- Hyperbolic Decline

Based on technical data for Gorisht-Kocul oil field such as annual oil extraction, average daily oil per well, cumulative oil, the number of wells in use for the period of ten years (showed in table 1), the practical implementation of the decline analysis was made, making possible the construction of the corresponding Cartesian and semi-logarithmic curves, the determination of the decline rate, including the nominal decline calculated by the method of least squares, as well as the effective decline rate for every year.

			YEARS									
Nr	Technical Data	Unit	2009	2010	2011	2012	2013	2014	2015	2002	2003	2004

1	Annual oil Extraction	Ton	25-27	25-29	24-27	25-26	23-26	22-23	17-23	140-152	148-156	154-162
2	Average Daily Oil Per Well	Ton/ Day* well	1.10	1.08	1.05	1.07	0.97	0.96	0.79	-	-	-
3	Cumulative Oil	Ton	11772775.80	11813873	11853051	11894119	11940041	11985482	12022100	53964	53475	53320.6
										11420900	11474375	11527696

Table 1-Technical Data for Gorisht-Kocul Oil Field in Albania

Since the decline determined based on the production data for the Gorisht-Kocul oil field presented in table 1 is an exponential decline, below the three basic formulas for calculating the decline rate are written in the case of exponential decline, including here the effective decline rate and nominal decline rate with their respective values, as well as graphs of rate-time dependence in Cartesian coordinates and semi-logarithmic coordinates, on which the type of decline (figure 1 and figure 2).

1. $D = \frac{\sum_{i=1}^{n} t * \ln\frac{q_i}{q_t}}{\sum_{i=1}^{n}(t^2)} = 0.03047$
2. $D^* = \frac{q_i - q}{q_i} = 0.0443$
3. $D = \ln\frac{q_2}{q_1} * \frac{1}{(t_1 - t_2)} = 0.04911$

Based on the values obtained for the three decline rates, an average was calculated and used to determine the theoretical rates.

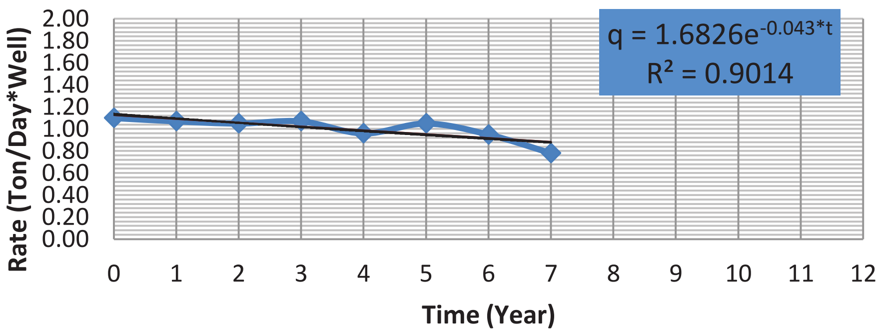

Figure 1- Rate-Time Dependence in Cartesian Coordinates

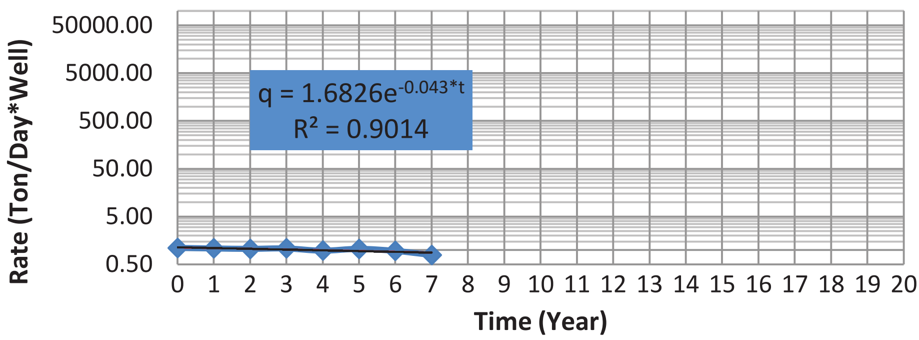

Figure 2- Rate-Time Dependence in Semi log Coordinates.

3. Results and Discussion.

Currently, the decline determined for the Gorisht-Kocul oil field is an exponential decline. In determining of this decline rate, the above three formulas were taken into consideration, which included both the effective decline and the nominal decline. Starting from the first two formulas where the decline rates are 0.03047 for the nominal decline calculated by the least squares method and 0.0443 for the effective decline or in other words the decline calculated at each point for each year, it was made possible to calculate the two theoretical rates and drawing the charts compatibility as following.

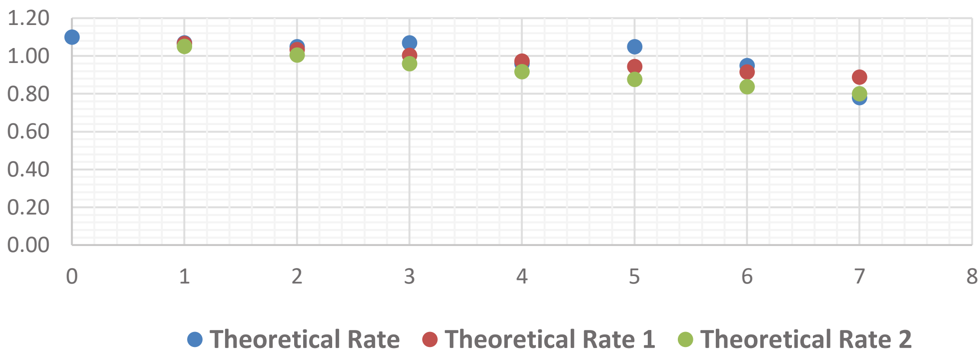

Figure 3- Matching the theoretical rate with the real rate

Fig. 3 shows a strong agreement between the theoretical and real rates, confirming that the average decline rate was calculated satisfactorily. Based on this, if no other method to increase production will be carried out at the oil field, i.e. the reservoir will be exploited based only on its natural energy, it becomes possible to forecast the yield for the coming years based on the value of this decline rate.

4. CONCLUSION.

Decline curve analysis can be applied to almost any manufacturing operation hydrocarbons, which is applied both in technical assistance for the forecasting and future development of underground oil and gas reservoirs, but also in a forecast and economic analysis in the various investments that will be developed in the field including here equipment and facilities such as pipelines, plants, and treating facilities. The production decline rate is a very important parameter not only in scientific studies and projects, but also in the Petroleum Agreements concluded between the institutions responsible for the hydrocarbon sector in Albania and various companies operating in the oil and gas fields. In this work, the production decline rate for the period taken into consideration has been analyzed for the Gorisht-Kocul oil field, in its entirety, including all the number of wells that have been in use and the effective days of their work. This analysis best expresses the actual energy of the layer and on the other hand the real value of the decline of this energy which affects the annual cumulative production.

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TRANSFORMING ABANDONED OIL WELLS INTO GEOTHERMAL HEAT SOURCES: A CASE STUDY IN PATOS-MARINZA

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ABSTRACT

This study explores the transformation of abandoned oil wells in the Patos-Marinza region into viable geothermal heat sources. The primary objective is to assess the technological requirements and engineering calculations necessary to convert these decommissioned wells into efficient heat providers for nearby residential homes and greenhouses. Utilizing geothermal heat pumps, the project aims to leverage the naturally occurring subsurface temperatures to create a sustainable and environmentally friendly heating solution.
The research involves a comprehensive analysis of the conversion process, detailing the required modifications to existing well infrastructure and the integration of geothermal technologies. Key engineering calculations focus on thermal conductivity, heat exchange efficiency, and energy output optimization to ensure maximum utilization of the geothermal potential. The study also examines the economic and environmental benefits, highlighting the reduction of greenhouse gas emissions and the repurposing of a once environmentally detrimental resource into a sustainable energy asset.
Additionally, the paper discusses the optimization of the conversion processes to enhance efficiency and minimize costs, setting a precedent for future applications in similar contexts. By converting abandoned oil wells into geothermal heat sources, the study opens up new possibilities for sustainable energy use, demonstrating how previously harmful resources can be transformed to support environmental and economic sustainability. The findings aim to serve as a model for other regions with similar geological and industrial profiles, fostering broader adoption of geothermal energy solutions.
Keywords: Geothermal Energy, Abandoned Oil Wells, Heat Pumps, Residential Heating, Greenhouse Heating.

1. INTRODUCTION

Abandoned oil wells present an opportunity for geothermal energy repurposing, offering a sustainable alternative to costly decommissioning.

With thousands of wells reaching the end of their productive life, repurposing them can reduce environmental risks while leveraging existing infrastructure for renewable energy. Geothermal energy, which harnesses Earth's heat for electricity or direct heating, typically requires deep drilling, but abandoned oil wells have already undergone this process, lowering exploration and development costs [1], [2]. The Patos-Marinza oil field is the largest onshore oil field in Europe and has been a key contributor to the country's energy sector for decades. With vast reserves of heavy crude, it has played a crucial role in Albania's economy, attracting significant investment and technological advancements in oil extraction [3]. However, as production declines and wells reach the end of their operational life, the field faces challenges related to decommissioning, environmental remediation, and economic transition. Repurposing abandoned wells for geothermal energy presents an opportunity to extend the usefulness of this infrastructure while supporting Albania's shift toward renewable energy. Given its geological characteristics, including substantial well depths (~1100-1800m) and temperature gradients (21.3°C/km) [4], Patos-Marinza holds strong potential for geothermal heat extraction. Transforming these wells could provide sustainable heating solutions for local greenhouses and communities, reduce reliance on fossil fuels, and mitigate the environmental impact of well abandonment, making the field a strategic candidate for geothermal redevelopment.

Figure 6. Location of oil wells in the Patos-Marinza field with potential for future geothermal energy use, highlighting the objects to be heated by this energy source.

In the Patos-Marinza field, over 2,000 wells have been drilled, the majority of which are currently inactive [5]. However, the protocol followed by the company managing the field involves sealing these wells with cement plugs to ensure their long-term integrity. The scope of this study will focus on the short- and medium-term potential of converting these existing production wells from pads M-27 and J-27A into geothermal wells. Wells that, in the near future, may no longer be viable for oil production. The study will specifically concentrate on the northern part of the oil field, near the village of Belinë, for two main reasons:

1. Patos-Marinza is an *edge-water drive* reservoir. In this case, the aquifer surrounds the oil-bearing formation laterally and pushes the hydrocarbons inward as production occurs. This causes the oil-water contact to advance, flooding several rows of wells and making them unsuitable for oil production. As a result, *the wells in this area tend to be decommissioned in a shorter time frame*.
2. *To minimize thermal losses,* the distance between the geothermal well and the heated facility should be as short as possible, reducing the need for extensive heat transport systems. The wells in pad J-27A are the nearest to the "Sotir Kola" school and the residential houses in the village of Belinë (Figure 1A), making them ideal for direct geothermal heating. Similarly, the wells in pad M-27 are the closest to the greenhouses in this area (Figure 1B), ensuring efficient heat delivery with minimal infrastructure requirements.

2. TECHNICAL FEASIBILITY

The Patos-Marinza field, part of the *Peri-Adriatic Depression,* features a complex geological structure with overlapping formations and extensive faulting. It is a gently dipping monocline with a 12-13° northwestward inclination, composed mainly of Tortonian-Messinian sandstones interbedded with shale and clay [6]. The field contains 38 hydrocarbon-bearing sandstone layers, with permeability and porosity varying across different suites. These include the Polovina, Rrogozhina, and Kucova Suite (depths of 1000-1200m); the Gorani Suite (depths of 1000-1200m); the Driza Suite (depths of 1200-1450m); the Marinza Suite (depths of 1450-1800m); the Bubullima Suite (depths >1800m); and the limestone formation, which is part of the Visoka reservoir (Figure 2) .

Given its location within the Peri-Adriatic Depression and the presence of various geological formations, the field also holds significant geothermal potential. The geothermal gradient in the region, particularly in the Peri-Adriatic Depression, reaches up to 21.3 m°K/m, with heat flow density values observed as high as 42 mW/m² [4]. This indicates a strong thermal profile, which could be leveraged for geothermal energy.

After 2004, all newly drilled wells in the field were horizontal. These wells would first penetrate the upper layers vertically and, upon reaching the target formation, continue horizontally within the productive reservoir. The horizontal section was reinforced with a liner and equipped with gravel packs to prevent sand production. Today, the majority of active wells in the field are horizontal and share these characteristics: Production Casing (D_{pc}=177.8mm), Production Tubing (D_{pt}=89mm), Conductor (D_c=244.5m), Liner, BOP in the surface.

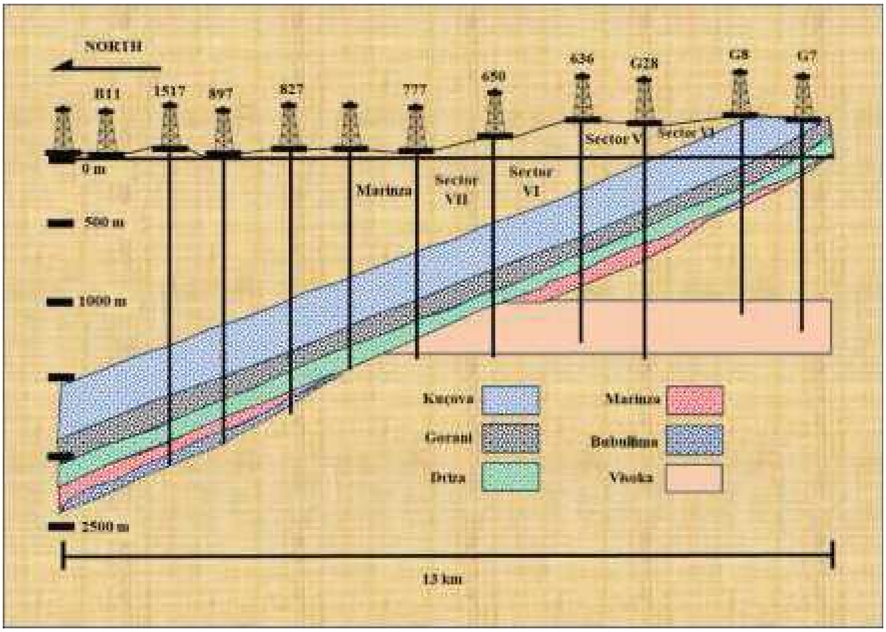

Figure 7. The geological profile of Patos-Marinza, South-North

There are two main types of wells that can be encountered in the field:

a) *Production wells* not only have the general structural characteristics but also contain a complete assembly of progressive cavity pumps inside the tubing, enabling oil extraction.

b) *Injection wells* are used to inject polymers into the reservoir. In addition to the general characteristics, these wells have a packer at the bottom of the tubing, ensuring casing isolation.

If we want to transform one of these wells into a geothermal well, we need to consider and undertake the following steps (Figure 3):

- *Reservoir Assessment:* Each of the wells in the reviewed pads exhibits suitable temperatures at the bottom (in accordance with the geothermal gradient).
- *Well Integrity Evaluation:* The wells under review, after the relevant testing, show excellent casing and tubing conditions. Furthermore, the cementing of the casing and liner is fully completed and well-executed.
- *Wellbore Adaptation*: Regardless of whether we are dealing with production or injection wells, replacing the existing tubing with thermally insulated tubing is necessary. Vacuum Insulated Tubing is recommended. VIT consists of a pipe-in-pipe structure where the annular space between the inner and outer pipes is evacuated to create a vacuum. This design significantly reduces heat transfer through conduction and convection [7]. The new tubing will be lowered into the well without additional elements such as the rotor-stator of the progressive cavity pump or the packer used in injection wells. Additionally, in the case of production wells, a longer tubing is required compared to the one previously used, with the aim of bringing it closer to the bottom of the well. (The tubing in production wells is relatively far from the bottom of the well). A crucial element is cementing the horizontal section of the well with thermal cement. While allowing water to flow through the formation over time would provide significant thermal benefits, it would also lead to substantial hydraulic losses and potentially compromise the feasibility of a closed-loop circulation system. Otherwise, water could enter the sandstone layers, causing losses, or conversely, formation fluids could migrate into the well, jeopardizing its structural integrity. To ensure high-quality cementing and complete hermetic sealing of the well, the need arises to shorten its bottomhole by 1-5 meters. Therefore, this vertical part of the well will also be filled with cement slurry.
- *Heat Exchange System Installation:* On the surface, a centrifugal pump is connected to the casing, pushing water into the well. The water circulates along the casing, enters the tubing, and rises back to the surface, where it is then directed through a pipeline to the heat pump. This is the only acceptable scheme under the conditions of an oil well with small diameters. The selection of circulation from casing to tubing is based on the fact that this configuration allows for the replacement or insulation of the tubing without affecting the casing, which remains fixed and securely cemented to the wellbore walls.

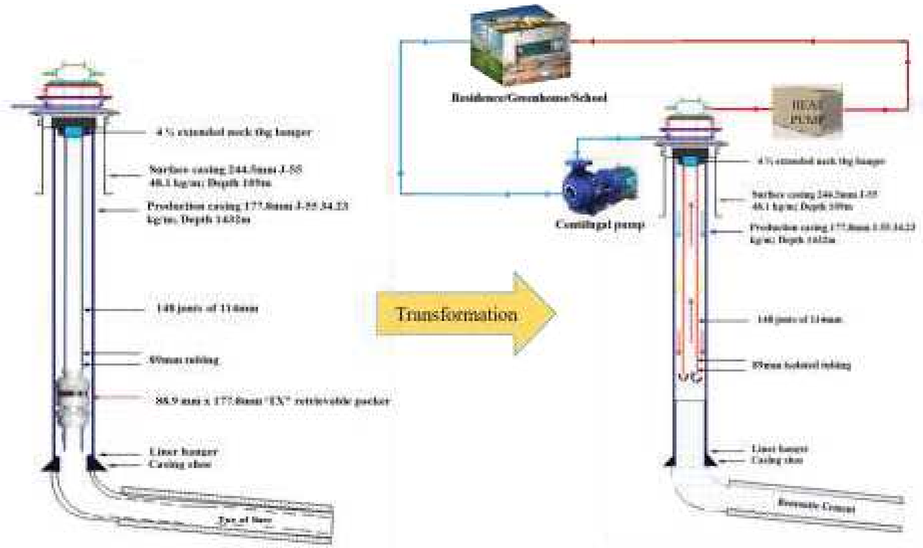

Figure 8. The transformation of a polymer injection well into a geothermal well. (Not to scale)

3. CASE STUDY: PATOS-MARINZA

In both pad sites under review, the well configuration remains the same. Therefore, analyzing well 5852 in Pad M-27 is sufficient, as the results can also be applied to well 5486 in Pad J-27A. The only difference is that well 5852 will be evaluated for its potential to heat nearby greenhouses, while the other well will be considered for heating residential buildings and the village school.

3.1. Estimating Heat Demand

The first step is to calculate the required amount of heat (kW) needed for the greenhouse to operate efficiently. Under these conditions, the following formula will be used:

$$\dot{Q} = U * A * \Delta T \qquad (1)$$

Where: $\dot{Q}$ - heat transfer rate (W);
U – Thermal Transmittance ($W/m^2 * K$);
ΔT – Temperature difference (K);
A – Surface Area (m^2);

Greenhouses have high thermal transmittance values due to their thin, transparent walls and roofs, which allow heat to pass through easily, impacting the internal temperature regulation. Table 1 presents the values of this coefficient for different materials used in greenhouses.

Greenhouse material	Typical U Values ($W/m^2 * K$)
Single layer glass	5.5-6
Double-layer glass	2.5-3.5
Polycarbonate (twin wall)	1.5-2.5
Polyethylene film (single-layer)	6.0-7.0
Polyethylene film (double-layer)	3.0-4.0

Table 2. Thermal Transmittance coefficient for different greenhouse material

The greenhouses considered in this paper are covered with a double layer of inflated polyethylene film, so the values of the thermal transmittance coefficient will be considered as 3.5. The floor of these greenhouses consists of silty soil, and as shown in Table 2, we will consider a thermal transmittance coefficient value of 1.2 due to its high moisture content. The reason we do not use the maximum value for this soil is closely related to the presence of organic materials in the soil.

Soil formation	Typical U Values ($W/m^2 * K$)
Clay Soil	0.7-1.6
Silt Soil	0.5-1.5
Sand Soil	0.2-1.5
Loamy Soil	0.25-1.2

Table 3. Thermal Transmittance coefficient for different soil formation

The surface area of the greenhouses under review is 0.24 ha (2400 m^2) with dimensions of 120 x 20 x 3.7 meters. Thus, the surfaces of the walls, ceilings, and floors will be as in Table 3.

As for the temperature differences, we will take the average low temperature of January, the coldest month in recent years, at -2°C. Meanwhile, the internal temperature should be an average of 22°C, as this is the optimal temperature for tomatoes, promoting healthy growth and fruit production.

Greenhouse elements	A (m^2)	U (W/m^2 ∗K)	ΔT (K)	$\dot{Q}$(W)
Front Walls	880 (440 each)	3.5	24	73920
Side Walls	148 (74 each)	3.5	24	12432
Floor	2400	1.2	24	69120
Celing	2400	3.5	24	201600
Total	**5828**	-	-	**357072**

Table 4. Heat Transfer Rate for the Greenhouse

As shown, heating the greenhouse to normal conditions will require approximately **357 kW** per hour.
We followed the same procedure for the "Sotir Kola" school and a house in the village of Belinë. All their measurements and calculations are presented in Table 4 and Table 5.

Residence elements	A (m^2)	U (W/m^2 ∗K)	ΔT (K)	$\dot{Q}$(W)
Front walls	44.7 (24.9) each)	0.5	22	491.7
Side walls	54 (27 each)	0.5	22	594
Ceiling	85.5	0.3	22	564.3
Floor	85.5	0.5	22	940.5
Door	2.1	3	22	138.6
Windows	7.2 (1.8 each)	2.5	22	396
Total	279	-	22	**3123.7**

Table 5. Heat Transfer Rate for the Residence

School elements	A (m^2)	U (W/m^2 ∗K)	ΔT (K)	$\dot{Q}$ (W)
Front walls	115.97 (61.52 each)	0.5	26	1507.61
Side walls	39.52 (19.76 each)	0.5	26	513.76
Roof	200	0.3	26	1560
Floor	200	0.5	26	2600
Door	6.15 (2.4+3.75)	3	26	479.7
Windows	16.32 (0.92 each)	5.5	26	2333.76
Total	495.41	-	-	**8994.83**

Table 6. Heat Transfer Rate for the School

The house has dimensions of 9 × 9.5 × 3 m, while the school measures 25 × 8 × 2.7 m. The house features four double-glass windows, each measuring 1.5 × 1.2 m, whereas the school has seventeen single glass windows of 1.2 × 0.8 m. Additionally, the house has one door with dimensions of 2.1 × 1 m, while the school has two doors measuring 2 × 1.2 m and 2.5 × 1.5 m.
Regarding the required indoor temperatures, the World Health Organization recommends maintaining 20°C in residential homes and 24°C in schools for optimal comfort and well-being. These values have be used as reference points in our heating demand calculations.
As shown, heating the residence and school to normal conditions will require approximately **3.15 kW** and **9 kW** per hour, respectively. Additionally, to make this project as reliable as possible, we will perform calculations to heat a block of 20 residential houses. This would bring the heating demand to **63 kW**.

3.2. Estimating Vertical Heat Exchangers Length

Based on the heating requirements, we will also determine the capacity of the heat pump that will be connected to the tubing. The heat pumps under consideration have a Coefficient of Performance (COP) of 5, so the pump capacity needs to be calculated using the following formula:

$$Q = \frac{\dot{Q}}{COP} \quad (2)$$

Where: Q – power of the heat pump (capacity);
$\dot{Q}$ - Required heating;
COP - Coefficient of Performance;

The length of the vertical heat exchanger required to handle each pump must also be calculated. For this, Equation 3 will assist us [8]:

$$L = \frac{Q}{U * \Delta t} \quad (3)$$

Where: Q - rate of heat exchanger for the whole heat exchanger length;
L - length of heat exchanger (m);
U - conductance rate for heat transfer from the circulating fluid to the earth for the operating conditions;
ΔT - difference in fluid temperature:

$$\Delta T = \frac{T_2 + T_1}{2} - T_0 \quad (4)$$

T_0 - earth temperature;
T_1 - fluid entry temperature;
T_2 - fluid exit temperature;

We will consider the scenario where the water returned to the well has an average temperature of 15.5°C, and at the bottom of the well, with a depth of 1400m, the temperature reaches 29.5°C. From the bottom of the well to the surface, the water maintains its temperature due to the use of VIT so **ΔT=7°C**. To calculate the required length of the vertical heat exchanger, the value of U will also be needed. It will be calculated from the formula:

$$U = \frac{2\pi}{R_p} \quad (5)$$

Where R_p – thermal resistance ($m^2 * K/W$)
Thermal resistance will be calculated as the weighted average of the thermal resistence coefficient values of all the layers encountered in the well. It's values and calculations are found in Table 6:

Layer	Thickness (m)	Weight Coefficent	R ($m^2 * K/W$)	Weig. R
Conglomerate-Sandstone	150	0.107	0.6125	0.0655
Sandstone-Conglomerate	200	0.143	0.6195	0.0885
Sandstone-Slit-Clay	380	0.272	0.6436	0.175
Slitstone - Clay	400	0.285	0.653	0.1861
Sandstone-Clay	270	0.193	0.6455	0.1245
Total	1400	1	-	**0.6396**

Table 7. Calculation of the thermal coefficient value inside the well

From Equation 5 we can calculate **U=9.81 W/m²K.**
From here we can use the Equation 3 to find the length of VHE. The results are summarized in Table 7:

Object	$\dot{Q}$ (kW)	Q (kW)	Q_{std} (kW)	L (m)
Block of Residences	63	12.6	13	189.31 m
Greenhouse	357	71.4	72	1048.49 m
School	9	1.8	2	29.12 m

Table 8. Length of Vertical Heat Exchanger

The only investment that justifies the acquisition is that for the heating of the greenhouses. The logic behind this conclusion lies in the fact that drilling 11 geothermal wells with a depth of 100 meters (or equivalent variations) incurs a higher cost than converting oil wells into geothermal wells. Meanwhile, the other two applications require shallow wells, approximately 30 meters for the school and two wells of 100 meters for the residential block.
This approach will have a positive environmental impact by utilizing existing wells for geothermal energy, which avoids the higher environmental impact associated with drilling 11 new wells of 100m. It will also benefit the local community by promoting sustainable agriculture and potentially creating jobs in the geothermal sector.

4. CONCLUSIONS

The transformation of abandoned oil wells in Patos-Marinza into geothermal heat sources is a technically and economically viable solution, particularly for greenhouse heating. The engineering calculations highlight the crucial role of thermal insulation in maximizing efficiency. Heat loss analysis shows that, despite their small surface area, windows significantly impact thermal performance. This underscores the need for high-quality insulating materials, such as vacuum insulated tubing for wellbore adaptation and low-U-value materials for heated structures. By integrating advanced thermal isolation techniques, the repurposing of oil wells can achieve optimal energy conservation and lower operational costs. The final calculations demonstrate that greenhouse heating is the most justified investment due to its high heat demand and energy cost savings. While residential and school heating could benefit from geothermal conversion, their lower heat loads make shallow borehole alternatives more cost-effective. Using existing oil wells for large-scale heating applications offers the best return on investment, reducing greenhouse gas emissions while enhancing agricultural sustainability. Future studies should assess the long-term performance of converted wells and potential declines in heat transfer efficiency. Additionally, research on hybrid geothermal systems—combining oil well conversion with shallow boreholes or solar integration—could provide a more comprehensive approach to sustainable heating. These findings highlight the potential for geothermal redevelopment in similar oil fields, supporting the broader transition to renewable energy.

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ADVANCEMENTS IN DRILLING TECHNOLOGY FOR BHE WELLS IN ALBANIA: INNOVATIONS AND CHALLENGES

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ABSTRACT

The growing demand for sustainable energy solutions in Albania has spurred significant interest in Borehole Heat Exchanger (BHE) systems, which offer a reliable means of harnessing geothermal energy. This article explores the advancements in drilling technology for BHE wells in Albania, focusing on innovations that have enhanced efficiency and effectiveness in geothermal energy extraction. Recent developments in drilling techniques, such as advanced rotary drilling methods, improved casing designs, and the application of real-time monitoring tools, have made BHE well installation more cost-effective and sustainable. However, despite these technological advancements, several challenges remain, including geological variability, limited infrastructure, and environmental considerations. This paper examines the ongoing efforts to address these obstacles through the adaptation of drilling technologies to local conditions and the optimization of drilling processes. By highlighting both the innovations and challenges in the field, the article provides a comprehensive overview of the current state of BHE well drilling in Albania and outlines future directions for research and development in this critical sector.
Keywords: Borehole Heat Exchanger, Drilling Technology, Geothermal Energy, Geotechnical Challenges, Environmental Impact

1. INTRODUCTION

A Borehole Heat Exchanger (BHE) is a subsurface system to extract and store geothermal energy from the ground and a geothermal heat pump for space heating and cooling with high efficiency and environment friendly. [1] This technology consists of a drilled vertical or horizontal borehole into the underground reservoirs with a U-pipe system that circulates a heat transfer or carrier fluid (water-antifreeze solution) to increase thermal exchange with the ground. [5]
The significance of BHE systems relates to the fact that:

- Geothermal energy is part of **Renewable Energies Sources**, as the heat comes from the underground and is influenced by radioactive phenomena and its geological activity. [2]
- Geothermal energy is considered one of the most **Environmentally Friendly** and reliable energy sources because CO_2 emissions and other harmful gases are at low levels. In this way, it has a much smaller impact on air pollution and climate change. [2]
- Geothermal energy is considered a **Highly Efficient Energy** sources. This is because it reduces electricity consumption by using Borehole Heat Exchangers and Ground Sources Heat Pumps compared to traditional heating and cooling methods, as they utilize the natural temperature of the underground. [2]

BHEs are an influential component of Ground Source Heat Pump (GSHP) systems, which utilize the stable underground temperatures of the earth for sustainable heating (Winter Operation) and cooling (Summer Operation). [3] Because of their efficiency and performance, BHE systems are extensively used in residential, commercial, industrial and agricultural applications, as part of an environmentally friendly heating and cooling systems, oftentimes economically.

In Albania traditionally the energy sector based on hydropower (2022) for over 98% of the country`s electricity generation and 2% from solar PV. [4] But the challenges related on seasonal and climatic changes, push Albania toward other alternative renewable energy sources. With significant geothermal resources potential, given that it is located in a region with active seismic activity and the presence of hot springs and geothermal reservoirs. Cities such as Ardenica, Kruja and Peshkopia possess geothermal waters with high temperatures, growing interest in alternative electricity generation and direct heating and cooling solutions. Albania is already in process of using directly geothermal technology. According to Kodhelaj et al. (2021), cities like Tirana, Korca and, Shkodra are only implementing geothermal heats pump with a total installed capacity of 2 MWt. However, BHE technology in Albania faces technical, financial, and regulatory challenges, requiring further research, investment, and policy support for large-scale adoption.

The purpose of this study is to explore the recent advancements in drilling technology for Borehole Heat Exchanger (BHE) wells, with a particular focus on innovations and applicability in Albania. This includes examining Technological Innovations, Assess the Potential of Geothermal Resources in Albania, Highlight Challenges, Explore Environmental and Economic Benefits and Provide Policy Recommendation. By addressing these points, the study will contribute to a better understanding of how BHE drilling technology can play a pivotal role in enhancing energy sustainability in Albania and how these innovations can be leveraged to meet the country`s heating, cooling and energy production needs in an environmentally responsible way.

2. MATERIALS AND METHODS

The main principles behind Borehole Heat Exchangers (BHEs) are the extraction and storage of thermal energy between the underground and the heat pump system for heating and cooling buildings and industrial applications. [5]

- Heat Extraction Mechanism: In colder months, the heat pump extracts heat from the rock mass through the BHEs and transfering the heated fluid with high temperature into the building's heating system. [5]
- Heat Storage Mechanism: In warmer months, the heat pump extracts heat that comes from a building and transfers it into the ground through the BHEs, effectively cooling the building and storing it for future use. [5]

2.1 Types of Borehole Heat Exchanger (BHE) Wells

a. Vertical Borehole Heat Exchangers

The most common and efficient type of heat transfer, based on depth (usually 50-300 meters), narrow boreholes, limited areas to install and stable underground temperatures. [6, 7, 9]

b. Horizontal Borehole Heat Exchangers

Less efficient type of heat transfer compared to vertical BHE wells, because of shallow depth (1–5 meters), deep boreholes, large land areas to install and unstability of seasonal temperature; but cheaper to install than vertical BHE wells. [6, 7]

c. Coaxial Borehole Heat Exchangers

Higher efficiency, well-suited for large-scale applications and deep boreholes but can be more expensive to install. [8]

2.2 Traditional Drilling Techniques for BHE Wells in Albania

Drilling is a key factor for BHE systems, as it impacts the system performance and cost; including factors like depth of boreholes, geological conditions and drilling techniques, (directly affect the heat exchange efficiency and system longevity). In Albania, the installation of Borehole Heat Exchanger (BHE) systems depends on traditional drilling techniques for geothermal energy extraction. Deeper boreholes, more efficiency heat exchange but higher installation costs (advanced drilling techniques and longer installations periods). [9] High thermal conductivity materials, for example, rock or wet clay improve the thermal performance of BHEs. On the other hand, low thermal conductivity materials such as, dry sand or gravel reduce system efficiency. [10]

a. Rotary Drilling: Is used for deeper geothermal resources and stable boreholes in various ground conditions. It is the most commonly technique for BHE installations in Albania, especially for deeper boreholes to reach geothermal heat resources in certain areas, utilizing a rotating drill bit throughout the ground, creating a borehole where the geothermal pipes will install. But deeper borehole, higher costs of drilling for specialized equipment, skilled labor and time-consuming. [11]

b. Percussion Drilling: Less effective for deeper, hard rock formations; less precise which may cause borehole wall damage and low-efficiency. This method is used for shallow boreholes, in certain areas in Albania with softer soil or loose rock formations, using a cable-tool drilling to break up rock mass or soil. But, Albania`s diversity geology characterized by karst regions with underground cavities and irregular rock structures, causing risk on drilling and disrupt the exchange of heat. [12] Also, in certain Albania regions are present groundwater or active aquifers, affecting the installation of geothermal pipes due to water influx into the borehole. In karst and aquifer regions, environmental impact is more present especially, contamination of local water sources and noise pollution. [13]

2.3 Innovations in Drilling Technology for BHE Wells

The advancements in drilling technologies for Borehole Heat Exchanger (BHE) systems, new drilling methods, advanced materials, and digital technologies are improving and revolutionized the future of geothermal energy sector, making it more efficiently, cost-effectively, sustainable and environmentally friendly.

a. Sonic Drilling

Sonic drilling is an improved technique of the drilling process, with higher efficiency than traditional methods. The sonic drill bit vibrates at high speeds for faster penetration through rock massif, reducing the drilling time and BHE installations costs. Compared to traditional methods, sonic drilling causes lower interference to the surrounding geological formations reducing the possibility of creating thermal short circuits, which can affect the low-performance of heat exchanging BHE systems, and improved hole stability. [14]

b. Directional Drilling

Directional drilling is used in geothermal systems to optimize the efficiency of heat exchanging BHE systems, drilling boreholes at an angle, rather than strictly vertical. In this way, directional drilling provides a better placement of the borehole in areas with complicated geological structures.[15]

c. Hydrothermal-Assisted Drilling

Hydrothermal-assisted drilling is an innovative technique used primarily in hard rock formations, injecting water or steam, reducting friction and assists in breaking up rock, increasing the penetration rate and reduced wear on drilling equipment. This results in cost-effectivity and overall sustainability of geothermal systems. [16]

2.4 Innovations in Drilling Materials and Equipment

- High-Performance Drill Bits and Casing Materials

The use of advanced casing materials, such as tungsten carbide drill bits and corrosion-resistant casing, and drilling equipment has improved the performance of BHE wells, as well as longevity of BHE installations. These materials improve heat transfer from the surrounding rock to the BHE pipe and making the BHE systems more durable and resilient. [18]

- Smart Drilling Systems with Real-Time Monitoring

These systems provide real-time data (such as temperature, pressure and rock type) about the drilling process, minimizing the limitations of traditional drilling methods (thermal short circuits or groundwater interference) and improving precision of future drilling operations. [18]

2.5 Automation and Digitalization in Drilling

- AI-Driven Drilling Optimization

Artificial intelligence (AI) algorithms, automation, sensors into the drilling process by analyzing data from sensors, past drilling processes and geological models, are being used to increase efficiency and reduce BHE installation costs. [18]

- Sensors and Remote Monitoring for Better Control and Efficiency

Sensors provide data, such as ground temperature, moisture levels, and pressure conditions in real-time during drilling allowing for faster and more accurate decision-making. [18]

3. RESULTS AND DISCUSSION

3.1 Challenges in Implementing Advanced Drilling Technologies in Albania [19]

Despite the significant advancements in drilling technology for Borehole Heat Exchanger (BHE) wells, Albania faces multiple challenges in adopting these innovations.

3.1.1 Geological and Environmental Complexity

a. Variability in Soil and Rock Formations Affecting Drilling Efficiency

• Unstability of several formations increase the risk of borehole collapse, requiring additional casing and stabilization methods.

• Hard rock formations (e.g., limestone and granite), delay the drilling process and increase costs of drilling equipments and materials.

• The groundwater layers in some regions, complicate borehole design, requiring specialized techniques to prevent contamination.

b. Environmental Concerns and Regulatory Limitations

• The risk of groundwater contamination by drilling fluid requires rigorous environmental monitoring.

• Drilling BHE wells near protected natural areas may be limited by conservation laws.

• Albania's environmental regulations regarding geothermal energy are still in development, causing uncertainties in project approvals and delays in permitting processes.

• The high initial investment for advanced drilling rigs and thermally enhanced grouts causes high cost of BHE installations.

• Importing modern drilling equipment due to the lack of local production increases logistical costs and delays.

• Small-scale projects may have financial difficulties to adopt the advanced drilling techniques without government subsidies or incentives.

b. Need for Skilled Workforce and Training

• The lack of trained drilling staff leads to the demand for foreign experts, thus increasing costs.

• The lack of professional or university training programs on geothermal energy creates a shortage of local expertis.

• Low involvement of the private sector as a result of the lack of return on investiment and the absence of market support.

3.2 Future Prospects and Recommendations

The advancement in drilling technologies for BHE systems in Albania, depends firstly on the adoption of innovative drilling technologies and secondary on supportive government policies to asures high-efficiency, cost-effectivity and friendly impact with the environment. [20]

Albania is well-positioned to adopt innovative drilling techniques, such as sonic drilling, directional drilling, and hydrothermal-assisted drilling owing to its geological diversity. Kruja, Ardenica and Peshkopia are areas with high geothermal potential, [19,21] and advanced drilling methods can provide efficiency of the BHE systems, reduce operational costs and drilling time (Frasheri et al., 2004):

- Ardenice-water has temperature between 35-40°C
- Kruja region-springs of Llixha Elbasan with temperature 55-68°C
- Peshkopi-water has a temperature between 43-45°C withflow of 14 liters/second.

The main geothermal springs and "geothermal wells" of Albania and some technical data on them are presented in Tabele 1 and 2. [19]

Tabele -1: Geothermal springs of Albania [19]

N°of Springs	Location	Temperature in °C	Salt in mg/l	Artesian Spring yield in $l.sec^{-1}$
1	Llixha Elbasan	60	6.3	15-18
2	Peshkopi	5-43	4.2	23
3	Lëngarica-Permet	6-31	1.65	>10
4	Sarandoporo-Leskovik	26.7	1.2	>10
5	Tervoll-Gramsh	24	2.5	>10
6	Mamurras-Tirana	21	5.4	>10
7	Steam Postenani springs			

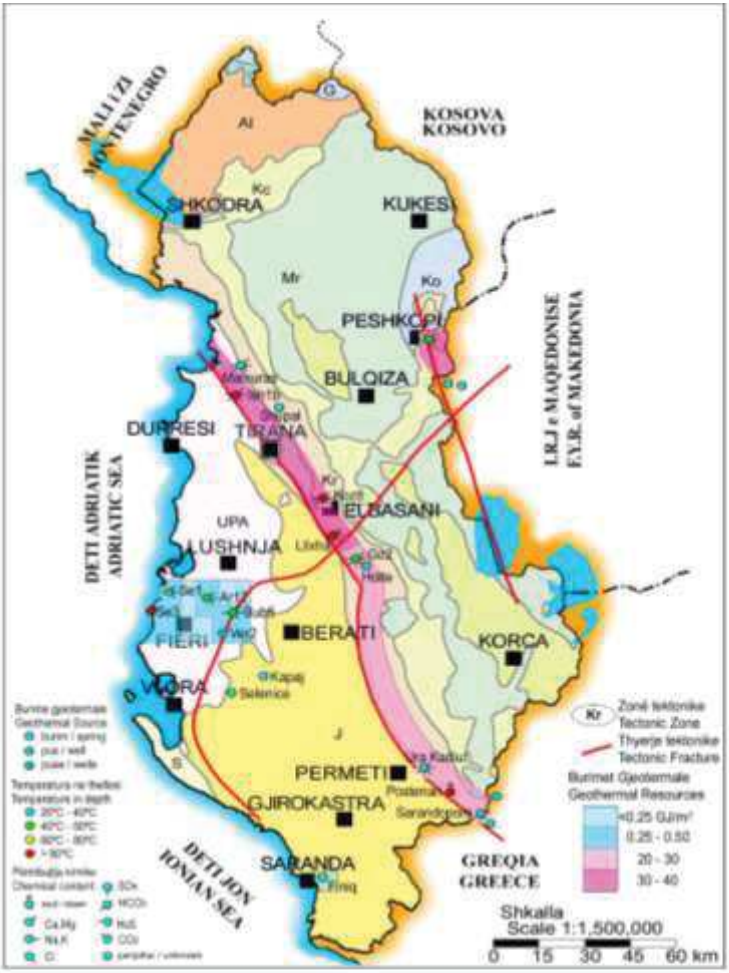

Figure 1: Geothermal map of Albania [19]

Tabele -2: Geothermal wells of Albania [19]

N°of Wells	Well Name	Temperature in °C	Salt in mg/l	Self- discharge in $l.sec^{-1}$
1	Kozani	65.5	4.6	10.4
2	Ishmi	64	15	4.4
3	Shupal- Tirana	29.5	1.6	1.6
4	Galigati	45-50	5.7	0.9
5	Bubullima	48-50	35	
6	Ardenica 3	38	38.2	15-18
7	Ardenica 12	32	53.6	5-18
8	Semani 1	35		5

	Semani 3	67	20.7	30
9	Verbasi	29.3	8.2	1-3

The experience from similar regions like Iceland, Belgium and Italy, which realise successful geothermal drilling projects by using these advanced techniques, shows that modern drilling technologies are more reliable, cost-effective and sustainable geothermal energy production, regardless of initial higher costs. [22]

3.2.1 Emerging Trends in Drilling Technology for BHE Wells [23, 24, 25]

a. Advanced Drilling Techniques

- The use of faster and more efficient drilling methods can reduce costs and energy consumption for the installation of BHE systems. Advanced automated and robotic drilling systems are increasing precision and reducing the need for labor.

b. Improved Thermal Conductivity Materials

- Thermally enhanced materials such as graphene, carbon nanotubes, and phase change materials (PCMs) are delivering highly satisfactory result in heat transfer. Composite casing materials with high-performance can increase the lifespan of BHE wells, while simultaneously reducing maintenance costs.

c. Smart Monitoring and AI Integration

- Real-time data collection through IoT sensors leads to the optimization of borehole performance. The use of artificial intelligence (AI) is advancing the modeling of underground heat transfer, increasing the overall efficiency of the system.

3.2.2 Policy Recommendations for Fostering Innovation in Albania [23, 24, 25]

a. Creating a Regulatory Framework for BHE Systems

- The Albanian state and government should develop policies for the installation, licensing, and overall operation of BHE systems. The creation and implementation of streamlined approval processes would create favorable conditions for investors to fund geothermal heating and cooling projects.

b. Financial Incentives and Subsidies

- The possibility of tax relief, subsidies, or low-interest loans for these geothermal projects would make them a more accessible model for households and businesses. The establishment of a national geothermal energy fund would serve as a catalyst for geothermal pilot projects.

c. Expanding Education and Workforce Training

- The development of technical and specialized programs in geothermal energy and advanced drilling technologies by universities and vocational schools. Government cooperation with international geothermal energy specialists could be an opportunity to build local expertise.

3.2.3 Potential for International Collaboration and Investment in the Sector [23, 24, 25]

a. Attracting Foreign Direct Investment (FDI)

- Albania's collaboration with European geothermal energy companies would provide an opportunity to adopt advanced drilling methods. Participation in specific EU programs related to renewable energy could create conditions for securing grants and technical support for BHE projects.

b. Research and Development Partnerships

- Establishing connections between research institutions and universities could drive the adoption of advanced methods and materials used in drilling. Albania's cooperation and participation in regional geothermal projects would position it as a leader in the development of this technology in the Balkans.

c. Public-Private Partnerships (PPPs)

- Supporting the private sector through PPP models would lead to a broader expansion of BHE projects in both urban and industrial areas. The interaction between the Albanian state and energy and technology companies would be a great opportunity to integrate BHE technology into heating and cooling systems.

4. CONCLUSIONS

This paper provided an overview of the advancements in Borehole Heat Exchanger (BHE well drilling technology in Albania, highlighting innovations, challenges, barriers, and future opportunities. Advanced BHE drilling technologies, such as rotary, sonic, and directional drilling, are improving project performance, efficiency, and overall costs. High-conductivity materials, such as thermally enhanced grouts and high-performance casings, have resulted in greater heat transfer efficiency while ensuring better maintenance and longer system lifespan. Automated systems and the use of artificial intelligence enhance drilling precision and increase overall system efficiency. Heterogeneous geological formations, high initial costs, and the lack of specialized personnel in Albania pose significant challenges to the adoption of these advanced BHE technologies. Although Albania has considerable geothermal potential, its full utilization remains dependent on government support, financial funding, infrastructure investments, establishment of training programs and international collaborations and partnerships. By supporting new techniques and establishing a favorable regulatory environment, Albania has the potential to become a strategic hub in the Balkans for adopting more sustainable and advanced alternatives for heating and cooling systems, reduce dependence on imported fuels, and leverage its own geothermal potential.

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ECONOMIC ANALYSIS OF WIND INTEGRATION FOR TEC VLORE SH.A'S ENERGY SYSTEM: A HOMER PRO SIMULATION

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ABSTRACT

This study examines the possibility of integrating 800 kW of wind energy into the TEC Vlora sh.a. system in Vlorë, Albania, using HOMER Pro software for modeling and optimization. The results show that incorporating wind energy significantly reduces the plant's dependency on electricity imports, lowers operational costs, and improves energy security. The combined wind and grid configuration achieves a renewable energy penetration of 74.1%, resulting in a Net Present Value (NPV) of €2.9 million, a Return on Investment (ROI) of 116.2%, and an Internal Rate of Return (IRR) of 121%. The system pays for itself in less than a year, making it a cost-effective solution for sustainable electricity production. The study highlights the potential of wind energy to improve the reliability of Albania's energy system and reduce dependence on current traditional sources.
Keywords: Wind Power, HOMER Pro, Return on Investment (ROI), Energy System Simulation, Net Present Value (NPV)

1. INTRODUCTION

The TEC Vlore (Vlora Thermal Power Plant), located in Vlora, Albania, is a 97 MW power station constructed in 2011. Despite its intended role as a significant contributor to Albania’s energy supply, the plant has remained non-operational due to various technical and environmental challenges. A critical defect in the cooling system [1], essential for initiating the steam turbine, has prevented its operation. Consequently, TEC Vlore currently functions solely as a consumer of electric energy, incurring annual operational costs of about €280,868. The plant is connected to the 20 kV distribution system, purchasing electricity from the national grid.

Albania's energy sector predominantly relies on hydropower, making it highly susceptible to seasonal fluctuations. During periods of low rainfall, hydropower generation diminishes, necessitating electricity imports to meet domestic demand. In 2022, Albania produced 7,002 GWh of electricity but consumed 7,924 GWh, requiring the importation of 922 GWh to bridge the gap [6]. This dependency on external energy sources affects energy security, increases operational costs, and reduces overall system resilience.

Renewable energy diversification is critical to address these challenges. Hybrid Renewable Energy Systems (HRES), which integrate wind energy with other sources such as solar, hydro, and biomass, have been widely studied. Research highlights the effectiveness of hybrid systems in optimizing energy supply, reducing costs, mitigating environmental impacts, and enhancing system reliability [7,2,13]. Due to TEC Vlore's favorable geographic position, in front of the Adriatic Sea, wind energy presents a promising solution. The coastal areas experience consistent sea breezes, making wind power a reliable and sustainable energy source.

This study evaluates, how wind energy can transition the plant from a passive energy consumer to a more self-sufficient and cost-effective system. The primary objective is to assess the feasibility of incorporating 800 kW of wind energy into TEC Vlore's energy system. The wind turbine can operate in grid-tied and off-grid modes, lowering electricity costs, and improving energy security [16]. By leveraging HOMER Pro software, the study uses hourly energy consumption data to model and estimate economic feasibility. HOMER Pro also enables sensitivity analysis, allowing variations in key parameters—such as wind speed and energy demand—to determine their impact on system efficiency and feasibility [4,5,8,14,].

The findings of this study aim to provide a strategic framework for TEC Vlore, demonstrating how wind energy integration can enhance energy independence and serve as a model for similar industrial-scale renewable energy transitions in Albania.

2. Literature Review

The integration of renewable energy sources into conventional power systems has been widely studied. Several research works highlight the economic and environmental benefits of wind energy adoption [10,12]. Previous studies [8,12,14] have demonstrated that wind power reduces dependency on fossil fuels, mitigates greenhouse gas emissions, and leads to long-term cost savings. HOMER Pro, a leading microgrid simulation tool, has been extensively used in similar studies to optimize renewable energy deployment [3,9]. This section synthesizes relevant literature on wind energy integration and its economic implications.

3. Case Study: TEC Vlore Wind Energy Integration

3.1 Methodology

To evaluate the feasibility of integrating wind energy into TEC Vlore's system, we utilized HOMER Pro software, a widely used optimization tool for modeling hybrid energy systems. HOMER Pro allows for the simulation of various system configurations and optimization based on technical, economic, and environmental factors.

3.2 Data inputs:

3.2.1Wind energy data

According to the NASA database (NASA, 2020) [11], the average monthly wind speed of the selected location for 30 years calculated at 50 m over the earth's surface is 5.04 m/s.

Figure 1. The average monthly wind speed

The wind speed ranges from 4.18 to 5.91 m/s, with the maximum wind speed observed in November. Several other months, including January, February, March, and December, exhibit similar values. The annual average wind speed was calculated to be 5.04 m/s.

3.2.2 TEC Vlore consumption data

The hourly data for electricity consumption was obtained from the Vlora Thermal Power Plant, the annual consumption (in kWh) and the electricity price per kWh were provided by the Electricity Distribution Operator (OSHEE).

Based on their data, the annual energy sold in 2024 was 1,233,541 kWh. The annual electricity consumption cost was 18.34 ALL/kWh; 0.19 €/kWh, excluding VAT, including all transmission and distribution costs up to the metering point, while the sell-back price for excess energy is €0.1/kWh. We have the daily profile and yearly profile respectively in Figure 2. (a, b).

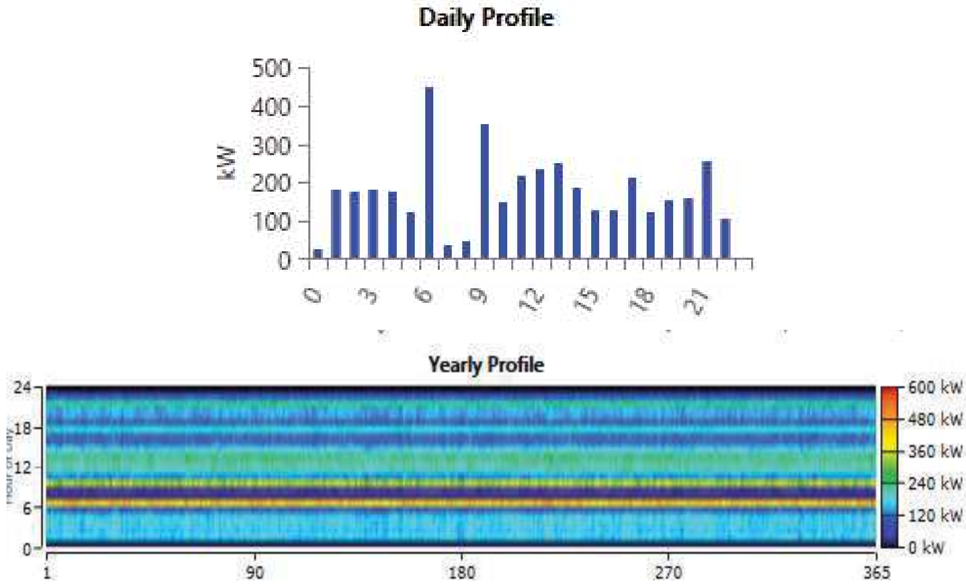

Fig.2. Energy consumption data from the TEC Vlore.

3.2.3 System configuration

The integration of wind energy into the TEC Vlore energy system is explored, focusing on the findings that the Karaburun Peninsula experiences stronger winds during the winter months, providing a reliable source of renewable energy that could significantly contribute to Albania's energy detailed assessment [15]. Their study analyzed wind profile characteristics, including wind speed, direction, and seasonal variability, and evaluated the potential for electricity generation using various turbine configurations. The most suitable

wind turbine was the E48, which has a hub height of 50m and a rotor diameter of 48m, achieving the highest capacity factor, ranging from 21.71% to 33.44%. The average wind power output ranged between 218.33 kW and 668.95 kW. We modeled a grid-tied system with 800 kW of wind turbine capacity, including a turbine cost of €200,000 (capital and replacement), and an O&M cost of €20,000 annually with a lifetime of 20 years.
Building on this foundational work, HOMER Pro [9] models and assesses the impact of integrating 800 kW of wind capacity into the TEC Vlore system. The configuration of the system is given in Figure nr.3

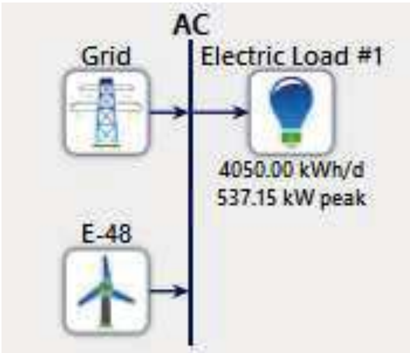

Fig. 3 The design of the hybrid system

3.2.4 HOMER Pro simulations:

The system configuration was modeled to assess the integration of 800 kW of wind energy into TEC Vlore's energy system. Sensitivity analysis was conducted to evaluate how variations in key parameters (e.g., wind speed, energy consumption) affect the system's performance [8].
Figure 3 presents the grid design. We have chosen a random variability of 5% on HOMER Pro to predict the wind speed fluctuation [10] around the average 4046 kW/day and peak load 536.62 kW during the day and between days, improving the accuracy of system performance estimates.

3.2.5 Results and Discussion

The HOMER Pro simulations indicated that incorporating 800 kW of wind energy into the TEC Vlore system could significantly reduce the plant's dependency on electricity imports. The optimized system configuration, which included the 800-kW wind turbine, demonstrated the following outcomes in Table 1.

Table 1. Economic and operational metrics for wind + grid vs. grid-only system

Metrics	Scenario 1 (Wind Turbine-Grid configuration)	Scenario 2 (Grid Configuration)
Net Present Cost, NPC (€)	€720,131	€3.63M
Levelized Cost of Energy, LCOE (€/kW)	€0,0291	€0.19
Renewable energy penetration (%)	74,1	0
Operation cost (€/yr)	€40,653	€280,867
Capital Expenditure, CAPEX (€)	€200,000	0
Energy Purchased (kWh)	653,034	1,478,250
Energy Sold (kWh)	1,059,947	0

NPC represents the total lifecycle cost (capital, replacement, O&M, and salvage) discounted to present value.
Scenario 1 is about 80% cheaper over the project lifetime, showing that integrating wind significantly reduces long-term costs.
The levelized cost of Energy (**LCOE**) represents the cost per unit of electricity generated over the system's lifetime. Scenario 1: €0.0291/kWh; Scenario 2: €0.19/kWh. Wind integration reduces energy costs by over 84%, making it a highly cost-effective solution. Scenario 1 uses wind energy for **74.1%** of its total consumption, drastically reducing dependence on grid electricity. The penetration of the wind energy is displayed in Figure 4. Scenario 2 relies entirely on grid power, leading to higher costs and no renewable contribution.

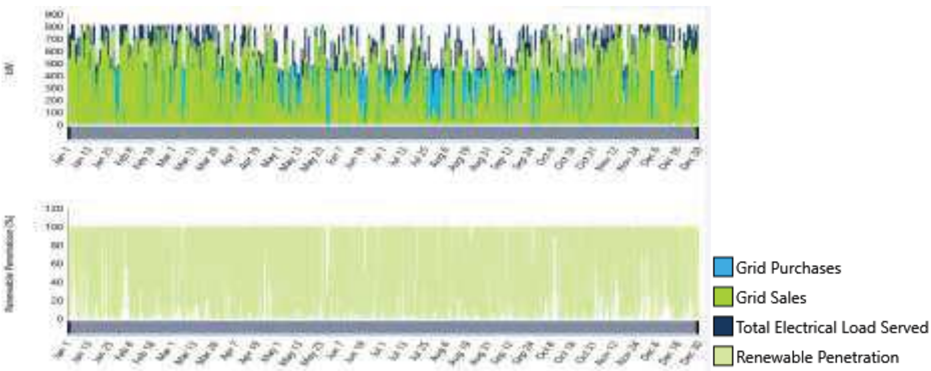

Figure 4. The Wind Penetration in the configuration proposed

The grid-only has 7x higher operational costs, largely due to the cost of purchasing electricity. Scenario 1 significantly reduces operational expenses, leading to long-term savings. **Capital Expenditure (CAPEX),** scenario 1 requires an initial investment for the wind turbine but saves substantial costs in the long run meanwhile, scenario 2 avoids CAPEX but incurs much higher operating costs over time. Wind Turbine-Grid configuration produces surplus wind energy and sells over 1 million kWh to the grid, potentially generating revenue. Grid-only does not generate or sell electricity if it will go on to stay under no-operation conditions. The graph below explains in detail for every month energy purchased (kWh) and Energy sold (kWh) during the year.

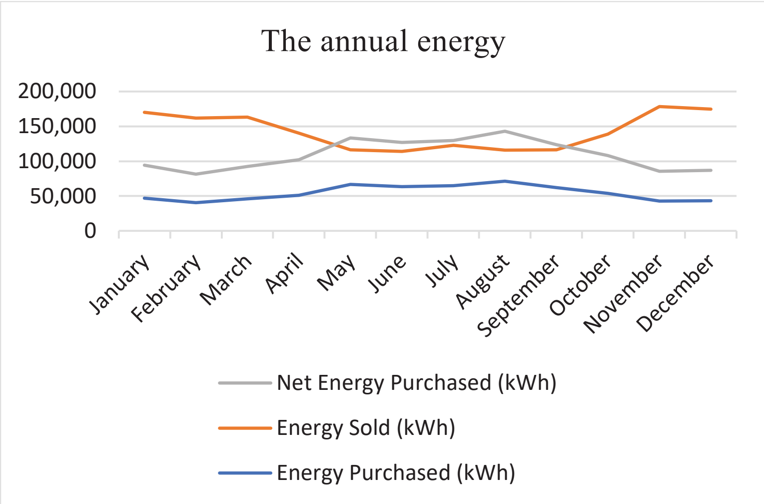

Fig. 5. The Annual energy in the grid.

Key performance metrics such as Net Present Value (NPV), Return on Investment (ROI), Internal Rate of Return (IRR), and payback periods are displayed in Table 2.

Table 2. Financial performance metrics for wind + grid configuration

NPV, (Present Value) (€)	€2,905,374
ROI, (Return on Investment) (%)	116.2
IRR, (Internal rate of return) (%)	121
Payback of period (yr)	0.83
Discount payback (yr)	0.87
Operating cost	€40,234

The project shows a very high NPV of €2.9 million; a substantial ROI of 116.2%; and An IRR of 121% indicating that is expected to generate exceptionally strong profits compared to typical investment opportunities. Operating costs are relatively low, enhancing profitability.
Payback period -0.83 approximately 10 months; Discount Payback -0.87 (approximately 10.5 months) highlights that the system will recover its initial investment in under one year, with the payback achieved through cost savings and revenue generation. In less than a year, the system essentially "pays for itself," demonstrating its high efficiency and strong appeal as an investment

4. CONCLUSION

This study demonstrates the economic, operational, and environmental benefits of integrating wind energy into TEC Vlore's energy system. The 800-kW wind turbine, TEC Vlore can significantly reduce its reliance on electricity imports, lower operational costs, and contribute to Albania's energy transition. The analysis confirms that wind energy is a cost-effective and sustainable alternative to conventional grid dependence, offering enhanced energy security and economic resilience.
From a financial perspective, the wind + grid system proves to be highly advantageous, with a Net Present Value (NPV) of €2.9 million, a Return on Investment (ROI) of 116.2%, and an Internal Rate of Return (IRR) of 121%. Additionally, the system achieves a payback period of just 0.83 years, reinforcing its financial viability. With low annual operating costs (€40,234) and a renewable energy penetration of 74.1%, this configuration outperforms a grid-only alternative.
Given these promising results, further studies are recommended to refine system design, explore complementary renewable energy sources, and evaluate long-term financial feasibility under various market conditions. TEC Vlore and Albania can take a significant step toward a more sustainable, cost-efficient, and resilient future by adopting wind energy.

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ELECTRICITY COST OF SOLAR PHOTOVOLTAICS, FACTORS INFLUENCING THE OPTIMAL FUNCTIONING OF THE PV SYSTEM. CASE OF STUDY NATIONAL PARK OF THETH, ALBANIA

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ABSTRACT

Energy from PV systems throughout Albania has started the last two years with a strong trend, especially after the government's incentives to support consumers and small businesses, especially in the tourism sector, since it is one of the key sectors for economic development. In this study, the situation for the application of on grid PV systems in the area of National Park of Theth, very attractive to all year tourisms, has been examined. The climate situation, and the various installations, on grid fixed and tracking system have been examined in detail. The performance of different PV installations is evaluated. Cost of electricity production is calculated as an indicator to evaluate the ratio between different systems, tracking system, vertical axis, inclined and two axes. The results show the best performance for two axis PV system. Difference in electricity cost eur/ (kWh) for PV on grid building integrated varies around 32% difference variation with slope angle, in higher altitude of selected location, cost of PV production is 18.1% higher compared to other potential solar areas, making it less attractive for large scale installed PV from investors. The cost in kWh for different technologies of PV systems on grid varies 0.061 eur/ kWh to 0.105 eur/ kWh, But on the other hand, compensating for the network switch, the low voltage problems of the main network, in the residential aspect, make it applicable for residential and small businesses, it is a fully justified investment.
Keywords— Photovoltaics systems; on grid PV systems; tracking system; vertical axis; inclined and two axes system; cost of electricity production

INTRODUCTION

The main source of energy in Albania comes from hydropower, but network problems are accumulated and losses exceed the value of 20% of production [1]. The development of winter tourism in Albania's mountainous areas, the part of the Alps, is one of the factors of economic growth in the areas, the tourism has increased in the past years. [2]. Power outages in Theth national park are very problematic, especially starting in October and till the end of spring season. In this study, is suggested the application of small photovoltaic implants in order to reduce the energy bill and the problem of lack of energy due to insulation of the area and as a cause of damaged network. The main goal is to present the climatic potential of this mountainous area with low average temperatures throughout the year, and evaluate the energy produced by photovoltaics. The Transmission System Operator of Albania (TSO) reported that the impact of renewable energy sources on the overall grid is not small, with capacity expected to increase significantly in the next years. According to the TSO document, in the end of 2023 the installed capacity is expected to reach 220 MW, an increase of almost 10 times compared to 2022 total capacity. Based on the market requirements, it is predicted that the connection capacities of wind and photovoltaic plants in the transmission network will reach by the end of 2023 more than 220.4 MW. In Albania only at the end of 2022, 291 businesses had connected to the network with photovoltaic small installations, under the pressure of the increase in the price of energy in the energy market from the main network [3].

There are many unexplored areas in Europe, especially in mountainous coordinates for potential of solar energy. A map for sustainability of solar power generation in Europe has been developed by comparing specific levelized cost of energy (LCOE) but with the conclusion that there are still unexplored areas, in terms of potential of radiation for PV system implementation within economic criteria [4]. According to another study, it is estimated that at least 25% of electricity production can come from photovoltaics, and currently this value in Europe stands at 5% [5]. Currently, the possibility of increasing the percentage of energy from PV is a combination of climatic conditions, investment costs, energy tariffs, appropriate legislation, and government incentives undertaken and supported. "Feed in tariffs" schemes for renewable energies should be widely implemented, and schemes where energy compensation is established by law. PV systems are specific suitable in countries when it combines government incentives, tariffs, initial investments and solar radiation. Photovoltaic systems together with storage systems can facilitate the network and this is an ideal solution especially for remote areas where network penetration is difficult. Photovoltaic systems are guaranteed by the manufacturers, their lifetime is up to 25 years [6, 7]. Is estimated up to 30% more electricity for double axis system compared to a fixed PV system. On the other hand, the optimal angle of the installation brings greater total annual energy compared to other cases, but the variation of the angle in some months results on greater energy, that is different from optimal yearly angle [8]. In general, many studies suggest areas where the solar potential is abundant, populated places close to the main grid [9]. The purpose of the study is to evaluate the performance of photovoltaic systems in the National Park in Albania, with the special climatic situation and on the other hand the unfavourable network energy conditions, to evaluate different types of installations and the change in cost per kWh for each selected type of photovoltaic systems. For different utility PV system is calculated the specific energy and cost for the selected location. Type of selected sun tracking systems PV in the study are chosen fixed system, vertical one and two axis system. The economic benefit in terms of PV electricity cost per kWh has been calculated. The comparison of configurations has been developed for the same size of selected system, 1 kWp. The total cost of the system in accordance with the study of market prices was set in an interval of minimum and maximum values including operation and maintenance costs.

METHOD OF STUDY

PVGIS tool

The detailed study of photovoltaic systems in terms of design, production output, and economic parameters can be developed with different simulations software, or with simulation methods according to the appropriate models. Their detailed accuracy can be realized by comparison with the data of the installed PV system [10]. In order to evaluate the electricity and other parameters is used PVGIS tool, Geographical Information System supported from European Commission and Joint Research Centre (JRC). PVGIS tools is a simulation tool and many studies have been referred to, drawing results in different aspects, the comparison of terrestrial and satellite measurements from the database of PVGIS. In the study, the database of SARAH 2 was chosen, the hourly values for global horizontal (W/m2) are compared and validated with ground measurements from a set of select ground measurements from BSRN [Baseline Surface Radiation Network]. The estimation model in PVGIS is anisotropic of two components. PVGIS calculates the cost of electricity for on-grid PV systems. Parameters in calculations to be taken into account are the cost of investments including the purchase of the product, installation, maintenance and financing, the comparison is made with the lifetime of the system, in the last systems it is suggested from fabrication to 25 years. Different comparative studies for the accuracy of the calculation and simulation data conclude that this tool is very scientific [11], [12], [13], [14]. In this study on grid PV system are considered. The data are obtained from geostationary satellites – METEOSAT [15]. This data covers the measured period from 2005 to 2020. PVGIS 5 also provides the solar radiation data on optimally inclined surfaces using the model described in this article.

Input data

The calculations in this work have been performed for on-grid photovoltaic systems, in accordance with the study of demand/offer in the photovoltaic market in Albania, increasing installed power of such systems in the private residential sector, as well as small business. Off-grid systems are not included for the main reason of the increased cost of batteries and their reduced life cycle, increasing the total cost of the system. The parameters of the configuration system with PVGIS include hourly, monthly and annual solar radiation data, averaged values of a typical year for the sun and wind. The geography of the selected position can be analyzed by identifying the exact coordinates. PVGIS uses data from the PVGIS-SARAH2 database selected for this study. For calculations and simulations, several types of module production have been chosen, crystalline silicon, CIS, CdTe. Installed power of photovoltaics is 1kWp, system losses in the value of 14% as a default in the inputs. For mounting position of the PV, fixed system, free standing system, buildings integrated are selected in the study. Slope of PV module is the fixed angle from horizontal plane. As inputs for calculations are:

a. One-axis tracking sun system.

b. Two-axes with modules to degrees of freedom for the rotation.

The result from PVGIS gives yearly values of energy production, and their parameters from simulations.

Cost Calculation for the PV rezidential project.

Levelized cost of electricity (*LCOE*) or levelized cost of energy is a measure in financial economy to compare different sources of energy in terms energy production, as the total cost of all included system (fabrication, installation, oparation) per unit of total amount of the life time expentancy. It can compare different projects of the same technology or different systems sources, wind, solar, etc. Discount rate is a specific economic criteria in evolution yearly in the criteria of *LCOE* exact calculation and reflect the risk for each project. Discount Rate r is an important indicator in the evolution of the cost of the system; it indicates the profitability of the total investment. In the discount rate calculations it will be a constant parameter, in fact in reality it depends on capital, taxes etc., for the purpose of the study, this economic parameter was not detailed. In the calculations the total cost of the PV system, include cost of the total PV components for installation, and include the operation and maintenance cost. In this study, some economic parameters were taken into consideration in the calculation of the cost of photovoltaic production, but the parameters that have variability in time are not included, so we will refer to it as production cost in eur/kWh and not LCOE, to be correct with the results.

RESULTS

Grid connected PV system performance in Theth's National Park.

Since the purpose of the study is to enable the installation of on-grid systems in residences and small tourist businesses in the area, the part of battery storage systems has not been discussed, which is specific and requires a different treatment due to the increase in system costs. With storage and battery life of about 5 years. For which the cost of the system increases, the payback years, and thus the LCOE.

PVGIS tool is intended for researching on solar radiation, solar performance system, PV production on basis on hourly, monthly and yearly data. Different system mounting of photovoltaics can be analyzed in terms of radiation data, temperature, energy production, variability year to year, and realize simulations for different configurations systems. Specifically for different type on grid PV system is calculated specifically yearly energy produced; size of the system was 1kWp as unit for the comparisons of results. It is important to understand this unit correctly, as the power produced by PV under standard conditions; the corresponding temperature is 25C, system loss 14%. In the table 1 are summarized the input from PVGIS.

TABLE I. PROVIDED INPUTS IN PVGIS

Latitude/Longitude	42.389,19.782
Horizon	Calculated
Database used	PVGIS-SARAH2
PV technology	Crystalline silicon/ CIS
PV installed	1kWp
System loss	14%

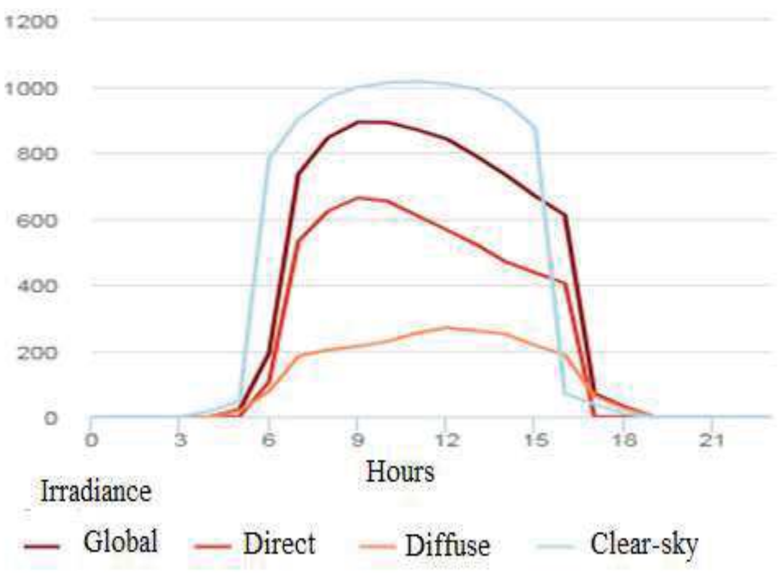

Fig. 1. Daily average irradiance [kW/m^2] on fixed plane with slope 35° and azimuth 0°

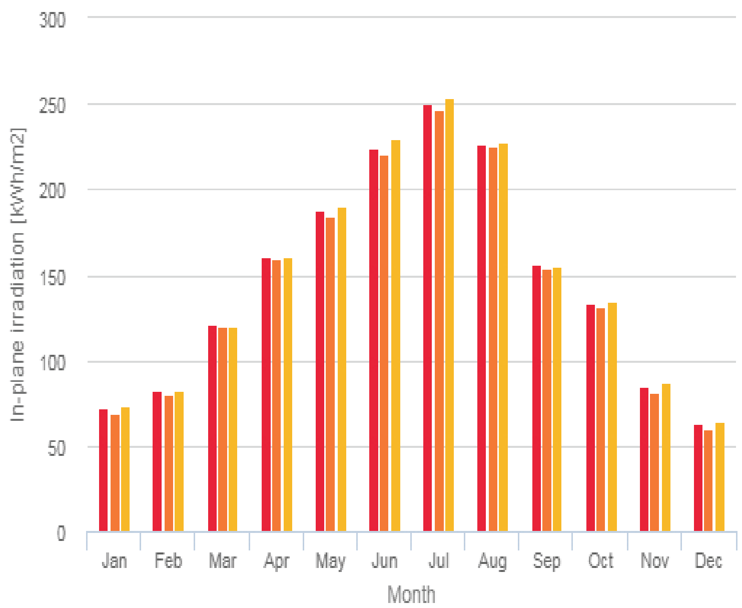

Fig. 2. In plane irradiation for three types, vertical axis, inclined axis, two axis

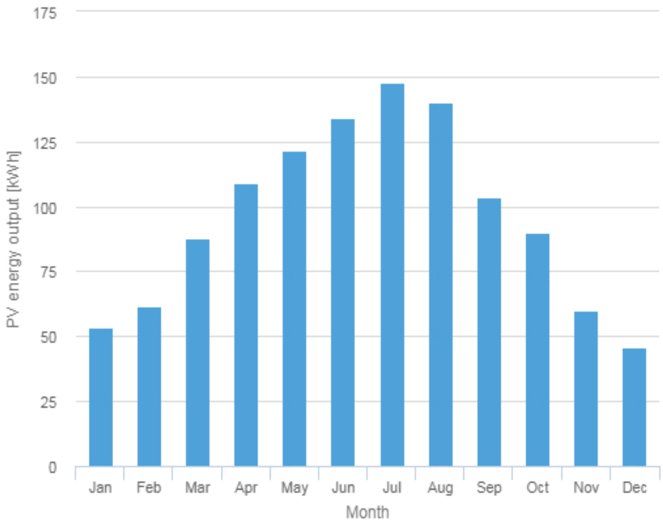

Fig. 3. Monthly energy output, on grid PV

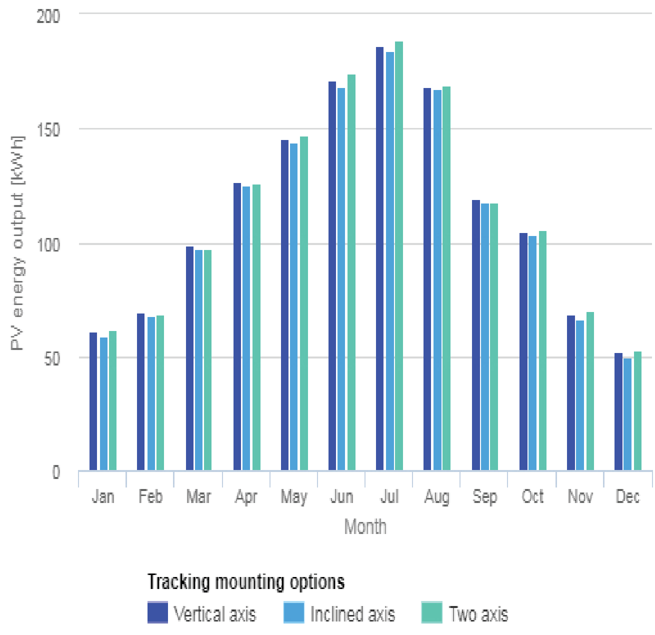

Fig. 4. PV output in vertical axis, inclined axis, two axis system

TABLE II. RESULTS OF SIMULATIONS, PERFORMANCE OF THE TRACKING PV SYSTEM

Type of tracking system	**Vertical Axis, Si**	**Inclined Axis, Si**	**Two Axis, Si**	**Vertical Axis, CIS**	**Inclined Axis CIS**	**Two Axis CIS**	**Vertical Axis, CdTe**	**Inclined Axis CdTe**	**Two Axis CdTe**
Slope Angle (^{0}) (opt)	35	45	---	50	35	---	45	35	---
Yearly PV energy production [kWh]:	1373.11	1349.53	1380.25	1534.9	1528.53	1563.12	1398.43	1376.11	1409.49
Yearly in-plane irradiation [kWh/m²]:	1762.83	1732.7	1777.1	1952.32	1944.2	1993.88	1762.86	1732.7	1777.1
Year-to-year variability [kWh]:	73.9	73.2	76.0	83.6	83.2	85.9	78.4	77.6	80.4
Angle of incidence [%],	-1.75	-1.73	-1.66	-1.65	-1.66	-1.59	-1.74	-1.73	-1.66
Spectral effects [%]:	0.96	0.95	0.96	----	----	----	1.51	1.51	1.51
Temp. and low irradiance [%]:	-8.69	-8.71	-9.03	-7.05	-7.07	-7.37	-7.52	-7.43	-7.61
Total Loss [%]	-22.11	-22.11	-22.33	-21.38	-21.38	-21.6	-20.67	-20.58	-20.69

TABLE III. SIMULATION OUTPUT FROM FIX-ANGLE PV SYSTEM (BUILDING INTEGRATED)

Slope Angle	**10°**	**20°**	**30^0**	**40°**	**50°**	**60°**	**70°**	**80°**	**90°**
Azimuth Angle	-17(opt)	-17(opt)	-17(opt)	-17(opt)	-17 (opt)	-17(opt)	-17(opt)	-17 (opt)	-17(opt)
Yearly energy production [kWh]	1093.81	1203.51	1154.31	1217.99	1186.93	1130.57	1048.93	942.79	813.19
Yearly in-plane irradiation [kWh/m²]	1447.5	1562.64	1535.22	1584.06	1542.71	1466	1356.47	1218.68	1056
Year-to-year variability [kWh]	49.69	58.08	56.69	63.27	63.71	62.41	59.56	55.15	49.34
Angle of incidence [%],	-2.65	-2.75	-2.37	-2.54	-2.61	-2.78	-3.12	-3.78	-4.88
Spectral effects [%]	0.92	0.95	0.98	1.01	1.04	1.07	1.1	1.14	1.19
Temp. and low irradiance [%]	-10.57	-8.78	-11.32	-9.18	-9.08	-8.74	-8.21	-7.57	-6.97
Total Loss [%]	-24.43	-22.98	-24.81	-23.11	-23.06	-22.88	-22.68	-22.64	-22.99
PV electricity (kWh) Min cost Instalation	0.066-0.082	0.063-0.079	0.064-0.078	0.065-0.078	0.066-0.081	0.070-0.085	0.075-0.091	0.084-0.102	0.098-0.118

PV electricity (kWh) Max cost Instalation	0.097-0.116	0.093-0.112	0.092-0.110	0.092-0.111	0.095-0.114	0.100-0.120	0.108-0.129	0.120-0.144	0.139-0.167

From the results for the three PV technologies, crystalline silicon, CIS, CdTe, the highest performance is for CIS modules, and for two axes tracking system. The market price of this technology is above the average price, so the cost of production of PV system also increases.

Solar potential is considered sufficient for energy use to be greater than a minimum of 1100kWh · m^{-2} per year. The lowest radiation values correspond in the winter months, but the annual balance exceeds the lower limit of the minimum radiation criterion.

TABLE IV. SIMULATION OUTPUT FROM FIX-ANGLE PV SYSTEM (FREE STANDING)

Slope Angle	**10º**	**20º**	**30⁰**	**40º**	**50º**	**60º**	**70º**	**80º**	**90º**
Azimuth Angle	-15(opt)	-15(opt)	-15(opt)	-15(opt)	-15 (opt)	-15(opt)	-15(opt)	-15 (opt)	-17(opt)
Yearly energy production [kWh]	1137.08	1184.29	1204.76	1198.46	1165.59	1107.04	1023.13	914.82	783.96
Yearly in-plane irradiation [kWh/m²]	1447.5	1508.04	1535.22	1527.77	1485.52	1409.4	1302.75	1167.56	1008.91
Year-to-year variability [kWh]	52.49	57.03	60.16	61.80	61.92	60.47	57.42	52,84	46.94
Angle of incidence [%],	-2.65	-2.46	-2.37	-2.36	-2.44	-2.6	-2.99	-3.64	-4.74
Spectral effects [%]	0.92	0.95	0.98	1.00	1.03	1.06	1.09	1.13	1.19
Temp. and low irradiance [%]	-7.03	-7.26	-7.44	-7.51	-7.43	-7.21	-6.87	-6.51	-6.27
Total Loss [%]	-21.45	-21.47	-21.53	-21.55	1.03	-21.45	-21.46	-21.65	-22.3
PV electricity (kWh) Min	0.065-0.079	0.063-0.076	0.061-0.075	0.062-0.075	0.064-0.077	0.067-0.081	0.072-0.088	0.081-0.098	0.094-0.115
PV electricity (kWh) Max	0.093-0.112	0.089-0.107	0.088-0.105	0.088-0.106	0.091-0.109	0.096-0.115	0.103-0.124	0.116-0.139	0.116-0.139

TABLE V. FIX-ANGLE, (BUILDING INEGRATED) OPTIMAL OPTION, THETH

Slope Angle	**32º (*opt*)**
Azimuth Angle	-17 (opt)
Yearly PV energy production [kWh]:	1155
Yearly in-plane irradiation [kWh/m²]:	1536.63
Year-to-year variability [kWh]:	57.19
Angle of incidence [%],	-2.36
Spectral effects [%]:	0.98
Temp. and low irradiance [%]:	-11.36
Total Loss [%]	-23.13
PV electricity (kWh) Min	0.064
PV electricity (kWh) Max	0.110

TABLE VI. FIX-ANGLE PV SYSTEM (FREE STANDING) OPTIMAL OPTION, THETH

Slope Angle	**32º (*opt*)**
Azimuth Angle	-15 (opt)
Yearly PV energy production [kWh]:	1205.79
Yearly in-plane irradiation [kWh/m²]:	1536.74
Year-to-year variability [kWh]:	60.70
Angle of incidence [%],	-2.36
Spectral effects [%]:	0.98
Temp. and low irradiance [%]:	-7.47
Total Loss [%]	-21.54
PV electricity (kWh) Min	0.061
PV electricity (kWh) Max	0.105

TABLE VII. FIX-ANGLE PV SISTEM (BUILDING INEGRATED) OPTIMAL OPTION, FIER.

Slope Angle	**35º (*opt*)**
Azimuth Angle	0º (opt)
Yearly PV energy production [kWh]:	1417.56
Yearly in-plane irradiation [kWh/m²]:	1944.11
Year-to-year variability [kWh]:	54.74
Angle of incidence [%],	-2.65
Spectral effects [%]:	0.82
Temp. and low irradiance [%]:	-13.61
Total Loss [%]	-27.08
PV electricity (kWh) Min	0.060
PV electricity (kWh) Max	0.090

TABLE VIII. FIX-ANGLE PV SYSTEM (FREE STANDING) FIER.

Slope Angle	**35º (*opt*)**
Azimuth Angle	0º (opt)
Yearly PV energy production [kWh]:	1480.67
Yearly in-plane irradiation [kWh/m²]:	1944.11
Year-to-year variability [kWh]:	58.29
Angle of incidence [%],	-2.65
Spectral effects [%]:	0.82
Temp. and low irradiance [%]:	-9.77
Total Loss [%]	-23.84
PV electricity (kWh) Min	0.057
PV electricity (kWh) Max	0.086

Comparison has been made, with the same situation and input of values for the district of Fier, where the solar potential in this area has optimal values. From the results, yearly PV energy production in Fier of 1944.11kWh for the PV system (free standing), 20.96% more than the situation in Theth. Photovoltaic energy production is 18.53% more in Fier for the building integrated system and 18.7% more. Cost of PV is 18.1% higher for the mountainous area of Theth, this is estimated for the maximum cost of the initial investment according to today's market conditions in Albania.

CONCLUSION

According to the presented results, the output production potential of on grid PV systems, global solar in plane irradiation In Theth National Park (fixed Angle) (PVGIS tool) varies from 57.12kWh/m2 -206kWh/m2 compared with Fier District (optimal solar potential in Albania) 101.07kWh/m2 - 226.38kWh/m2 varies from 45.7kWh-154.44kWh (December-July) for Theth National Park, compared to Fier District 82.89 Wh-163.62kWh. PV electricity cost compared between two different climatic solar potential is 18.42% higher than in Theth location. From the simulation it results that two axes tracking PV is the best option in extracting the maximum solar radiation as PV output. As expected, spectral effects are less sensitive in mountainous areas, as well as losses from other system effects, but slightly different, 23.47% in Fier District, 22.33% in Theth. The best interval; for cost of electricity varies 0.061 eur/kWh to 0.105 eur/Kwh, in Theth, these values depend on the cost of technology, installation.

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