Leadership and Innovation

Education | Research | Training | Consulting | Certification

PROCEEDINGS

14 UBT ANNUAL INTERNATIONAL CONFERENCE

25-26 OCTOBER

UBT Innovation Campus

INTERNATIONAL CONFERENCE ON ENERGY EFFICIENCY ENGINEERING

Proceedings of the 14 th Annual International Conference

International Conference on Energy Efficiency Engineering

Edited by
Edmond Hajrizi

October, 2025

Conference Book of Proceedings

International Conference

Pristina, 25-26 October 2025

ISBN 978-9951-982-59-7

International Conference on Business, Technology and Innovation
Pristina, Kosovo 25-26 October 2025

Editor: Edmond Hajrizi

Publisher,
UBT

Editor Speech of IC - BTI 2025

The International Conference on Business, Technology, and Innovation (IC-BTI 2025) is the 14th international interdisciplinary peer-reviewed conference which publishes the works of scientists as well as practitioners in the areas where UBT is active in education, research, and development. The UBT aims to implement an integrated strategy to establish itself as an internationally competitive, research-intensive institution, committed to the transfer of knowledge and the provision of a world-class education to the most talented students from all backgrounds. It is delivering diverse academic programs across science, management, and technology, fostering innovation and excellence in research. This year we proudly celebrate our 24th Anniversary as an institution dedicated to advancing science, education, and global collaboration. The main perspective of the conference is to connect scientists and practitioners from different disciplines in one place, make them aware of the recent advancements across research fields, and provide them with a unique forum to share their experiences. It is also an important platform to support new academic staff in conducting research and publishing their work at international standards.

This conference consists of sub-conferences in various fields, including but not limited to:

Medicine – Nursing and Medical Technical Sciences
Computer Science and Communication Engineering
Fashion
Dentistry
Modern Music and Audio Production
Performing Arts
Art and Digital Media
Pharmaceutical and Natural Sciences
Applied Medicine and Nursing
Language and Culture
Security Studies
Sport, Health and Society
Management, Business and Economics
Mechatronics, Systems Engineering and Robotics
Energy Efficiency Engineering
Information Systems and Security
Architecture – Spatial Planning
Civil Engineering, Infrastructure and Environment
Law
Journalism, Media and Communication
Political Science & International Relations
Agriculture, Food Science and Technology
Integrated Design
Psychology
Education and Development

This conference is the major scientific event of UBT. It is organized annually and supported by an extensive network of regional and international academic, institutional, and professional partners, whose collaboration enriches the scientific quality and global reach of the conference.

We would like to express our sincere gratitude to all authors, partners, sponsors, reviewers, and the conference organizing team for making this year’s event a truly international scientific gathering. In 2025, we have seen increased participation, submissions, and publications, demonstrating the growing relevance and impact of IC-UBT.

Congratulations! Edmond Hajrizi,
Rector of UBT and Chair of IC - BTI 2025

CONTENTS

SF_6-Free Solutions: Blue GIS and Clean Air in MV/HV Power Systems

Armend Ymeri[1], Diamant Gashi[2], Nexhmi Krasniqi[3]*

[1]University for Business and Technology, Pristina, Kosovo
[2]University for Business and Technology, Pristina, Kosovo
[3]*University for Business and Technology, Pristina, Kosovo
Armend.ymeri@ubt-uni.net, dg75513@ubt-uni.net
nexhmi.krasniqi@ubt-uni.net

Abstract. Sulfur hexafluoride (SF_6) has been the predominant insulating and switching medium in medium-voltage and high-voltage (MV/HV) gas-insulated switchgear (GIS) for several decades, primarily due to its superior dielectric properties. However, SF_6 is also the most potent greenhouse gas, with a global warming potential (GWP) 23,500 times that of CO_2 and an atmospheric lifetime exceeding 3,000 years, making its substitution a critical environmental priority. This paper evaluates emerging SF_6-free alternatives, with particular emphasis on Blue GIS technology, which combines vacuum switching with clean air insulation. The study analyzes their technical performance, operational reliability, safety characteristics, life-cycle environmental impact, and economic feasibility in comparison with conventional SF_6-based systems. Large-scale European projects and case studies are reviewed to demonstrate practical deployment and operational experience. Findings confirm that SF_6-free GIS provides a robust, reliable, and environmentally sustainable pathway for modernizing electrical grids, supporting decarbonization strategies and advancing the transition toward carbon-neutral power systems.

Keywords: Gas-Insulated Switchgear, Medium Voltage, High Voltage, Sulfur Hexafluoride, Blue GIS, Clean Air, Vacuum Interruption, Sustainable Power Systems.

Introduction

The modernization of power networks requires compact, reliable, and environmentally sustainable solutions for transmission and distribution infrastructure. Gas-insulated switchgear (GIS) has played a critical role in meeting these needs by offering high reliability, reduced footprint, and minimal maintenance requirements. Historically, GIS has relied on SF_6, a gas with excellent dielectric and arc-quenching properties. However, SF_6 poses severe environmental concerns, being the most potent greenhouse gas in use today. International agreements, such as the European Green Deal and the Kyoto Protocol, are driving research and deployment of alternatives.

The process of stepping down transmission voltage to distribution levels at substations strategically located near consumers not only delivers substantial economic benefits but also enhances the reliability of electricity supply. In response to these demands, an advanced type of switchgear has been developed, designed to minimize spatial requirements while complying with contemporary operational standards and maintaining full environmental compatibility [1].

In addition to the transmission lines, the substation comprises essential components such as transformers, switchgears, disconnectors, circuit breakers, and related elements [2].

A Gas Insulated Switchgear (GIS) is a high-voltage installation in which the primary conducting components are enclosed within a sealed chamber filled with a dielectric gas, typically sulfur hexafluoride (SF_6), serving as the insulating medium. A typical GIS comprises a metallic, grounded enclosure (earthed vessel), a central conductor, solid insulators, and the insulating gas. The system is divided into separate gas-filled modules, each designed to

maintain mechanical strength, electrical reliability, and complete gas-tight integrity, thereby ensuring safe and efficient operation [3].
Under normal conditions, the breaker contacts are closed, but when a failure occurs in the electrical system, these contacts separate and an arc occurs between them. The displacement of the mobile contacts is synchronized with that of a valve that allows the entry of high-pressure SF_6 into the chamber where the arc is occurring. The dielectric strength of the gas increases notably, so the arc is extinguished.
GIS systems are a key component in the distribution of electrical energy, providing a reliable and efficient solution for energy management. GIS is available in different configurations for medium and high-voltage applications, each tailored to meet specific operational requirements:
GIS Systems for Medium Voltage
Medium – voltage Disconnection Systems: Primarily applied at medium-voltage levels, these systems facilitate secure power distribution by ensuring dependable isolation, protection, and operational control.
Separation Modules: Designed to segregate electrical power into independent subsystems, they provide enhanced flexibility, operational efficiency, and reliability in network management.
GIS Systems for High Voltage
High-voltage Disconnection Systems: Specifically designed to provide secure isolation and enhanced protection, thereby improving the operational safety of high-voltage installations.
Integrated Transformers:Employed to convert voltage levels with high precision, supporting stable power flow, efficient energy transfer, and overall reliability of the distribution system.
The adoption of GIS is driven by several technical, economic, and environmental advantages [4]:
Reduced land requirements: GIS installations occupy significantly less ground space compared to conventional substations, making them highly suitable for densely populated or urban areas.
Minimal maintenance needs: The enclosed design and reliable insulation properties result in nearly maintenance-free operation.
Lower installation time and cost: Prefabricated and modular components reduce on-site erection time and associated costs.
Suitability for urban expansion: GIS is particularly advantageous for rapidly growing metropolitan areas, where land availability is limited and expensive.
Due to its high climate-harming potential and its long atmospheric lifetime, SF_6 is banned for most applications with exception of the electricity sector. However, as part of the European Green Deal, the European Commission is currently reviewing the regulation of fluorinated gases. Over the last decade Siemens Energy has invested in the development of chemical-free alternatives to SF_6 and as a result introduced the future-proof Blue portfolio which operates completely free of any F-gases and thereby goes beyond the common safety and environmental standards. It not only emphasizes the green aspect of the transmission technology, but also provides many other benefits for gas-insulated switchgear, circuit breakers and instrument transformers [5].
SF_6 requires careful handling throughout its life cycle to prevent gas leakage into the atmosphere, as it is a high global warming potential (GWP) greenhouse gas with a very long lifetime. In order to improve the sustainability of the energy supply and to reduce the GIS-related global warming impact, research on SF_6 alternative solutions have been worked on internationally for years. The alternative solutions offered today are clean air, CO_2 and fluoroketones or fluoronitriles, with mixtures of N_2, O_2 or CO_2, which are used as arc extinguishing and insulating media. On this basis, different products were developed, and first grid applications were started. In the article [6], the status of the alternative solutions is summarized from the high-voltage switchgear point of view. On the other hand, the SF6-free 145 kV blue GIS 8VN1 based on clean air and vacuum switching technology is also represented.

The search for alternative gases for use in power applications has been ongoing since about two decades ago [7][8].
Siemens has started to implement the Blue GIS technology based on fluorine-free gas insulation with Clean Air (i.e. 20% oxygen with 80% nitrogen) and vacuum circuit breakers. Latest developments show first applications of the Blue GIS technology for 66 kV offshore wind-turbine applications and for the 145 kV voltage level [9].
This paper aims to assess SF_6-free solutions, particularly Blue GIS and Clean Air technologies, as sustainable pathways for future MV/HV power systems.
The paper is structured as follows: Comparison of SF_6 Gas and Emerging Alternatives in Electrical Power Systems is presented in section 2; Challenges Associated with GIS and Clean Air Systems are presented in section 3; Large-Scale GIS Implementations in Europe are presented in section 4 and Finally Conclusions of this paper are summarized in section 5.

SF_6 Gas and Its Alternatives

2.1 Properties and Advantages of SF_6

Sulfur hexafluoride (SF_6) possesses exceptional dielectric strength, approximately two to three times higher than that of air or nitrogen at atmospheric pressure. This property enables the design of compact, space-efficient switchgear that maintains reliable insulation even under demanding operating conditions. In addition, SF_6 is chemically inert, thermally stable, and non-flammable, which contributes to its safe application in high-voltage environments. Its arc-quenching capability is superior to that of most alternative gases, ensuring rapid interruption of fault currents and minimizing equipment damage. Furthermore, SF_6-insulated systems are characterized by long service lifetimes and minimal maintenance requirements, making them economically attractive and operationally reliable in both medium- and high-voltage applications.

2.2 Environmental Challenges of SF_6

Despite its widespread use and technical advantages, SF_6 is recognized as the most potent greenhouse gas regulated under the Kyoto Protocol and subsequent international climate frameworks. It has a global warming potential (GWP) approximately 23,500 times greater than CO_2 over a 100-year horizon and an estimated atmospheric lifetime exceeding 3,000 years, meaning that any emissions have long-lasting and cumulative effects on global warming. Even minimal leakage rates—often measured in fractions of a percent per year—can result in substantial greenhouse gas emissions when considered over the operational lifetime of GIS equipment.
In addition to its direct contribution to climate change, SF_6 poses indirect environmental and safety risks through its toxic decomposition products, which are generated during electrical arcing. Compounds such as sulfuryl fluoride (SO_2F_2), sulfur oxyfluoride (SOF_2), and hydrogen fluoride (HF) are corrosive, toxic to humans, and harmful to the environment. Consequently, strict handling protocols are required across the entire SF_6 lifecycle, from manufacturing and installation to maintenance, gas recovery, and end-of-life decommissioning.
Regulatory pressure is intensifying: the European Union F-gas Regulation has already restricted SF_6 use in many applications outside the power sector, and revisions currently under discussion are expected to further limit or phase out its role in electrical equipment. These regulatory developments, combined with the environmental urgency of reducing greenhouse gas emissions, underscore the necessity of transitioning toward SF_6-free technologies.

2.3 Emerging Alternatives

In response to the environmental challenges associated with SF_6, significant research and industrial development efforts have been devoted to identifying sustainable alternatives that combine technical reliability with reduced environmental impact. The most promising categories of substitutes include natural gases, such as Clean Air and CO_2, as well as engineered gas mixtures, including fluoroketones and fluoronitriles.

Clean Air, consisting of approximately 80% nitrogen (N_2) and 20% oxygen (O_2), has gained particular attention as a sustainable insulation medium. This mixture is abundant, non-toxic, non-flammable, and has a global warming potential (GWP) of zero. When combined with vacuum interrupters for switching operations, Clean Air-based systems demonstrate insulation and arc-quenching capabilities comparable to SF_6, making them suitable for MV/HV applications. Field implementations up to 145 kV have already validated their reliability and long-term stability.

Carbon dioxide (CO_2) has also been explored due to its lower environmental impact compared to SF_6 (GWP = 1). However, its dielectric strength is considerably weaker, typically requiring higher operating pressures or larger equipment dimensions to achieve equivalent performance. While CO_2 can serve as a partial substitute or as a component in gas mixtures, it is generally less favorable as a stand-alone solution in high-voltage applications.

Fluoroketones and fluoronitriles represent another category of alternatives. These engineered gases offer significantly lower GWPs than SF_6 and provide strong dielectric properties. Fluoroketone mixtures, for example, have demonstrated insulation performance close to SF_6 while reducing GWP by more than 99%. However, challenges remain, including higher costs, the need for careful handling due to material reactivity, and uncertainties about long-term environmental behavior.

Among these options, Clean Air combined with vacuum switching technology currently appears the most mature and viable solution for large-scale deployment in MV/HV systems. It balances technical robustness, operational safety, and complete environmental neutrality, aligning with regulatory trends and global decarbonization objectives. Continued innovation and standardization are expected to enhance the performance and economic competitiveness of these alternatives, further accelerating the phase-out of SF_6.

3. Blue GIS and Clean Air Technology

3.1 Principles of Blue GIS

Blue GIS represents a new generation of gas-insulated switchgear that eliminates the use of fluorinated gases by combining vacuum switching technology with Clean Air insulation. Unlike conventional GIS, which relies on SF_6 for both insulation and arc interruption, Blue GIS separates these functions into two complementary technologies.

The vacuum interrupter is employed for arc quenching. In a vacuum, the absence of gaseous molecules prevents the arc from sustaining once the contacts are separated, enabling highly efficient interruption of fault currents. Vacuum interrupters are well established in medium-voltage applications and are increasingly being extended into higher voltage ranges due to improvements in design, contact materials, and manufacturing techniques. Their performance ensures fast switching, long mechanical life, and minimal maintenance.

For insulation, Clean Air, a mixture of approximately 80% nitrogen and 20% oxygen—is used to replace SF_6. Clean Air provides reliable dielectric strength under standard pressure conditions and can be applied safely without environmental or health hazards. While the dielectric strength of Clean Air is lower than that of SF_6, equipment design compensates through optimized geometries and slightly larger clearances, ensuring compliance with international insulation standards.

Together, the integration of vacuum switching and Clean Air insulation provides a climate-neutral and technically robust solution. Blue GIS achieves zero direct greenhouse gas emissions, eliminates risks from toxic SF_6 decomposition by-products, and simplifies end-of-life recycling and disposal processes. Moreover, the modular design of Blue GIS facilitates scalability across voltage levels—from medium-voltage distribution grids to high-voltage transmission systems up to 145 kV and beyond.

In practice, Blue GIS demonstrates performance comparability with traditional SF_6 GIS, including high dielectric withstand capability, reliable arc interruption, and long operational lifetimes. Its adoption thus represents a key technological step toward sustainable, safe, and future-proof power infrastructure.

3.2 Technical Characteristics

Blue GIS has been successfully developed and deployed for medium- and high-voltage applications, with commercially available solutions currently operating up to 145 kV and short-circuit ratings exceeding 40 kA. Ongoing research and pilot projects indicate its scalability to even higher voltage levels, positioning it as a future-proof alternative for both transmission and distribution networks.

One of the most significant differences compared to SF_6 GIS is the equipment footprint. Since Clean Air exhibits a lower dielectric strength than SF_6, Blue GIS requires approximately 20–25% more physical space to maintain equivalent insulation performance. This is achieved by optimizing internal clearances, insulation distances, and component geometries, without compromising operational reliability. Despite the increase in size, Blue GIS remains suitable for urban and industrial environments due to modular designs that optimize installation layouts.

In terms of insulation performance, Clean Air provides stable dielectric withstand capability under a wide range of environmental conditions, including humidity and temperature variations. Unlike SF_6, it does not degrade into harmful by-products under arcing conditions, which enhances both reliability and safety.

For arc interruption, Blue GIS relies on vacuum circuit breakers, which have demonstrated extremely high endurance, with mechanical lifetimes often exceeding 10,000 to 30,000 switching operations. This durability significantly reduces maintenance requirements compared to traditional GIS technologies.

Other technical characteristics include:

Thermal performance: Efficient heat dissipation due to natural air composition, ensuring reliable operation under high current loads.

Operational flexibility: Compatibility with digital monitoring systems and condition-based maintenance strategies.

Lifecycle benefits: Simplified handling, recycling, and disposal processes, as Clean Air is abundant and non-toxic.

Overall, Blue GIS delivers comparable technical reliability to SF_6-based GIS, while achieving complete elimination of fluorinated greenhouse gases. Its deployment across multiple grid levels demonstrates both its maturity and suitability for large-scale integration into modern power systems.

Fig 1 Blue GIS / CleanAir Technology

3.3 Environmental and Safety Advantages

Clean Air systems offer significant environmental and safety benefits, making them a sustainable and future-oriented choice for medium- and high-voltage switchgear applications.

These systems utilize a gas mixture composed primarily of natural, abundant, and non-toxic components, such as nitrogen and oxygen, which are readily available in the atmosphere. Unlike traditional insulating gases such as SF_6 (sulfur hexafluoride), a potent greenhouse gas with a global warming potential (GWP) over 23,000 times that of CO_2, Clean Air has a GWP of zero, making it inherently climate-neutral.
One of the most critical advantages of Clean Air technology lies in its exceptional safety profile. Because the gas mixture is non-toxic and chemically inert, it does not pose a health hazard to workers during normal operation or maintenance activities. In the event of internal arcing or equipment failure, Clean Air does not produce toxic or corrosive by-products, unlike SF_6, which can decompose into dangerous substances such as sulfur dioxide and hydrofluoric acid under high-temperature conditions. This enhances occupational health and safety, reducing the need for complex safety procedures, protective equipment, and specialized training for handling gas leaks or post-arc cleanup.
Additionally, Clean Air systems simplify regulatory compliance. Because the gas mixture does not fall under the scope of fluorinated greenhouse gas regulations (such as the EU F-Gas Regulation), operators face fewer legal obligations related to gas monitoring, leakage reporting, and end-of-life gas recovery. This translates into lower operational costs and fewer administrative burdens, while also supporting corporate sustainability goals and environmental responsibility initiatives.
In summary, Clean Air switchgear technologies offer a compelling combination of environmental neutrality, worker safety, and regulatory ease, positioning them as a preferred alternative in the ongoing transition to greener and safer electrical infrastructure.

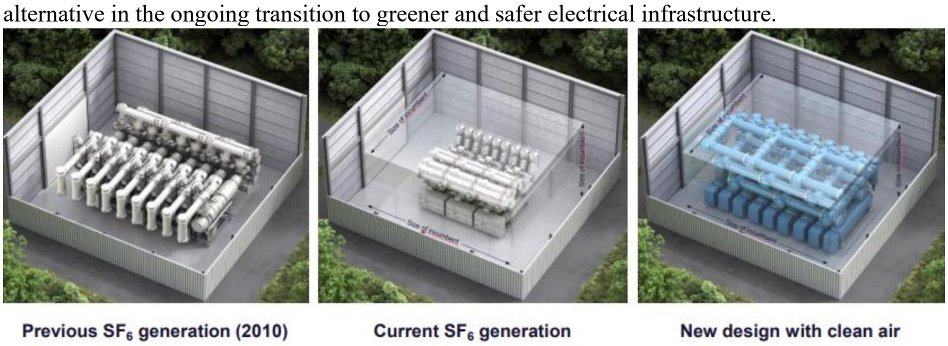


Fig. 2 Systems GIS vs Clean Air system

The figure below shows the difference in physical dimensions of the Clean Air system on the right and the GIS system on the left.

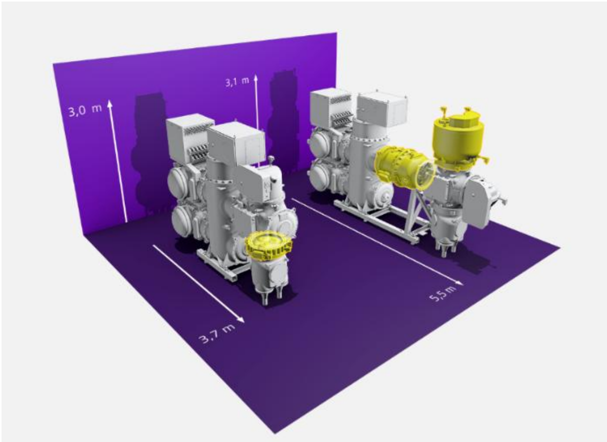


Fig. 3 Difference in physical dimensions of the Clean Air system and the GIS system

4. Challenges and Considerations
4.1 Challenges of Conventional GIS
While Gas-Insulated Switchgear (GIS) has long been valued for its compact footprint, reliability, and ability to operate in harsh environments, conventional GIS systems—particularly those using SF_6 (sulfur hexafluoride) as an insulating medium—present a number of operational, financial, and environmental challenges. These issues are increasingly relevant as utilities and industries transition toward more sustainable and future-proof grid solutions.

High Capital Investment
One of the foremost challenges of conventional GIS is its high initial capital expenditure. The design and manufacturing of GIS involve complex engineering, precision sealing, and the use of specialized materials to contain high-pressure insulating gas. In addition, installation often requires custom civil works, such as reinforced enclosures and controlled environments, especially in urban or space-constrained locations. The overall cost of procurement, site preparation, and commissioning can be significantly higher compared to air-insulated alternatives, making GIS a less attractive option for budget-conscious projects or rapidly expanding infrastructure.

Integration Issues with Legacy Infrastructure
Retrofitting or upgrading existing electrical infrastructure to accommodate GIS can be technically and logistically complex. Many legacy substations and distribution networks were not designed with GIS compatibility in mind, leading to issues such as mismatched interfaces, limited spatial allowances, and differing voltage or insulation standards. Integrating GIS with older systems may require custom adapters, layout reconfigurations, or complete equipment replacement, which increases both time and cost. These integration challenges can delay modernization projects and limit the scalability of GIS in mixed-technology environments.

Standardization Gaps and Interoperability
A persistent concern with conventional GIS is the lack of full standardization across manufacturers. Variability in design specifications, component dimensions, communication protocols, and maintenance practices can hinder interoperability between different systems or vendors. This fragmentation complicates equipment sourcing, spare parts inventory management, and long-term asset maintenance. For utility operators managing multi-vendor

environments, this often translates into higher lifecycle costs, reduced flexibility, and a dependence on proprietary solutions, which can stifle innovation and vendor competition.

Workforce Requirements and SF_6 Handling

Conventional GIS systems rely heavily on SF_6 gas, which, while highly effective as an insulating and arc-quenching medium, is also an extremely potent greenhouse gas. The handling, maintenance, and disposal of SF_6 require specialized training, certifications, and safety protocols to mitigate risks associated with leaks or gas decomposition. Skilled personnel must be equipped to manage pressurized systems, detect leaks, and conduct gas recovery or recycling in compliance with environmental regulations. The need for qualified technicians not only increases operating costs but also creates a talent bottleneck, particularly as regulations around SF_6 become stricter and fewer professionals are trained in managing aging GIS assets.

4.2 Challenges of Clean Air Alternatives

Clean Air insulation technologies, which utilize natural gas mixtures such as nitrogen and oxygen, represent a promising and environmentally responsible alternative to traditional SF_6-based switchgear. However, as with any emerging technology, their broader adoption comes with a set of technical, economic, and institutional challenges that must be addressed to enable widespread deployment.

Larger Footprint

One of the most frequently cited challenges of Clean Air alternatives is the larger physical footprint required compared to SF_6-based GIS systems. Because natural gases have lower dielectric strength than SF_6, equipment using Clean Air must typically feature larger clearances and bigger enclosures to maintain the same voltage ratings and safety margins. This can be a limiting factor in urban environments, underground installations, or retrofits where space is constrained. While this may not pose an issue for greenfield projects, it can increase the complexity and cost of integrating Clean Air systems into existing substations or infrastructure with limited room for expansion.

Higher Initial Costs

Although Clean Air systems offer long-term environmental and operational benefits, they generally involve higher upfront capital investment. The need for larger components, specialized designs, and enhanced monitoring systems increases both equipment and installation costs. Furthermore, as a relatively newer technology, Clean Air alternatives may lack the economies of scale that have driven down costs for conventional SF_6 GIS over decades of widespread production and use. This can create a cost barrier for utilities and project developers, particularly in regions with tight budgets or cost-sensitive procurement policies.

Knowledge Gaps Among Stakeholders

The shift to Clean Air technologies also highlights a significant knowledge and awareness gap across various stakeholder groups. Many utility engineers, procurement officers, and decision-makers are still more familiar with SF_6-based systems, which have been industry-standard for decades. This lack of familiarity can result in hesitation or resistance to adopt new technologies, particularly when perceived risks around performance, reliability, or long-term support are not well understood. In addition, training programs, user manuals, and industry guidelines for Clean Air systems are still maturing, which can slow down knowledge transfer and capacity-building efforts.

Regulatory Uncertainty

While regulatory pressure to phase out SF_6 is increasing—particularly in the European Union—there is currently a lack of harmonized international standards specifically tailored to Clean Air switchgear technologies. This regulatory ambiguity can delay investment decisions, create inconsistency in testing and certification processes, and complicate efforts to gain project approvals across different jurisdictions. Manufacturers and utilities may face difficulties navigating conflicting requirements or the absence of clear guidance, especially in countries where environmental regulations are evolving rapidly but lack coordination with global best practices.

Monitoring and Maintenance Needs

Clean Air systems require advanced monitoring tools to ensure consistent performance over time. Because the insulation properties of natural gases are more susceptible to pressure and temperature changes than SF_6, continuous or periodic monitoring becomes essential to maintain reliability and detect any deviations. This necessitates more sophisticated sensors, data acquisition systems, and analytics platforms, as well as trained personnel to interpret the data and take corrective action. For utilities accustomed to the relative stability and lower monitoring needs of SF_6 systems, this represents a paradigm shift in asset management and can add to both operational complexity and maintenance training requirements.

In summary, while Clean Air technologies present a clear pathway toward sustainable and SF_6-free grid solutions, their adoption is not without challenges. Overcoming these barriers will require strategic investments, regulatory alignment, targeted education efforts, and industry collaboration to unlock their full potential.

4 Large-Scale GIS Implementations in Europe

Gas-Insulated Switchgear (GIS) technology has been widely deployed across Europe for several decades, enabling the modernization, efficiency, and reliability of national power systems. Several large-scale projects highlight the role of GIS in supporting energy transition and ensuring grid stability:

The National Grid (UK): Deployment of GIS solutions to enhance reliability and efficiency

In Great Britain, GIS has been adopted extensively within the National Grid to manage and monitor the high-voltage electricity transmission system. The integration of GIS allows for real-time equipment monitoring, optimization of power distribution, and enhanced reliability of supply. This project has significantly improved operational efficiency while reducing transmission losses.

TenneT (Netherlands & Germany) : Integration of SF_6-free GIS to support renewable energy and cross-border flows

TenneT, the transmission system operator in the Netherlands and parts of Germany, has deployed GIS technology to enhance energy network management. The system supports the integration of renewable energy sources, facilitates cross-border electricity flows, and optimizes grid operations. Through GIS, TenneT has strengthened grid sustainability and resilience against increasing energy demands.

RTE (France): Adoption of Clean Air technologies for improved reliability and safety

Réseau de Transport d'Électricité (RTE), the French transmission system operator, has implemented GIS across its network to ensure secure and efficient management of high-voltage lines, substations, and transformers. The adoption of GIS has improved infrastructure monitoring, enhanced grid reliability, and contributed to the safe integration of distributed generation resources.

Vattenfall (Sweden): Deployment in transmission and distribution to facilitate renewable integration

Vattenfall, one of Europe's largest energy companies, has incorporated GIS systems into its transmission and distribution networks. The technology is utilized for infrastructure planning, operational optimization, and improved asset management. This project has also facilitated the integration of renewable energy sources and contributed to higher overall energy efficiency.

Siemens Projects (Germany, Norway, Offshore): Demonstrations of Blue GIS at 66 kV and 145 kV levels, validating operational performance.

Fig 4 During the Implementation of Clean Air Systems

Conclusions

The comparative evaluation of SF_6-based GIS and SF_6-free alternatives indicates that Blue GIS and Clean Air technologies can provide equivalent technical performance with significantly lower environmental impact. Although they require higher upfront investment and occupy more space, lifecycle costs are reduced through simplified maintenance, avoidance of carbon-related penalties, and compliance with evolving regulations. The transition toward SF_6-free technologies aligns with EU decarbonization targets and supports large-scale integration of renewable energy sources.

This study demonstrates that SF_6-free solutions, particularly Blue GIS and Clean Air systems, offer a technically robust and environmentally sustainable alternative to conventional GIS. Key findings include:

Clean Air insulation with vacuum switching ensures reliable performance up to 145 kV.

SF_6-free GIS eliminates direct greenhouse gas emissions, contributing to carbon neutrality goals.

Operational safety is enhanced due to the use of non-toxic and non-flammable gases.

Economic assessments suggest higher upfront costs are offset by long-term savings in maintenance and compliance.

The widespread adoption of SF_6-free GIS is essential for future-proofing power systems and achieving global decarbonization objectives. Future research should focus on further compacting designs, developing international standards, and expanding applications to higher voltage levels to accelerate the full phase-out of SF_6.

References

[1] Niadu, M.S., Gas Insulated Substations, I.K International Poblishing House Pvt, Ltd, New Delhi, 2008.
[2] Siemens. (a.d.). Planinng of Electric Power Distribution.
[3] Habert, J. L., Grid, A., GIS Substation Design and Excecution. IEEE Transactions, vol. 119, 2014.
[4] Rajmohan, R., Gas Insulated Substation (GIS).
[5] Siemens Energy, Siemens Energy seals largest order for SF_6-Free Gas-Insulated Switchgear in Europe, Power Magazine, 2021.
[6] Kuschel, M., Kunde, K., Katschinski, U., "Technically Advanced and SF_6-Free 145 kV Blue GIS," Transformers Magazine, 2019.
[7] L. Niemeyer, A Systematic Search for Insulation Gases and Their Environmental Evaluation, Gaseous Dielectrics Vol VIII, pp. 459-464, 1998.
[8] L. Christophorou, J. K. Olthoff, and D. S. Green, Gases for Electrical Insulation and Arc Interruption: Possible Present and Future Alternatives to Pure SF6, US Department of Commerce, Technology Administration, National Institute of Standards and Technology, 1997
[9] Lutz, B., Kuschel, M., Pohlink, K., Kurte, R., Gas Handling and Assessment of Gas Quality in GIS Containing Clean Air, Siemens Ag, TechCon 2020, 2020.

Digital Technologies for Modernizing Coal-Based Power Systems in Kosovo

Agron Bislimi[1], Arbesa Nikaj[2],

1 University for Business and Technology, Prishtina, Kosovo
agron.bislimi@ubt-uni.net, an64369@ubt-uni.net

Abstract: Kosovo continues to rely heavily on lignite for its electricity generation, making coal a dominant and unavoidable part of its energy landscape for the foreseeable future. Rather than pursuing an abrupt replacement, this paper advocates for the modernization of existing coal infrastructure through digital technologies that enhance efficiency, reduce emissions, and improve operational transparency. Smart monitoring, predictive maintenance, and real-time control systems are emphasized as cost-effective solutions to improve the performance of current power plants. At the same time, these digital upgrades lay the foundation for the gradual integration of renewable energy sources, particularly solar and wind, into the power system. This dual approach recognizes the short-term necessity of coal while strategically preparing the sector for a more sustainable and diversified energy mix in the long term. The paper presents a set of realistic, data-driven strategies tailored to Kosovo's present energy challenges and future ambitions, highlighting the importance of digital modernization as a bridge toward sustainability.

Keywords: Coal power, digital solutions, energy modernization, emission reduction, renewable readiness, Kosovo

Introduction Kosovo's energy sector remains heavily dependent on lignite, which continues to dominate the country's electricity supply. Reliance on aging thermal power plants raises significant concerns regarding efficiency, emissions, and overall reliability. Although renewable energy deployment is gradually increasing, a rapid transition to clean energy is constrained by financial, technical, and infrastructural limitations. In this context, Industry 4.0 represents the integration of advanced digital technologies to modernize and optimize existing energy systems.

Previous studies [1–3] have highlighted the role of digitalization and decentralized solutions in modernizing energy systems and integrating renewable sources.

Kosovo [4–8], applying these insights to modernize coal-based power plants. Smart monitoring, predictive maintenance, and real-time control enhance plant performance while enabling gradual integration of solar and wind, balancing short-term coal needs with long-term sustainability. Voltage stability is also considered, analyzing node and load behavior to highlight the need for assessing limits and preventing voltage collapse.

AI, Big Data, and digital twin technologies can modernize coal plants through real-time monitoring and predictive maintenance [9–10]. Kosovo's Energy Strategy supports gradual renewable integration while maintaining coal short-term [11], and global examples stress digital solutions for efficiency and a sustainable energy mix [12].

These technologies include connected devices that collect and exchange real-time data, enabling advanced monitoring and control, as well as large-scale data analytics to support informed decision-making and process optimization. Automated and intelligent workflows improve efficiency and reliability, while predictive algorithms anticipate potential issues to minimize downtime and enhance operational performance. In addition, virtual replicas of physical systems enable simulation and testing without disrupting actual operations. Together, these digital solutions transform power plant operations by enhancing efficiency, flexibility, and innovation. For Kosovo, the adoption of such technologies in coal-based plants offers a pathway to reduce emissions, optimize performance, and prepare the energy system for a gradual integration of renewable sources, effectively bridging the gap between current infrastructure and a sustainable energy future.

2. Current Challenges of Coal-Based Power in Kosovo

Kosovo remains heavily reliant on lignite, which continues to dominate the country's electricity supply. The main thermal power plants, Kosova A and Kosova B, have exceeded their expected operational lifespans—over 50 years for Kosova A and more than 40 years for Kosova B—raising concerns regarding efficiency, safety, and reliability. Aging equipment results in frequent outages, high transmission and distribution losses, and elevated air pollution, undermining both system performance and environmental sustainability. Limited financial resources and outdated infrastructure further constrain modernization efforts. Hence, compliance with increasingly stringent EU environmental and emission standards intensifies the need for cost-effective and transformative solutions within Kosovo's energy system.

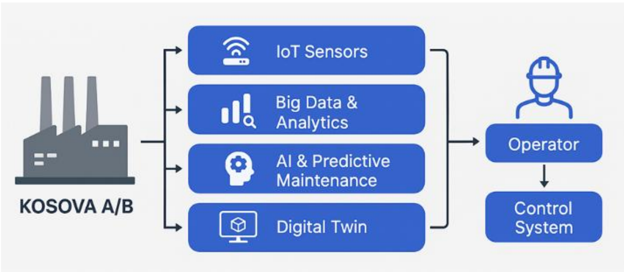


Fig. 1. Deployment of IoT Sensors with AI, Predictive Maintenance, and Digital Twin in Kosovo (Types A & B).

Kosovo Energy Corporation (KEK), traditionally reliant on coal, is preparing to build the Solar4Kosovo 1 photovoltaic plant near Prishtina, on land previously used as a coal ash dump. The project will have a 100 MW connection capacity (120 MW peak) and is expected to generate approximately 169 GWh annually, connecting underground to the existing Kosovo A substation.

The initiative is financed through a combination of EU grants and loans, including a €32 million grant from the EU's Western Balkans Investment Framework, a €33 million loan from the European Investment Bank, and additional support from Germany's KfW Development Bank, with total investment estimated at around €107 million. The project also includes a 30 MW solar thermal facility for Prishtina's district heating and a 20 MW network extension supplied from Kosovo B.

This development marks a significant step toward decarbonization and diversification of Kosovo's energy mix, reducing reliance on the aging Kosovo A and B coal plants [3].

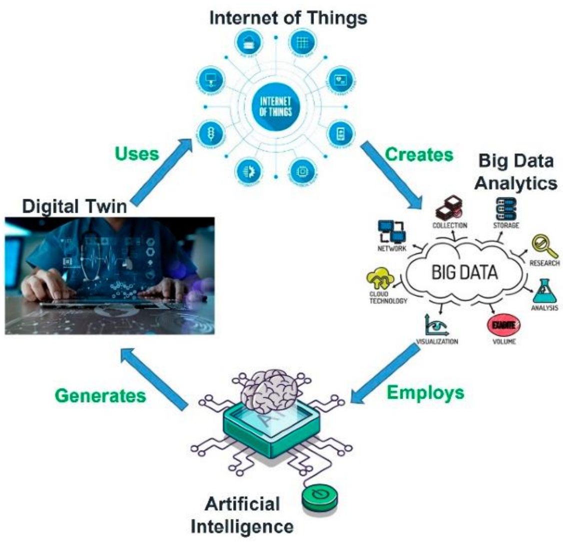


Fig. 2. Contribution of Different Technologies to Digital Twin Development in Healthcare [10]

Digital monitoring and predictive maintenance enable smarter operation of coal-based power systems in Kosovo, while process digitalization and AI-driven optimization enhance efficiency and sustainability.

Between now and 2030, electricity consumption in the EU is expected to increase by 60%. Given the current trends, the U.S. Energy Information Administration (EIA) warns that global energy demand may outpace efficiency gains, potentially driving continued emissions growth by 2050.

These factors are likely to result in additional regulatory pressure on energy companies to expand renewable energy production and implement emission reduction measures. To address these challenges, industry leaders are investing in the following digital technologies.

3. Role of Digital Technologies in Power Plant Modernization

Modernizing coal-based power plants requires innovative approaches that enhance performance, reduce downtime, and minimize environmental impacts. Digital technologies provide practical, cost-effective solutions to bridge the gap between existing infrastructure and future renewable integration. Their role can be highlighted through the following key applications:

Smart monitoring employs advanced sensors and real-time data analytics to track critical parameters such as temperature, pressure, and fuel consumption. Continuous monitoring improves operational transparency and provides early warnings of inefficiencies or abnormal conditions, enabling faster corrective actions.

Predictive maintenance, powered by artificial intelligence and machine learning algorithms, detects potential failures before they occur. By forecasting equipment degradation, plant operators can reduce unexpected outages, optimize spare part usage, and extend the operational life of aging infrastructure.

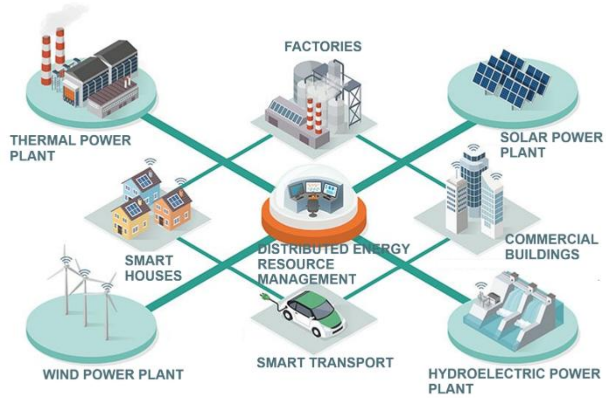


Fig. 3. Modernization of the Electricity Grid.

Automated, real-time control systems enhance the dynamic optimization of plant operations. By instantly adjusting combustion parameters, load distribution, and other operational factors, these systems improve efficiency, minimize fuel waste, and reduce emissions, all while maintaining grid stability.

A digital twin creates a virtual replica of the power plant, enabling engineers to simulate operations, test scenarios, and assess the impact of process changes without interrupting actual production. This tool reduces operational risks, supports informed decision-making, and provides valuable insights for long-term modernization strategies.

A fog gateway is an intermediate computing node that processes and filters IoT data locally before transmitting it to the cloud, reducing latency and network congestion while enabling real-time decision-making. Sensors (Sensor Motes) are deployed across various energy sources, including coal-based thermal power plants, hydro, wind, solar, nuclear, geothermal, and the power grid. The collected data is transmitted through Edge and Fog Gateways, processed, and sent to the Cloud Platform for forecasting energy demand, generation, and pricing.

This system illustrates how IoT, edge, and fog computing are integrated to manage and digitalize energy systems. (see Fig. 4).

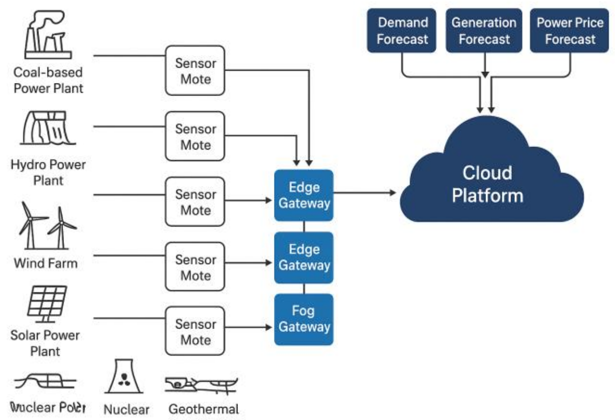


Fig. 4. IoT Based on Real-Time Monitoring of Generation Stage Using Edge and Fog Gateway

4. Benefits of Digital Modernization

Digital solutions improve power plant performance by optimizing combustion processes and monitoring operational parameters in real time, allowing more electricity to be generated per unit of fuel while reducing overall consumption and operational costs. Advanced monitoring and control systems lower greenhouse gas and particulate emissions by enabling precise combustion control and better filtration, helping plants meet stricter environmental standards and protect public health. Predictive maintenance and automated control reduce the risk of sudden failures, minimize interruptions, and enhance energy security, which is particularly important for Kosovo, where stable electricity supply is a national priority. Furthermore, real-time data sharing improves transparency, supports regulatory compliance, and strengthens decision-making and public trust, enabling more efficient and sustainable operation of coal-based power systems.

5. Integration with Renewable Energy

The modernization of coal-based power plants through digital technologies not only improves their immediate performance but also prepares the energy system for a gradual transition toward renewables. Digital upgrades such as advanced monitoring, predictive maintenance, and automated control systems create a more flexible and responsive operational environment. This flexibility is essential for integrating variable renewable sources like solar and wind, whose production is less predictable compared to conventional generation.

A key enabler of this transition is the development of smart grids, which can balance the fluctuations of renewable generation with the stable output of coal-based plants. By enabling real-time coordination between different energy sources, smart grids help ensure that supply and demand remain balanced, even when renewable production is intermittent.

Ultimately, these digital improvements enhance overall grid stability, reduce the risk of blackouts, and enable Kosovo to move toward a cleaner and more diversified energy mix without compromising reliability

Fig. 5. Electricity mix in Kosovo (2025): 91% coal/lignite and 9% renewable sources.

Currently, about 91% of Kosovo's electricity is generated from coal/lignite, with the remainder from other sources. Kosovo aims to reach a 32% share of renewable energy (RES) by 2030, emphasizing the role of digital technologies in efficiently integrating and managing these sources [11].

6. Case of Kosovo: Strategic Recommendations

Modernization of Kosovo's coal-based power plants should prioritize Kosova B, whose newer and less degraded condition makes it the most suitable candidate for digital upgrades. Implementing advanced monitoring, predictive maintenance, and real-time control systems at Kosova B can serve as a pilot, providing a model for broader energy sector applications.

Successful modernization requires leveraging international partnerships for financing and technology transfer. Collaboration with global energy companies and research institutions can accelerate adoption of advanced solutions, reduce technical risks, and bring best practices to Kosovo's context. State policies and incentives are equally critical. Beyond constructing new plants, the government should promote retrofits and digital upgrades of existing infrastructure through financial incentives, regulatory support, and streamlined approvals. These measures can enhance efficiency, reduce emissions, and strengthen energy security.

By combining strategic plant selection, pilot digital deployment, international collaboration, and supportive policies, Kosovo can modernize its coal-based assets, enable smoother renewable integration, and advance toward a sustainable energy mix.

7. Conclusion

This study highlights the challenges and opportunities associated with the digital modernization of coal-based power plants in Kosovo. Despite continued reliance on lignite, advanced digital technologies—such as smart monitoring, predictive maintenance, real-time control systems, and digital twins—offer a practical pathway to improve efficiency, reduce emissions, and enhance operational reliability.

These measures represent a transitional step rather than a final solution. While digital modernization does not eliminate the long-term need for renewable energy adoption, it provides the operational flexibility and infrastructure readiness necessary for a gradual, stable transition. By embracing digitalization, Kosovo can maintain a stable and secure electricity supply in the near term while preparing for a cleaner, diversified energy future. In this way, modernization of coal-based systems serves as a realistic bridge between the current energy landscape and a greener energy mix.

These digital modernization measures complement Kosovo's broader energy strategy, which targets at least 32% renewable electricity by 2030, improvements in energy efficiency, system modernization, market integration, and protection of social and environmental interest

References

1. Singh, Rajesh; Akram, Shaik Vaseem; Gehlot, Anita; Buddhi, Dharam; Priyadarshi, Neeraj; Twala, Bhekisipho. *Energy System 4.0: Digitalization of the Energy Sector with Inclination towards Sustainability*. Sensors. 2022, 22(17), 6619. DOI: 10.3390/s22176619

2.https://balkangreenenergynews.com/ngen-showcases-solutions-at-bef-2025-for-decentralized-electricity-grid-of-tomorrow/

3. Balkan Green Energy News. (2025, September 15). *Coal plant operator KEK to begin construction of Solar4Kosovo PV plant.* https://balkangreenenergynews.com/coal-plant-operator-kek-to-begin-construction-of-solar4kosovo-pv-plant/

4. Bislimi, A., & Nikaj, A. (2023). *Analyzing Solar Energy Integration in Smart Grids with a Focus on Demand Response, Energy Management, and Grid Stability*. UBT International Conference 2023, University for Business and Technology.

5. Bislimi, A., & Spahiu, S. (2024). *Decarbonizing through Solar and Wind Energy Integration: Optimizing Performance and Stability.* UBT International Conference 2024, University for Business and Technology.

6. Bislimi, A., & Spahiu, A. (2024). *Strategic Energy Planning and Coal's Role in Kosovo's Future*. UBT International Conference 2024, University for Business and Technology.

7. Bislimi, A., & Gashi, D. (2022). *Challenges, Stability and Reliability of the Energy Network After the Continuous Addition of Renewable Energy Sources*. UBT International Conference 2022, University for Business and Technology.

8. Bislimi, A. (2025). *Simplified Representation of Kessel/Glawitsch's Method.* International Journal on Energy Conversion (I.R.E.CON.), 11(6), 234–241

9. Rathore, M. M. U., Shah, S. A., Shukla, D., Bakiras, S., & others. (2021). The role of AI, machine learning, and big data in digital twinning: A systematic literature review, challenges, and opportunities. *IEEE Access, PP*(99), 1–1. https://doi.org/10.1109/ACCESS.2021.3060863
10. Khan, S., Saied, I. M., Ratnarajah, T., & Arslan, T. (2022). Evaluation of unobtrusive microwave sensors in Healthcare 4.0—Toward the creation of digital-twin model. *Sensors, 22*(21), 8519. https://doi.org/10.3390/s22218519
11. Energy Strategy of the Republic of Kosovo 2022–2031 (PDF)
12. https://discoveryalert.com.au/news/chinas-coal-dependency-2025-evolution-challenges

Evaluating the Role of Transformer Aging in Active Energy Losses for a Sustainable Energy Transition in Kosovo's 110/x kV Transmission Network

Kjani Guri[1], Kadri Kadriu[2]

[1,2] University for Business and Technology, Prishtina, Kosovo
kjani.guri@ubt-uni.net, kadri.kadriu@ubt-uni.net

Abstract: This paper presents the analysis and comparison of active energy losses measurements in power transformers 110/x kV in the Kosovo's transmission network. Like any electrical machine, also in power transformers are caused active energy losses occurring due to electromagnetic processes.
It is absolutely evident that the amount of active energy losses in all power transformers represents a significant value in the overall losses of the transmission network. As we known, power transformers are key devices in the transmission network, it is extremely important to analyze and to investigate the possibilities of their losses optimization; with small changes we can achieve better results.
The comparison of active energy losses in power transformers it's done between energy meters and the results of modeling / simulation of active energy losses through the PSS / E software, based on the same value of loads.

Keywords: power transformer, active energy losses, transmision network, optimization, energy meters, PSS/E - simulink software.

Introduction The generated electricity through transmission and distribution networks is delivered to the industrial and residential consumers.
In each power systems in real time, equality is maintained generation and consumption of electricity, the generators produce as much receive customers including energy losses in network between generation and consumers. During the transmission and distribution of electricity, the energy losses are unavoidable in different elements of the power system, are caused.
While active energy losses in the transmission network are relatively small (about 2 - 5%), in the distribution network these energy losses are several times higher (about 5 - 15%). The main elements of the power system which cause energy losses are the transmission lines and power transformers of the transmission and distribution network. As main elements of the power system (after generators) power transformers have a key role in the operation of the transmission and distribution network, enabling the transformation of high voltage into medium voltages.
The types of power transformers that are mostly used to transmission networks in our region are:
400/220kV,
400/110kV,
220/110kV and
110/x kV.

Their number by type varies depending on the size of the power system. While the number of power transformers 400/220kV, 400/110kV and 220/110kV is relatively small, the number of power transformers as 110/x kV is several times higher. The reason lies is that the configuration of the 110kV network is several times longer (length in km) than the 400kV or 220kV network. Because of configuration the power system, the number of 110/x kV power transformers is relatively large, the energy losses caused by their operation in the power system are evident and have a direct impact on the overall losses of the Power System, and in particular in the transmission network.

2. Understanding Technical Losses in Power Transformers

Technical losses in power transformers are a consequence of the electromagnetic processes that occur during the transformation process of voltage from a high voltage to medium voltage. These losses depend on the power transformer's electromagnetic characteristics as well as by their working regime [5]. The technical losses in power transformers are divided according to the cause of their appearance as:
no load losses, and
on load losses

As is known, no load losses are assumed to be constant while they are depended from voltage level, on load losses are dependet from the power flow through power transformer.

3. PERFORMANCE OF 110/X KV POWER TRANSFORMERS IN KOSOVO'S TRANSMISSION NETWORK

General Overview of Kosovo's Transmission Network

Kosovo's Transmission Network operating with high voltage transmission lines 400kV, 220kV and 110kV. Currently, the Kosovo's transmission network is connected to neighboring countries through seven cross-border lines. In December 2015, the construction of the eighth cross-border line (new OHL 400kV with Albania), which is expected to become operational, has been completed.

Table 1. Length of OHLs in Kosovo's Transmission Network by voltage (2018y)

Voltage (kV)	Length (km)
400kV	279.5
220kV	238.5
110kV	913.4
Amount	1,431.4

Except transmission lines, part of Transmission Network are substations including power transformers 400/220kV, 400/110kV, 220/110kV and 110/ x kV too. Number of substations and number of power transformers connected in Kosovo's Transmission Network are shown through below table.

Table 2. No. of Substations and Power Transformers (2018y)

Transformation (kV/kV)	No. of Substations	No. of Power Transformers	Power Capacity (MVA)
400/220kV	1	3	1,200
400/110kV	2	4	1,200
220/110kV	4	11	1,350

110/35/10kV	5	5	220
110/35kV	7	19	610
110/10kV	16	34	1,042
Amount	35	76	5,844

Based on data from above table, part of analyzing of energy losses in power transformers will be only power transformers 110/x kV connected with distribution networks (35kV and 10kV).

3.2 Categorization of 110/x kV Power Transformers Based on Voltage and Ageing

In below table are presented total number of power transformers 110/x kV depend of transformation voltage levels connected in Kosovo's transmission network and participation in percentage.

Table 3. Power transformer categorized by voltage level [3]

Power Transformers	No. of Power Transformer	Participation in %
110/35/10kV	5	9%
110/35kV	18	34%
110/10kV	30	57%
Amount	53	100%

Also, in Table 4 are presented categorized number of power transformers 110/x kV depend of ageing power transformers 110/x kV connected in Kosovo's transmission network and participation in percentage.

Table 4. Power transformer categorized by ageing

Age (years)	110/35/10kV	110/35kV	110/10kV	by Age	
00 – 15y	5	1	14	20	38%
15 – 30y	0	8	2	10	19%
30 – 40y	0	9	9	18	34%
40 – 50y	0	0	3	3	5%
> 50y	0	1	1	2	4%
Amount	5	19	29	53	100%

As we can see in above table, the ageing of power transformers connected in transmission network is:
about 38% are under the 15 years old,
about 19% are between 15 – 30 years old,
about 34% are between 30 – 40 years old,
about 5% are between 40 – 50 years old, and
about 4% are older than 50 years old.

4. TRANSFORMERS THROUGH ENERGY METERS IN KOSTT'S TRANSMISSION NETWORK

Overview of Metering Systems Installed in KOSTT

Each metering systems installed in Kosovo's transmission network, managed by KOSTT, including instrument transformers (CTs and VTs) is built based on the metering requirements presented on Metering Code for TSO, approved by Energy Regulator Office of Kosova [1].

All metering devices (CTs, VTs and energy meters) are in accordance with IEC standards for accuracy [4]:
Current Transformers (CTs) are in accordance with IEC Standards (IEC 60044-1:2003), accuracy class 0.2S, security factor FS=10 and burden of dedicated cores for metering are 15VA (for 110kV), 5-10VA (for 10kV and 35kV);
Voltage Transformers (VTs) are in accordance with IEC Standards (IEC 60044-2:2003), accuracy class 0.2S, and burden of dedicated windings for metering are 30VA (for 110kV), 5-10VA (for 10kV and 35kV);
Energy Meters are product of Landis+Gyr/Switzerland, High Precise Meter, Type ZMQ202, with two profiles, first profile is every 15min and second profile is every 1min. Accuracy class of the energy meters is according with IEC Standards (IEC 2053-22 and IEC 61268). Accuracy class for active energy is 0.2S, while 0.5 is for reactive energy.

The commercial border between TSO's network and DSO's network is medium voltage (35kV and 10kV) of power transformers 110/x kV. Based on this, at commercial border in secondary (and tertiary) side (M2 and M3) of TR are installed two identical energy meters (as Main and Check) as per Metering Code requirements, until at primary side(M1) of TR is installed only one energy meter (as Check Meter).

Design of the existing metering systems installed for each kind of power transformers 110/x kV is shown as below [4]:

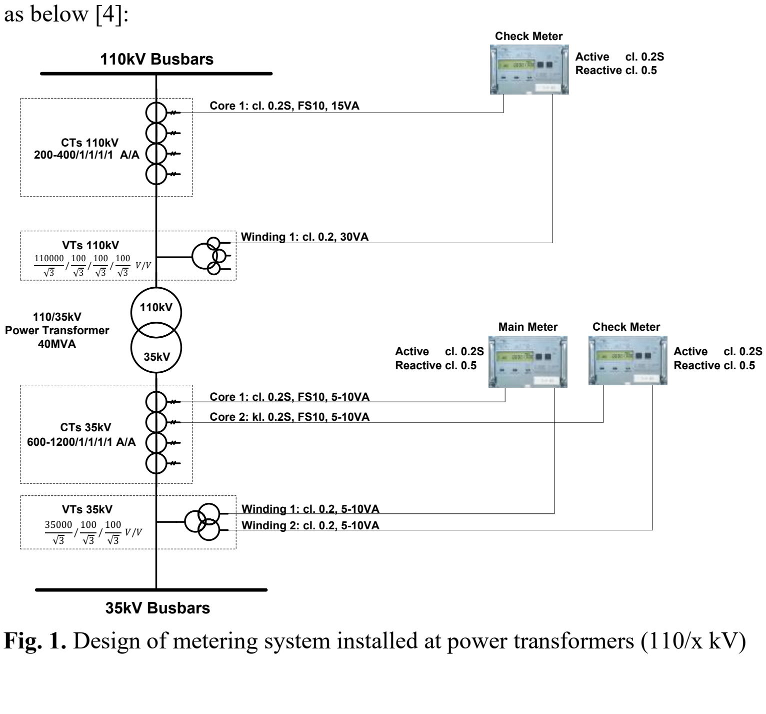


Fig. 1. Design of metering system installed at power transformers (110/x kV)

Configuration of metering systems according type of power transformers (110/x kV)

All configuration types of metering systems at power transformers 110/x kV is shown as below figure [4].

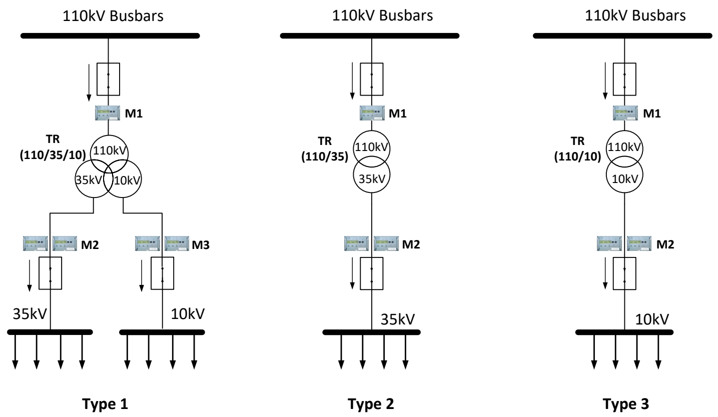


Fig. 2. Configuration of metering systems according type of power transformers (110/x kV)

Measured of energy losses in power transformers 110/x kV by energy meters

Calculation measured active energy losses (ΔW) in power transformers are done based on measured active energy by energy meters (M1, M2 and M3) at primary, secondary and tertiary side of power transformers [7]:

at Type 1 of power transformers(110/35/10kV), active energy losses are calculated as difference between M1 and Σ(M2+M3): ΔW = M1 – (M2+M3)

at Type 2 and Type 3 of power transformers (110/35kV and 110/10kV), active energy losses are calculated as difference between M1 and M2: ΔW = M1 – M2

Table 5. Measured of active energy losses by type of power transformers 110/x kV (during 2024y)

Power Transformers	No. of TR	Measured energy flow at primary side (110kV)	Measured energy flow at secondary & tertiary side (35kV & 10kV)	Energy Losses in TR	%
		MWh	MWh	MWh	
		a	b	c = a – b	d = c/a
110/35/10kV	5	720.873	718.721	2.152	11,31%
110/35kV	18	1.728.134	1.721.243	6.891	36,22%
110/10kV	30	2.314.262	2.304.278	9.984	52,47%
Amount	53	4.763.269	4.743.521	19.748	100%

Based on measured active energy in power transformers, in the below table will be shown active energy losses (ΔW) by age of power transformers 110/x kV[7]:

Table 6. Measured of active energy losses in Power transformers 110/x kV by Age (during 2024y)

Age of Power Transformers (by years)	No. of TR	Measured energy at primary side (110kV)	Measured energy at secondary & tertiary side (35kV & 10kV)	Energy Losses in TR	%
		MWh	MWh	MWh	
		a	b	c = a – b	d = c/a
00 – 15y	20	1.892.513	1.884.421	8.092	0,43%
15 – 30y	10	654.727	651.943	2.784	0,43%
30 – 40y	18	1.365.942	1.359.593	6.349	0,46%
40 – 50y	3	193.319	192.330	989	0,51%
> 50y	2	156.768	155.955	813	0,52%
Amount	53	4.263.269	4.244.242	19.027	0,45%

Measured of active energy losses in power transformers 110/x kV by PSS/E simulations

The PSS/E simulation is performed for the system conditions as per year 2024, with 1480MW system peak. Simulations results by PSS/E software [6] are presented in below table.

Table 7. Power Transformer active power losses calculated by PSS/E for different voltage

Power Transformer active power losses during the system peak 2024					
Power Transformer	No. of TR	ΔP_{Fe} [MW]	ΔP_{Cu} [MW]	Total Power Losses [MW]	%
		a	b	c = a + b	
TR 110/35/10kV	5	0.20	0.40	0.60	14%
TR 110/35kV	18	0.35	0.90	1.25	28%
TR 110/10kV	30	0.85	1.70	2.55	58%
Amount of TR losses	53	1.40	3.00	4.40	100%

As is shown in the above Table, 58% of total transformer losses is caused by the 110/10 kV power transformers, 28% at the 110/35 kV transformers and 14% at the three winding transformers 110/35/10 kV. From total transformer peak losses around 68% is caused by the load losses and 32% is caused by the no load losses.
Considering that no load active losses are constant, the total active energy losses caused by the no-load losses in the all power transformers close to distribution network can be calculated as follows:

$$\Delta W_{Fe} = \Delta P_{Fe} \cdot T_{year} = 1.40MW \cdot 8760h = 12264\ MWh$$

The on load active energy losses are calculated based on system load duration characteristic which determines that total hours of the system losses for the year 2024 in Kosovo's Transmission Network are around $T_{\Delta} = 2455$ hour.

Calculated transformer active energy losses caused by on load losses are as follow:

$$\Delta W_{cu} = \Delta P_{cu} \cdot T_{\Delta} = 3.00MW \cdot 2455h = 7365\ MWh$$

The total active energy losses caused in the power transformers close to the distribution network based on calculations are:

$$\Delta W = \Delta W_{Fe} + \Delta W_{cu} = 19629\ GWh$$

Based on the calculated results the share of the power transformer, the active energy losses is 62% caused by no load losses and 38% caused by the on load losses.

COMPARING AND ANALYSING ACTIVE ENERGY LOSSES IN POWER TRANSFORMERS

When we compare the measured energy results by energy meters and calculation results with PSS/E is can be noted that the error of calculated active energy losses is:

$$\varepsilon = \frac{\Delta W_{meas.} - \Delta W_{calc.}}{\Delta W_{meas.}} = \frac{19027 - 19629}{19027} \cdot 100\% = -3.16\%$$

The very low level of error shows that selected methodology for calculation of active energy losses for power transformers is appropriate and can be used for other elements of the system which causes active energy losses such a lines, cables, generators etc. For error calculation we have considered the measurements as referent value.

CONCLUSION

In this paper are presented the calculation of active energy losses in all power transformers 110/x kV connected in Kosovo's Transmission Network. Comparing results between measured energy by energy meters and energy calculation by the PSS/E software is done for last year (2018). Based on the obtained results from measured energy by energy meters and obtained results from calculation energy losses by PSS/E software we see a small difference of energy losses calculation. This difference is shown because in normal condition during system operation some of the power transformers 110/x kV has been out of operation for any reasons (maintenance, optimisation, project of refurbishment any of substations, etc.).

The obtained results of calculated of energy losses are showing that the energy losses in power transformers 110/x kV are increasing by ageing. Except fact that energy losses increasing in power transformers with increasing the load, so energy losses growing up by the ageing of power transformers. Increasing ageing of power transformer has influence in increasing the total energy losses in power transformer too.

Regarding the power losses in power transformers, during preparation phase of technical requirements for new power transformers 110/x kV should have in consideration especially requirements for power losses (no load and on load losses in kW), because their impact is very high during the life of power transformer.

References

Energy Regulator Office of Kosova, www.ero-ks.com, Kosovo, 2018
KONČAR Tehnički Pripučnik, 5th Edition, Croatia, November 1991
http://www.kostt.com//Transmission_Development_Plan_2017-2026.pdf
Metering Sector, System Operator, KOSTT, March 2019

Hadi Saadat, “Power System Analysis“, Tat McGRaw – Hill Education, 2nd Edition, 2002
PSS/E Software simulations, KOSTT, Kosovo, March 2024
AMR system, KOSTT, March 2024

Integration of Intelligent Systems in Civil Installations

Avni Alidemaj*, Arbnor Lekaj**

* UBT-Higher Education Institution, 10000, Prishtinë, Kosovë
** A+Electric sh.p.k, Prishtinë, Kosovë
e-mail: avni.alidemaj@ubt-uni.net, lekajarbnor@gmail.com
*Coresponding author: lekajarbnor@gmail.com

Abstract: Proper management of electrical energy and its efficient use have gained increasing importance over the past decades, due to the growing demand for energy and the need for environmental sustainability. In this context, the development of modern technologies for building automation and energy management has become an essential part of technological transformations in both the energy and construction sectors. This approach not only aims to reduce energy consumption but also contributes to creating a greener and more sustainable environment, while simultaneously enhancing safety, comfort, and control for users.

This paper addresses the design and implementation of an intelligent system for energy and home appliance management using KNX technology – an international standard for building automation. The proposed system includes advanced features such as remote control, real-time monitoring, security management, and energy consumption optimization for both indoor and outdoor environments. All devices are integrated into a centralized network that can be remotely controlled through mobile devices, offering user convenience, flexibility, and operational efficiency.

Programming will be carried out using the professional ETS 5 software, a standard tool for configuring KNX systems, while the Z41 application will be used for graphical interface and control. The implementation foresees the use of devices from various manufacturers, thereby illustrating the flexible and open nature of the KNX system. Another important aspect discussed in this project is cybersecurity, which is essential due to the interconnection of all devices within digital networks. This paper aims to present a functional and practical model of an integrated energy management system that can be adapted to residential buildings or commercial facilities

Keywords: Intelligent system, cybersecurity, energy efficiency, devices, effectiveness.

Introduction Imagine how convenient it would be to turn on your air conditioner ten minutes before arriving home on a hot July afternoon. Or to have a security system that can detect smoke, excessive electricity usage, burglary attempts, or unauthorized movements within your property-and immediately notify you about it.

Now imagine a system that can recognize and identify you, automatically adjust the lighting according to your preset preferences, open doors for you, play your favorite music, and switch on safety lights during the night and turn them off in the morning. All of these features are made possible through an Intelligent System.

In other words, this system can be described as follows:

An intelligent system is a platform for managing and monitoring your building through your smartphone. It allows you to control and supervise essential functions at any time, simplifying daily life, saving energy, and keeping you informed about what is happening in your property while enabling you to manage it efficiently and easily.

The intelligent system provides complete control over your premises by interconnecting all devices within the building so that they can communicate with each other and with the user. Everything in the building that uses electrical energy can be integrated into the intelligent

system and placed under the user's command. This control can be executed through voice commands, remote control, smartphone, or computer.
Such a system enables your building to become an active partner in managing your busy lifestyle. KNX systems for smart buildings not only provide enhanced control and greater comfort but also significantly reduce energy costs by continuously monitoring and adjusting operational settings for every device connected to the KNX network.

2. What Are Intelligent Systems

A sustainable intelligent system is one that fulfills three fundamental conditions as follows:
Modular system: allowing gradual expansion step by step according to the environment, requirements, or available resources.
Open system: compatible with third-party manufacturers' products and adaptable to future technologies even after many years.
System operating through power lines (Power Line): functioning without the need for additional cabling or dependency on wireless operation.
The KNX intelligent system represents a network within a building—integrating lighting, security systems, heating, air conditioning, household appliances, water flow management, as well as external components such as the garden, garage, swimming pool, and gate.
All devices are networked and equipped with intelligence, enabling them to communicate with each other and with the occupants. The intelligent system adapts to the needs and preferences of each resident, relieving them of daily routine tasks, promoting well-being, ensuring higher safety standards, saving energy, and ultimately increasing the overall value of the property [1].
KNX systems for smart homes and commercial buildings not only provide better control and greater comfort, but KNX also significantly reduces energy costs by continuously monitoring and adjusting the operational settings of each device connected to the KNX line. Figure 1 illustrates the elements that can be controlled both locally and remotely [1], [2].

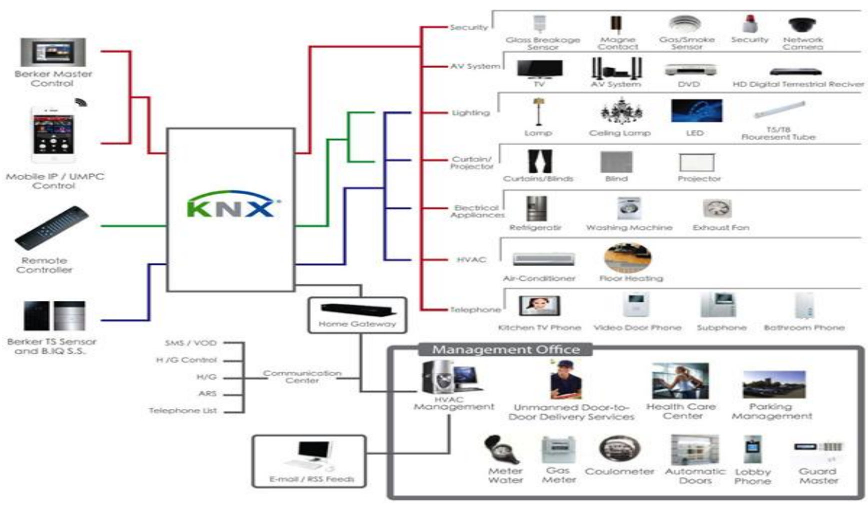


Fig. 1. Illustration of a KNX system and the elements controlled by this system

2.1 Main Components of Intelligent Systems

A KNX device consists of a microcontroller, a line transmitter, and an application module. Devices can be categorized into **active** and **passive** types.

Passive devices do not have a controlling function; they only play a **supporting role**. They do not communicate with other devices but are essential components within the line system, such as **power supply units** and **interfaces** used to connect devices during programming.
Active devices can be divided into the following types:
Filters-Protect the system from interference and cyberattacks.
Couplers-Their role is to optimize the communication efficiency between system lines.
Sensors-Provide information to the line systems, for example, room temperature measurement, water leakage detection, or smoke and gas detection.
Actuators-Represent the "conductors" of the system; they connect electrical consumers to the line systems.
The components also include the **central control unit**, which is installed in the fuse panel, and **microcomputers** in the form of colored terminals that are mounted on devices or in junction boxes. By installing the central unit, a **digital infrastructure** is created, allowing the system to be expanded indefinitely according to preferences and possibilities. This is particularly beneficial for **construction companies** that wish to provide their clients with the necessary **digital infrastructure** alongside the electrical one in newly constructed buildings [3].

Advantages of Intelligent Systems

There are many benefits to transforming a building into a smart one. Starting from usage data and the ability to control almost every function of your property from an electronic device (phone, tablet, or computer), you will be surprised by the additional advantages listed below.
Whether it is your security system, lighting, or television, being connected to various types of smart devices throughout your building can save you time, money, and energy. Not to mention the peace of mind it provides, knowing that all these systems constantly communicate with each other.
This means that you have the power to control different systems of your property at any time and from anywhere [4].
The interconnectivity of the platform allows you to adjust your thermostat, review security camera footage, control lighting, and much more. Want to turn on the air conditioner a few minutes before arriving home? Or switch on the outdoor lights if you hear a noise-without leaving your bedroom? All of this is possible through an intelligent system.
Intelligent systems offer several remarkable (and undeniable) practical advantages for building automation. Here are some examples [4], [5].

3.1 Managing All Electrical Devices from a Single Location

The **convenience factor** here is significant. Being able to keep all the technology in your building connected through a single interface represents a major advancement in both technology and building management. In theory, all you need to do is learn how to use one application on your phone or tablet, and you will be able to access and control countless functions and devices throughout your property. This makes it much easier to achieve the level of operation and customization you truly desire for your building.

3.2 Flexibility for Existing and New Devices

Intelligent systems tend to be highly flexible when it comes to accommodating both existing and new devices and technologies. No matter how modern your current devices may seem, newer and more impressive models will continue to emerge over time. Beyond that, you are likely to expand your collection of devices as you replace older ones or discover new technologies to enhance your indoor and outdoor spaces. The ability to integrate these seamlessly makes your role as a property owner much easier and allows you to stay aligned with the latest advancements in smart living.

3.3 Increased Security within the Building

When you integrate security and surveillance features into your smart home network, your overall home safety can be significantly enhanced. There are thousands of options available-only a fraction of which are commonly used today. For example, home automation systems can

connect motion detectors, surveillance cameras, automated door locks, and other tangible security measures throughout your home, enabling you to activate them from a mobile device before going to bed.
You can also choose to receive security alerts on your various devices depending on when an alarm is triggered, and you can monitor real-time activity, whether you are at home or halfway around the world.

3.4 Remote Control of Building Functions
Do not underestimate the power of being able to control your building's functions from a distance. On an extremely hot day, you can command your home to start cooling just in time before you return from work. Or, if you're in a hurry to start dinner but still at the store, you can activate your oven to preheat while you're on your way home. You can even check whether you left the lights on, see who is at your front door, or ensure that all your devices are turned off while you are away.
3.5 Increasing Energy Efficiency
Depending on how you use your smart building technology, it is possible to make your space more energy efficient. For example, you can have precise control over your heating and cooling systems with a programmable smart thermostat that learns your schedule and temperature preferences, then suggests optimal settings for energy efficiency throughout the day. Motorized lights and shades can be programmed to switch to an evening mode when the sun sets, or lights can automatically turn on and off when you enter or leave a room, ensuring you never have to worry about unnecessary energy loss [6].

The Impact of Intelligent Systems on Energy Management
Over the past few decades, electricity consumption has shown a continuous increase, especially in both developing and developed countries. The majority of this consumption occurs in buildings, particularly public, commercial, and residential ones. Alongside research on renewable energy sources and energy efficiency in buildings, electrical devices, and vehicles, considerable attention has been given to effective energy management.
As a result, the European Union has established the well-known 20-20-20 target, which aims for:
a 20% reduction in annual energy consumption in EU countries,
a 20% decrease in greenhouse gas emissions, and
ensuring that 20% of total energy consumption comes from renewable energy sources by the year 2020 [7].
As energy costs continue to rise, consumers are increasingly interested in reducing their energy consumption. Modern technologies available today are designed with the potential to save at least 40% of electrical energy use in most devices. The vast majority of households are assumed to already possess most of the necessary electrical appliances.
With the introduction of smart meters, intelligent devices, and automated energy management products, it is possible to significantly reduce electricity expenses. However, due to their relatively high cost, smart devices will not be able to fully replace traditional appliances in all households and institutions anytime soon. Therefore, there is a growing need for users to manage their consumption by utilizing their existing devices more efficiently.
Furthermore, we are surrounded by an increasing number of electrical and electronic devices, many of which continue to consume power without our awareness. Most electronic devices-such as multimedia systems, televisions, and computers-when turned off but still plugged in, enter a "standby mode." Although consumers often assume these devices are off, they continue to draw a small amount of electricity until manually unplugged. The greater the number of such devices in a household or office, the higher the cumulative energy consumption becomes. While a single device may seem insignificant, collectively, these "standby" devices can contribute to a substantial energy waste [5], [7].

In the past decade, many research projects have focused on smart grids, new technologies for improving the efficiency of electrical devices, developing intelligent energy management systems, and discovering ways to reduce electricity consumption. Previous limitations in measurement and consumption data have hindered the development of accurate statistical methods for analyzing and forecasting energy usage. However, the rapid advancement of intelligent system technologies has helped overcome these barriers.
In addition to monitoring and storing data, intelligent systems can take actions that directly influence energy efficiency.
Where KNX systems are installed, residents are informed about their current energy consumption, enabling them to use energy more economically. When KNX is used to control and monitor various home devices, total energy consumption is significantly reduced. Moreover, users can track their actual energy use on visual displays (smartphones, tablets, PCs, etc.) and take action to reduce it as much as possible-whether they are at home or away.
By integrating all applications into a single KNX installation, it becomes possible to monitor and record real-time data (such as temperature, energy, and water consumption), providing a comprehensive overview of usage and enabling users to take further actions toward improved efficiency [6], [7].
In **Figure 2,** several **intelligent system devices** are presented, which enable us to **monitor and record data** from our equipment

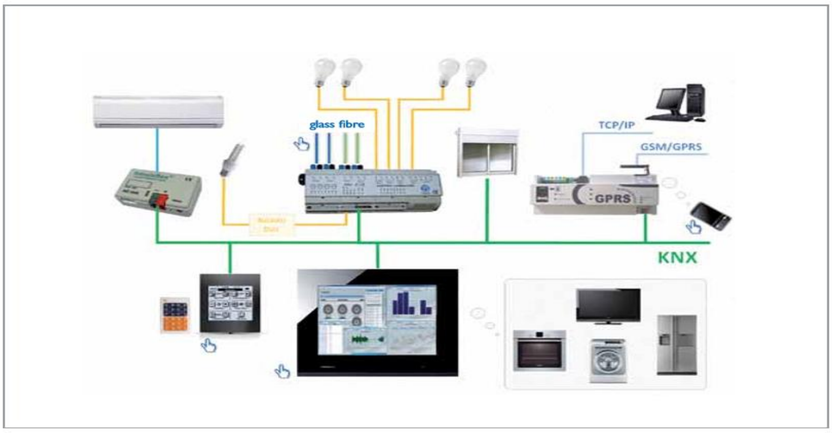


Fig. 2. Real-time monitoring and data recording through the KNX system.

4.1 Management of Electricity Tariffs
It is in the consumer's best interest to avoid unnecessary electricity usage during certain periods of the day-especially during peak hours, when energy demand is very high and electricity prices are more expensive. Considering that there are typically two different electricity tariff periods during the day (a high-rate tariff and a low-rate tariff), it becomes challenging for consumers to manually ensure that specific tasks are carried out during the lower-priced hours due to the fast pace of daily life.
This is where the intelligent system plays a key role-it manages energy usage automatically without disrupting the user's daily routine.
In Figure 3, the diagram illustrates how electricity tariff management is achieved through the KNX intelligent system [4], [5].

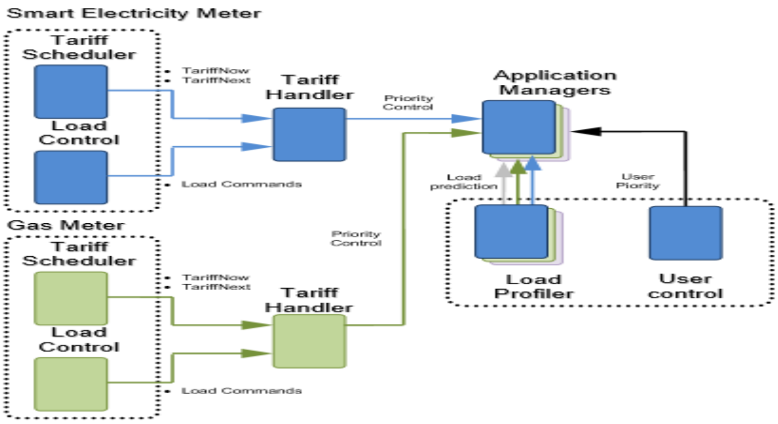


Fig. 3. Tariff Management with KNX.

4.2 Energy Saving

It is a scientifically proven fact that the use of control devices in buildings has a significant positive impact on overall energy consumption, thanks to intelligent optimization algorithms applied to systems such as HVAC, lighting, and their intercommunication.

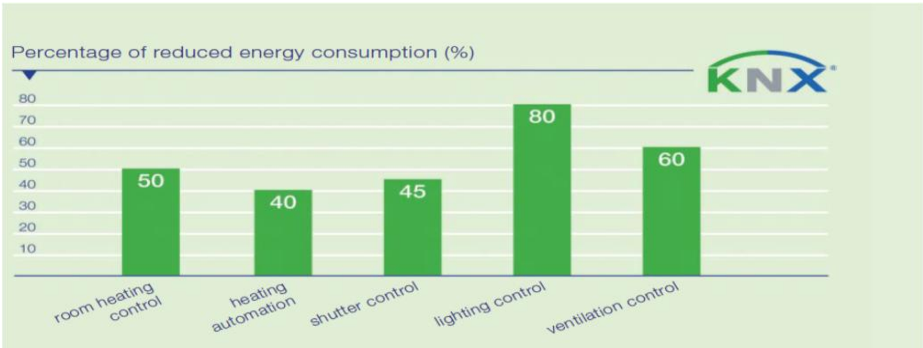
Below are some examples of how intelligent systems help us save electrical energy:

Sensors ensure that when windows are open, the heating or air conditioning system is automatically switched off.

Presence detectors ensure that rooms are heated, cooled, and/or illuminated only when occupied.

Light intensity sensors automatically dim or turn off artificial lighting depending on the level of natural daylight.

The use of an intelligent system not only raises awareness about energy consumption but also



provides practical tools for households and buildings to save energy. This is especially important in a world where energy costs have become an increasingly critical factor in the operational expenses of any facility.

In **Figure 4**, the reduction of energy consumption that can be achieved by using the **KNX intelligent system** is presented.

Fig. 4. Reduction of energy consumption with KNX.

A proper security concept is based on adequate prevention of access by unauthorized persons. In the case of KNX installation, this means that only authorized individuals (the installer, caretaker, and user) will have physical access to the KNX system. When designing and installing, the critical elements of each KNX medium should be protected in the best possible way [6], [7].

5. Conclusion

This paper has presented what an intelligent system is and which essential components are required to build an intelligent system from the KNX family.
Firstly, a network infrastructure is needed to transmit the information received from the system controller.
Secondly, a software architecture must be adapted to utilize this information. To achieve this, an approach should be taken to ensure the most appropriate service provision through the system's sensors.
Studies reveal that KNX-based building network control allows up to 50% energy savings, making KNX ideally suited to meet the increasingly stringent energy consumption requirements of modern buildings. Through the intelligent control of building system technologies using KNX, a building's energy consumption can be reduced by half. Automating the building significantly reduces maintenance costs. KNX enables a decrease in energy consumption for lighting, heating, ventilation, and air conditioning-all while maintaining the same level of comfort.
With annual energy consumption for lighting alone, the investment would pay back within just one year using KNX line control. Ultimately, it is not only investors who benefit from reduced energy consumption-the environment benefits as well.
In summary, KNX enables the following energy savings:
Up to 40% with KNX climate control
Up to 50% with KNX hotel room control
Up to 80% with KNX lighting control
Up to 60% with KNX ventilation control
KNX simplifies professional life and saves time by allowing you to take control of the building in your hands, via remote management through your smartphone.

References

KNX Association, "KNX Basics," 2017.
KNX Association, "KNX Project Design Guidelines," 2018.
KNX Association, "Smart Metering with KNX," 2017.
KNX Association, "KNX for Metering, Displaying and Energy Management," 2016.
KNX Association, "KNX Security," 2015.
Marijon Pano, "Intelligent Management of Electrical Energy in Residential Buildings and Institutions," 2018.
Mounir Mokhtari, Bessam Abdulrazak, "Smart Homes and Health Telematics," 2018.

The role of coal in the implementation of the green transition agenda in Kosovo

Nexhmi Krasniqi[1] Armend Ymeri[2]

UBT –Higher Education Institution, Kalabria Neighbourhood p.n Prishtina, Republic of Kosovo
*Corresponding author e-mail: armend.ymeri@ubt-uni.net

Abstract: The recent global energy crisis—fueled by geopolitical tensions, increased energy demand, and persistent dependence on fossil fuels—has highlighted the fragility of current energy systems and the urgent need for a sustainable transformation. High and inefficient energy consumption, closely linked to industrial growth and urban development, continues to undermine ecological balance and accelerate climate change. While technological progress has improved access to renewable sources and advanced energy systems, it has not yet reached the scale or pace required to fully counteract the environmental consequences of unsustainable practices. In response, the European Union has placed the Green Transition and full Decarbonization at the core of its climate and energy policies, aiming to reach net-zero emissions by 2050. However, recent crises—including price volatility, supply chain disruptions, and regional conflicts—have led to a temporary delay in parts of the agenda, necessitating revised implementation timelines and more resilient strategies. This paper explores the implications of the global energy crisis on energy transition policies, with a special focus on developing countries. The Republic of Kosovo is analyzed as a case study, based on its Energy Strategy 2022–2031, which outlines commitments to align with EU objectives, phase out coal dependence, and promote renewable energy integration. The study assesses institutional readiness, technological infrastructure, and socio-economic constraints, and concludes with recommendations to strengthen energy security while accelerating progress toward a low-carbon future.

Keywords: Energy crisis; Decarbonization; Energy transition; Green Agenda; Renewable energy; Kosovo Energy Strategy; Energy efficiency; Sustainable development.

Introduction As a result of globalization trends, in recent years the energy sector has undergone a major transition toward the production of "clean energy", accompanied by the accelerated development of new technologies for generating electricity from renewable sources, which are becoming increasingly available on the market.

With the adoption of the Integrated Pollution Prevention and Control Directive (IPPC Directive – 96/61/EC), the European Union set an ambitious objective to raise the overall level of environmental protection and introduced the concept of sustainable development across a wide range of polluting industrial activities, including mining, metallurgy, energy, and several other sectors.

In light of the obligations arising from this directive, it is essential to acknowledge that coal utilization will face significant challenges in the coming period.

This development was further reinforced by the Western Balkans Leaders' Declaration during the Sofia Summit, which brought together the region's highest state representatives to sign the "Green Agenda". Through this agenda, Western Balkan countries committed to implementing measures addressing environmental changes and pollution prevention, the development of

sustainable energy, mobility, and the circular economy, as well as the advancement of biodiversity, sustainable agriculture, and food production.
Initial concrete steps include:
the promotion of a carbon dioxide (CO_2) emissions tax,
the development of market models for the use of renewable energy sources, and the gradual phase-out of coal subsidies.
Some of the key measures to be implemented are:
alignment with EU legislation, with the goal of achieving climate neutrality by 2050,
setting energy and environmental targets for 2030 in line with the EU Energy Community legal framework,
and developing and implementing national energy and climate plans with clear actions for reducing greenhouse gas (GHG) emissions.
The implementation of the "Green Agenda" also includes:
cooperation on preparing a socio-economic impact assessment of decarbonization at both national and regional levels,
ensuring a just transition,
enhancing energy efficiency across all sectors,
increasing the share of renewable energy sources in the energy mix,
and creating the necessary conditions for investment.
According to many researchers, from both a technical and economic standpoint, there is no long-term alternative to a 100% renewable energy system.
In this context, it is worth emphasizing that the scenarios developed in the national strategies of many countries, including Kosovo, foresee a diversified energy mix generated from sources such as: wind, biomass, natural gas, hydro, geothermal energy, and solar panels (photovoltaic systems).

2. Coal Reserves

According to research conducted by the Anatolia Agency and BP, global coal reserves in 2016 were estimated to reach 1,141 billion and 791 million tons, of which approximately 411 billion tons are attributed to hard coal reserves.
Coal, recognized as one of the largest sources of energy production, is found in almost every part of the world. These reserves are distributed across many countries, with 75% of the currently known coal reserves located within the territories of just five countries.
It is projected that, at the current rate of coal consumption, global reserves could meet energy demands for approximately the next 120 years.

Table 1 – Global Coal Reserves According to 2016 Publication

	Country	Coal Reserves 10^6(t)	%
1	USA	254197	22.07
2	Russia	176771	15.35
3	Australia	159634	13.86
4	China	149818	13.01
5	India	107726	9.35
6	Germany	39802	3.46
7	Ukraine	37892	3.29
8	South Africa	35053	3.04
9	Poland	28451	2.47
10	Kazakhstan	28225	2.45
11	Indonesia	24910	2.16

12	Kosovo	13910	1.21
12	Turkey	12514	1.09
		1141791	100

Lignite is the most important energy resource in Kosovo, accounting for approximately **95% of total electricity production**. The first coal explorations in Kosovo began in the early 20th century, when it was confirmed that the country possesses significant reserves of this resource. Underground coal exploitation started in **1922**, in the locality of **Hade**, followed later by operations in **Babush, Lipjan**. Systematic geological investigations of coal in the Kosovo basin were conducted during the period **1952–1957**.
The most important coal basins in Kosovo are:
the **Kosovo Basin**,
the **Dukagjini Basin**,
and the **Drenica Basin**,
which together contain an estimated **14 billion tonnes** of lignite-type coal.

Kosovo Coal Basin

The Kosovo Coal Basin is located in the central part of the country. Geomorphologically and geographically, it represents a typical lowland area with a longitudinal axis stretching in a **northwest-southeast direction**, from **Mitrovica in the north to Kaçanik in the south**. The basin extends approximately **85 km in length** and has an average width of about **10 km**. It covers a total area of around **850 km²**, while the productive coal-bearing area spans roughly **300 km²**.
Dukagjini Coal Basin

The Dukagjini Basin, in a broader sense, represents a distinct morpho-tectonic unit formed on top of older, more complex geological structures. The basin's axis extends in a **northeast-southwest direction**. The total surface area of the basin is approximately **1,700 km²**, with the **White Drin River** flowing through its center.
The Dukagjini Basin benefits from good transportation connections. The **Fushë Kosovë – Pejë railway line** passes through its southern part, with a branch line leading to **Prizren**. The entire basin is intersected by several asphalt roads, including **Pejë – Gjurakovc – Mitrovicë**, **Pejë – Klinë – Prishtinë**, as well as **Gjurakovc – Istog** and **Gjurakovc – Klinë**. Given this well-developed road and railway network, any future coal exploitation must consider appropriate solutions for relocating infrastructure objects that lie within the exploitation zones.

Drenica Coal Basin

The Drenica Basin lies between the **Kosovo Basin** to the east and the **Dukagjini Basin** to the west. It consists of two sub-fields:
the **Skenderaj Field** in the north, with an area of approximately **3.97 km²**, and
the **Gllabar-Drenas Field** in the south, covering **1.5–2.0 km²**.
The basin stretches in a **north-south (meridional) direction**, with a slight westward deviation. It has a total length of about **30 km** and a maximum width of approximately **10 km**. Traffic and transport connections to nearby urban centers are favorable. The coal deposit is accessible via the **Skenderaj–Drenas asphalt road**, connected further through **Prishtinë – Pejë** and **Mitrovicë – Podgoricë**, and **Drenas** is linked by the **Prishtinë – Pejë railway line**.

In terms of hydrography, all surface waters from the northern part of the Drenica Basin drain into the **Klinë River**, which subsequently flows into the **Drin River**.

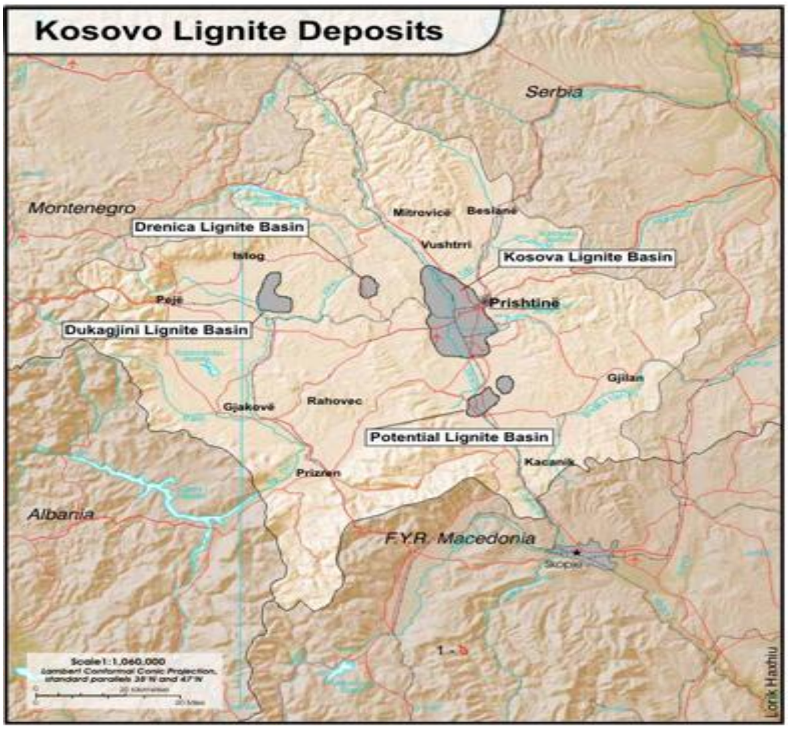


Fig. 1. Kosovo Coal Basin

3. Global Trend in Coal Utilization

According to the International Energy Agency (IEA), global coal usage is expected to reach a record high in 2024. This projection comes during a year that is likely to become the hottest ever recorded. Despite growing calls to phase out the most polluting fossil fuel—coal, which is a major driver of climate change—the IEA anticipates that global coal demand will hit an all-time high for the third consecutive year.

Scientists have consistently warned that greenhouse gas (GHG) emissions must be drastically reduced to prevent global warming and avoid catastrophic impacts on both the planet and humanity. The year 2024 is already marked by severe droughts in Italy and South America, fatal floods in Nepal, Sudan, and Europe, intense heatwaves in Mexico, Mali, and Saudi Arabia, and deadly cyclones in the U.S. and the Philippines that have claimed thousands of lives.

Table 2 – The Largest Coal Producers

Annual coal production 10^6 [t]									
Country	**2023**	**2022**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**
China	4362	4153	4126	3902	3846	3698	3523	3411	3747
India	969	863	767	720	730	715	671	653	632
Indonesia	781	693	614	564	616	558	461	434	392
USA	524	539	524	486	641	686	702	661	813
Russia	480	461	435	401	437	442	411	385	373
Australia	443	464	467	500	512	502	481	493	485
South Africa	238	244	236	247	258	250	252	251	252
Kazakhstan	118	115	84	96	98	101	101	103	107
Germany	102	131	126	107	131	169	175	176	183
Poland	89	108	107	100	112	122	127	131	136
Turkey	79	84	86	75	87	84	100	71	58
Serbia	33	35	36	40	39	38	40	38	38
Greece	11	14	12	14	27	37	38	33	48
Kosova	7	9	9	8	8	9	8	10	9
Brazil	7	6	7	6	5	6	7	8	8
Global level	**8695**	**8360**	**8065**	**7687**	**8059**	**7923**	**7629**	**7419**	**7900**

The IEA's newly released "Coal 2024" report forecasts that global coal use will peak by 2027, following a new record high of 8.77 billion tonnes surpassed this year. However, this trajectory depends heavily on China, which over the past 25 years has consumed 30% more coal than all other countries combined. The primary driver of this consumption has been the increasing electricity demand in China, with more than one-third of global coal combustion occurring in Chinese thermal power plants.

While China has made significant efforts to diversify its energy mix—including a massive expansion of solar and wind capacity—the IEA estimates that China's coal demand will hit a record 4.9 billion tonnes in 2024. This growing demand from China, India, and Indonesia has offset declines in coal consumption seen in developed economies.

In the European Union and the United States, coal consumption is expected to fall by 12% and 5% respectively in 2024, compared to 23% and 17% declines observed in 2023. However, the rate of decline has slowed, raising concerns among experts—particularly in light of a potential shift in U.S. leadership—that climate commitments by the world's largest economy may be weakened.

Coal production has also reached an all-time high, surpassing nine billion tonnes for the first time, with major producers China, India, and Indonesia setting new production records.

4. Coal Consumption in Europe

Demand for coal in Europe has increased due to a greater shift from gas to coal, driven by high gas prices and reduced Russian gas flows. However, European coal demand is expected to fall below 2022 levels by 2025, according to the report. Global coal-fired power generation is projected to reach a new record of around 10.3 terawatt-hours this year, while coal production will increase by 5.4 percent to approximately 8.3 billion tonnes, also an all-time high. The three largest coal producers — China, India, and Indonesia — are set to achieve record production this year. Despite high prices and healthy margins for coal producers, there are no signs of increased investment in export-led coal projects. This indicates investor and mining company caution regarding the medium- and long-term outlook for coal, the report states.

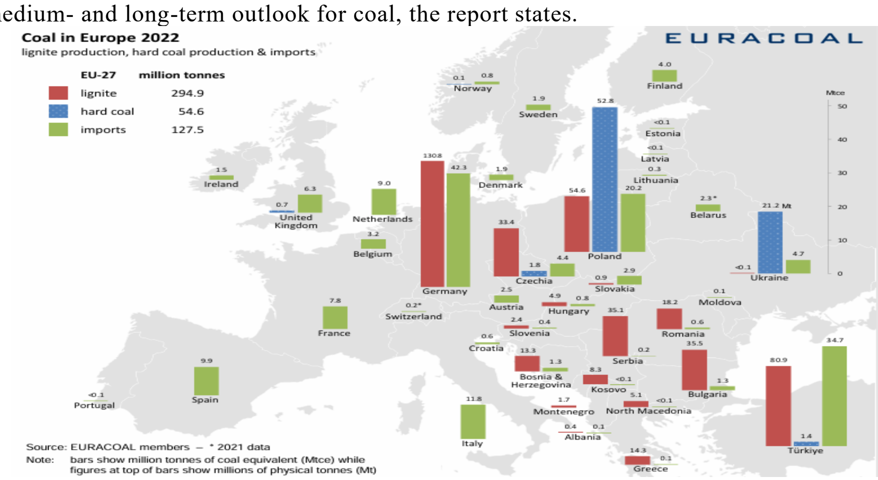


Fig. 3. Coal Consumption in Europe for the Year 2022

5. Electricity Production and Consumption

The total electricity production in the Western Balkans region reached 69.5 TWh in 2022, with coal-fired power plants contributing 43.8 TWh (63%). The largest share of coal-fired power plants in the electricity generation mix is in Kosovo (92%), followed by North Macedonia (72%) and Serbia (70%). Albania does not have any coal-fired power plants in its generation portfolio.

In the Western Balkans region, 36 coal-fired power units were operational in 2022, with a total installed capacity of 8,255 MW. Approximately 46,000 workers were directly employed in coal-fired power plants and associated coal mines. Additionally, between 80,000 and 100,000 workers were indirectly employed in 2022 in related sectors, such as hard coal production, which produced 23.5 TWh (34%).

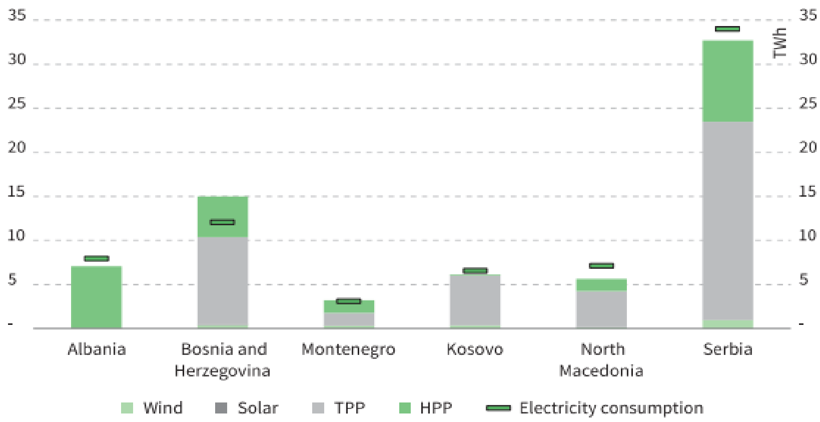


Fig. 4. Electricity Production and Consumption in Western Balkan Countries in 2022

A comparison was made with Germany (as the largest economy in Europe). The main parameter guiding this study is the high percentage of electricity production generated from coal in these countries (for the period 2011–2022). The following figure presents the basic characteristics related to electricity in these countries. As can be seen, there are significant deviations regarding the values of gross domestic product (GDP) per capita and total gross electricity production — the ratios clearly favor Germany. For the period from 2011 to 2020, the average electricity production per capita in Kosovo was approximately 3.75 MWh/person, in Poland 4.33 MWh/person, and in Germany 7.68 MWh/person — clearly showing a significant difference in favor of Germany. This relationship gives Kosovo reason to better utilize its energy potential, which it certainly has, especially coal (as it is currently being exploited).

It has long been known that the future of energy does not lie in coal. The reasons for this are not only policies aimed at combating climate change and air pollution but also the significant decline in the cost of electricity generated from renewable sources, which are now competitively priced against fossil fuels. The global trend of abandoning coal and imposing carbon emissions taxes will undoubtedly continue. If Kosovo does not seriously approach a plan to transform its energy system, it risks becoming a black hole—initially on the map of Europe, and eventually on the global stage.

Our coal-fired power plants are among the largest polluters in Europe, and according to data from the World Health Organization, air pollution causes thousands of premature deaths annually in Kosovo. Because of all these factors, many countries worldwide are actively working to phase out this energy source.

The future of coal for electricity generation mainly depends on the following factors:

Climate policies defined through EU guidelines for each individual country (CO_2, NO_x, SO_2, and coal dust emissions),

Electricity demand, which varies depending on the level of regional development and tends to increase,

Prices of alternative energy sources, which may change over time and affect the competitive price per kWh of electricity generated from coal,

Revitalization of old coal-fired power plants or potential construction of new, more modern coal power plants (both replacement capacities and new facilities).

According to the 2021 Implementation Report of the Energy Community, actual emission values in Kosovo compared to the limits were 197% for SO_x, 223% for NO_x, and 177% for dust. Some provisions of the Industrial Emissions Directive (2010/75/EU) have been applicable since January 1, 2017, for new plants in the contracting parties of the Energy Community. Existing plants are also expected to comply with the provisions of Chapter III and Annex V, especially in the case of renovation.

Table 3 – Energy Production Structure in the EU-27 in 2022

	Power plant	**Country**	**CO_2 emission 10^3 [t]**	**Coal type**	**Installed capacity [MW]**	**Report [10^3t CO_2/MW]**	**Electricity Production [GW]**	**Report [10^3tCO_2/GW]**
1	Belchatow	Poland	25540	Lignite	5097	5.00	27400	0.93
2	Neurath	Germany	22100	Lignite	3800	5.80	31300	0.71
3	Nikola Tesla	Serbia	17464	Lignite	3036	5.70	17623	0.99
4	Niederaussem	Germany	16100	Lignite	3021	5.30	24500	0.66
5	Kozienice	Poland	15900	stone coal	3994	4.00	11000	1.45
6	Boxberg	Germany	15500	Lignite	2582	6.00	18000	0.86
7	Janschwalde	Germany	15200	Lignite	3210	4.70	20000	0.76
8	Weisweiler	Germany	14500	Lignite	1595	9.10	13400	1.08
9	Schwarze Pumpe	Germany	11800	Lignite	1600	7.40	10000	1.18
10	Lippendorf	Germany	11100	Lignite	1868	5.90	11000	1.01
11	Opole	Poland	10700	stone coal	3332	3.20	24000	0.45
12	Turow	Poland	10193	Lignite	1948	5.20	10060	1.01
13	Maritsa Iztok	Bulgaria	9600	Lignite	2510	3.80	10923	0.88
14	**Kosova A^B**	**Kosovo**	**6660**	**Lignite**	**1290**	**5.20**	**6350**	**1.05**
15	Polaniec	Poland	6029	stone coal	1674	3.60	6840	0.88
16	Pocerady	Czech Rep.	5389	Lignite	1000	5.40	4600	1.17
17	Javorzno 3	Poland	5369	stone coal	2255	2.40	6073	0.88
18	Kostolac	Serbia	5340	Lignite	1010	5.30	5717	0.93
19	Emshaven	Netherlands	5306	stone coal	1740	3.00	6952	0.76

20	Abono	Spain	5176	stone coal	916	5.70	3072	1.68

Energy production is responsible for the formation of the greenhouse effect, which causes climate change, primarily due to the burning of fossil fuels. Despite efforts to reduce these emissions, the global trajectory of CO2 emissions remains significantly higher than what is required to avoid the worst impacts of climate change.
Carbon dioxide (CO2) emissions from the energy sector in the European Union decreased by approximately 7.6% in 2023, reaching 2.5 billion metric tons (Gt CO2). EU CO2 emissions are now at their lowest level in the past 58 years.

Table 4. CO2 Emissions from Coal-Fired Power Plants in 2021

	CO_2 emission 10^6[t]	***Report [t CO_2/km^2]***	***Report [t CO_2/1 resident]***	***Report [kg CO_2/1 MWh]***
Kosovo	6.66	618	3.75	1049
Serbia	22.8	294	3.43	960
Polond	155	496	4.08	1120
Germany	184	515	2.21	1132
EU	688	162	1.54	248

6. Decarbonization and Promotion of Renewable Energy in Kosovo

The path towards reducing carbon dioxide (CO2) emissions in the energy sector, according to Kosovo's Energy Strategy (2022-2031), will be accompanied by the development of large renewable energy capacities (renewable energy sources), based on their technical and economic potential. The reduction of electricity generation based on lignite contributes to the decrease of pollution and greenhouse gas emissions; however, its effects on supply security and generation are compensated by increasing support for clean domestic energy sources.

Strategic Objectives

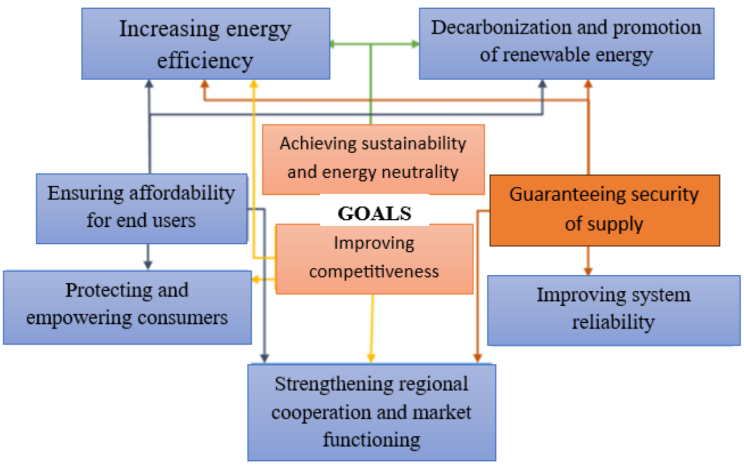


Fig. 5 – Strategic Objectives According to Kosovo's Energy Strategy (2022-2031)

Moreover, considering that renewable energy technologies have reached costs comparable to traditional energy sources, their utilization will result in lower energy costs over a longer period. New renewable energy capacities, using existing and innovative technologies, will gradually replace coal usage, aiming to phase out coal use by no later than 2050.
This strategic objective is addressed through three specific goals:
Gradual implementation of carbon pricing;
Promotion of renewable energy in the electricity generation mix;
Promotion of the use of renewable energy for heating.

"Assumed installed capacity in the two analyzed scenarios for the years 2026, 2028, and 2031."

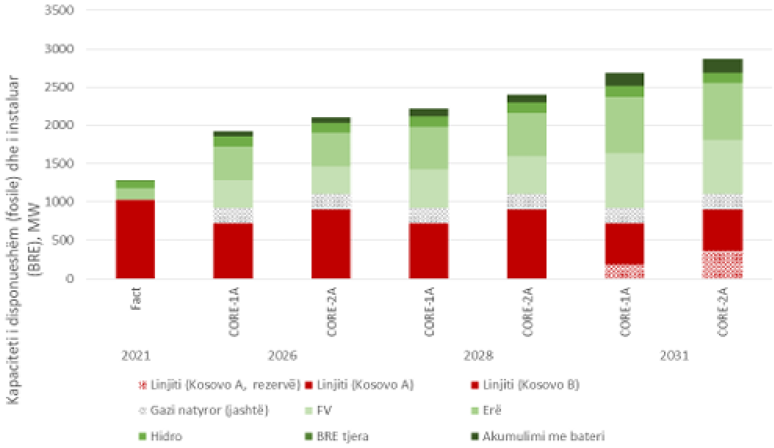


Fig. 6: Mix of installed capacities in the two analyzed scenarios for the years 2026, 2028, and 2031.

7. Conclusion

Kosovo is a signatory of the Sofia Declaration and has thus joined the EU initiative "Green Agenda for the Western Balkans," under which the energy sector is committed to implementing the decarbonization process by 2050. This means a gradual phase-out of the so-called "dirty way of electricity production" from coal, lignite, peat, oil, etc., and a transformation towards investments in green projects for electricity generation from wind and solar energy. However, these remain largely dead letters on paper.
In the regional plan for the Western Balkans, the EU has allocated over €9 billion in grants and guarantees and €20 billion in new investments. Although Kosovo has committed to environmental protection and increasing the profitability of energy production by closing coal-fired power plants and mines, there has still been no substantive discussion on this issue. Kosovo has approved its Energy Strategy, pledging to use renewable energy sources and aiming to reach around 40% participation in total final energy consumption by 2031.
Moreover, Kosovo has committed to reducing SO_2, NO_x, and particulate emissions by 2028 compared to 2017 levels. Regarding CO_2 emission reductions, the following targets have been set:
Completion of all preparations for implementing a carbon pricing system by 2026,
Reduction of greenhouse gas emissions in the energy sector by at least 32% by 2031,
Coverage of at least 35% of electricity consumption from renewable energy sources (RES) by 2031,

Development of new RES capacities (600 MW wind, 600 MW photovoltaic, 20 MW biomass, and at least 100 MW from prosumers) to reach a total installed RES capacity of 1600 MW by 2031.

Due to the current crisis, coal use is increasing significantly in some countries. Many experts consider this a worrying indicator, showing how far the world still is from achieving the goal of zero emissions, especially given the short but feasible deadline of 2050. As outlined in many analyses and studies of this nature, if the nationally approved plans for net-zero emissions by 2050 are implemented, the global cost of decarbonizing electricity production is projected to reach around $6 trillion.

Nevertheless, achieving the global zero-emission target by 2050 – which, according to current scientific forecasts, could prevent the average global temperature from rising by about 1.5°C – is crucial. This cost should also include an additional $9.5 billion to cover the "human resources" involved, estimated to be around 8.4 million workers globally currently engaged in coal extraction,

References

K. Rennings, P. Markewitz, S. Vögele, "How Clean is Clean? Incremental Versus Radical Technological
Change in Coal-Fired Power Plants", Discussion Paper A2-23 No. 09-021, ZEW Centre for European Economic Research, ftp://ftp.zew.de/pub/zew-docs/dp/dp09021.pdf

L. Schmoe, Bechtel, "IGCC – Expected plant availabilities and efficiencies", Presentation at Platts

Schröder, T. Traber, C. Kemfert , "Market Driven Power Plant Investment Perspectives in Europe: Climate
Policy and Technology Scenarios until 2050 in the Model EMELIE-ESY 1 ", German Institute for Economic Research, DIW Berlin, Berlin, pp. 1-18, 2013.

Kennedy, D. (1999), Competition in the Power sectors of Transition Economies, Working Paper No. 41, EBRD, London.

Energy Agency IEA, Paris, France, pp. 1-38, 2012. Brown, N. (2013, 07 27). *Easy Peasy Kids*. Hentet 04 18, 2021 fra How I teach children Acceptance: https://easypeasykids.com.au/acceptance/

Rudnick H., Quinteros R. (1998), Power System Planning in the South America Electric Market Restructuring, paper presented at the Symposium of Specialist in Electric Operations and Expansion Planning, Bahia, Brazil.

EURACOAL, Coal Industry Across Europe, https://public.euracoal.eu/download/Public-Archive/Library/Coal-industry- across-Europe/EURACOAL-Coal-industry-across-Europe-7th.pdf

Srategjia e Energjisë e Republikës së Kosovës 2022-2031

EUROSTAT, Energy, transport and environment indicators, 2020, https://doi.org/10.2785/522192

European coal regions, https://visitors-centre.jrc.ec.europa.eu/tools/coal- report/

Coal Matters, Divestment & the future role of coal, https://www.whitehavencoal.com.au/wp content/uploads/2015/02/Coal_Matters_Divestment_Future_Role_Coal.pdf

International Energy Agency - Report: Coal 2021, https://iea.blob.core.windows.net/assets/f1d724d4-a753-4336-9f6e-64679fa23bbf/Coal2021.pdf

IEA, Key World Energy Statistics, 2021, https://www.iea.org/reports/key- world-energy-statistics-2021

Global energy observatory, Power plants data, http://globalenergyobservatory.org/

IEA, Resources to Reserves, 2013, https://iea.blob.core.windows.net/assets/afc6bec5-22e8-4105-a1b3-ceb89eaec1e9/Resources2013.pdf

Cogeneration of energy

Marigona Krasniqi

University for Business and Technology, Pristina, Kosovo
marigona.krasniqi@ubt-uni.net

Abstract: Cogeneration is the process of producing electricity and thermal energy at the same time. Generating energy through this process means using only one energy source, which results in higher energy efficiency. In the energy crisis the world is facing, cogeneration is being considered as a promising alternative for reducing environmental pollution, increasing energy security, supporting the energy transition and economic stability. This paper will describe the cogeneration process and its role in the energy sector, how cogeneration affects energy efficiency and what are the main benefits of this process.
Keywords: cogeneration, efficiency, electricity, thermal energy

Introduction Cogeneration of energy means the production of both electrical and thermal energy at the same time using the same energy source. In recent years, the world energy crisis, energy demands, global warming and environmental impacts have begun to become major issues, and therefore attention has necessarily been focused on alternatives that could provide solutions to these problems or at least offer improvements to the energy production process. In addition to the inclusion of renewable energy sources, new technologies, and education about the wiser use of energy, cogeneration of energy also remains a very welcome way in the group of methods supporting a lower carbon reality. Energy production through cogeneration, unlike traditional energy production, significantly increases energy efficiency, reduces the consumption of energy resources, regulates energy policies, helps the energy transition, significantly reduces negative environmental impacts and many other benefits. Since the number of benefits through the cogeneration process is large, this paper will examine and analyze the way in which the energy cogeneration experiment is carried out, its importance in the energy field, and the obstacles encountered during the implementation of such processes.

The process of cogeneration of energy

In condensing turbines, the entire amount of steam (or most of it) expands to the pressure of the condenser where it condenses, and through the cooling water this heat is then released through the cooling tower into the outside atmospheric air. The pressure of the water vapor, which condenses in the condenser, is lower than the atmospheric pressure. In this way, a greater difference in pressure is created between the water vapor at the inlet and outlet of the water vapor turbine, which consequently increases the power of the power plant. Thus, as far as the mechanical work produced by the turbine is concerned, it is of interest that the steam parameters (water vapor pressure) at the turbine inlet to be as high as possible, while the turbine outlet parameters (pressure) of the steam in the condenser to be as low as possible. High-pressure turbines are considered turbines into which water vapor enters at a pressure of up to 224 bar. Turbines operating at a pressure higher than 224 bar are called supercritical pressure turbines. Regarding the increase in steam parameters at the turbine inlet, there are limitations related to the durability of the materials from which steam turbines are manufactured. For example, the steam turbine at the Kosovo B thermal power plant has subcritical parameters: the steam pressure at the turbine inlet is 177.4 bar and the temperature is 540°C. Also, reducing the pressure at the turbine outlet, respectively in the condenser, there are limitations related to the energy costs for increasing the vacuum that is achieved with the help of ejectors. In TC Kosovo

B, the steam pressure in the condenser in a nominal operating mode is 0.0608 bar. In backpressure turbines, the pressure of the water vapor at the turbine outlet is higher than the atmospheric pressure, so p2>po, and as a result the steam initially expands, providing all the mechanical work, and instead of going to the condenser, it communicates the heat to the thermal consumer through a surface heat exchanger. The steam pressure at the turbine outlet must fully meet the needs of the thermal consumer (heating or preparation of hot water for sanitary purposes). In this way, the thermal and electrical consumers in this case are closely linked to each other. In these thermal power plants, mechanical (electrical) energy is used in its entirety, which is provided in the electric generator, and also thermal energy, which is used for heating or for carrying out a certain technological process, and as a result, it is achieved 100% efficiency. The shaded areas in this graph represent the following:: surface (1 - 2 - a - b- 2'-3 - c - d -1) - the heat that is brought to perform the work cycle; the useful work (the useful mechanical or electrical work that is produced) by the turbine is indicated by the surface (1 - 2 - 2' - 3 - c - d - 1), meanwhile the surface (a - 2 - 2'- b -a) in the diagram, represents the useful heat which, as sufficient, is communicated to the thermal consumer. In conditions where the thermal consumer does not need thermal energy, the operation of the thermal power plant with a backpressure turbine must be stopped. Even with maximum efficiency of heat utilization brought to the power plant, the close connection that exists between the electrical and thermal consumer presents a serious challenge regarding the application of such power plants. In this way, they find application and are very efficient only in cases where there is a permanent thermal and electrical consumer throughout the year.

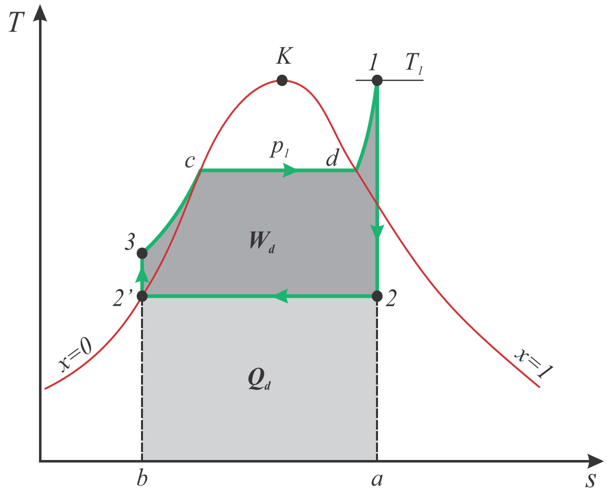


Fig.1. Rankine work cycle with backpressure turbine with efficiency ηTC=1

Since in the case of the application of backpressure turbines, the thermal and electrical consumers are interconnected, which represents a certain drawback of backpressure turbines, a more acceptable solution is the application of condensing turbines with variable water vapor intake to meet the needs of the electrical consumer. The steam intake from the turbine as a whole must be such that it fully meets the needs of the thermal consumer (heating or the needs of a certain technological process in terms of pressure and temperature). Since the pressure of the steam flowing through the turbine varies along the turbine, it is necessary to determine the place from which a certain amount of water vapor can be obtained, which fully meets the needs of the thermal consumer. Mainly, water vapor is taken from the turbine between the turbine stages with parameters slightly higher than the parameters required by the thermal consumer. In the event of a turbine failure, the thermal consumer is supplied with thermal energy through line (1-7), by first reducing the steam pressure to the designed pressure with the help of the throttling valve VD.

The heat input to perform the work cycle is defined by the expression:

$$Q_f = \dot{m}_4 (h_1 - h_4) \quad (1)$$

The heat extracted from the work cycle is determined by the expression:

$$Q_n = \dot{m}_2 (h_2 - h_{2'}) \quad (2)$$

The useful work produced in the turbine is defined by the expression:

$$\dot{W}_t = (\dot{m}_1 - \dot{m}_5)(h_1 - h_6) + (\dot{m}_1 - \dot{m}_5 - \dot{m}_6)(h_6 - h_2) \quad (3)$$

The heat that is usefully used by the thermal consumer is given by the expression:

$$\dot{Q}_{kt} = \dot{m}_5 h_5 + \dot{m}_6 h_6 - \dot{m}_7 h_7 \quad (4)$$

The efficiency of the work cycle is given by the ratio of useful work and heat input into the work cycle

$$\eta_{TEC} = \frac{\dot{Q}_d}{\dot{Q}_f} = \frac{\dot{W}_t + \dot{Q}_{kt}}{\dot{Q}_f} \quad (5)$$

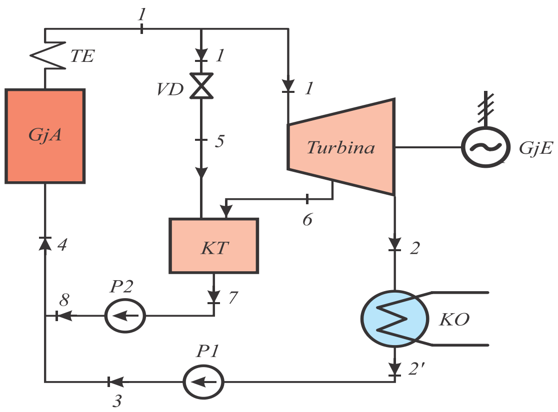


Fig.2. Scheme of a condensing type thermal power plant with steam extraction to meet the needs of the thermal consumer

2. Case of implementation of the cogeneration process from the turbine of the Kosovo B thermal power plant

Steam turbines consist of three cylinders (turbines) which are: high pressure turbine TPL, medium pressure turbine TPM and low pressure turbine TPU. The shafts of these turbines are connected by couplings. The amount of 910.29 t/h=252.859 kg/s superheated water vapor produced in the steam generator with parameters: pressure 177.4 bar and temperature of 540°C are fed into the high-pressure turbine, producing mechanical work (electric power) in the high-pressure steam turbine (TPL), next in the medium pressure steam turbine (TPM) and in the low pressure steam turbine TPU. For the heating needs of the city of Pristina from the pipeline connecting TPM dhe TPU, for this purpose are taken around 100 t/hour =27.715 kg/s superheated water vapor with parameters: pressure 2.4 bar and temperature of 191.8° C. The rest of the water vapor continues to expand in the low-pressure turbine (TPU) cylinder up to condenser pressure. The steam obtained from the turbine for heating needs is sent to the surface heat exchanger, which is located near the power plant, and thus from this heat exchanger, about 70 MW of thermal energy is communicated for the needs of the thermal consumer, which in this case is the supply of thermal energy for heating the city of Pristina. Two such surface heat exchangers are located near TC Kosova B, each with a capacity of 70 MW of thermal energy. Both blocks of TC Kosova B are connected to these two heat exchangers. This means that the steam taken for this purpose from the turbine of TC Kosova B1 can also send water vapor to the heat exchanger of TC Kosova B2, and vice versa, the steam taken from the turbine of TC Kosova B2 can also send steam to the heat exchanger of TC Kosova B1. This created opportunity increases the security of the city's thermal energy supply even in conditions when, for example, one of the thermal power plant units is out of operation. This thermal energy is transferred by pumps from the surface heat exchanger near the thermal power plant to the Prishtina city heating plant Termokos with pipes. From the city heating plant, thermal energy is communicated to the thermal consumer, respectively to the thermal substations. Cogeneration carried out by a TEC means the combined production of electricity and thermal energy in the thermal power plant by using a certain amount of water vapor which, after being expanded in the high pressure turbine TPL and the medium pressure turbine TPM, is sent to an external surface heat exchanger which is located near the thermal power plant and serves to heat the water which is used for heating the city of Prishtina (external thermal consumer). From the two blocks of the Kosovo B TPP, about 2x70=140 MW of thermal energy can be communicated to the city heating. Since the amount of water vapor taken from the steam turbine has not continued its expansion in the low-pressure turbine (TPU), the production of electricity in the thermal power plant from only one block of the TPP is reduced by the value:

$$\Delta N_{B1} = \Delta N_{B2} = m_G \cdot (h_G - h_K)\eta_m \cdot \eta_g =$$

$$27.715 \cdot (2851.2 - 2372.9) \cdot 0.97 \cdot 0.98 = 12600\, kJ/s = 12600 kW = 12.6 MW$$

where: η_m, η_g- are the mechanical efficiency and the efficiency of the electric generator of the power plant.

h_G, h_K, kJ/kg - are the enthalpy of water vapor at the point of steam extraction for heating needs (point G according to the scheme) and the enthalpy of water vapor at the outlet of the low-pressure steam turbine, respectively at the inlet of the condenser.

For the two blocks of TEC Kosovo B, electric power production is reduced by the value:

$$\Delta N = 2 \cdot \Delta N_{B1} = 2 \cdot 12.6 = 25.2 MW$$

In one surface heat exchanger, about 315.1 kg/s of water circulates, which returns from the thermal consumer (the heating plant of the city of Prishtina) with a temperature of about 73°C. This amount of water, in the surface heat exchanger, is heated to a temperature of about 125.7°C

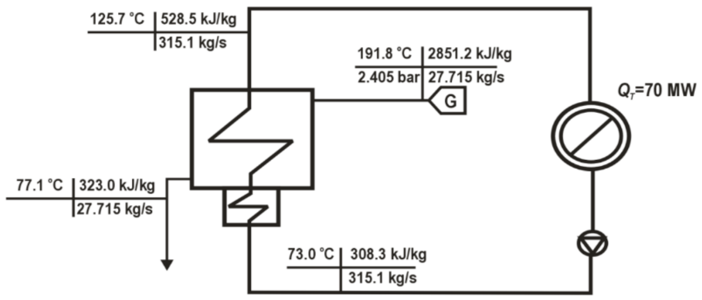


Fig. 3. Connection of the thermal consumer to the cogeneration system of mechanical energy and thermal energy from the thermal power plant

3. Advantages and disadvantages of energy cogeneration

After thermodynamic analysis, comparing traditional energy production and combined energy production, we can list some of the advantages of the cogeneration process. From the formulas, we conclude that through this process, thermal losses are reduced. The list of benefits also includes the minimization of fossil fuels, the improvement of the development of the thermodynamic cycle, and the increase in energy efficiency of somewhere between 75-90%, which is a very high percentage compared to traditional energy production. Cogeneration, besides being beneficial in increasing energy efficiency, also faces many implementation difficulties. Some of the obstacles and problems encountered when talking about the implementation of such processes are grouped into: technical, economic, spatial, environmental and social. The group of technical obstacles is characterized by the very high primary investment in the entire cogeneration system, and these systems are also very complex when compared to systems that produce only one type of energy. Such systems, in addition to being high in cost and complexity, also require regular and detailed maintenance. In the group of economic obstacles, one of the first to be mentioned is the very high primary investment for a system that has shortcomings and a very long payback period. The lack of various subsidies from the country, etc., is also listed as an obstacle. In the group of spatial obstacles, the largest one is the proximity of the power plant that co-produces energy to consumers. Such power plants would be better built in places where consumers are as close as possible to it, because this would result in lower energy losses during the time when the energy is transmitted to the consumer. It is also worth mentioning the compatibility in the place where such power plants can be built. Not all places are worthy and legal for construction, therefore this remains a spatial problem. In the group of environmental obstacles, it is known that among the main ones is the emission of greenhouse gases (carbon dioxide, nitrogen monoxide, etc.) which negatively affects the environment. Also, if the power plants that co-produce energy use only fossil fuels, which are not renewable, it affects their consumption. Since noise is considered a pollutant, it is worth noting that large plants can cause noise and disturb the peace of residents. In the group of social obstacles, some of the most important are listed: the noise produced by the plant, then ignorance and lack of education of people about this method of energy production does not affect the increase in awareness.

4. Conclusion

Cogeneration of energy is proving to be among the most sustainable solutions in the wake of energy problems. Such a conclusion is reached from the deep and detailed analysis of traditional energy production and by energy cogeneration. By analyzing the energy performance of both processes, and analyzing a case of implementing this system in a power plant in Kosovo, we conclude that the process of cogeneration of energy increases the overall level of energy efficiency, it significantly reduces the use of new fuel, reduces environmental pollution and is very beneficial as a way of ensuring people's comfort and well-being. The implementation of the cogeneration process as a promising project, needs political and economic support.

References

Krasniqi Alidema, D.: Energy and exergy analysis of working cycles with cogeneration of coal-fired thermal power plants, Monograph. 2019.

Habib M.A., Zubair S.M.: 2^{nd} - Law-based thermodynamic analysis of regenerative-reheat Rankine-cycle power plant, Energy, vol.17, Pergamon-Elsevier Science Ltd., 1992, pp. 295-301.

[3] Voshtina L, Krasniqi F. : Menaxhimi dhe prodhimi i kombinuar i energjisë, Tiranë-Prishtinë, 2006

Krasniqi F. :Termofikimi dhe rrjetet termike, ASHAK, Prishtinë, 2010

Katalogimi në botim – (CIP)
Biblioteka Kombëtare e Kosovës "Pjetër Bogdani"

621.3(062)
061.3(496.51)"2025"

Proceedings of the 14th Annual International Conference : international Conference on Energy Efficiency Engineering : 25-26 October 2025 / edited by Edmond Hajrizi. - Prishtinë : UBT, 2026. - 55 f. : ilustr. ; 30 cm.

1. Hajrizi, Edmond

ISBN 978-9951-982-59-7

INTERNATIONAL CONFERENCE ON BUSINESS,TECHNOLOGY AND INNOVATION

CHAPTERS:

- Computer Science and Communication Engineering
- Management, Business and Economics
- Mechatronics, System Engineering and Robotics
- Energy Efficinecy Engineering
- Information Systems and Security
- Architecture - Spatial Planning
- Civil Engineering, Infrastructure and Environment
- Law
- Political Science
- Journalism, Media and Communication
- Food Science and Technology
- Pharmaceutical and Natural Sciences
- Design
- Psychology
- Education and Development
- Fashion
- Music
- Art and Digital Media
- Dentistry
- Medicine & Nursing
- Sports, Health and Society
- Security Studies
- Language and Culture

ISBN 978-9951-982-59-7

9 789951 982597

Lagjja Kalabria p.n KS - 10000, Prishtinë

+383 38 541 400

+383 38 542 138

www.ubt-uni.net

conferences@ubt-uni.net