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TRANSFORMATION OF THE ROLE OF ENERGY ENGINEERS IN THE SERBIA - FROM A TRADITIONAL SYSTEM TO SOCIETY 5.0

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Abstract:
Abstract: This paper analyzes the necessity of transforming the role of energy engineers in the Serbia within the context of the global energy transition and the shift towards the concept of Society 5.0. Starting from the chronic problems of the domestic energy sector, such as high dependence on low-calorie coal, high energy intensity, and an outdated centralized system, the paper points out the inadequacy of the traditional operational approach. A new paradigm is presented in which the energy engineer transforms from a technical executor into an entrepreneur, manager, and innovator, while the focus of development shifts to small and medium-sized enterprises and innovative technological ventures in the environmentally friendly and energy technology sectors (Cleantech and Energytech). Through the analysis of decentralization processes, the affirmation of the prosumer concept, and the implementation of smart grids and virtual power plants (VPP), it is concluded that the success of the transition requires a close synergy of advanced Industry 4.0 technologies and innovative business models. The ultimate goal of this transformation is the creation of a sustainable, human-centric energy system that will ensure long-term economic competitiveness and energy independence for the Serbia.

Keywords: *Energy transition, Environmental transition, Sustainable development*

Introduction

The global energy sector is at the center of the most complex structural transformation since the first industrial revolution. This change is primarily driven by the so-called "3D" paradigm: decarbonization, decentralization, and digitalization. Accelerated and increasingly pronounced climate changes, the systemic depletion of traditional fossil fuels, the tightening of global environmental regulations (such as the Paris Agreement and the European Green Deal), and geopolitical instabilities directly affecting energy supply chains, have necessitated an urgent and uncompromising transition to sustainable, renewable energy sources (RES).

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Alongside these fundamental changes in the energy production process itself, modern society is entering the era of the so-called Society 5.0 [1]. This concept, originally defined and strategically adopted in Japan, represents a technological and sociological leap forward from the information society (Society 4.0). Society 5.0 implies a highly integrated, technologically advanced, and primarily human-centric society in which cutting-edge Industry 4.0 technologies [2], such as artificial intelligence (AI), Big Data analytics, the Internet of Things (IoT), machine learning, and blockchain technologies are not exclusively used to optimize industrial processes, but primarily to solve dominant social, economic, and environmental problems. At the core of this concept lies the integration of physical and cyber space, enabling optimal decision-making in real-time that enhances the quality of life for individuals and society as a whole.

In such a dynamic and high-tech environment, energetics transcends the boundaries of a rigid infrastructural branch focused exclusively on the production, transmission, and distribution of electrical energy. It becomes a flexible, bi-directional, and highly complex cyber-physical structure. For the Serbia, this transition represents one of the most complex socio-economic challenges in modern history, but simultaneously a unique opportunity for deep economic modernization and the abandonment of obsolete, technologically outdated solutions that threaten to make the domestic economy uncompetitive on the European market.

At the very center of this structural change is the energy engineer. Their traditional role, historically and organizationally tied in this region to working in large state monopolistic systems, designing conventional solutions, and operatively maintaining thermal power plants and distribution networks, requires a fundamental redefinition. The modern engineer is no longer expected to possess solely expertise in the fields of electrical engineering or thermodynamics [3]. They must possess a highly multidisciplinary approach that combines engineering precision with advanced IT knowledge, an analytical understanding of market economics, green financing, and international regulatory frameworks.

The aim of this paper is to analyze in detail the current state of the energy sector in the Serbia, identify its systemic shortcomings, and clearly indicate the directions for transforming the engineer's role in contemporary conditions. The paper will demonstrate how the engineer of the future must transcend the role of a technical executor within the system and become a proactive innovator, entrepreneur, and driver of change, capable of guiding Serbian energetics through the challenges of the Society 5.0 era.

1. Current State and Structural Problems of the Energy Sector in Serbia

To understand the essential need for a new educational and professional profile of engineers, it is necessary to carefully analyze the inherited problems the Serbian energy sector has faced for decades. The energy system of Serbia was strategically designed in the mid-to-late 20th century according to a model of pronounced vertical and horizontal centralization. This model followed the needs of the heavy industry and accelerated electrification of that time, with a dominant reliance on large fossil-fuel-based production capacities and large hydroelectric power plants. However, the architecture of this system is highly inflexible today and faces the problem of technological equipment obsolescence, making it inadequate for the dynamic demands of the 21st century and the rapid integration of variable renewable energy sources.

1.1. Dependence on Low-Calorie Coal, Environmental Consequences, and the Risk of Stranded Assets

The backbone of electricity production in the Serbia (which historically varies between 65% and 70%) consists of lignite-fired thermal power plants, located predominantly in the Kolubara and Kostolac mining basins. The central problem is the energy source itself: it is low-calorie coal with a high share of moisture and ash. Its exploitation requires the use of vast land areas, leading to environmental degradation, while its combustion in technologically obsolete plants - many of which have exceeded their projected 40-year operational lifespan - results in low energy efficiency and reduced reliability in the operation of the power system.

The environmental consequences of using such technology are highly unfavorable. Lignite combustion emits significant amounts of carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter (PM10 and PM2.5). Besides negatively affecting the public health of Serbian citizens and causing increased costs in the healthcare system, this energy mix is becoming completely economically unsustainable. In light of the European Green Deal and the upcoming implementation of the Carbon Border Adjustment Mechanism (CBAM) [4], Serbian industry faces a serious challenge. CBAM functions as a carbon footprint taxation mechanism. The introduction of these taxes on products exported to the European Union (such as steel, cement, fertilizers, aluminum, and electricity) will directly threaten the price competitiveness of the entire Serbian industry if it continues to be supplied with electricity produced with high greenhouse gas emissions. Further investment in such a model also carries a high financial risk of creating so-called stranded assets investments in carbon-

intensive production capacities that will have to be shut down due to high environmental taxes before the initial investment is recovered.

1.2. High Energy Intensity, Transmission Losses, and Infrastructural Inefficiency

In addition to challenges in the production sector itself, the Serbia faces critical problems in the domain of energy consumption and distribution. Data from the World Bank [5] indicate that the energy intensity of Serbia (the amount of energy required to generate one unit of Gross Domestic Product) is several times higher than the average of European Union countries. This data clearly points out that the economy and the household sector consume energy with a high degree of inefficiency. The causes are systemic: the application of energy-inefficient technological processes in industry, a decades-long lack of capital investments in the thermal insulation of residential and commercial buildings, as well as the widespread use of electricity for primary space heating during the winter months, which puts critical pressure on the entire power system.

Simultaneously, the electricity distribution system faces a high level of losses. These are categorized as technical losses (arising from dilapidated equipment, old transformer stations, inadequate conductor cross-sections, and long distribution lines) and commercial losses (which include unauthorized electricity consumption, as well as errors in meter reading and billing processes). In certain distribution areas, these losses significantly exceed the standards prescribed in the European Union, generating multi-million financial losses at the national level every year.

Solving these accumulated structural problems requires an approach that goes beyond the simple replacement of equipment or the construction of new conventional power plants. It primarily demands the digital transformation of the entire system the massive implementation of advanced technological solutions such as Advanced Metering Infrastructure (AMI), sensor networks, SCADA systems for real-time monitoring and control, and predictive maintenance software tools based on artificial intelligence. Alongside technological upgrading, the systematic education of consumers is necessary. Such a complex task can no longer be independently realized by the traditional engineering model focused exclusively on centralized management and capacity expansion. A multidisciplinary and entrepreneurial approach by the new generation of engineers is indispensable.

2. New Paradigm: The Engineer as an Entrepreneur, Manager, and Innovator

The realization that the complex and deeply rooted structural problems of Serbian energetics cannot be solved effectively and timely by relying on strictly centralized, capital-intensive, and time-consuming state investments has opened up space for an entirely new engineering paradigm. The transition from the traditional power system model to the postulates of Society 5.0 requires an exceptionally high degree of organizational, operational, and technological adaptability. Such agility, freed from the constraints of traditional corporate procedures, is primarily characteristic of small and medium-sized enterprises (SMEs) and innovative technological ventures. In this transformative process, the engineer transcends the boundaries of a technical executor and assumes the role of an architect of new business models.

2.1. Development and Affirmation of Cleantech and Energytech Sectors

Modern-profile experts in the Serbia are increasingly abandoning the roles of passive executors in traditional state and corporate structures, opting instead to found innovative business entities. These entities primarily operate in the sectors of environmentally friendly technologies (Cleantech) and modern, digitalized energy services (Energytech) [6]. These engineer-entrepreneurs possess the ability to identify specific market segments (such as optimizing industrial consumption, integrating e-mobility, or managing local energy flows) and develop scalable software and hardware solutions for them.

Their activities encompass the development of advanced metering systems, the implementation of the Industrial Internet of Things (IIoT) for the predictive maintenance of critical network infrastructure, and the creation of peak shaving algorithms. Consequently, the work of the modern engineer is no longer strictly technical but encompasses a broad spectrum of competencies: applied economics and financial modeling, evaluation processes and attracting venture capital (VC) and risk capital funds, the application of agile methodologies in product development, as well as a deep knowledge of complex and constantly evolving international energy law. They are expected to understand the entire life cycle of an innovation from the conceptual technical design, through prototyping, to full commercialization on the market [7].

2.2. System Decentralization, the Prosumer Concept, and Energy Communities

One of the most significant structural and regulatory shifts in Serbian energetics, further normalized by the implementation of the modern Law

on the Use of Renewable Energy Sources [8], is the development and accelerated affirmation of the prosumer (producer-consumer) concept. Citizens, public institutions, and business entities are increasingly installing photovoltaic systems on their own facilities, thereby shifting electricity production from centralized power plants to the very point of consumption, fundamentally decentralizing it according to official data from the national distribution system operator and competent institutions [9], [10].

The role of the modern engineer in this propulsive domain is multi-layered and of crucial importance. Their engineering task implies solving the complex technical challenges brought about by the bi-directional flow of electricity (reverse power flows) in distribution networks that were not initially designed for such an operating regime. The engineer designs local microgrids, optimally dimensions hybrid energy systems (combining photovoltaic panels, modern inverters, and battery energy storage systems), and ensures the preservation of power quality (voltage conditions and harmonic distortions) [11]. Furthermore, engineer-entrepreneurs take on a key role in the formation and technical management of energy communities models where multiple users at the local level associate for the joint production, consumption, and sharing of energy, thereby providing advanced energy management services to end-users and democratizing the energy market.

2.3. Digitalization, Smart Grids, and Virtual Power Plants (VPP)

For decentralized, variable, and intermittent energy sources to function within the national power system without compromising its reliability, operational stability, and security of supply, the massive implementation of Smart Grids is a technological imperative [12], [13]. However, the upgrade to this system is constituted by Virtual Power Plants (VPPs), which represent the pinnacle of innovative engineering entrepreneurship in the era of Society 5.0.

Virtual power plants are highly integrated software platforms supported by advanced artificial intelligence and machine learning algorithms. Their function is to digitally unite and synchronize numerous distributed, geographically separated producers, consumers with flexible demand (Demand Response), and energy storage systems. Such an aggregated entity can participate in the wholesale electricity market with the same capacity and reliability as a single large-capacity conventional power plant. In addition to commercial participation, VPP software developed by engineering teams enables the provision of ancillary and system services to the transmission system operator (such as primary and secondary frequency regulation), directly contributing to

the stability of the entire national grid. The management and development of such complex systems require the engineer to possess advanced software programming skills, the application of Data Science for precise prediction of meteorological conditions and consumption patterns, as well as highly professional knowledge of economic laws and the functioning mechanisms of electricity exchanges.

3. Conclusion: Transformation of the Role of Energy Engineers in the Era of Society 5.0

Based on the conducted analysis, it is unequivocally concluded that the role of the energy engineer in the Serbia is undergoing a process of fundamental professional transformation. Their function ceases to be exclusively operational and technical in nature and must take on a managerial, entrepreneurial, and innovative dimension. The energy sector no longer represents merely a technical system for electricity transmission but a complex socio-economic and technological structure requiring a high level of multidisciplinary.

The complex challenges posed by the energy transition and the implementation of Society 5.0 principles cannot be successfully overcome solely through conventional, centralized infrastructural projects. Effective adaptation to climate change and market fluctuations requires the synergy of advanced digital technologies (IoT, Big Data analytics, artificial intelligence) and modern business models implemented by a new generation of engineers. These experts must integrate technical knowledge with financial expertise and a detailed understanding of international risk management regulatory frameworks. In the modern organization of the energy market, small and medium-sized enterprises, as well as innovative technological entities, are assuming the function of primary drivers of development. Thanks to high organizational flexibility, these entities are able to apply engineering knowledge to solve long-standing problems in the Serbian energy system, primarily in the areas of reducing energy intensity and optimizing technological processes. This economic segment possesses the capacity to develop solutions that will transform the identified shortcomings in energy transmission and production into a space for efficiency improvement and value creation.

Through the active development of decentralized production systems, engineers are fundamentally restructuring the architecture of the electricity market. Through the affirmation of prosumers, consumers transition from a passive to an active role in the market. By implementing smart grids and aggregating distributed sources through virtual power plant concepts, a

highly flexible and reliable power system is established. The expert's role is central in the processes of designing such systems and creating algorithms for dynamic grid balancing. Technological progress in modern energetics is not an isolated phenomenon, but an instrument for creating measurable socio-economic benefits. By optimizing the sector, engineers create new market values, secure jobs in high-tech sectors, and directly contribute to the implementation of a sustainable social model. This fulfills the basic postulate of Society 5.0 utilizing the capacities of Industry 4.0 to overcome social challenges such as energy poverty. Consequently, an adequate response to the challenges of modern energetics requires experts who can apply engineering knowledge in the creation of sustainable economic models. The higher education system, the economy, and state institutions must recognize the necessity of this structural change and systematically support the education of such personnel, considering that the economic stability and energy independence of the Serbia directly depend on the level of their technological competence and innovativeness.

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