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Principles of convergence and synergy of the system of intellectual support of sustainable development

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Abstract: *The features of realization of the principles of convergence and synergy of components of the system of intellectual support of sustainable development of societies are considered. Characteristic features of post-industrialism, which does not act as an alternative to industrial-market civilization, are shown. The approach to increasing the level of intellectual potential in the functioning of society is proposed. This approach based on the development of cluster structures of the scientific-educational-production complex, which provide synergistic effects due to the integration of intellectual resources that contribute to the creation of new-generation innovations.*
KEYWORDS*:* POST-INDUSTRIAL ECONOMY, KNOWLEDGE ECONOMY, INTELLECTUAL SUPPORT OF INNOVATION ACTIVITY, SYNER-GY AND CONVERGENCE OF COMPONENTS, CLUSTER STRUCTURES OF INNOVATIVE DEVELOPMENT

1. Introduction

The current stage of economic development, positioned as "post-industrial development", is characterized by a permanent increase in the role of knowledge in economic activity, both of individual business entities and regional, state and interstate complexes. The non-alternative innovative strategy of post-industrial development is based on the comprehensive use of the intellectual factor in all spheres of economic and socio-political activity. "Innovate or die" – is the main postulate of improving the economic activity of industrial enterprises of various forms of ownership, departmental subordination and functional purpose.

Modern researchers define the post-industrial economy as the "knowledge economy" ("information economy"), emphasizing the decisive role of products of intellectual activity in various forms of manifestation (knowledge) in sustainable development in the near and long term.

The driving forces of the modern economy differ significantly from the traditional factors of the development of the industrial economy. In the current economy, sustainable growth and development of economic systems takes place taking into account the predominant use of the following factors and processes [1–5]:

1) knowledge and processed information representing intellectual capital, which have become a strategic factor in development;

2) changes in the development strategy of a business entity and continuous dynamic and multifactorial processes create uncertainty and increase risks, but are a necessary condition for progressive development;

3) globalization, manifested in new mechanisms and concepts for the creation of scientific and technical developments, technologies, production, systems of investment, trade, communication and information interactions, has led to the development of special economic systems, the formation of global hypercompetition and interdependence of businesses;

4) communication development, which characterizes the company's ability to receive, process and transmit reliable information to the internal and external environment adequately to its goals and objectives;

5) A special role is played by the system of increasing the intellectual potential of members of societies, including high-level scientific research, professional training and social education of the individual.

The noted features of the modern economy, characterized as post-industrial, testify to the transformation of traditional approaches to the activities of the subject of industrial production in all its aspects – production, technological, administrative, managerial, etc., with a significant increase in the role of intellectual capital and the system of its formation, development and practical implementation in new types of commodity products and requires the development of new ones methodological approaches to its implementation in economic activity.

2. Results and discussion

In accordance with the theory of multi-structured economic development, the strategy of economic activity of socio-political systems that determine the trends in the functioning of global production complexes in the post-industrial economy is based on innovative technologies in all spheres of activity with their expressed adaptation to the basic principles of the Concept of Sustainable Development [1].

Modern researchers characterize the economic system within the framework of the fifth and sixth technological modes by the basic principles of the concept of post-industrialization, interpreted according to Vodopyanov P.A. in "... as the highest stage of evolution of modern Western civilization ..." The implementation of this concept at all levels of the functioning of societies presupposes *"... transition from market principles to post-economic values and active social change of previous methods and forms of labor, to the maximum use of the creative potential of workers, the formation of a new type of family and new forms of social partnership, increasing the role of scientific knowledge and changing the education system..."* [3, 4].

Rudensky O.V. and Rybak O.P. believe that in the era of post-industrial *development "... a fundamentally new format for the technological restructuring of the world economy is being set."* According to researchers of the leading industrially developed countries, who form the basis of trends in world economic development, post-industrial development will be carried out within the framework of fundamental (basic, global) technologies – *"... a system of converged NBIC technologies that determine the main directions of progress in science* and *technology at the present stage of* social *development"* [5].

Earlier, it was noted that it was necessary to form innovative receptivity of both individual participants in production, research, educational, managerial and other processes that determine the trends in the functioning of the technosphere, and socio-political systems of various levels in all aspects of their life. infrastructure that adequately responds to the processes of economic, socio-political, technological, scientific, administrative, and regulatory legal functioning at the subjective, regional, state, and supranational levels [6, 7].

The real embodiment of the concept of post-industrialism and its modifications – "knowledge economy", "innovation economy", "super-industrialism", "post-Fordism", "new economy", "information revolution", "information society", etc. – did not lead to the achievement of the declared results, first of all, in the social sphere, the effectiveness of the functioning of which is traditionally evaluated by the real benefits provided to the individual, with the unconditionally comprehensive effect of normative legal norms on the regional, state and supranational levels, regulating its relations with aspects of societies.

As P.A. Vodopyanov and Ch. S. Kirvel rightly noted, *"... today's post-industrialism does not act as a humanistic alternative to industrial-market civilization, but leads to new, even more severe challenges to nature and culture..."* [3].

The analysis of literary sources devoted to the problems of implementing the Concept of Sustainable Development with a pronounced innovative strategy for the functioning of economic and social systems at various levels indicates the increasing role of

intellectual support for the process of development of the technosphere and sociosphere in the formation of harmonious interaction with the environment (ecosphere), the global task of which is the creative behavior of individuals at all stages life cycle.

The statements of M. Leontiev are fair that *"... overcoming the crisis... involves the search for a new socio-economic paradigm, which should be based on moral principles" and "... Economic growth and production cannot be perceived as an end in themselves for the development of society. Priorities can be personal growth..., human communication, consumption of cultural products"* [8].

In this regard, the development of a methodology for intellectual support of innovative industries should include not only the development of basic knowledge and competencies of specialists who ensure the functioning of a business entity, but also permanent personal improvement, taking into account the concept of noosphere development developed by P.G. Nikitenko, with the dominance of the "ecological imperative" in various manifestations of professional activity and social behavior.

The prospect of sustainable development of the socio-economic complex of Belarus is associated with the formation of cluster-type production and technological complexes, the concept of which is stipulated by the adopted Resolution of the Council of Ministers [9, 10].

In the practical implementation of this Concept, it is necessary to take into account not only the realities of the scientific, technological, resource, personnel and organizational potential that has developed in the Republic, but also modern trends in innovative development based on noospheric approaches to harmonizing the interaction of the technosphere, ecosphere and sociosphere.

Studies devoted to the cluster development of the domestic economy mainly consider traditional approaches to the formation of production and technological complexes using linear models for summing up the potential of research, production, and management components combined into a cluster structure.

With the undoubted effectiveness of such an approach, based on the theory of clusters developed by M. Porter, and its modifications, it is necessary to recognize its incomplete compliance with the modern principles of convergence and synergy of basic (fundamental) technologies (NBIC-technologies), which, as noted above, determine the fundamental possibility and prospects for the functioning of economic and socio-political systems in the near and distant future. At the same time, Rudensky O.V. and Rybak O.P., it is assumed that *"... Technology convergence opportunities... will make it possible to change not only the physiological, but also the spiritual essence of a person, his thinking and mind, ... to change the very nature of man"* [5].

The principles of convergence and synergy in the basic (global) technologies of innovative development of economic systems should, in our opinion, be provided by adequate technologies of intellectual support, which are not only converging (converging) at the level of their individual components (research, educational, managerial, production, administrative), but also provide a non-additive effect from their synergistic interaction.

The intellectual resource of the cluster should have the necessary potential not only for assimilation of the components of the information field in various forms of manifestation (databases, technologies for processing, storing, exchanging and selling information), but also for development by generating knowledge of a new level for the creation of innovations and their practical implementation. The convergence of the components of the innovation cluster contributes to the formation of integrated intellectual support for innovative activities.

Our research in the field of methodology of intellectual support for innovative activities of industrial entities allowed us to propose an integration model for the formation of intellectual support for a cluster structure, including scientific, educational and production components, at all stages of the product life cycle. Such an approach, in our opinion, contributes to the practical implementation of innovative activities in accordance with the State Strategy for Sustainable Development in the implementation of cluster principles of infrastructure functioning.

In the integration model of intellectual support, there is a formal and informal convergence (convergence) of the basic components of the scientific, educational and production cluster – the Academy of Sciences (AS), the Higher Educational Institution (HEI) and the Innovative Enterprise (IE) with the formation of joint innovation units – scientific and educational (SEC), research and production (RPC) and educational and production complexes (EPC), in which the aggregate intellectual potential and material, technical, technological, instrumental, research resources of the AS, IE, HEI.

The convergent cluster structure of the highest level is the Scientific, Educational and Production Complex (SEPC), which is capable of implementing a synergistic effect due not only to the generalization of material intellectual resources, but also to their percolation (from the latin *Percolatio* – filtration) in the volume of the innovation cluster.

The fact of the presence (construction) of an innovation infrastructure using modern technologies and means is a necessary, but not sufficient condition for its functioning and progressive development with the production of innovative products with a growing number of consumer characteristics.

An innovation structure, including the cluster type, should have a permanently renewable resource that extracts from its components (material, technical, informational, technological, managerial, research, etc.) the creative component, which is the basis of innovations – knowledge and competencies of a new level and content. Such a percolation resource is an integrated intellectual resource that includes basic and variable components. Therefore, the cluster innovation structure should provide conditions for the permanent development and improvement of the variable (labile) component of the intellectual resource using the achievements of converged technologies, primarily NBIC technologies.

The principle of percolation (filtration) of intellectual resources ensures the formation of a single matrix field, in which high-level intellectual resources are located, capable of forming innovative products (goods, technologies and services) on the basis of the creative application of basic (stable) and labile (acquired) knowledge, which are a prerequisite for innovative development and the result (intellectual product) of scientific activity, which, as noted by Rudensky O.V. and Rybak O.P. "... is dominant of basic and converged technologies" [5].

The synergistic effect of the process of percolation ("filtration") of intellectual resources in the cluster structure consists both in the adaptation of the developed innovations and educational programs to the resources of the existing industrial component (innovative development of traditional technologies), and in targeted research and professional training in the scientific and educational components for the development and application of innovations of a new generation (the creation of innovative, including "high-tech") technologies). Convergence (convergence with interpenetration) of the resources of the basic components of the cluster structure (AS, HEI, IE) – intellectual, material, technical, technological, informational – ensures the formation of creative thinking of participants in the innovation process while destroying stereotypes due to the traditional educational paradigm.

It is especially necessary to emphasize the characteristic feature of the process of percolation of intellectual potential in the infrastructure of the integration cluster, which consists in changing the educational paradigm in the training of specialists with traditional (routine) thinking, to the training of specialists with basic competencies that meet the requirements of the sustainable development strategy. At the same time, it is possible to form practical skills of cognitive thinking among specialists, which are not given due attention in the current educational code.

The educational paradigm operating in the CIS (Commonwealth of Independent States), formed on the basis of traditional (routine) methodological approaches without taking into account modern trends and prospects for the development of post-industrial societies, trains mainly a "consumer specialist", and not a "creator specialist".

The approximation of the educational concept to foreign standards actually ensures the adaptation of individuals from various socio-political systems differing in the level of technological development

to the current paradigm of economic and socio-political development and the system of characteristic values (cultural, religious, moral) of the leading powers by suppressing and transforming the basic distinguishing features formed by national, cultural, educational and other traditions with the subsequent consolidation of the imposed stereotype in behavior and thinking through subsequent permanent training (retraining) in the employer's own interests. An individual reformatted in this way, even with progressive and high competencies, is not able to fully adapt to another socio-political and economic system that does not have similar signs of a technological, administrative, regulatory legal structure and the level of material support for a comfortable and safe life.

3. Conclusion

In the post-industrial economy , the percolation interaction of the components of the integration cluster, manifested in the joint use and activation of intellectual resources belonging to each component, contributes to their convergence and provides a synergistic effect in solving the aggregate problem of achieving optimal economic benefits with the adequate development of corporate culture, creative thinking and innovative receptivity of all members of the structure through the implementation of the process of permanent cognitive learning using advanced achievements in the sustainable development of the post-industrial economy at the subjective, regional and global levels, taking into account the synergy and convergence of priority (global) NBIC technologies.

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Waste-to-energy solutions for bulgaria's industrial and municipal waste management

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Abstract: *This paper evaluates the potential of waste-to-energy (WtE) solutions in managing industrial and municipal waste in Bulgaria. It provides an overview of current WtE technologies, including thermal, biochemical, and innovative processes, and assesses their applicability within the Bulgarian context. The study highlights environmental and economic benefits such as reduced landfill use, decreased greenhouse gas emissions, and energy recovery. By examining successful implementations in Bulgaria and other EU countries, the paper identifies key challenges and opportunities for scaling WtE solutions. The findings suggest that with the right policy support and investment, WtE can significantly contribute to sustainable waste management in Bulgaria.*

Keywords: *Waste-to-Energy, Industrial Waste Management, Bulgaria, Thermal Processes, Biochemical Processes, Environmental Benefits, Economic Benefits, Sustainability.*

1. Introduction

Effective waste management is a critical challenge for modern societies, particularly in countries undergoing rapid industrialization and urbanization. Bulgaria, like many nations, faces significant hurdles in managing its industrial and municipal waste. Traditional waste disposal methods, such as landfilling, not only consume valuable land resources but also contribute to environmental degradation through greenhouse gas emissions and potential soil and water contamination.

Waste-to-Energy (WtE) technologies offer a promising solution to these challenges by converting waste materials into valuable energy resources. These technologies not only help in reducing the volume of waste destined for landfills but also generate electricity, heat, and even fuel, thereby contributing to the circular economy. The adoption of WtE solutions can play a pivotal role in achieving sustainable waste management and environmental goals in Bulgaria.

This paper investigates the potential of WtE solutions for managing Bulgaria's industrial and municipal waste. It provides a comprehensive overview of current WtE technologies, including thermal, biochemical, and innovative processes. By examining successful implementations in Bulgaria and other EU countries, the study highlights the environmental and economic benefits of these technologies, such as reduced landfill use, decreased greenhouse gas emissions, and energy recovery.

Additionally, the paper explores the challenges and opportunities associated with the adoption of WtE solutions in Bulgaria. It discusses technical and infrastructural hurdles, the need for supportive policy frameworks, and the prospects for public and private sector investment. Through this analysis, the paper aims to offer insights into how Bulgaria can effectively leverage WtE technologies to enhance its waste management practices and move towards a more sustainable future.

By drawing on case studies and examples from countries like Germany and Sweden, which have successfully integrated WtE technologies into their waste management systems, this paper explores the potential for adopting similar strategies in Bulgaria. The findings suggest that with the right policy support and investment, WtE can significantly contribute to sustainable waste management in Bulgaria, aligning with broader European sustainability goals.

2. Types of Waste-to-Energy Technologies

Waste-to-Energy (WtE) technologies are integral to the waste management hierarchy and are responsible for converting non-recyclable waste into valuable products such as heat, electricity, and transport fuels. These technologies process various types of waste, including semi-solid, liquid, and gaseous forms. The transformation of waste into energy not only saves landfill space and reduces disposal costs but also converts waste into valuable fuels, fertilizers, and electricity. WtE technologies are broadly categorized into thermochemical and biochemical processes. [1]

2.1. Thermochemical Technologies

Thermochemical processes apply thermal energy to waste components in a closed vessel, breaking the molecular bonds and decomposing the waste into smaller molecules. These processes release more energy than they consume, effectively destroying harmful waste components while recovering energy. [2]

2.1.1. Incineration

Incineration is a well-established technique for energy recovery from municipal solid waste (MSW). It involves the complete combustion of organic waste substances to recover heat and reduce the volume of MSW significantly. Typically, the combustion temperature in incineration plants is about 850℃, producing primarily CO_2 and H_2 O. Non-combustible materials like glass and metals form solid slag (incinerator bottom ash) and require pre-separation from MSW, which demands additional energy.

Incineration reduces waste weight by 70-80% and waste volume by 80-95%, thus significantly decreasing the required landfill space. It is the most mature WtE technology, suitable for both rural and urban areas, with relatively low capital requirements and high power generation efficiency. However, incineration can emit toxic gases like dioxins and furans, necessitating advanced pollution control technologies that increase construction and operational costs. [3]

2.1.2. Gasification

Gasification is a thermochemical process that converts organic material (biomass or MSW) into syngas through a chemical reaction in a low oxygen environment. The syngas, composed mainly of CO and H_2 , can be used to produce energy, transportation fuels, fertilizers, and chemicals. This process occurs at high temperatures (~800℃) and is highly efficient, with gas yields up to 85%. Gasification reduces waste volume by 90%, producing only 8-12% ash, which is less than incineration.

Despite its advantages, gasification can release pollutants like tars, alkaline compounds, and heavy metals, which pose operational and environmental challenges. The capital costs are also high, making it a significant investment. [4]

2.1.3. Pyrolysis

Pyrolysis thermochemically decomposes carbonaceous materials in the absence of oxygen, producing syngas, char, and oils. The composition of these products can be modified by adjusting the process conditions such as temperature, heating rate,

and feedstock properties. Pyrolysis operates at various temperatures, resulting in different product distributions: low temperatures favor liquid products, while high temperatures favor gaseous outputs.

Pyrolysis reduces waste volume by 70-90% and produces valuable by-products like bio-oils and syngas, which can be used for energy generation. However, the process is sensitive to feedstock properties and requires significant preprocessing, including sorting, shredding, and drying, which can increase operational costs. [5]

2.2. Biochemical Technologies

Biochemical technologies use microorganisms to degrade waste, converting it into gases like methane and carbon dioxide, and leaving behind nutrient-rich by-products. These processes are influenced by factors such as moisture content, pH, and nutrient balance. [6]

2.2.1. Anaerobic Digestion

Anaerobic digestion breaks down biodegradable materials in an oxygen-free environment, producing biogas (methane and CO_2) and digestate, which can be used as fertilizer. This process involves multiple stages, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis, facilitated by various microbial communities.

Anaerobic digestion is highly efficient for processing organic waste, producing biogas that can be used for heat and electricity generation. It is cost-effective compared to thermal technologies and has low environmental impact. However, it does not fully digest waste, and the digestate may contain contaminants, reducing its market value. [7]

2.2.2. Fermentation

Fermentation uses microorganisms to convert organic materials into ethanol and other by-products. This process operates under anaerobic conditions and involves the breakdown of sugars into alcohols and gases. Fermentation is similar to anaerobic digestion but stops at the production of ethanol instead of methane.

Fermentation produces ethanol, a valuable biofuel, and is less energy-intensive than thermal processes. However, it requires significant preprocessing of feedstock and produces CO_2 as a by-product. [8]

2.3. Innovative Processes

Innovative processes in waste-to-energy (WtE) technologies encompass cutting-edge methods that go beyond traditional thermochemical and biochemical approaches. These advanced technologies aim to enhance efficiency, reduce environmental impact, and leverage new scientific discoveries.

2.3.1. Biological Hydrogen Production

One such innovative process is the biological production of hydrogen from waste. Hydrogen, the most abundant element on Earth, is not found in its elemental form. Its industrial production primarily involves steam reforming of natural gas, water-splitting electrolysis, and by-products from various industrial processes. Current global hydrogen production exceeds one billion cubic meters per day, sourced from natural gas (48%), oil (30%), coal (18%), and water electrolysis (4%). As researchers anticipate, hydrogen is poised to become the "fuel of the future," with renewable biohydrogen energy potentially replacing non-renewable fuels globally.

Producing hydrogen from waste via biological methods is gaining traction due to its renewable and sustainable nature. Microorganisms can convert municipal solid waste (MSW) into biohydrogen through flexible metabolic mechanisms. Biologically synthesized hydrogen is advantageous because it requires low energy input, has a low investment cost, and offers a high energy yield of 142 kJ per gram, which is 2.75 times greater than any hydrocarbon fuel. Additionally, it is free of greenhouse gases and is a high-calorific-value fuel, making it an essential feedstock for the chemical industry.

Hydrogen production methods can be categorized into physical-chemical and biological processes. Physical-chemical methods are energy-intensive and produce greenhouse gases that contribute to global warming. In contrast, biological methods are environmentally sustainable, reduce energy depletion, and use low-cost substrates. Biological hydrogen production is primarily facilitated through anaerobic fermentation, which can be classified into light-independent and light-dependent processes. Currently, biohydrogen production is a burgeoning area of research, attracting significant scientific interest due to its potential environmental and economic benefits. [9]

3. Benefits of Waste-to-Energy Solutions

3.1. Environmental Benefits

3.1.1. Reduction in Landfill Use and Greenhouse Gas Emissions

Waste-to-energy (WtE) technologies are essential for minimizing the volume of waste directed to landfills. By converting non-recyclable waste into energy, these technologies significantly decrease the reliance on landfills, which are known to produce methane, a potent greenhouse gas. Methane emissions from landfills contribute substantially to climate change. WtE processes, such as incineration and anaerobic digestion, help mitigate these emissions by diverting waste from landfills and converting it into useful energy forms, thereby improving air quality and reducing greenhouse gas emissions. According to the European Environment Agency, WtE technologies have contributed to a significant reduction in landfill use across several EU countries, highlighting their effectiveness in environmental protection. [10]

3.1.2. Contribution to a Circular Economy

WtE technologies also support the principles of a circular economy by transforming waste into valuable resources. This includes not only the generation of energy but also the production of by-products such as ash and digestate, which can be utilized in construction and agriculture. By converting waste into energy and other useful products, WtE processes help close the loop in waste management, promoting sustainable practices and reducing the environmental footprint associated with waste disposal. The role of WtE in achieving a circular economy is crucial for maximizing resource recovery and minimizing waste. [11]

3.2. Economic Benefits

3.2.1. Energy Recovery and Potential Cost Savings

One of the primary economic benefits of WtE technologies is the ability to recover energy from waste. This energy can be used in the form of electricity, heat, or biofuels, which can power homes, businesses, and vehicles. By generating energy from waste, these technologies reduce the dependence on fossil fuels, leading to cost savings and enhanced energy security. The revenue generated from selling the recovered energy can also offset the costs of waste management, making WtE a financially viable option for both municipalities and private enterprises. According to various research, WtE plants provide a reliable source of energy and can play a crucial role in energy recovery and cost savings. [12]

3.2.2. Job Creation and Stimulation of Economic Growth

The development and operation of WtE facilities can stimulate economic growth by creating jobs in various sectors, including construction, engineering, facility management, and waste collection. These job opportunities range from technical and engineering positions to operational and administrative roles. Moreover, the establishment of WtE infrastructure attracts investments, fosters innovation, and promotes the growth of related industries. This economic activity not only boosts local economies

but also contributes to national economic development, providing a sustainable and resilient economic model. Job creation through WtE facilities is significant in improving waste management practices and supporting economic development. [13]

4. Case Studies and Examples

4.1. Successful Implementations in Bulgaria

4.1.1. Green Biomass Energy Project: Hiteck's Sustainable Biofuel Initiative

Hiteck, a company in rural Bulgaria specializing in wood products, partnered with Norwegian company Standard Bio AS – Utgard AS to introduce green technology through a Norway Grants project. The initiative focused on producing biofuel from waste wood materials, a significant portion of which comes from one of Bulgaria's largest forest plants located in Banite. This project marked the first time waste wood was utilized for eco-innovative business development in the region, contributing to both environmental sustainability and economic growth.

The Norwegian partner provided critical expertise and technology, particularly in energy-efficient drying and grinding processes. This collaboration led to the development and installation of a biofuel production line that uses 16,000 cubic meters of bio-waste annually, reducing the need for burning wood and thus lowering energy demand. The new technology allows Hiteck to produce 4,000 tons of pellets per year, equating to a climate impact of approximately 8,000 tons of CO_2 if replacing coal use.

The project had a significant impact on the local community, generating 15 new jobs in an area with high unemployment rates. It also enabled local forest companies to supply waste wood that had previously been discarded, optimizing costs and utilizing otherwise lost material for heat production. This initiative under the Business Development, Innovation and SMEs Growth Programme in Bulgaria, supported by Norway Grants, showcases the potential of green technology to foster sustainable business practices and community development. [14]

4.1.2. Bulgaria's Hydroenergy Company: Transforming Waste into Energy

The Bulgarian Hydroenergy Company, with funding from Norway and in collaboration with Norwegian partner Hydrogenpartner AS, implemented a groundbreaking waste-to-energy project. Before 2016, Bulgaria lacked combined heat and power generation plants utilizing wood waste, primarily due to high initial investment costs and economic infeasibility. The Norway Grants 2009-2014 programme supported a project that found a sustainable and profitable way to convert waste into energy.

The project consisted of two interconnected sub-projects: a wood pellets plant and a combined heat and power plant. The waste from the pellet production process serves as the raw material for the waste treatment plant, creating a highly efficient and profitable system. This innovative approach not only produces electricity from wood waste but also utilizes thermal energy directly in both plant processes and indirectly for district heating, drying, and refrigeration.

The cooperation with Hydrogenpartner AS, which brought technical and operational know-how, was crucial for the project's success. The system burns approximately 7,073 tonnes of waste annually, generating 3,537 MWh of renewable electricity and 2,052 MWh of thermal power, enough to supply 1,500 average households and reduce CO_2 emissions by 3,480 tonnes. Additionally, the project helps address the issue of hazardous waste management, including hospital waste, by incinerating it safely and reducing valuable landfill space usage.

The project's results include the installation of a 250 kW electrical capacity combined heat and power system, a 7,200 tons/year pellet production line, and various wood production facilities. Moreover, it created 15 new jobs, further supporting local economic growth. [15]

4.1.3. Burgas Waste Management Installation: EU-Funded Environmental Innovation

In a significant step towards meeting EU environmental standards, a new waste management installation has been inaugurated in Burgas, Bulgaria. The project, co-funded by the European Commission and Bulgarian institutions with EUR 14 million from the European Regional Development Fund, addresses the pressing waste management needs of the municipalities of Burgas, Nessebar, and Pomorie.

This state-of-the-art facility features an anaerobic installation with a capacity of 30,652 tons per year, comprising eight bioreactors, a biogas system, gas storage, and other essential equipment. Utilizing dry methanation for anaerobic digestion, the facility efficiently processes waste to produce biogas. Complementing this is a composting installation with six tunnels, equipped with advanced systems to manage the fermentation process.

The project emphasizes energy efficiency by incorporating a cogeneration system that generates both electricity and heat from the biogas produced. The infrastructure supporting the facility includes roads, supply and sewage pipes, and a network of 11,315 containers for biodegradable waste collection, along with 10 waste collection trucks and 2 front-end loaders.

This initiative not only tackles biodegradable waste challenges but also sets a precedent for sustainable waste management practices. It creates jobs, promotes a cleaner environment, and aligns with EU sustainability goals, demonstrating a strong commitment to environmental stewardship and responsible resource utilization. [16]

4.2. Failed Projects

4.2.1. Sofia Incinerator Project: A Controversial Initiative

The Sofia Incinerator Project, initiated nearly a decade ago, was intended to revolutionize waste management in the Bulgarian capital by converting waste into thermal and electrical energy. However, on May 2, 2024, the Supreme Administrative Court of Bulgaria definitively rejected the project, citing significant environmental and health concerns raised by local citizens and environmental groups.

The project, largely funded by European resources, aimed to construct an incinerator to burn fuel derived from city waste. It was part of a broader waste management strategy that included substantial investments, amounting to tens of millions of Euros. The European Regional Development Fund had allocated approximately 130 million Euros for the initial phases and was set to contribute an additional 77 million Euros for the incinerator's construction. The European Investment Bank was also expected to provide significant financial support.

Despite these substantial investments, the project faced numerous setbacks. Local environmental groups, notably the "Za Zemiata" ("For the Earth") association, strongly opposed the incinerator due to concerns over the emissions and their potential impact on the already heavily polluted city of Sofia. These groups argued that the environmental impact assessment provided was inadequate and unreliable.

In September of the previous year, the project faced its first legal rejection. The final decision by the Supreme Administrative Court reinforced the earlier ruling, declaring the environmental reassurances insufficient. As a result, the Sofia administration must now reconsider its waste management strategy, which had been oriented towards the incinerator solution for over ten years.

The cancellation of the incinerator project means that the municipality of Sofia will have to return 35 million Euros already

allocated by the EU. This significant financial setback requires a re-evaluation of waste management policies, possibly shifting towards more environmentally friendly alternatives such as enhanced separate waste collection and recycling efforts.

This case underscores the complexities and challenges of implementing large-scale waste management projects in urban areas, especially those involving incineration, which faces increasing scrutiny due to environmental and public health concerns. [17]

4.3. Ongoing Projects with Uncertain Outcomes

4.3.1. Simitli Waste-to-Energy Project: Turning Waste Plastic into Energy

The small mountain town of Simitli in Bulgaria is set to potentially host the country's first installation converting plastic waste into energy. This initiative, spearheaded by the UK company Hydrogen Utopia International (HUI), involves a letter of intent signed with the town's mayor, Apostol Apostolov. The technology to be used is relatively new, with the first such facilities becoming operational in Poland, like the Konin facility which has seen significant progress in its planning and investment phases.

The project utilizes Distributed Modular Gasification (DMG), a proprietary technology developed by Britain's Powerhouse Energy. This technology converts plastics into synthetic gas (syngas), which can then be used to produce electricity, heat, and hydrogen. The process involves a thermochemical reaction (pyrolysis) that breaks down waste plastic into a mixture of methane, hydrogen, carbon monoxide, and carbon dioxide. The syngas produced can replace natural gas in various industrial processes or be used directly for electricity and hydrogen production.

The DMG system can handle any type of plastic, including non-recyclable and end-of-life plastics, without releasing harmful emissions. The process leaves behind inert residues, typically less than 5% of the initial waste volume, which can be safely disposed of or repurposed.

HUI's proposed investment for the Simitli project is around 25 million euros. The plant is expected to convert 40 tonnes of plastic feedstock daily into 45 tonnes of syngas, which can produce 85 megawatt hours of electricity or a combination of 50 megawatt hours of electricity and 3 tonnes of high-purity hydrogen.

The choice of Simitli as the location for this plant is strategic. The town's connection to coal makes it an ideal candidate for transitioning to clean energy solutions. The project will be situated near existing waste remediation facilities, and the municipality has pledged support in sourcing and purchasing suitable land and obtaining necessary permits.

The success of this project depends on various factors, including securing the required funding, regulatory approvals, and community support. If successful, it could pave the way for similar projects in other parts of Bulgaria, particularly in regions like Stara Zagora, known for their coal-fired power plants.

The Simitli project represents a significant step towards innovative waste management and clean energy production in Bulgaria, aligning with broader European sustainability goals. [18]

4.4. Examples from Other EU Countries

4.4.1. Germany: Muellverwertung Rugenberger Damm (MVR) Waste Treatment Facility

Germany has long been a leader in waste-to-energy (WtE) technologies, exemplified by the Muellverwertung Rugenberger Damm (MVR) waste treatment facility in Hamburg. Established in response to the City of Hamburg's 1993 resolution to cease landfilling municipal solid waste (MSW), the MVR facility has set a global standard in the WtE field.

Since its full-scale commercial operation began in 1999, the MVR facility has achieved more than 90% availability each year, processing post-recycled, curbside-collected solid waste. The facility's comprehensive approach includes recovering electricity, industrial steam, district heating hot water, and a variety of marketable by-products such as ferrous and non-ferrous metals, hydrochloric acid, gypsum, construction aggregate, and industrial salts for mine reclamation.

The MVR facility boasts an impressive recycling rate of 98-100%, making it one of the most environmentally sustainable WtE solutions globally. The bottom ash generated from combustion is processed to remove soluble salts and metals, resulting in a construction material comparable to processed demolition waste.

MVR utilizes Advanced Thermal Recycling technology, which allows for high energy production and material recovery. This technology, combined with the facility's cogeneration capabilities, enables it to sell both steam and electricity, similar to conventional power plants but with waste as the fuel source instead of coal, oil, or gas.

The environmental impact of the MVR plant extends beyond energy production. Ecological compensation measures included converting 13 hectares of industrial land into natural habitats and implementing green roofs on the facility, creating large areas of green space that benefit local flora and fauna.

The MVR facility demonstrates the economic feasibility and environmental responsibility of advanced WtE technologies. By transforming waste into valuable resources and energy, it reduces landfill dependency, minimizes environmental pollution, and supports sustainable urban development.

The success of the MVR plant serves as a model for other cities and countries seeking to implement effective WtE solutions, showcasing how advanced technology and robust environmental management can coexist to create a sustainable future. [19]

4.4.2. Sweden: Integration of WtE Plants with District Heating Networks

Sweden's district heating systems are a cornerstone of the country's sustainable energy practices, playing a crucial role in both its economy and environmental strategy. This system significantly reduces CO_2 emissions while supporting sustainable economic growth, showcasing Sweden's commitment to innovative energy solutions.

The first district heating system in Sweden was established in Karlstad in 1948, and since then, the number has grown to over 500 systems across the country. Today, district heating in Sweden primarily uses renewable and recycled heat sources, which constituted 90% of its power by 2017. This transition has been instrumental in Sweden exceeding its climate goals, such as those set by the Kyoto Protocol.

The Swedish Environmental Protection Agency has highlighted the efficiency of these systems in reducing emissions and promoting sustainable growth. The integration of renewable energy sources like wind, solar, and hydropower has further solidified Sweden's position as a leader in sustainable energy.

Sweden's district heating systems incorporate advanced technologies to maximize efficiency. Combined heat and power (CHP) plants, which produce both electricity and heat from waste incineration, achieve over 90% energy efficiency. These plants utilize low-grade heat sources, including industrial waste heat and geothermal heat, which are not cost-effective for individual buildings but highly efficient in centralized systems.

In addition to CHP plants, Sweden has been at the forefront of integrating heat pumps into district heating systems. Heat pumps extract and amplify heat from the environment, further boosting the efficiency of lower-temperature heat sources. This reduces the need

for fossil fuel-based backup systems, enhancing the sustainability of the heating network.

The shift to district heating systems powered by renewable energy has had a significant impact on Sweden's environmental footprint. By replacing fossil fuels with renewable sources, Sweden has substantially reduced greenhouse gas emissions. The use of biomass from the extensive forestry industry has also been a key factor in this transition.

Economically, district heating systems have created numerous jobs and fostered innovation in green technologies. Sweden's approach serves as a model for other EU countries aiming to enhance their energy efficiency and sustainability. The European Green Deal and the 'Fit for 55' package recognize the importance of decarbonizing the heating and cooling sector, with Sweden's district heating systems exemplifying this transition.

Looking ahead, Sweden is focused on further optimizing the sustainability of its district heating network. This includes increasing the integration of low-carbon or renewable heat sources and enhancing the energy efficiency of heat pumps. By continuing to invest in research and innovation, Sweden aims to maintain its leadership in sustainable energy and support the EU's broader climate goals. [20]

5. Challenges and Opportunities

5.1. Technical and Infrastructural Challenges

Implementing waste-to-energy (WtE) technologies involves several technical and infrastructural challenges. One significant issue is waste heterogeneity, which affects the efficiency and consistency of energy production. Different types of waste require specific processing technologies, and integrating these advanced technologies into existing waste management systems can be complex and costly. For instance, the Green Biomass Energy Project in Bulgaria, as discussed in Section 4.1.1., demonstrated success by utilizing specific waste wood materials, but such targeted solutions may not be universally applicable due to varying waste compositions.

Additionally, the need for sophisticated infrastructure to support these technologies cannot be overstated. Projects like the MVR facility in Germany, as highlighted in Section 4.4.1., and the district heating systems in Sweden, as explored in Section 4.4.2., have shown the importance of robust infrastructure. These facilities require substantial initial investments and ongoing maintenance to ensure their efficiency and environmental compliance.

5.2. Policy and Regulatory Considerations

Supportive policy frameworks and regulations are crucial for the successful adoption of WtE technologies. As evidenced by Sweden's integration of WtE plants with district heating networks, strong government policies can drive the transition towards sustainable energy solutions. The success of these systems is largely attributed to Sweden's stringent environmental regulations and proactive energy policies, which have facilitated the adoption of renewable energy sources and the decarbonization of the heating sector.

Conversely, the failure of the Sofia Incinerator Project, as covered in Section 4.2.1., underscores the consequences of inadequate regulatory frameworks. The project's rejection by the Supreme Administrative Court was partly due to insufficient environmental impact assessments, reflecting the critical need for comprehensive and reliable regulatory oversight. Ensuring that WtE projects meet high environmental standards is essential for gaining public trust and achieving long-term sustainability.

5.3. Investment Opportunities and Potential for Innovation

Investment in WtE technologies presents significant opportunities for both the public and private sectors. Projects like the Simitli Waste-to-Energy Project in Bulgaria, as detailed in Section 4.3.1., highlight the potential for innovation and economic growth through strategic investments. The collaboration between local authorities and international companies, supported by European funding, showcases the role of public-private partnerships in advancing WtE initiatives.

Moreover, technological advancements continue to enhance the feasibility and efficiency of WtE solutions. Innovations in Distributed Modular Gasification (DMG) and advanced thermal recycling, as seen in the MVR facility, offer promising avenues for improving waste management and energy production. These technologies not only contribute to environmental sustainability but also provide economic benefits through the generation of renewable energy and the creation of green jobs.

In summary, the successful implementation of WtE technologies hinges on addressing technical and infrastructural challenges, establishing robust policy and regulatory frameworks, and leveraging investment opportunities to foster innovation. By building on the lessons learned from various projects discussed in this paper, stakeholders can enhance the effectiveness and sustainability of waste-to-energy solutions.

6. Conclusion

In conclusion, the adoption of Waste-to-Energy (WtE) solutions presents a viable pathway for enhancing waste management practices in Bulgaria. Through the integration of advanced technologies such as thermal, biochemical, and innovative processes, Bulgaria can significantly reduce its reliance on landfills, decrease greenhouse gas emissions, and recover valuable energy resources. The successful implementations of WtE projects in other EU countries, such as Germany and Sweden, provide valuable insights and models that Bulgaria can adapt to its unique context, highlighting both the potential benefits and the challenges that need to be addressed.

However, the realization of these benefits is contingent upon overcoming several technical, infrastructural, and regulatory challenges. It is imperative that Bulgaria develops robust policy frameworks and fosters public-private partnerships to secure the necessary investments for WtE projects. By addressing these challenges and leveraging the opportunities for innovation and investment, Bulgaria can make substantial strides toward sustainable waste management, contributing to its environmental and economic goals.

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Industry 4.0 and human resources management

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Abstract: *A theoretical analysis of Industry 4.0's effects on human resources management (HRM) is provided in this article. It looks at the potential and difficulties presented by the digital revolution, emphasizing the necessity of Smart HR 4.0. Workforce planning, job design, hiring, and staff development in response to emerging technologies like AI and big data are some of the major issues that have been studied. The significance of Education 4.0 in educating the labor force for jobs of the future is also emphasized in the essay. It emphasizes the necessity of HRM methods that change to meet Industry 4.0's changing demands.*
Keywords*: INDUSTRY 4.0, MART HR 4.0, DIGITAL TRANSFORMATION, WORKFORCE PLANNING, JOB DESIGN*

1. Introduction

Industry 4.0 will strongly impact the work environment, organization, and workforce through enhanced collaboration, software importance, and evolving technologies. HR research aims to understand these effects and develop strategies for shaping the future workplace, qualifying workers, and building digital capabilities [1].

These changes affect everyday life and work since enterprise systems depend on people. HR management (HRM) encompasses planning, recruitment, hiring, training, assessment, remuneration, career management, compliance, compensation, redundancy, termination, and negotiations [2]. Rapid technological changes create a gap between workforce skills and job requirements, necessitating new HR development approaches. Addressing these changes involves focusing on Smart HR 4.0, Education 4.0, and the future workplace [3].

2. Materials and Methods

2.1. Smart HR 4.0Грешка! Източникът на препратката не е намерен.

In the 21st century, through Industry 4.0, new innovations are taking place in the form of smart business or smart factories [4]. Human resource management is not immune to this phenomenon, so there is considerable pressure to adapt. Smart Human Resources 4.0 (SHR 4.0) portrays a vibrant can- vas for digital transformation across the various functions of human resource management. Thus, SHR 4.0 represents a new concept that is evolving during the fourth industrial revolution and is characterized by innovations in digital technologies such as the Internet of Things, Big Data and analytics, artificial intelligence, high-speed data networks such as 4G and 5G to effectively manage next generation workers.

SHR 4.0 provides a set of implementation challenges and a set of benefits, which are summarised in the table below.

Table 1: *Implementation challenges and benefits of Smart Human Resource 4.0*

Challenges of SHR 4.0	Advantages of SHR 4.0
Choosing the right combination of new technological tools.	Attracting, developing, and retaining the next generation of talents.
Modification of the existing organizational culture.	More efficient and faster HR operations.
Managing multi-generational work-force expectations.	Building leaner human resources departments.

Traditionally, HR departments manage the entire employee lifecycle from recruitment to exit. Although HR plays a crucial role in corporate growth, many departments are limited to operational tasks due to inefficient processes and outdated technology. The solution is precisely the introduction of the SHR 4.0 concept, which is driven by emerging technologies and next-generation workers [5], with the aim of attracting, developing and retaining multi-generational workers, and satisfying HR processes with leaner departments with error-free data, and easily accessible in an ongoing interactive format.

SHR 4.0 is driven by emerging technologies and a next-generation workforce with the potential to transform human resource management processes covering all aspects from onboarding talent through to offboarding. After an extensive literature review, we agree with Sivathan and Pillai's proposed conceptual framework for SHR 4.0, which we enrich with additional insights from the field of human resource management.

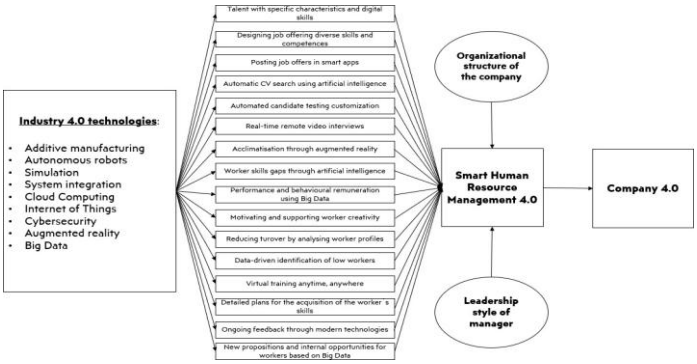


Fig. 1 *Smart HR 4.0 diagram*

Human resources planning

Automation and connected systems drive workforce transformation, requiring businesses to attract, retrain, and upskill resources for new technologies. Strategic workforce planning in Industry 4.0 focuses on acquiring skilled workers for new roles and adapting existing jobs to new methods. Training and development become key for workforce evolution and development. Chinachoti [6] suggest reducing reliance on human resources in planning and assessing the necessary skills for optimal job performance. Familiarity with technology and information systems is crucial.

A new generation of workers, the so-called millennials, is entering the labor market. Their specific characteristics will shape the future of businesses through competition for high potential in the upcoming years [7, 8].

Jobs design

The emergence of advanced technologies in Industry 4.0 impacts human resource practices, including job design [9]. Industry 4.0 principles influence job design and practices in companies. Designing jobs in SHR 4.0 should focus on flexibility and openness to accommodate continuous change, facilitate teamwork and collaboration, and require a diversity of skills. Effective job design in Industry 4.0 human resource management processes is visible when operations successfully transform through automation [10]. However, the lack of empowerment can hinder Industry 4.0's development. Therefore, enrichment approaches in job design are recommended to align with Industry 4.0 principles [10].

Recruitment and employee selection

The rise of smartphones has led to smart apps, with Generation Y and Z receiving job ads based on their profiles. Big Data and AI automate resume searches and candidate preferences, saving time and effort. Interviewing now includes automated and customized testing, improving predictions of future job performance. Faster networks (4G/5G) enable remote interviews through real-time video, shortening the recruitment cycle [5].

AI chatbots interpret and verify candidate responses in real-time, narrowing down interviewees and automating the assessment process, including scheduling interviews and checking references. Only 10% of businesses currently use AI, expected to increase to 36% soon. AI has improved the entire hiring process, giving HR professionals more time for strategic human resources tasks. Challenges remain, including staff training and concerns about losing administrative jobs due to automation.

Augmented reality/virtual reality (AR/VR) could assist new hires with onboarding and track productivity from day one.

Employees development

Workforce development is crucial in HR management for navigating Industry 4.0 uncertainties. Trained workers can adapt to frequent job changes in the uncertain Industry 4.0 environment. Innovative workers work smart, overcome uncertainties, and stay competitive [4].

Training is essential in HR practices for upskilling workers in roles transformed by automation and high technology. SHR 4.0 aims to develop workers' skills and capabilities for Industry 4.0. Sivathanu and Pillai [5] stress the importance of increasing knowledge and skills for today's competitive environment.

AI identifies worker knowledge gaps based on market demands. Generation Y and Z seek targeted training to achieve their professional goals. Faster networks enable virtual training from anywhere. Staff morale and productivity greatly influence learning and development. Training programs boost worker morale and are a major investment for successful businesses [11]. Training aids career advancement, reduces absenteeism, and increases worker satisfaction and commitment.

Career management and planning

Ordinary human capital will no longer drive the workforce; individuals who can think critically and innovate will be the most valuable assets. The National Career Development Association's Facilitating Career Development guide [12] encourages career professionals to help clients find new career paths that match their existing or potential skills.

Mowlaee [13] suggests that as part of career planning, individuals should assess their knowledge, set clear goals, and prioritize activities. They should identify new skills that align with strategic business priorities and leverage technology to enhance their career, including acquiring analytical skills and utilizing data through smart systems and analytics in real-time to improve processes. Becoming IoT experts also supports maximizing Industry 4.0's potential within a digital culture.

Performance evaluation and management

In Industry 4.0, performance evaluation should prioritize workforce development through outcome-based and behavior-based methods to promote learning and innovation [4]. Workers need regular feedback and objective evaluations using quantitative metrics. The process involves setting standards, measuring performance, comparing results, discussing feedback with employees, and taking corrective action as needed [8].

Management by objectives (MBO) is a popular evaluation method in Industry 4.0 [4]. It involves setting and assessing mutual goals based on specific objectives. For participative decision-making, managers and workers determine goals through mutual discussion and consensus. Each goal has a defined deadline, and feedback allows managers and workers to monitor activities and take corrective measures when needed [8].

Remuneration

Due to the lack of skilled workforce in Industry 4.0, HR management must develop an effective remuneration system to retain and develop existing workers and attract new talent [9]. Innovativeness and willingness to learn support remuneration systems in enterprises. Adjusting rewards preemptively can help reduce turnover.

Human resources practitioners should adopt the SHR 4.0 concept to analyze workers' performance, activities, and evaluations to predict and prevent departures [14]. Motivating employees to communicate expectations can reduce stress and the desire to leave [13]. Remuneration should motivate skilled workers, in material or non-material form, to promote human capital creativity in Industry 4.0 [13].

Work environment

In the coming years, the massive adoption of digitalization will shape enterprise work environments [15]. Workers will face new demands in digital competence, problem solving, and human-machine communication [10]. The 2016 Future of Jobs report notes that almost all modern workplaces will require mathematical and interpersonal skills [15].

Frey and Osborne's study on the future of jobs found that nearly half of the jobs analyzed in America will be threatened by digitalization in the next 10 to 20 years [16]. In Germany, experts noted that technical automation's impact cannot be equated with changes in employment rates. While machines may change workplaces, they don't replace all affected jobs. Digital transformation could create many new jobs, such as those in new technologies. The working environment will change significantly, and companies must develop an effective HR management strategy as part of their corporate strategy to navigate these changes [10].

Employee offboarding

Analyzing a worker's profile can predict their intention to leave, allowing HR to proactively retain high-performing employees through better internal opportunities. Low performers can be identified through ongoing annual evaluations rather than just supervisors' assessments. Programs to encourage worker performance should be tailored to individual skill gaps. Though implementing Smart HR 4.0 seems promising, HR should also consider changes in leadership styles and organizational structures [5].

Credit Suisse, employing over 48,000 people worldwide, implemented SHR 4.0 to reduce employee exhaustion and turnover rates by 1%, saving $75-100 million in a year [14]. Companies should adopt SHR 4.0 to navigate Industry 4.0's transformation, automating HR processes for more efficient and leaner HR teams. Effective implementation requires timely responses to changes in organizational structure and leadership style, enabling HR to take a strategic role in organizational growth [5]. Schaar et al. [8] note that Industry 4.0 implications will reduce HR team sizes, allowing HR departments more time for strategic tasks.

2.2. Education HR 4.0

Although the concept of Industry 4.0 is based on modern technologies, the human factor will remain at the centre. This fact is strictly emphasised in the German government's High-Tech Strategy, which states that the philosophy of Industry 4.0 is not based on an industry without humans, but on a human-centered change based on the principle that technology should serve people. Technological trends will undoubtedly continue to bring radical changes within education as well as to other areas of life. Therefore, it is essential to anticipate the impact of technology at every stage of education and take the necessary actions [9].

Education 4.0 represents a desirable approach to education that is aligned with the emerging industrial revolution [14]. A new model of education that responds to the requirements of Industry 4.0 should take into account: linking networks of systems and easy access to knowledge; artificial intelligence, automation, and robotic systems; new media and big data; the speed of innovation; the development of new skills and continuous knowledge [17].

The relationship between the industrial and educational ongoing period leads to the emergence of new professions that require certain specific skills. With this in mind, it is essential that educational institutions are structured to meet the requirements of the highly skilled workforce of the ongoing dynamic transformation process [16].

Cyber-physical systems are being integrated into various industries, which affects the hard and soft skills requirements of the workforce. The World Economic Forum [15] prepared a report examining these changes. The table below shows the most important skills that employers consider essential by 2025.

Table 2: *Top 15 skills by 2025.*

Top 15 skills	
Analytic thinking and innovation	Resilience, stress tolerance and flexibility
Active learning and learning strategies	Reasoning, problem solving and ideas generation
Complex problem solving	Emotional intelligence
Critical thinking and analysis	Troubleshooting, and user experience
Creativity, originality, and initiative	Service orientation
People leadership and social influence	Systems analysis and evaluation
Use of technology, monitoring, and control	Persuasion and negotiation
Technology design and programming	

We agree with the World Economic Forum [15] report that Education 4.0 is about evolving along the time, and for higher education institutions it is a commitment to understand what is required of their future graduates in practice. Technology also allows us to be constantly connected, and as a result, job roles are gradually becoming more flexible and adaptable.

3. Results and Discussion

3.1. The future of jobs

Many workers fear losing their jobs to robots. While robots may replace manual tasks, workers can adapt by learning to control and optimize robot use, discovering new applications. Human-robot interaction may be challenging initially, but proper training can help. Learning about how a robot works, its capabilities, roles, requirements, limitations, benefits, and placement in the system is very important, especially for older workers who are not as tech-savvy as the younger generations Y and Z [17]. The "Future of Jobs 2020" report by the World Economic Forum [15], states that employers expect the share of increasingly redundant jobs to fall from 15.4% to 9% (a 6.4% decline) by 2025 and that the number of new occupations will rise from 7.8% to 13.5% (a 5.7% increase) of the total workforce. On the basis of the above data, it is estimated that by 2025, 85 million jobs may be replaced by a change in the division of labour between humans and machines, while 97 million new jobs may be created that are more adapted to the new division of labour between humans, machines and algorithms. The survey was carried out across 15 sectors and 26 economies.

Jalali and Singh [14] report that Sophia, a Hanson Robotics robot, is the first to receive Saudi citizenship and predict AI could reduce jobs by 27% in less than 20 years, affecting routine roles like drivers and factory workers. Surprisingly, jobs like CEOs, mergers and acquisitions experts, and publicists may also be impacted. Hanson Robotics CEO Jeanne Lim suggests current trends could increase communication with AI as younger generations interact more with devices than humans. Schneider [1] questions the mass production of robots that may take jobs essential for people's survival.

While many manual jobs will be automated, occupations such as barber, handyman, farm worker, cleaner, cook, gardener, repairman, carpenter, and caregiver will likely remain stable due to their complex manual and intellectual skills [16]. Around 19% of workers in OECD countries are employed in these complex manual jobs, a number expected to remain stable [18]. The World Economic Forum's "The Future of Jobs" [15] report highlights jobs with increasing and decreasing demand across various sectors.

Table 3: *Jobs with increased or decreased demand across sectors*

Increasing demand	Decreasing demand
Data analysts and scientists	Data inputters
Artificial intelligence and machine learning specialists	Administrative and executive secretaries
Big Data specialists	Accountants
Digital marketing and strategy specialists	Accountants and auditors
Process automation specialists	Assembly and factory workers
Business development specialists	Client information and customer service workers
Digital transformation specialists	General and operational managers
Information Security Analysts	Material and warehousing and stock control clerks
Software and application developers	Financial analysts
Internet of Things specialists	Postal service workers
Project managers	Sales representatives, wholesale, and manufacturing
Data base and network experts	Relationship managers
Robotics engineers	=Bank tellers and similar clerks
Strategic consultants	Door-to-door
Management and organisation analysts	´´Electronics and telecommunications installers and repairers
FinTech engineers	Human resources specialists

Human capital will need to interact with robots through special mobile devices, using software and knowledge bases tailored to each enterprise [14]. Communication with co-workers via special social networks fosters social relationships and boosts workers' internal motivation. When workers feel motivated and satisfied, they won't feel redundant in an automated environment [12].

Robot-robot interaction is becoming crucial in Industry 4.0. Robots can analyze production processes, make decisions, plan resources, and alert human controllers with suggestions for corrective actions [7]. Robot-robot communication automates

process planning and logistics, but human supervision is essential to ensure automation is beneficial and not harmful [5].

Critics of Industry 4.0 predict unprecedented job losses and unemployment as smart machines replace human labor in business processes. Full-time jobs may shift to uncertain work arrangements, requiring businesses to constantly restructure management practices to manage workforce diversity. This could negatively impact workers' job security and self-esteem [6].

4. Conclusions

Both research and practice highlight risks in the digital workplace, such as job insecurity and technological anxiety, potentially leading to social isolation [17]. Constant learning and challenges in separating work and non-work activities may cause stress and burnout for those unable to adapt. Negative consequences could hinder creativity and critical thinking, as workers may be confined to narrow tasks controlled by machines' pace and rhythm [3].

Reskilling will become routine as new jobs demand higher qualifications. Workers must continually acquire new skills due to shifts in expectations with computers, digitization, and automation in work. To stay competitive, lifelong learning must be prioritized. OECD research [18] recommends investing in skills, improving schools, teacher quality and pay, supporting adult learning, and fostering entrepreneurial skills.

3. Acknowledgments

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Evaluation of the performance of garment production company using energy key performance indicators

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Abstract: *Monitoring and acting on basic energy consumption data in garment production does not provide information about performance improvement. The use of an energy Key Performance Indicator or metric is an effective method for overseeing, analysing, and optimizing any process related to energy. Typically, these performance indicators are employed by manufacturers who rely on energy as a crucial input in their production. Nowadays, for all garment production companies in Albania, energy is a key input in production and all are interested in having low energy Key Performance Indicators.*
The main purpose of this study is to evaluate the performance of a garment production company time to time, through energy Key Performance Indicators and discuss the results.
The study has shown that the energy Key Performance Indicators help optimize any kind of energy relevant process and by comparing energy Key Performance Indicators the company performance can be evaluated time to time.
From the results for two different periods, the second year showed better energy efficiency or performance. Comparing the Key Performance Indicators of the same months over two years resulted in a significant decrease in the second year, but however different factors can influence (the complication of models, operators leave, etc). Average Key Performance Indicator decreased by 68.38 percent in the second year. The company has been able to produce more and use less energy. The fastest and most cost-effective ways to save money can be achieved by utilizing energy more efficiently.
Taking different measures led to a decrease in Key Performance Indicators (new efficient technologies, Photovoltaic system implementation, awareness raising, which will be discussed in future studies), which means better energy efficiency or performance.
Keywords*: ENERGY KEY PERFORMANCE INDICATORS; ENERGY; GARMENT PRODUCTION*

1. Introduction

Electricity is the first source of energy in garment production companies in Albania. Monitoring and acting on basic energy consumption data (kW h) is not always a good idea. All garment production companies are interested in decreasing energy consumption but it doesn't always mean that the business performance or energy efficiency improved. Energy efficiency is closely related to quality improvement and productivity.

The main purpose of this paper is to evaluate the garment production company's performance through Energy Key Performance Indicators. The evaluation is made through a business case.

Production data and energy consumption for 12 months were obtained and KPIs have been defined. Then the same data were received, but for following year and KPIs have been defined. Evaluation of company performance through KPIs and discussion of results is done. Energy consumption bills and data of production in two years are used. The data are taken in one of them. The criteria for selecting the research object have been a garment production company that operates full package, that is interested in energy efficiency, that need energy as a key input in their production.

This paper consists in verification of the hypothesis that the energy KPIs are important and efficient way to measure, monitor activities of leading business and evaluate the performance of the business time to time. An energy KPI or metric is an efficient way to supervise, analyze and optimize any kind of energy relevant process. Mostly these performance indicators are used by garment manufacturers that need energy as a key input in their production. In Albania, now days, for all garment production companies, energy is a key input in production.

A decrease in energy consumption was observed, which resulted in a decrease in KPIs.

2. Materials and methods

This study is carried out in garment production companies in Albania. The data are taken in one of them. Energy consumption bills and data of production in two years are used. Energy consumption is given in kW h and production in pieces. Other sources of materials used in this study are; invoices from suppliers, receipts/bills, inventory, weighbridge data and incoming goods records.

This paper consists in verification of the hypothesis that the energy KPIs are important and efficient way to measure, monitor activities of leading business and evaluate the performance of the business time to time.

The method includes:

1. Production data and energy consumption for 12 months were obtained
2. KPIs have been defined.
3. Then the same data were received, but for the following year and KPIs have been defined.
4. Evaluation of company performance through KPIs
4. Discussion of results.

The criteria for selecting the research object have been a garment production company that operates full package, that is interested in energy efficiency, that need energy as a key input in their production.

3. Results and discussions

The main purpose of this paper is to evaluate the garment production company's performance through Energy Key Performance Indicators.

The production data and energy consumption for 12 months were taken and then the KPIs were determined. Then the same data are collected, but for the following year.

The table below presents the production in pieces, electricity consumption in kWh and calculation of specific energy consumption. From the data obtained, December, October and August are the months with the higher production in pieces, and from electricity consumption, July and August are the months with the notable higher consumption. November and June have a lower electricity consumption, but it doesn't always mean that the business performance or energy efficiency improved. The goal is to produce more and consume less energy.

***Table 1**: Electricity consumption per month, production and KPI (November 2020-October 2021)*

Period	Tot. production	Electricity	KPI (kWh/pcs)
	[pcs/month]	kWh/month	
Nov. 2020	13614	5400	0.397
Dec. 2020	24846	8000	0.322
Jan. 2021	10303	11050	1.073
Feb. 2021	3901	12250	3.140
Mar. 2021	4595	13500	2.938
Apr. 2021	5947	8600	1.446
May 2021	4514	8050	1.783
Jun. 2021	6512	7500	1.152
Jul. 2021	11813	20300	1.718
Aug. 2021	20635	19750	0.957
Sep. 2021	17116	13850	0.809
Oct. 2021	23398	12950	0.553

The figure below shows specific energy consumption in 12 months (November 2020 – October 2021).

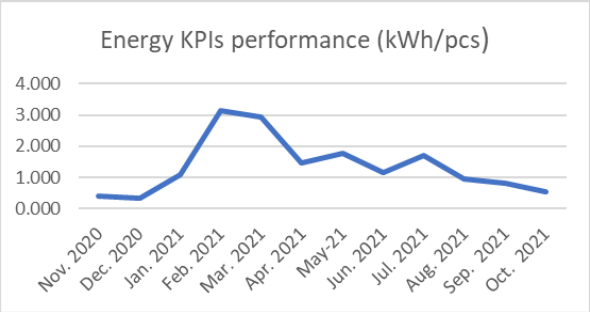


***Fig. 1** Specific electricity consumption (November 2020-October 2021*

Compared with other months, February and March are the months with the higher KPIs, followed by May, April and other months in continuation. This means that in February and March is consumed more electricity and produced less. All garment companies are interested in having KPIs as low as is possible.

The table below shows electricity consumption per month, production and calculated KPIs in following year (November 2021–October 2022). November 2021, September 2022 and October, are the months with the higher production in pieces. From electricity consumption, July and August are the months with the higher consumption. Evaluation of company performance must be done through energy KPIs. October 2022 is the month with better specific electricity consumption.

***Table 2**:. Electricity consumption per month, production and KPI (November 2021-October 2022)*

Period	Tot. production	Electricity	KPI (kWh/pcs)
	[pieces/month]	kWh/month	
Nov. 2021	24000	5366	0.224
Dec. 2021	22000	5992	0.272
Jan. 2022	14 750	7848	0.532
Feb. 2022	16284	6594	0.405
Mar. 2022	8 000	4563	0.570
Apr. 2022	9000	3535	0.393
May 2022	8 500	5967	0.702
Jun. 2022	15 000	5290	0.352
Jul. 2022	12 500	10180	0.814
Aug. 2022	25 500	9904.6	0.388
Sep. 2022	26 000	6945.7	0.267
Oct. 2022	28 000	6494.4	0.231

From the data in two years, in the first year, energy consumption is higher and production in pieces is lower. But what does it mean in terms of the performance or energy efficiency? For example, by compering November 2020 and November 2021, electricity consumption is almost the same value, but production in pieces is notable higher in November 2021. November 2021 is more energy efficient than November 2020. The company, in general, has produced more and consumed less energy in November 2021. Energy KPIs show that November 2021 has a better energy efficiency and company performance too (energy KPI is 43.57% lower in November 2021). By compering May 2021 and May 2022, May 2022 has a better Energy KPI (60.62% lower). In May 2022 the models produced have been more complicated and operators have been on vacation for a weak.

So, we can conclude that in different months the performance is different and different factors have influence. But however, from the point of Energy KPIs November 2021-October 2022 has a better performance and energy efficiency. Energy efficiency means the use of less energy to perform the same task or produce the same result [12, 13]. Average KPIs is 68.38 % lower in the period November 2021-October 2022. This means that the company has produced more and used less energy. Using energy more efficiently will bring the fastest, most cost-effective ways to save money [14].

The figure below shows specific energy consumption in 12 months.

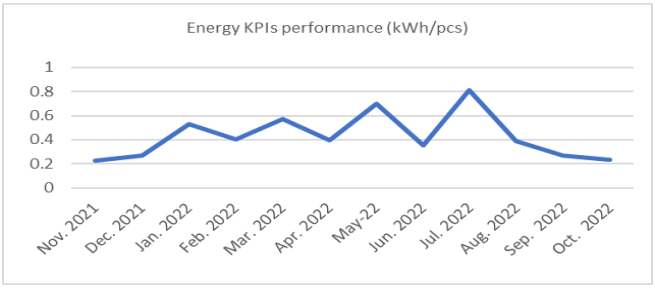


***Fig. 2** Specific Energy Consumption in one year*

Figure 3, shows the comparison of KPIs in two years. Is notable that November 2021-October 2022 has a better KPIs.

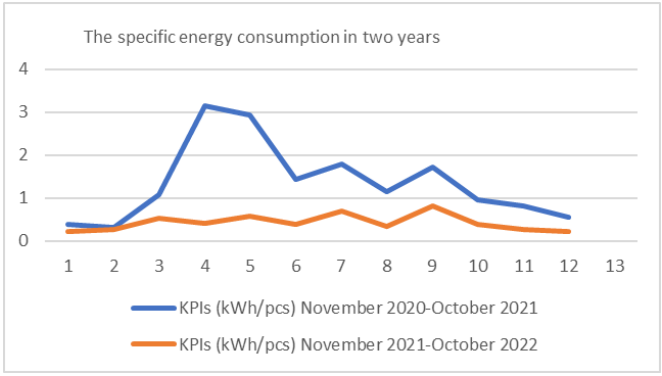


***Fig. 3** Comparison of KPIs in two years*

Every garment production company is interested in having low energy KPIs [15, 16, 17].

So, this proves the hypothesis that the energy KPIs are important and efficient way to measure, monitor activities of leading business and evaluate the performance of the business time to time.

This study proposes a method for garment production companies in Albania to evaluate their performance in different periods.

3. Conclusions

An energy KPIs are used like an efficient way to supervise, analyse and optimize any kind of energy relevant process. Are used these indicators, because energy is a key input in the production of the company.

By comparing the KPIs before and after, a very important decrease is seen.

This study proposes a new method for garment production companies in Albania to evaluate their performance in different periods. Using energy more efficiently will bring the fastest, most cost-effective ways to save money.

KPIs are important and efficient way to measure, monitor activities of leading business and evaluate the performance of the business time to time.

Mostly these performance indicators are used by garment manufacturers that need energy as a key input in their production. In Albania, now days, for all garment production companies, energy is a key input in production.

Interest is having Energy KPIs as low as possible; producing more and using less energy.

From the KPIs resulted in two different periods, second year has a better energy efficiency or performance. Comparing the KPIs of the same month in two years, resulted in significant decrease of them. Average KPIs is 68.38 % lower in the second year, but however different factors can influence (the complication of models, operators vacations etc). This shows that the company has achieved a decrease in energy cost, optimization and decrease in product cost.

Undertaking different measures can lead in KPIs decrease (producing more and using less energy), that means better energy efficiency or performance.

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Prediction of consumed electricity in residential spaces

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Abstract: *This report presents an approach for predicting energy consumption in a specific living space based on experimental data on the indoor microclimate. The data for the analysis of the temperature in the room and the external temperature of the environment is used for the period from 01.01.2016. until 31.12.2023, and a period of 18:00 - 24:00. Regression analysis is used to create a model for increasing energy consumption.*
Keywords*: PREDICTING, ENERGY CONSUMPTION, REGRESSION ANALYSIS, LIVING SPACE, TEMPERATURE MODEL*

1. Introduction

This study aims to propose a method for forecasting the required electricity for heating a predefined and defined residential area. For the purposes of the research, regression analysis is used based on data obtained through the measurement of temperature characteristics related to the desired comfortable living conditions in the space. The parameters of the residential space and the values for air temperature and humidity were measured during different periods of the day, as well as across the four seasons and several consecutive years - from the beginning of 2016 to the end of 2023. The measurements reflect the "state of affairs as they are," i.e., data on the environment, temperature, humidity, and the amount of electricity consumed according to (and solely based on) the subjective comfort perception of the tenants while minimizing costs. The measured data and the results of their analysis and processing will be used to constructively improve the environment and/or undertake measures to minimize current expenses. This report, in a sense, serves as a continuation and enhancement of another report by the author [1].

2. Conditions of the experimental measurement

In Fig.1 and Fig.2 the dimensions and location of the living space are presented - in practice, one room of an apartment in a residential building.

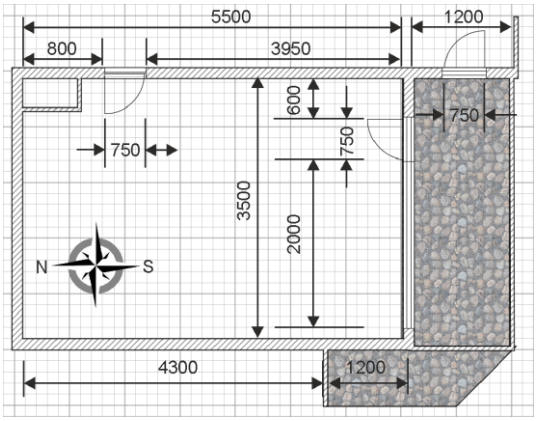


Fig. 1 *Living space dimensions [mm].*

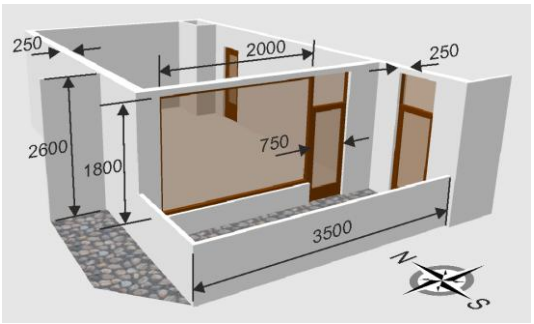


Fig. 2 *3D model of living space [mm].*

All doors and windows are of the energy-saving type – corresponding PVC and solid wood, the walls are built of bricks and are 250 mm thick. The glazing of the exterior doors and windows is made of double 4 mm ordinary glass. The floor is insulated with extruded polystyrene XPS Fibran 20 mm and cement plaster, on top of which 8mm thick laminated flooring is placed. The ceiling is of the "suspended" type with installed mineral wool insulation with a thickness of 80 mm. The walls are plastered and painted with latex - they are not insulated, but the apartment has no external walls and all the neighbouring apartments are occupied by tenants.

The following parameters are measured:

- internal temperature;
- external temperature;
- atmospheric pressure;
- indoor and outdoor air humidity;
- wind speed and direction;
- current precipitation and cumulative values.
- electricity consumption.

A weather station OPUS TFA 35.1112 IT, presented in Fig.3, is used to measure the above [2].



Fig. 3 *Weather station OPUS TFA 35.1112 IT.[2]*

Table 1*: Technical specifications of OPUS TFA 35.1112 IT.*

Technical specification	Value
Type	Weather station
Temperature measurement (OUT)	Yes
The range of temperature	-40° C - + 60° C
Additional features	The weather forecast, preservation temperature, clock, alarm clock, regular calendar
Moisture measurement	In/outdoors, in the range of 1-99%
Wind characteristics	Speed, direction
Remote sensor	Wireless (range 100 m)
Data transfer	Transmission frequency 868 MHz
Power supply	Autonomous, battery LR14

Technical specification	Value
	(included), display of battery level
Displaying information	Numbers and symbols, the choice of measurement units
Sound indication	Yes
USB interface	Yes

For the purposes of the study, it is accepted:

• the day is divided into 4 periods: 00:00-06:00, 06:00-08:00, 08:00-18:00, and 18:00-24:00, the reason for this division is as follows:

- 00:00-06:00 – rest time, heating devices are not working in the room, a lower temperature is required;
- 06:00-08:00 – the room needs a comfortable temperature, after 08:00 there are no people in the room;
- 08:00-18:00 – day mode, there are no people present in the room and the heating devices are not working;
- 18:00-24:00 – evening mode - comfortable conditions are necessary, and heating, air conditioning and lighting devices are usually turned on.

The annual cycle is divided into 4 quarters as follows:

• 01 January – 31 March – Winter;
• 01 April – 30 June – Spring;
• 01 July – 30 September – Summer;
• 01 October – 31 December – Autumn.

For the purpose of this study, the above division of the annual cycle does not contradict the astronomical seasons, due to the visible observation of a shift in the real climatic conditions, for example, spring is "late", it is cold and humid, the real summer "comes later", the autumns are long and warm. The adoption of this condition is also convenient from the point of view of the monthly accounting of the consumed electricity. The created temperature model of the room presents:

• average value of the temperature in the room by months (seasons) and years in the defined time intervals; [1]

The tenants' lifestyle (during the period from 18:00 to 24:00) is not associated with cooking in the room and/or other activities that typically require high electricity consumption. For the cited period of the day, electricity is used for heating (climate control) and other relatively small energy needs, such as lighting, periodic use of laptops and charging mobile phones. The latter do not have a significant impact and are thus disregarded in this context. Since the beginning of 2024, the consumption of heating devices is measured exclusively using the eMylo Smart WiFi Energy Meter (Fig.4), which allows for the collection of accurate data.



Fig. 4 *eMylo Smart WiFi Energy Meter.[3]*

3. Obtained results

The data from the measurements regarding the average monthly temperatures for the period from Jan 1, 2016, to Dec 31, 2022, are shown in Table 1. The following values are distinguishable:

• Average monthly indoor temperatures – InTemp;
• Average monthly outdoor temperatures – OutTemp;
• Average daily electricity consumption – Day;
• Average nightly electricity consumption – Night;
• Average monthly total electricity consumption – All.

Table 1*: Data on average monthly temperatures in the room, the environment (for the period 18:00-24:00), and average monthly electricity consumption for the period January 1, 2016 – December 31, 2022.*

Month	Period - 01.01.2016 - 31.12.2022				
	InTemp	OutTemp	Day	Night	All
1	22,42	2,38	556	128	684
2	22,50	6,50	458	128	586
3	22,35	8,92	378	82	460
4	23,17	15,20	330	83	413
5	24,11	19,53	290	89	379
6	25,88	24,49	241	81	322
7	27,55	27,12	210	61	271
8	28,04	28,28	271	58	329
9	26,49	23,76	267	76	344
10	23,65	17,10	253	76	329
11	22,84	9,72	336	77	413
12	23,00	4,98	499	112	611

From the table, it is clear that the measured values for indoor temperature (InTemp) fall within the range of so-called "comfortable living conditions" [4]. This is also reflected in the electricity consumption across different seasons - for the months of June to August, electricity consumption is the lowest, while for the months of December to January, consumption is the highest. Specifically for the period from 18:00 to 24:00 hours by year, the data are presented in Table 2:

Table 2*: Average Temperature (Ave InTemp), Average air humidity (Ave InHum) and their standard deviations (respectively StdDev InTemp and StdDev InHum) for 2016-2022 (18:00-24:00)[1].*

Ave Temp, StdDev Temp [C°], Ave Hum, StdDev Hum [%]				
Year	Ave InTemp	Ave InHum	StdDev InTemp	StdDev InHum
2016	24,3	51	2,6	6
2017	23,8	50	2,8	6
2018	24,0	51	2,6	6
2019	24,4	51	2,5	7
2020	24,7	51	2,3	6
2021	24,7	51	2,7	7
2022	25,0	51	2,2	5
Average:	24,4	50,8	2,5	6,3

The sensor for measuring the internal air temperature is placed at a height of 1.5m from the floor of the room, on an internal wall and more than 3.0m from the door leading to the outside space. The sensor to measure external air temperature is installed in a container that excludes direct sunlight and the temperature effect of air flows. All measurements were taken under identical conditions, with the weather station's functional components remaining stationary.

The data analysis was performed using regression analysis, with two software products used for result verification, as follows:

• MatLab – https://www.mathworks.com/ [5]
• Orange - https://orangedatamining.com/ [6]

Regression analysis can be used to examine phenomena for which a certain number of observations are known. Each observation has two or more characteristics. Following the assumption that at least one of the characteristics depends on the others, a relationship between them is established… that is, a function is found that sufficiently well matches some characteristics or variables with others. In the general case, when we have one or more independent variables that are not labeled, but we have their realizations, the goal is to determine (almost) completely the coefficients of a function of the type (for multiple linear regression):

$$Y = A_1x_1 + A_2x_2 + A_3x_3 + \ldots + A_nx_n;$$

... thus creating a model of the interaction between them. The state of Y depends on the quantities X_1, X_2, … X_n – they are independent, but the high correlation between the quantities does not necessarily imply a causal relationship between them.

In fact, linear (multiple) regression, as a toolkit, determines the coefficients A_1, A_2, ... A_n, and then it is possible to predict future (probabilistically forecasted) values of Y with a set of input data for x_1, x_2, … x_n or to restore lost (missing, undelivered) data for independent variables based on known values of Y.

In this specific case, we have the variable Y – consumed electricity, and two variables x_1 and x_2 – respectively indoor (for the room) and outdoor temperature (of the environment). The results of the study conducted with MatLab and Orange are presented in Fig.5 and Fig.6.

Step 1. Input Datas.

```
evndatas = readtable('datas.xlsx','ReadRowNames',true);
```

Step 2. Model and Result.

```
evnmodelspec = 'AllEVN ~ InTemp + OutTemp';
mdl = fitlm(evndatas,evnmodelspec)
```

```
mdl =
Linear regression model:
    AllEVN ~ 1 + InTemp + OutTemp

Estimated Coefficients:
                   Estimate      SE       tStat       pValue
                   ________    ______    _______    _________

    (Intercept)    -354.14     347.51    -1.0191      0.33478
    InTemp          47.049     16.488     2.8536      0.018978
    OutTemp        -23.144      3.7909    -6.1051    0.00017815
```

Fig. 5 *Regression analysis with MatLab program.*

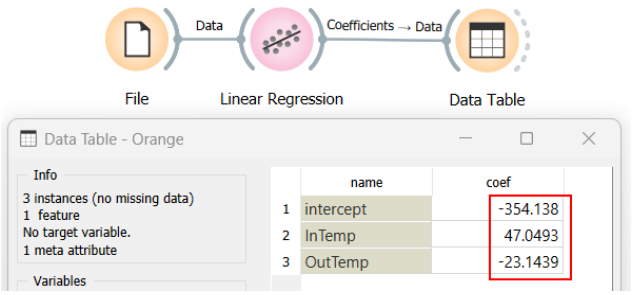


Fig. 6 *Regression analysis with Orange program.*

Received results (Fig. 5 and Fig. 6) are identical, and the sought model of consumed electricity for the period takes the form:

$$Y = -354 + 47x_1 - 23{,}144x_2 \quad (1)$$

Expression (1) can be used to forecast future electricity consumption or to fill in missing data for surveyed (or future) periods. We also have data for consumed electricity for 2023, and we will use the same for verifying the accuracy of the model.

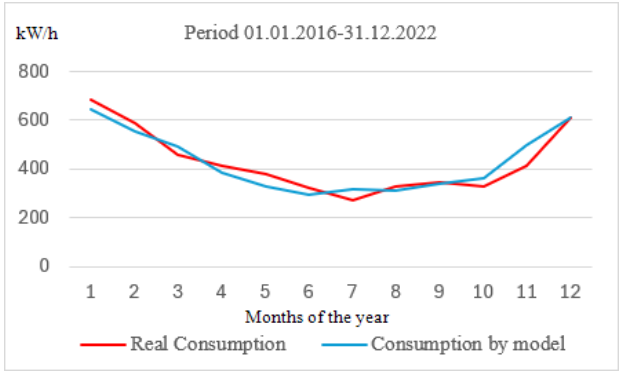


Fig.7 *Model (1) conformity for the testing period.*

Fig. 7 and Fig. 8 illustrate how expression (1) relates to the actually measured data for the period from 01.01.2016 to 31.12.2022 and for the period from 01.01.2023 to 31.12.2023.

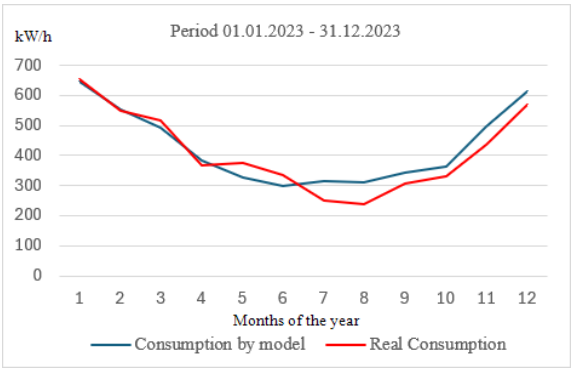


Fig. 8 *Correspondence of model (1) to data for 2023.*

A "critical reading" of the energy consumption data would suggest that this is the electricity consumed for the entire apartment, but it should be remembered that: (i) the people living in the apartment are two tenants with established habits of food (outside the home), (ii) they spend all (almost, all others are negligibly few) weekends away from home, (iii) expenses for lighting, electricity, water for heating are a constant amount and the main consumption is related to heating the premises during the winter period and cooling the premises during the hot days.

All measured data are reliable because, in the last 2 years, parallel measurements have been made with another weather station Weather Screen PRO DNT000008 [7], sensors for measuring air purity, solar radiation and lightning detector within a radius of 40km have been added to it. The measured data are uploaded to the Internet at: http://www.ecowitt.net.

3. Conclusions

The recommended levels of air humidity (according to Regulation No. RD-07-3 [4] and the American Association ASHRAE [8]) are 40%–60%, and the optimal temperature levels for cold and warm periods are 20-23°C and 22-25°C, which are defined and permissible limit values. During the target periods (18:00-24:00) optimal values of temperature and air humidity are maintained.

The proposed approach for forecasting the required electricity consumption is suitable for the temperature partitioning (1) of the room. The study will also be conducted under conditions considering the energy consumption for each individual activity of the building's tenants (for each separate circuit of the electrical installation).

The data show that the costs incurred for thermal insulation are justified and at this stage, there are no better solutions on the market, except for a more modern type of glazing for external doors and windows.

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Smart Microfactory Concept Development at TTK UAS

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Abstract: *The aim of this research is to develop and implement a smart microfactory concept for use in engineering studies as well as for the overall promotion of technical studies at TTK Tallinn University of Applied Sciences. The microfactory allows students to directly engage with a small-scale manufacturing cycle which includes many of the processes found in an actual industrial factory, such as production planning, material handling, quality control and production feedback and optimisation. Pencil sharpening was chosen as the production task. For this purpose, several devices were designed and manufactured which utilise a variety of different sensors and a collaborative robot UR3. The production unit also incorporates a manufacturing execution system (MES) that students can develop and refine themselves. Thanks to a hands-on approach which combines both theoretical studies and practical experience, students are able to observe the effect of their decisions to a production process in a miniature yet realistic environment.*
Keywords*: MICROFACTORY, PROJECT-BASED LEARNING, PRODUCTION PLANNING, MANUFACTURING EXECUTION SYSTEM.*

1. Introduction

In the context of this research, a microfactory is a factory that is small in size and can fit into a university laboratory while including all the processes typical of a real modern factory (planning, material purchase and storage, work-in-progress (WIP) warehouse [1], production and quality control).

The classical approach to university engineering studies is based on theoretical lectures and various technological laboratories. In this case, the student must first learn the theoretical foundations and then, step by step, they can begin to apply them in practice. The microfactory concept offers a different approach and is built on the project-based and problem-based learning methods [2]. In the factory, all processes necessary for production have been implemented based on an industrial knowledge model [3]. Production is initially set up in such a way that it is relatively easy to detect quality issues and waste based on a lean or just-in-time (JIT) production model.

The student's task is to improve and optimize the production process. Changes are introduced into the production process in stages, with the student immediately seeing the consequences of the change. All changes are planned based on the continuous improvement process cycle: identify, plan, execute, review. The operation's qualitative and quantitative run data are sent back to the manufacturing execution system (MES) so that immediate feedback (utilization, overall equipment effectiveness (OEE), throughput (T) etc.) can be implemented in the next improvement cycle. The overall planning of the production unit (quotes, orders, bill of operations (BOO), bill of materials (BOM), production planning (PP), product tracking and quality management are also done through the MES.

2. Microfactory development

The production task and the product of the TTK Tallinn University of Applied Sciences Microfactory is the sharpening of different (diameter, length, colour, accessories) pencils. For this purpose, several devices and mechanisms that make up a whole production unit were designed and manufactured. The main purpose of the microfactory is to be a marketing and advertising object used to promote engineering, therefore the primary focus during the design was both on the appearance as well as the functionality of the unit. It is important that the microfactory is capable of being completely autonomous, reliable and that it can give students the opportunity to experience a modern industrial process on a reduced scale.

The raw materials (unsharpened pencils) are placed in the warehouse where the collaborative robot arm UR3 picks one pencil at a time, inserts it into the sharpener, sharpens it and transports it to another warehouse for shipment to the customer [4]. The collaborative robot was chosen based on a suitability analysis [5]. The production process of the factory is shown in Fig. 1 and the general layout in Fig. 4.

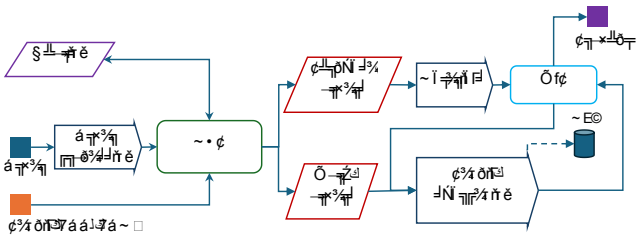


Fig. 1. *Microfactory production process.*

In the production area, there is a container (WIP warehouse) filled with pencils (blank material). When a production order is created and all requirements are met, the rotary conveyor releases a blank.
A DC motor (see Fig. 2 pos. 1) located under the container rotates a belt-driven shaft that holds the unsharpened pencil inside a groove. The shaft is rotated about 105°, after which the pencil falls off the shaft due to gravity. After a few seconds, the motor turns the shaft back to its initial position with reversible control of the motor being carried out by means of two limit switches (pos. 2) and two relays.
The released blank rolls down the ramp to the two supports where the robot can pick it up. Raw material inspection is also performed at this station. It is possible to identify the length, colour, diameter and other characteristics of the pencil. An induction sensor is located next to one of the supports that detects the metal ring of the eraser and thereby determines the orientation of the blank.

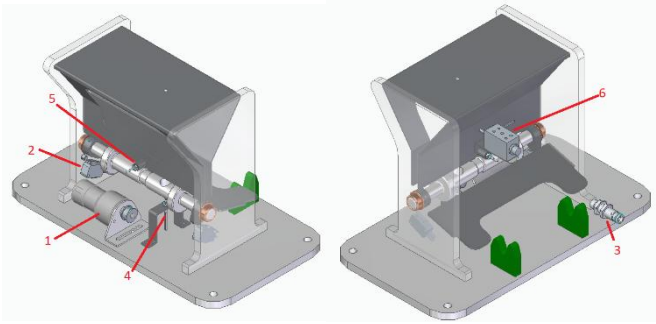


Fig. 2. *WIP Warehouse.*

To detect the presence of pencil blanks in the container and the possible jamming of the pencils at the narrowing of the container, two fibre optic sensors are mounted on the unit (Fig. 3). One is a reflected beam type sensor (Fig. 2 pos. 4) and the other is a sensor with a transmitter/receiver pair (pos. 5). The reflected beam sensor is located under the container and is pointed upwards through a hole in the conveyor shaft. On the cover of the container, just above the sensor, there is a reflector, which reflects the light beam back to the sensor. The transmitter and receiver of the second sensor are located opposite each other on the metal walls of the container and are perpendicular to the axis of the second pencil in a stack of blanks. If the first sensor detects a pencil, but the second sensor does not, then it is clear that the pencils are present in the container, but there is a

gap between them, which can only be caused by a blockage. However, if neither sensor detects a pencil, then the container is empty of blanks.
The production unit uses both reflected beam and transmitter/receiver type optical sensors with a fibre optic cable, because it was not possible to use the same type of sensor in all situations. Together with other sensors and detectors used in the unit, this helps to better demonstrate the different types of sensors to students.

For automatic removal of blockages, a solenoid (pos. 6) is attached to one of the metal walls of the container, which knocks against the wall when activated. By repeatedly switching on the solenoid, it is possible to create enough vibration to release the stuck blanks from each other. However, should the problem not disappear after a while, a message will be displayed on the robot's control panel that calls for human intervention and manual elimination of the blockage.

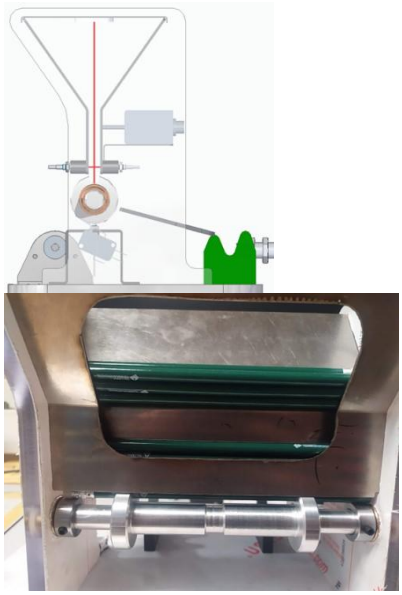


Fig. 3. *Blank detection (left) and material jamming (right).*

A UR3 robot manipulator with a gripper is used to grab, move and sharpen the pencils. The robot picks up the pencil, moves it to the sharpening machine, turns it in the right direction, and plunges it straight into the sharpener. A fibre optic sensor transmitter/receiver pair is attached to the opposite slots perpendicular to the sharpening machine inlet. The pencil entering the sharpener cuts through the sensor's light beam and the approximate distance of the pencil tip is calculated in the control program. Based on this, the feed length is calculated, which ensures that sharpening is always done to the same depth, even with pencils of different lengths. After sharpening, the robot manipulator moves the product to the storage position (see Fig. 4 pos. 5), releases it, and returns to its original position to await the next command. An optical sensor is attached to the pencil holder which detects the presence of a pencil. The production cycle is finished, and the necessary data, such as overall equipment effectiveness (OEE) and throughput, can be calculated.

In the production unit, all equipment is controlled by the UR3 robot controller. The movements of the robot manipulator are programmed using the teach pendant. Communication with sensors and other components is carried out using 24 V DC digital inputs and outputs. Since some components, such as the DC motor and solenoid, require 12 V DC voltage, an external power supply and relays controlled by digital outputs have been added to the system.
While choosing different sensors the main criteria was that they needed to be able to operate at 24V DC to match the inputs and outputs of the UR3 control panel and thus keep the system as simple as possible.

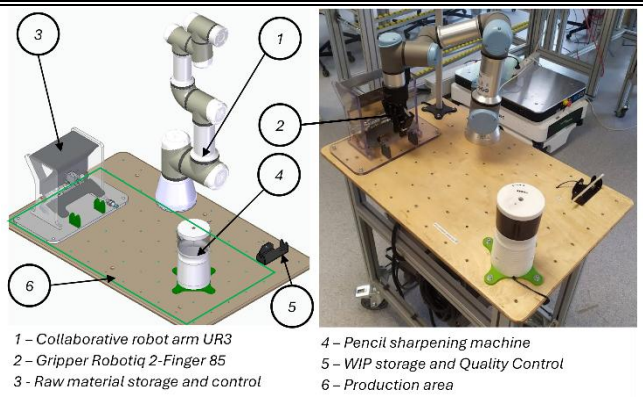


Fig. 4. *Microfactory layout.*

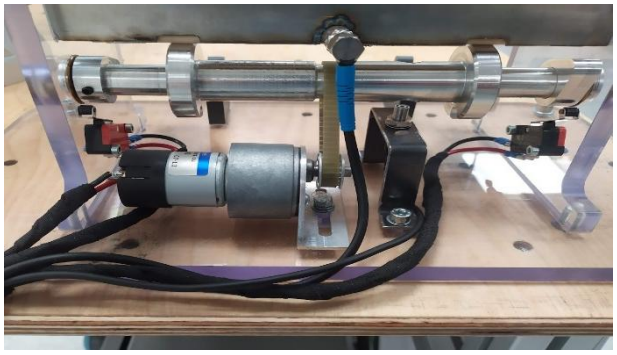


Fig. 5. *Sensors and actuators used in the microfactory*

All the components of the production unit are easily moveable to anywhere in the work envelope which gives students the possibility to assemble and program the microfactory in any way they see fit. This allows for a hands-on approach which gives both practical experience in mechanical assembly and an understanding of the effect of planning and layout on production efficiency.

3. Production management

The task of the production management system is to organize production in both a narrower and a broader sense. It is crucial to have all the necessary resources to perform production operations, such as raw material, semi-finished products, jigs along with time and technical equipment required for production machinery, and of course the necessary personnel. Comprehensive systems that take into account all the characteristics of a specific production unit and fulfil the above-mentioned task are called manufacturing execution systems [6]. The use of such systems in modern production is essentially unavoidable and is therefore widespread among industrial enterprises. However, if we look at these systems from the perspective of the student and especially of learning, the following shortcomings of using the existing solutions can be observed:

- Ready-made solutions are end-user products which do not provide the student insight into the development of different functions,
- the altering of functions requires high-level programming skills,
- functions take into account a very large number of different variables (which is difficult from the perspective of learning),
- the student may lack the motivation to closely study the inner mechanics of a solution that already works,
- availability of necessary software and licenses.

Since the TTK Microfactory concept is primarily intended for comprehensive learning of production systems, it is reasonable to use the problem-based learning methodology. In order to better understand the overall system and its limitations, a new system is created every time, which is student-centred. To create the system, spreadsheet software and additional devices enabling various inputs and outputs are generally used, such as the Arduino Uno development board.

In terms of production management, the TTK Microfactory concept has three levels, where each level has inputs and outputs that direct the resource forward linearly (Table 1). The whole process starts with the production order, goes through all the levels and ends with the closing of the order.

Table 1. *Levels of production management in the Microfactory.*

Input	Level	Output
Production order, forecast	III Planning and design	Technological preparation (BOO, BOM)
Order plan, technologies	II Management	Production plan, work orders
Work orders, technological information	I Operational level	Product/service, key performance indicators

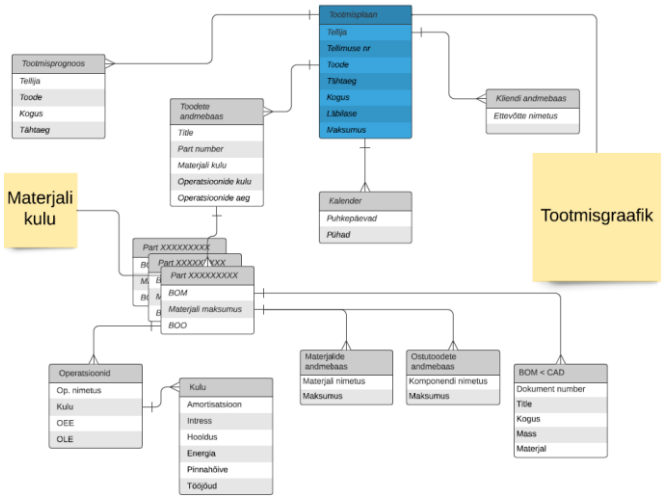


Fig. 6. *TTK Microfactory MES structure.*

Functionally, the TTK Microfactory solution (TTK MF MES) (Fig. 6) must have the following functions:

- virtual warehouse of raw material and semi-finished products: brand, shape, and other characteristic parameters,
- overview of performed operations: preparation and completion times, unit cost, etc.,
- overview of the overhead cost of operations: depreciation, rent, maintenance, etc.
- product specific information: Bill of Materials (BOM) and Bill of Operations (BOO),
- the time and cost resources required to manufacture the product,
- production forecast and order inclusion,
- creation and updating of the production plan,
- creation of work orders,
- feedback from production, such as OEE. Production feedback is carried out in TTK MF MES by summing up the parts completed at the time according to the order. The collected information can be used in the production plan by utilising the Arduino Uno platform [7].

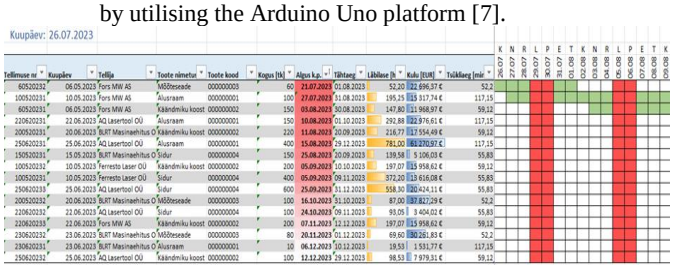


Fig. 7. *Production planning and feedback.*

When creating functions, students start from a blank sheet and, with the help of different study materials and literature, improve the functionality until a satisfactory result is reached (Fig. 7). The previously listed functionality is the minimum required and the student is encouraged to create additional functions, for example, optimisation of operation times, calculation of the cost price of a real product, etc. It is important that the created solution is compatible with the TTK Microfactory and that the planning decisions made are also reflected in the real production process.

4. Results and Discussion

In this study, a concept microfactory was created based on the principles of Industry 4.0 robot-integrated production. Project-based and problem-based learning was implemented, in which the students control the entire process. Physical production is managed using a MES system, where data is collected and processed from the production unit.

Pencil sharpening was chosen as the production process, which consists of preparatory, working and finishing operations. Raw material and finished product movement between operations is done using a collaborative robot. The location of operations in the production area and their parameters can be easily changed. Every change is also immediately reflected in the production feedback, because of which it is possible to find the production optimum. The Microfactory concept allows students to learn a variety of different technical skills such as how to setup a production area, program a collaborative robot along with external devices as well as how to manage and optimise manufacturing. The Microfactory itself can be considered to still be in development, as there is potential to incorporate new production processes and create an even more comprehensive production management system around it.

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Development of an eco-friendly commercial deep fryer with filter system

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Abstract: *In commercial kitchens, deep fryers are essential for frying various foods, particularly frozen products. These appliances, available in multiple models and capacities, typically use gas or electricity and utilize significant amounts of cooking oil. For instance, a standard commercial deep fryer may have a cooking chamber with a capacity of 22 liters of oil. However, over time and with repeated use, the quality of the cooking oil deteriorates, leading to the formation of waste oil. This waste oil affects the quality of fried foods and presents significant environmental challenges. The improper disposal of waste oil contributes to environmental pollution, necessitating businesses' careful management and disposal. In response to these concerns, our research and development (R&D) efforts have focused on designing and developing a novel eco-friendly commercial deep fryer with an integrated filter system. Unlike existing models in our product range, this innovative deep fryer is designed to achieve energy savings and reduce the amount of waste oil produced. Specifically, the new deep fryer has demonstrated energy savings of at least 25% compared to our current models. Additionally, this fryer can operate using alternative solid oil, offering further flexibility and sustainability in commercial kitchen operations.*
Keywords: *COMMERCIAL DEEP FRYER, ECO-FRIENDLY PRODUCT, FILTER SYSTEM, ENERGY SAVING, DESIGN*

1. Introduction

In big cities, especially in the face of population growth and daily workload, food consumption habits have also changed in recent years. The fast-food sector is also growing rapidly in this direction. For this reason, the demand for various cooking devices used in the food sector is also increasing. Commercial deep fryers are widely used especially for cooking frozen foods in a short time.

Depending on the preference of the business, commercial deep fryers are used in different models and capacities, such as electric or gas. Our company has commercial deep fryers in various models and capacities. In line with customer demands, the filtered model aims to reduce the amount of waste oil and obtain an environmentally friendly prototype, as well as to contribute to energy saving.

While the amount of oil consumption varies depending on the frequency of use of commercial fryers in businesses, the waste oils that are formed pose a danger to the environment. For this reason, the waste oils used in fryers must be stored by the business and delivered to the relevant official institutions. The storage of waste oils by the business creates an additional cost for the business. The demand for filtered commercial fryers is also increasing in order to eliminate this problem.

In literature reviews, evaluations were found on the cooking performance of fryers, especially regarding oil quality, cooking conditions (oil temperature, cooking time, etc.). Various literature studies on this subject are summarized below.

Garayoa and his team reported that cooking in oil-using fryers is widely used worldwide and that oil temperature is one of the important factors on the cooking quality of the oil. They also emphasized that there are significant differences between different oil change frequencies or types of oil [1].

Chew and his team emphasized that deep-frying is one of the popular methods for food preparation because it improves the taste and sensory quality of foods. Among vegetable oils, palm oil is one of the most used oils for deep-frying. During deep-frying, some of the oil is absorbed by the food and is later consumed with the food. Therefore, the quality and stability of the oil used is critical for food safety [2].

Rani and his team stated that frying in a deep fryer for various foods is one of the most common cooking methods. It was emphasized that frying in oil causes physico-chemical changes in foods at macro and micro levels. They emphasized the need to reduce oil absorption by developing various methods to limit the amount of oil in foods and obtain foods with less calories and fat. The schematic representation of oil absorption and moisture loss and simultaneous heat and mass transfer during the frying process is given in Fig. 1 [3].

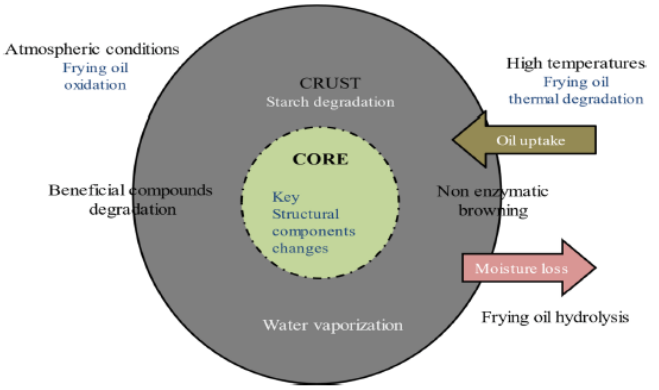


Fig. 1 *Schematic representation of heat and mass transfer simultaneously with oil absorption and moisture loss during the frying process [3].*

Lioumbas and his team studied the oil and temperature loss of potatoes in a commercial fryer. They evaluated the moisture loss with the temperature of the potato. They conducted tests at two different initial oil temperatures (150°C and 180°C) and two different oil types (olive and palm). Temperature changes of two different oils with respect to time in the oil whose initial oil temperature is 180°C are given in Fig. 2 [4].

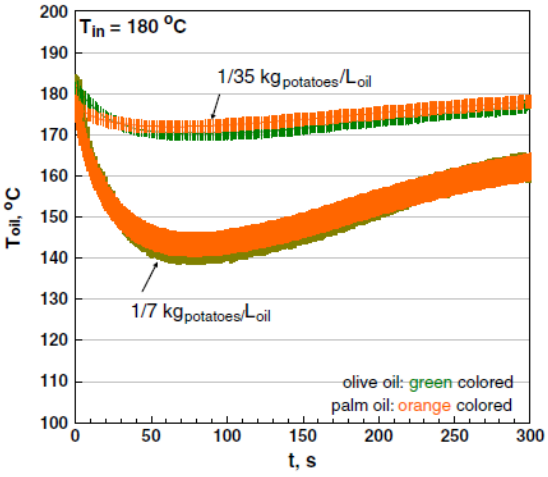


Fig. 2 *Temperature changes of two different oils with time in a commercial deep fryer with an initial oil temperature of 180 °C [4].*

Sivaranjani and his team investigated various frying techniques such as deep fryer, microwave, vacuum, air and spray frying. It was emphasized that deep fat frying is one of the most widely used methods to improve the texture and sensory properties of foods. They stated that physicochemical changes during the frying process change both the product and the quality of the fried oil. The deep fat frying mechanism is shown schematically in Fig. 3 [5].

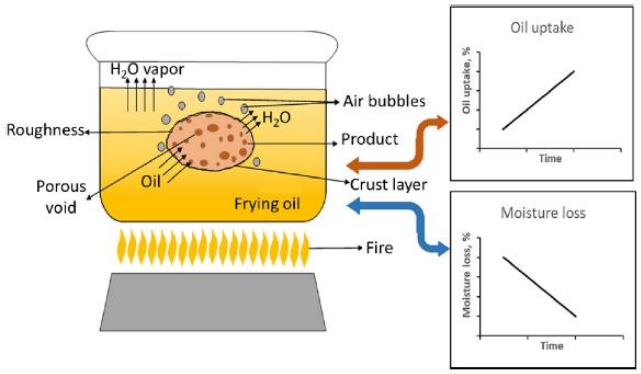


Fig. 3 *Schematic representation of the deep fat frying mechanism [5].*

Zhang and his group conducted evaluations on various frying methods. They stated that new alternative frying technologies (microwave-assisted vacuum frying, pulsed-spray microwave vacuum frying, and power ultrasound and microwave-assisted vacuum frying, etc.) are effective in frying foods with lower oil content and better texture properties compared with conventional frying [6].

Carvalho and his group stated that the oil frying process involves immersing the food in heated oil (150–190°C) and then mass exchange and heat transfer are achieved between the frying oil and the fried food. They emphasized that under deep-frying conditions, the oil, which is in contact with oxygen and moisture from the food, eventually undergoes hydrolysis, oxidation and thermal degradation reactions [7].

Apart from the above-mentioned issues, there are also various studies in the literature on the effects of different oils in the deep-frying process [8-15].

2. Methodology

Commercial kitchen products, unlike home kitchen products, are generally manufactured from stainless steel due to difficult and intensive use conditions.

The main body of the design-specific filter commercial deep fryer prototype is made of AISI 304 quality stainless steel and the cooking chamber is made of AISI 316 quality stainless steel.

Original designs of the filtered commercial deep fryer prototype were first developed. Then, the prototype manufacturing and assembly phase was started. In the last phase, performance tests were performed on the obtained prototype.

The filtered commercial deep fryer with double cooking chamber was designed so that each chamber has a capacity of 22 Lt.

In addition, 8500 W resistance was used in each cooking chamber on the prototype.

During the testing phase, measurements were made under equal conditions by adding the highest level of oil to the developed prototype and standard commercial deep fryer.

3. Test Procedure

Electrical safety measurements were first performed on the developed filtered commercial deep fryer prototype in accordance with the EN 60335-1 standard. The developed prototype met all electrical safety requirements (power input and current, leakage current and electric strength etc.).

The oil usage cycles and energy consumption values of the developed filtered commercial deep fryer and the standard commercial deep were compared and the differences between them were presented.

While the PID control system was used in the basically developed prototype, a contactor was used in the standard commercial deep fryer.

The photograph of the commercial deep fryer prototype with filter system (with two frying chambers) is given in Fig. 4.



Fig. 4 *Photo of the filter system commercial deep fryer prototype (with two frying chambers).*

The control panel photo of the filter system deep fryer prototype (the ability to set different foods, different cooking modes and times) is given in Fig. 5.



Fig. 5 *Control panel photo of filter system deep fryer prototype (possibility to set different foods, different cooking modes and times).*

The photo of solid or liquid oil selection on the control panel of the filter system commercial deep fryer prototype is given in Fig. 6.



Fig. 6 *Selection of solid or liquid oil on the control panel of commercial deep fryer prototype with filter system.*

A photo of frying potatoes on commercial deep fryer prototype with a filter is given in Fig. 7.



Fig. 7 *Photo of frying potatoes on commercial deep fryer prototype with filter.*

The electrical properties of commercial deep fryer prototype comply with the EN 60335-1 standard.

Evaluations regarding the operating performance of the filtered commercial deep fryer prototype are given in Table 1.

Table 1. *Operational performance evaluations of commercial deep fryer with filter prototype.*

Loading amount (Kg)	Loading temperature (°C)	Minimum oil temperature during cooking (°C)	Total cooking time (min.)
1+1=2 (double basket)	178	138	5
1+1=2 (double basket)	198	154	4.5
1+1=2 (double basket)	190	157	5
1 (single basket)	185	178	3.5

The evaluations regarding the cooking performance of the filter deep fryer prototype are given below.

- The time for the maximum level of liquid sunflower oil to reach 185°C from 29°C in the filter fryer prototype was determined as 7 minutes.

- 9x9 mm finger potatoes taken from the deep freezer were used in the cooking performance.

- The loadings were made one after the other in the cooking performance.

- It was observed that the resistances were activated within 10 seconds after loading.

- The internal temperatures of the potatoes after cooking were measured as 76.3°C in 2 kg loading and 81.8°C in 1 kg loading.

In the commercial deep fryer prototype with filter system, solid state relays were used instead of contactors, ensuring noiseless operation. The energy consumption values of the filtered prototype (PID controlled) developed with the commercial deep fryer using a standard contactor are given in Table 2.

Table 2. *Operational performance evaluations of commercial deep fryer with filter prototype.*

Time (hour)	Filtered Commercial Deep Fryer (Wh Values for 240 V 17 kW)	Standard Commercial Deep Fryer (Wh Values for 230 V, 18 kW)
1.	1754	2457.6
2.	2083	3285.9
3.	2400	3990.2
4.	2711	4708.4
5.	3025	5516.7

The energy consumed in the filtered commercial deep fryer prototype (PID controlled) was lower at all operating times compared to the standard commercial deep fryer (contactor controlled), as seen in Table 2.

4. Conclusions

The results of our testing phase indicate that the newly developed deep fryer offers significant advantages over traditional models. Most notably, commercial deep fryer prototype demonstrated a reduced energy consumption of at least 25%, a critical factor in reducing operational costs for commercial kitchens. Additionally, the enhanced filter system effectively extended the life of the cooking oil, leading to a measurable decrease in the amount of waste oil generated. This reduction in waste oil benefits the environment and reduces the burden on businesses to manage and dispose of waste oil.

In conclusion, developing an eco-friendly commercial deep fryer with a filter system marks a significant step forward in sustainable kitchen technology. The fryer's ability to reduce energy consumption and waste oil while also being compatible with alternative solid oils positions it as a valuable tool for businesses looking to enhance their environmental performance. Future research and development efforts will focus on further optimizing the filter system and exploring additional sustainable materials and technologies that can be integrated into commercial kitchen appliances.

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Application of satellite technology in air pollution monitoring analysis of carbon monoxide measurements, pm10, pm2.5 levels and weather index

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Abstract: *The use of satellite technology in monitoring air pollution has become increasingly important for understanding and managing environmental health. This article explores the advancements in satellite-based monitoring of air pollutants, specifically focusing on the measurements of carbon monoxide (CO), particulate matter (PM10 and PM2.5), and weather indices. Satellite remote sensing provides extensive spatial and temporal data, addressing the limitations of ground-based monitoring networks [1]. Recent studies show that geostationary satellites have great potential for continuous and wide-ranging monitoring of air quality. These satellites enable accurate estimation of surface concentrations of pollutants, allowing for real-time assessment and trend analysis [2]. The integration of satellite data with ground measurements improves the reliability of air quality monitoring systems [3]. The analysis also highlights the usefulness of satellite data in understanding the dynamics of air pollution, including the dispersion patterns and the impact of weather conditions on pollutant levels. The use of advanced satellite instruments, such as those on the Sentinel-5P satellite, has shown significant improvements in detecting and quantifying CO and particulate matter concentrations [4]. Overall, the application of satellite technology in air pollution monitoring not only provides valuable insights into pollutant levels but also supports the development of effective mitigation strategies and policies to protect public health [5].*

KEY WORDS: *AIR QUALITY, SENTINEL-5P SATELLITE, POLLUTANT GASES, CARBON MONOXIDE*

1. Introduction

The increasing awareness of environmental health and the pressing need to address air pollution have driven significant advancements in the methods used to monitor and analyze atmospheric pollutants. Among these advancements, satellite technology has emerged as a powerful tool for providing comprehensive data on air quality over large geographical areas. This study leverages satellite data from the Sentinel-5P mission and meteorological data from OpenWeatherMap to examine air pollution levels, focusing on key pollutants such as carbon monoxide (CO), particulate matter (PM10 and PM2.5), and related weather indices.

Sentinel-5P, part of the European Space Agency's (ESA) Copernicus program, is specifically designed to monitor atmospheric composition with high spatial resolution and temporal frequency. Equipped with the Tropospheric Monitoring Instrument (TROPOMI), Sentinel-5P provides detailed measurements of various atmospheric gases, including carbon monoxide, ozone, nitrogen dioxide, and methane. The high precision and global coverage of Sentinel-5P make it an invaluable resource for studying air pollution trends and identifying pollution sources. Data from Sentinel-5P enable researchers to conduct detailed spatial and temporal analyses of air quality, offering insights into how pollution levels fluctuate over time and across different regions [6].

In addition to satellite observations, meteorological data play a crucial role in understanding the dispersion and concentration of air pollutants. Weather conditions such as temperature, humidity, wind speed, and direction significantly influence the behavior of pollutants in the atmosphere. To incorporate these factors, this study utilizes data from OpenWeatherMap, a widely used platform providing real-time and historical weather data. OpenWeatherMap offers a robust API that delivers accurate and up-to-date weather information from numerous weather stations around the world. By integrating meteorological data from OpenWeatherMap with satellite data from Sentinel-5P, this study aims to create a comprehensive framework for analyzing air pollution.

The combination of these datasets allows for a more holistic approach to air quality monitoring. Satellite data provide a broad overview of pollutant concentrations, while ground-based weather data add context and depth to the analysis, helping to explain variations in pollution levels [7]. This integrated methodology enhances our ability to monitor and model air quality, ultimately supporting the development of more effective strategies for pollution control and public health protection. In this study, we will first describe the datasets used and the methodology for data integration. Next, we will present the results of our analysis, focusing on the spatial and temporal patterns of carbon monoxide, PM10, and PM2.5 levels. Finally, we will discuss the implications of our findings for air quality management and future research directions.

By leveraging the advanced capabilities of Sentinel-5P and the comprehensive meteorological data from OpenWeatherMap, this research aims to contribute to the ongoing efforts to monitor and mitigate air pollution. The insights gained from this study will not only enhance our understanding of atmospheric pollutants but also provide valuable information for policymakers and environmental agencies tasked with protecting public health and the environment [8].

2. Results and discussion

The study focuses on Poland as the geographic area of interest. Poland, located in Central Europe, faces significant challenges with air pollution, particularly in urban areas where industrial activities and vehicular emissions are prevalent. The research aims to analyze air quality across various regions within Poland to identify patterns and sources of pollution.

The time frame for this study encompasses the entire year of 2023. This period allows for a comprehensive examination of seasonal variations and long-term trends in pollutant levels. By covering all four seasons, the study captures the impact of different weather conditions and human activities on air quality. Data collected throughout the year provide a robust dataset for assessing the effectiveness of current pollution control measures and identifying areas needing further intervention.

The Sentinel-5P satellite, part of the European Space Agency's Copernicus program, is equipped with the Tropospheric Monitoring Instrument (TROPOMI). This advanced instrument provides high-resolution data on various atmospheric gases. For this study, we specifically focus on the measurements of carbon monoxide (CO) obtained from Sentinel-5P. Carbon monoxide is a significant pollutant with serious implications for human health and the environment, making it an important parameter for air quality assessment.

In addition to the satellite data, the OpenWeatherMap Weather API provides essential ground-based measurements that enhance the overall understanding of air pollution. The Weather API offers real-time and historical data on several key pollutants, including:

- Carbon Monoxide (CO): Complements the satellite data, providing a more granular view of CO levels at ground level.
- Particulate Matter (PM2.5 and PM10): These fine particles are particularly harmful to respiratory health and are important indicators of air quality.
- Air Quality Index (AQI): A composite index that takes into account the concentrations of various pollutants to provide a clear and understandable measure of overall air quality.

The first step in data integration involves matching the geographic coordinates from both data sources. Sentinel-5P provides satellite data with high spatial resolution, capturing atmospheric measurements over large areas. These measurements are mapped to specific geographic locations within Poland. Similarly, the OpenWeatherMap Weather API provides ground-level data from numerous weather stations distributed throughout the country. By aligning the geographic coordinates of satellite and ground-based data, we ensure that the information from both sources corresponds to the same locations.

The second step in the integration process involves synchronizing the data based on the time of measurement. Sentinel-5P continuously captures atmospheric data, providing temporal coverage that includes daily and even hourly measurements. The OpenWeatherMap Weather API also offers real-time and historical data with timestamps. By aligning the timestamps of satellite and ground-based measurements, we can accurately compare and combine the data from both sources.

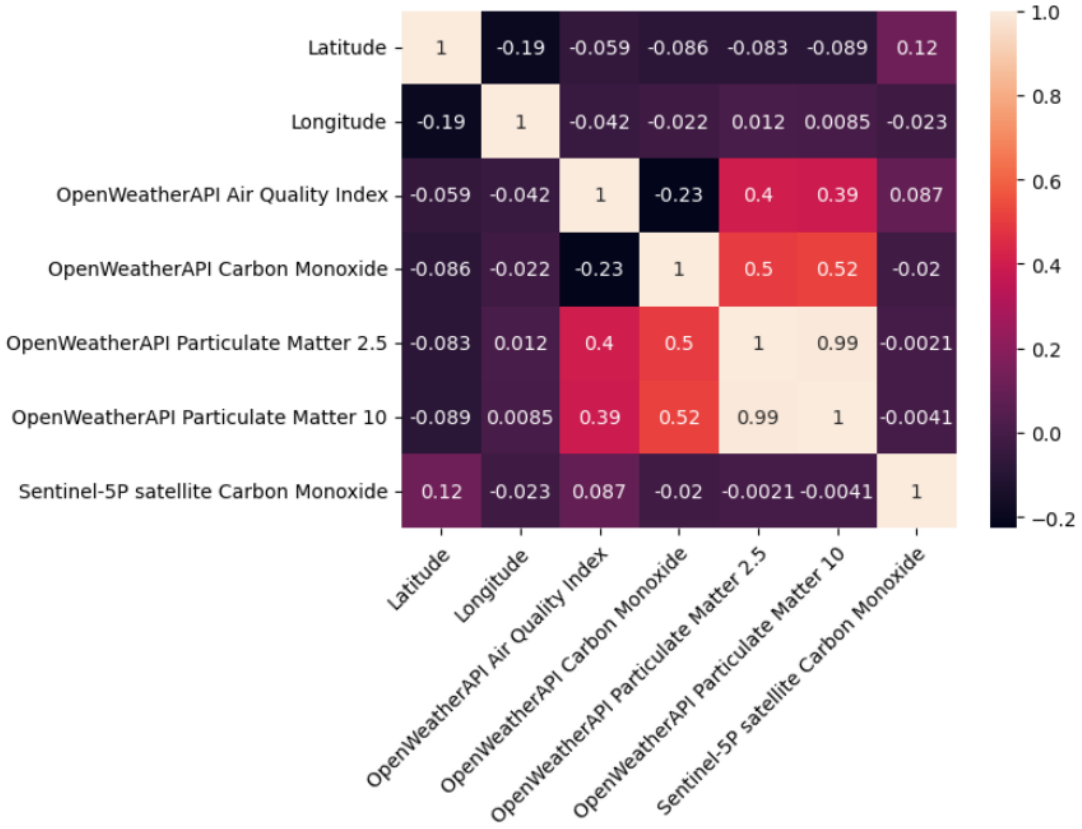


Figure 1 *Correlation matrix.*

This combined approach allows for a detailed analysis of air quality by providing a multi-dimensional perspective. The satellite data offers broad coverage and high-altitude measurements, while the Weather API data provides precise, ground-level observations. Together, they create a comprehensive dataset that enhances the accuracy and depth of our analysis.

In the following sections of this study, specific abbreviations will be used to differentiate between the sources of data for carbon monoxide (CO) measurements. Understanding these abbreviations is essential for interpreting the results accurately.

- Weather CO: This abbreviation refers to the carbon monoxide data recorded by the OpenWeatherMap Weather API. These measurements are taken at ground level by various weather stations distributed across Poland.
- Satellite CO: This abbreviation indicates that the carbon monoxide data were obtained from the Sentinel-5P satellite. The measurements provided by Sentinel-5P are collected from the atmosphere at a higher altitude and offer a broad spatial coverage.

The provided correlation matrix (Figure 1) displays the relationships between various environmental variables. Latitude shows a weak negative correlation with longitude (-0.188788), AQI (-0.059035), Weather CO (-0.086040), PM2.5 (-0.083310), and PM10 (-0.088942). It has a weak positive correlation with Satellite CO (0.123106).

Longitude has a very weak negative correlation with AQI (-0.041640), Weather CO (-0.021636), and Satellite CO (-0.023325). It has a very weak positive correlation with PM2.5 (0.011748) and PM10 (0.008463). AQI exhibits a moderate negative correlation with Weather CO (-0.226235). It has a moderate positive correlation with PM2.5 (0.404642) and PM10 (0.388478). There is a very weak positive correlation between AQI and Satellite CO (0.087329). Weather CO shows a moderate positive correlation with PM2.5 (0.498754) and PM10 (0.517268). It has a very weak negative correlation with Satellite CO (-0.019941). PM2.5 has a very strong positive correlation with PM10 (0.993529). There is a very weak negative correlation between PM2.5 and Satellite CO (-0.002102). PM10 shows a very weak negative correlation with Satellite CO (-0.004113). Satellite CO has very weak correlations with all other variables, indicating it is not strongly related to any of the measured weather parameters. The strongest positive correlation is between PM2.5 and PM10 (0.993529), suggesting that these two air pollution indicators are very strongly related to each other. Other variables generally have weak correlations with each other, indicating no clear relationships among them.

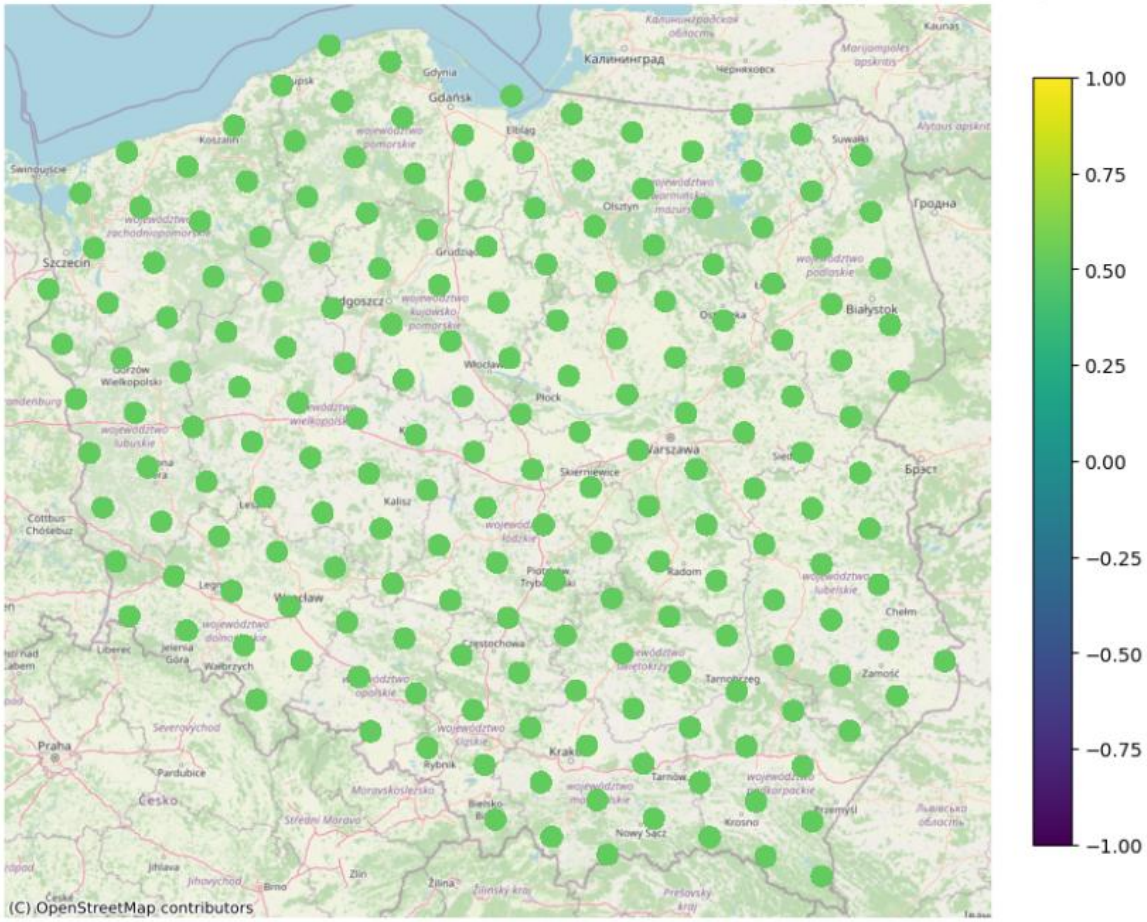


Figure 2 *Correlation Visualization of Carbon Monoxide and Particulate Matter 10 (both OpenWeatherAPI).*

The analysis of the correlation matrix reveals significant relationships between Carbon Monoxide (OpenWeatherAPI CO) and particulate matter (PM10 and PM2.5) as shown in Figure 2. The correlation between OpenWeatherAPI CO and PM10 is 0.517268, indicating a moderate positive correlation. This suggests that higher levels of carbon monoxide in the weather data are associated with higher levels of PM10. When carbon monoxide concentrations increase, PM10 levels also tend to increase, indicating that areas with higher carbon monoxide pollution are likely to also have higher concentrations of coarse particulate matter. Similarly, the correlation between OpenWeatherAPI CO and PM2.5 is 0.498754, also indicating a moderate positive correlation. This implies that higher levels of carbon monoxide are associated with higher levels of PM2.5, suggesting that fine particulate matter levels are also influenced by carbon monoxide pollution, although the correlation is slightly weaker compared to PM10.

These positive correlations highlight that areas experiencing higher carbon monoxide levels, possibly due to vehicular emissions, industrial activities, or other sources, are likely to also have higher particulate matter pollution. Monitoring and controlling carbon monoxide levels could potentially help in managing particulate matter pollution, as these pollutants often coexist and have common sources. Overall, the correlations between OpenWeatherAPI CO and particulate matter underscore the importance of comprehensive air quality management strategies that address multiple pollutants simultaneously.

3. Conclusion

The correlation analysis between various environmental variables revealed significant relationships between carbon monoxide and particulate matter PM10 and PM2.5. The correlation between OpenWeatherMap data for CO and PM10 is 0.517268, indicating a moderate positive correlation. This means that higher levels of carbon monoxide in meteorological data are associated with higher levels of PM10. Similarly, the correlation between CO and PM2.5 is 0.498754, also indicating a moderate positive correlation. This suggests that higher levels of carbon monoxide are associated with higher levels of PM2.5, although the correlation is slightly weaker compared to PM10.

These positive correlations indicate that areas with higher levels of carbon monoxide, likely due to vehicular emissions and industrial activities, also have higher concentrations of particulate matter. Monitoring and controlling carbon monoxide levels can potentially help in managing particulate matter pollution, as these pollutants often coexist and have common sources. These correlations highlight the importance of comprehensive air quality management strategies that address multiple pollutants simultaneously.

Satellite technology, combined with meteorological data, is a powerful tool for monitoring and analyzing air pollution. High-resolution data from the Sentinel-5P satellite, supplemented with precise ground-based measurements from OpenWeatherMap, enable detailed spatial and temporal analyses of air pollution. Correlations between carbon monoxide and particulate matter PM10 and PM2.5 indicate common sources of these pollutants, suggesting that air quality management strategies should consider controlling various pollutants simultaneously.

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RUF Guitars - innovative, carbon composite electric guitar design and production for enhanced ergonomics

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Abstract: *The aim of the project is to develop an innovative line of electric guitars "RUF Guitars" made of composites. The guitars will be characterized by unprecedented ergonomy, weight and will contain a number of improvements not offered by the competition. Key innovations included: ultra-thin griffin (less than 15mm), significantly reduced weight (less than 1,5kg), protection of the griffin with nano-silver particles reducing sweating of the hand, increased stiffness of the griffin and resistance to temperature and humidity changes and innovative design solutions.*
KEYWORDS*: COMPOSITE GUITAR, GUITAR QUALITY CONTROL, GUITAR PRODUCTION MANAGEMENT, AI IN GUITARS, GUITAR MEASUREMENT, NON-CONTACT GUITAR MEASUREMENT METHODS, GUITAR PRODUCTION OPTIMISATION*

1. Introduction

Wooden guitars are prone to damage and tone inconsistencies [1]. To neutralise the negative side effects of using wood RUF Guitars created an instrument purely out of composite materials. Composites show great promise in replacing wood, as they are lightweight, much stronger and significantly less sensitive to environmental changes [2]. The combination of infused carbon fibre and original Ruffaine composite allowed for sturdy body construction. It made the guitar more resilient to impact forces and weather conditions, resulting in a substantially more stable instrument at no weight premium.

2. Methods

2.1 Climate Test

The tuning stability test was the most significant one in the context of musical instruments. All three test guitars were carefully set up and tuned with an accuracy of about 1 cent. After measuring their initial temperatures and air humidity levels, the guitars underwent a climate test. They were kept in a cooler until their temperature didn't lower at least 10°C. Air in the cooler was roughly 30% less humid, putting additional strain on the examined instruments. After about 15 minutes, the guitars were checked with a tuner and left to revert to room temperature. We conducted the test 10 times, re-tuning all guitars before each test run. The average measured note difference equaled 5%, exactly 20% lower than the target difference value.

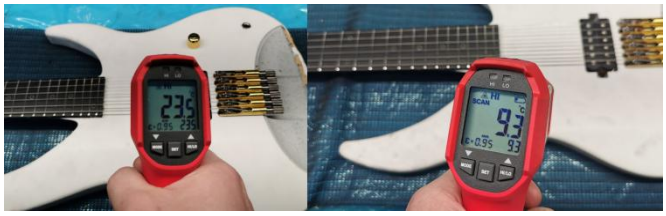


Fig. 1. *Guitar's temperature difference during the climate test*

2.2 Durability Test

The most notable technical improvement we have achieved is the slim neck width and improved durability around the headstock area. This region is infamous for being susceptible to damage. Despite technical challenges, we have brought the neck width below 15 millimetres, measured at 1st fret. The composite material still enables it to withstand over 1200N (almost 120kg) of force with less than 0,01mm/N neck flex, even at that minuscule thickness. It's far more than any wooden guitar could ever withstand.

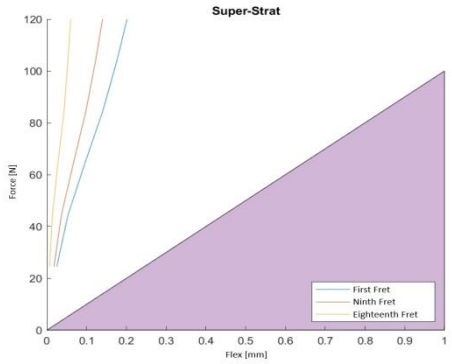


Fig. 2. *Guitar neck flex measurement*

2.3 Weight Reduction

The lightweight characteristics of carbon fibre allow for making some of the lightest instruments in the world. After infusion, the guitar's shell is rigid enough for typical use. Despite the reduced weight, it is as stable as other instruments filled out with Ruffaine. We have produced three prototype models, all coming under 1,5 kilograms. The lightest, a 6-string single-cut type guitar, measured 1,23 kilograms. Such weight savings are beneficial to artists as heavy instruments are less and less desirable on the market.



Fig. 3. *Weight measurement of a 6-string single-cut type guitar*

2.4 Antibacterial Carbon Layer

By adding colloidal silver to the carbon fibre, we created a surface more resilient to bacteria found in human sweat. We have settled for the concentration of 400PPM (particles per million) since concentrations of 200-250PPM already allow for germicidal effect. This silver admixture lowered the bacteria activity by 83% on average.

3. Results

All designated milestones have been achieved. Every prototype came in under the weight threshold of 1,5 kilograms, at 1.23kg, 1.35kg and 1.44kg respectively. Their neck thickness was maintained below 15 millimeters at the 1st fret. Measured values for all prototypes came in at 14.84mm, 14.39mm and 14.96mm. All guitars achieved less than 0.01mm/N neck flex with values ranging from 0.0019mm/N to 0.0085mm/N. Every prototype also managed to surpass the tuning stability expectations. The average note deviation equaled 5% of a semitone, which is 20% better than the 6,25% target value.

4. References

[1] Rollins, Ryn. "Composite Guitar." *ScholarWorks@CWU*, 10 June 2020, digitalcommons.cwu.edu/undergradproj/141. Accessed 12 Aug. 2024.
[2] Roest, Max. "Design of a Composite Guitar." *TU Delft*, 24 Aug. 2016, repository.tudelft.nl/record/uuid:919fdb70-55a1-4be9-8795-fb7ef87d3382. Accessed 12 Aug. 2024.