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Properties of innovation management and innovative solutions portfolio planning

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Abstract: Innovation management is the process of making decisions in an ever-changing environment, constantly studying innovative programmes and reviewing them both in general and in parts. An innovation leader recognizes that his or her activities are surrounded by uncertainties, both internal and external. He is never immune to the emergence of unforeseen technical problems, the need to reallocate resources, new assessments of market opportunities. The system for planning and managing innovative technology in management must be sufficiently flexible. The most comprehensive and flexible innovation management systems are primarily focused on the development of prospective products as well as the transformation of innovation management functions.

Keywords: INNOVATION MANAGEMENT, PLANNING, FLEXIBLE INNOVATION MANAGEMENT, COMPANY'S ACTIVITIES

1. Introduction

Innovation management is the process of making decisions in an ever-changing environment, constantly studying innovative programmes and reviewing them both in general and in parts. An innovation leader recognizes that his or her activities are surrounded by uncertainties, both internal and external. He is never immune to the emergence of unforeseen technical problems, the need to reallocate resources, new assessments of market opportunities. The system for planning and managing innovative technology in management must be sufficiently flexible.

In the context of innovation management, a project must start with a clearly defined objective, which, like the end result, depends on the needs of the market [1, 3]. First and foremost, it is the relevant segment and its characteristics, represented by size, acceptable price, technical efficiency requirements and product take-up time. Products should be defined by their efficiency, price and date of appearance. These characteristics are interrelated and therefore some iterative process is needed to refine the purpose.

With particular care it is necessary to consider what technical level of product is required for the particular market segment likely. Too many parameters can increase research and development (R&D) and production costs as well as development time and thus reduce profitability.

The initial definition of a project should focus on the market need and its satisfaction, not on decisions about the type of final product. The definition of the project should be short, not limiting the freedom of employees to find new solutions. At the same time, formulate clear objectives, standards for technical, cost criteria and development time. The innovation portfolio can be filled with a variety of projects: from large to small, near completion and in the early stages of development.

Limited resources will need to be allocated to each project. Some projects will be terminated during implementation, their components will vary in number and resource requirements, etc. As a consequence, the process of drawing up plans and modifying R&D plans is continuous. The number of projects included in the portfolio is determined by two factors: the size of the projects and the total R&D budget. The structure of the portfolio is determined by its manageability by management and the corporate R&D policy.

As the number of projects increases, the likelihood of at least some of them being completed effectively increases. Moreover, it is easier to 'pair' small projects with each other in the R&D process using available private resources (e.g. pilot production facilities). However, small projects usually have a moderate profit potential, resulting in products with limited market prospects. This is hardly equivalent to a company's marketing policy.

The ultimate success of any project is as much determined by technical and market strengths as it is by the quality of project management. Good governance is a critical resource for most companies and should not be scattered across many projects. Indeed, these are most often divided into phases, and the art of management lies in staggering their launches over time to ensure the effectiveness of the entire portfolio.

Innovation Portfolio Management (IPM) is an amalgamation of activities that facilitate every company to select, build, and market a

new flow of initiatives. The kind of flow that fuels business's short term and long-term goals. Innovation portfolio management is a tool to transform strategic objectives into innovation activities that are project-based. On the basis of risk profile, an innovation portfolio gives a framework to convert roughly produced ideas into real investment opportunities [7, 8].

Moreover, the innovation portfolio is a time management tool too. It helps in assessing the time required to complete to start a new initiative [2, 8]. Also, it can be used to reflect on potential opportunities that can be judiciously used as leverage in technologies, markets, and products or services. Portfolio management is also the perfect way to manage the success of innovation. The success of innovation is most of the time measured by dividing the total number of successfully implemented innovation projects BY the total amount of started projects. The main goal of portfolio management is to measure and optimize the performance of innovation projects [7].

2. Managing innovation in personnel management

Qualified staff is a major resource for any company or organisation. The constant search for innovations that will enable qualified assessment of the effectiveness of activities and personnel management is the basis for successful business development.

A personnel management system is created at the moment when any company starts to operate, if it plans to become successful and has the necessary qualities that are inherent in any innovation. Personnel management is an administrative function within an organization that oversees the hiring, organization and support of employee positions. A branch of human resources, personnel management focuses on recruiting the right individuals to fit a position and supporting those already working for the company. This area also functions as a tool for evaluating the hiring process and gaining insight into employee satisfaction. Personnel management professionals work to provide the resources and tools staff members need to thrive in their work environment every day [7, 8]. Types of personnel management:

- Strategic.
- Tactical.
- Operational.

Personnel management can be broken down into several elements as listed below:

1. Job analysis: This function of personnel management determines how a position fits into the overall company framework. It's a measure of the role and not the employee.
2. Strategic personnel planning: Also called strategic workforce planning, this element involves hiring the most qualified individual to fit a necessary role in an organization. It ensures that hiring processes are consistent, fair and effective.
3. Performance appraisals: Identifying how employees are evaluated is the function of this element of personnel management. Using this element, professionals in personnel management decide how often employees are

assessed and the methods used to rate employee performance.

4. Benefit coordination: Determining the type of benefits employees receive and planning for their distribution is an essential part of personnel management. This element also involves choosing plans such as personal health care benefits.
5. Continuing education: To keep staff involved in growing their career and investing in their workplace, personnel management oversees employee development through continuing education. This may include offering seminars, learning lunches or arranging for staff to attend professional conferences.
6. Pay and salary distribution: Another part of the operational activities of personnel management staff is to ensure employee payroll functions correctly. It may also involve setting pay scales or job levels.
7. Attendance and leave: Managing personnel also means overseeing time off for sick and personal days. This function also involves leaves of absence or short-term disability.

The emergence and development of a system goes through all phases of the innovation process, which corresponds to key economic laws. All transformations are aimed at increasing the efficiency of employees and thus the success of the company as a whole.

A study of the HRM system itself as an innovation should be conducted with a focus on these criteria [1, 4]:

1. Personnel development and career management: curricula are designed in conditions of mismatch between qualification requirements and actual competencies of employees, therefore individualization of the learning process is necessary in order to obtain the most effective result at the minimum cost.
2. Building an incentive system: traditional incentive factor- It is the employee's salary which is determined by the value of a particular job. In addition to this, a rewards system is also prevalent, which involves a variable wage component that is determined by each employee's monthly contribution to the work of the department and the organization as a whole.
3. Shaping corporate culture: if every employee is aware of the core values and mission of the company, it has a positive impact on the effectiveness of his work and the process of transferring these values is the corporate culture.
4. Developing a competency model: This innovation is intended to regulate the multifunctionality of a multitude of workplaces and competently build a technological chain that avoids conflicts and focuses on quality and efficiency of work.
5. Computer technology in management: software products not only allow to keep records of personnel according to various parameters, but also to generate the necessary reporting documents, which can be easily transferred in electronic form.

At the heart of innovative approaches to personnel management is the consideration of the characteristics of human resources:

- Humans are intelligent beings who respond to external influences emotionally and meaningfully rather than automatically, so the interaction between the organisation and the employee is reciprocal.
- People strive for continuous improvement and development, thus improving the quality of each enterprise.
- On average, a person's work activity lasts from 30 to 50 years, which means that the relationship between

employees and the company can be characterized as long-term.

- People choose their work intelligently, they are guided by certain goals and in return they expect their ideas to be realised. The further course of cooperation depends on how satisfied the employee is with the interaction with the organization and vice versa.

Innovation or innovation is the result of creative activity aimed at the development, creation, distribution and profitable use of new types of competitive products, modern technologies, the introduction of new organizational forms and management methods. Innovation is characterised by the efficiency of investment in the development of the economy, providing cost savings or creating the conditions for such savings.

The role of innovation continues to grow. In most industrialised countries, the number of people involved in scientific development, research and experimental processes doubles approximately every ten years. A decisive factor in scientific and technological progress is the high rate of technical renewal of production, the introduction of high-efficiency products and technologies. The most important feature of innovation is therefore the novelty of consumer characteristics, with technical novelty playing a secondary role.

The methodology for systematically describing innovation in a market economy is based on international standards. A group of national experts on science and technology indicators has been set up to coordinate the collection, processing and analysis of information on science and innovation within the Organisation for Economic Co-operation and Development (OECD). Innovation management is a system for managing innovation, the innovation process and the economic relationships that arise from this management.

Innovation management is based on the following basic points: the purposeful search for an idea that serves as the basis of this innovation; the organization of the innovation process to create this innovation; this involves carrying out an organizational and technical complex of work to turn the idea into an innovation; the process of promoting and introducing the innovation to the market, which requires a creative approach and active action of salespeople. The foresight function in innovation management covers the long-term development of changes in the technical, technological and economic state of the management object as a whole and its individual parts. The result of forecasting is a prognosis, i.e. an assumption about the possible direction of the respective changes. The hallmark of innovation forecasting is the alternative nature of the technical and economic indicators included in the process of innovation creation. Alternativeness implies the need to choose one solution among mutually exclusive options.

3. The use of innovation management in the company's activities

The need for innovative enterprise development places new demands on the organisation, content and methods of management activities. The organisation of innovation management in an enterprise is a system of measures aimed at rational integration of all its elements into one innovation management process. The innovation management organisation combines the above elements of the innovation management process into a single system.

Table 1. The process of innovation management organisation in the enterprise

Stage 1	Defining the goal of innovation management.
Stage 2	Choosing an innovation management strategy.
Stage 3	Definition of innovation management techniques.

Stage 4	Developing an innovation management programme.
Stage 5	Organisation of work on the implementation of the programme.
Stage 6	Control over the implementation of the planned programme.
Stage 7	Analysis and evaluation of the effectiveness of innovation management techniques.

The organisation of innovation management is already laid in the creation and implementation of the innovation, i.e. in the innovation process itself. The innovation process serves as the basis of the force on which the effectiveness of the use of innovation management techniques will depend. The important stages in the organization of innovation management are the development of an innovation management program and the organization of the work to carry out the planned work. An innovation management programme is a set of measures agreed in terms of timing, outcomes and financial support to achieve a set objective.

An integral part of innovation management is the organisation of work on the implementation of the planned action programme, i.e. the determination of certain types of activities, the volume and sources of funding for this work, specific implementers, deadlines, etc.

Innovative economy is the economy of a society based on knowledge, innovation, on benevolent perception of new ideas, new machines, systems and technologies, on readiness for their practical implementation in various spheres of human activity. In the innovation economy, under the influence of scientific and technological knowledge, the traditional spheres of material production are transformed and radically change their technological base, because production that does not rely on new knowledge and innovation proves unviable in the innovation economy. The most significant features of the innovation economy include [52]:

- Any individual, group of persons, enterprise anywhere in the country and at any time can obtain any necessary information about new or known knowledge, innovations on the basis of automated access and telecommunication systems.
- Modern information technology and computer systems are produced, shaped and made available to every individual, group of persons and organizations, thus ensuring the implementation of the previous paragraph.
- Infrastructures are in place to ensure the creation of national information resources in the quantities needed to support the ever-accelerating pace of scientific and technological progress and innovative development;
- A process of accelerated automation and computerisation of all spheres and sectors of production and management is underway; radical changes in social structures are taking place, resulting in the expansion and activation of innovative activity in various fields of human activity.

Given that innovations are currently a necessary factor for increasing the competitiveness of a company, it is necessary to focus on measuring and evaluating their performance. Measuring innovation performance covers a wide range of entities, from simple innovation projects to the entire economy. Different existing levels and categories of innovation activities to be measured must be defined and partially extended to all significant levels of performance measurement.

4. Conclusion

Each proposal for an innovation plan should be based on a selected variant of a comprehensive business strategy, respecting the strategy of cost-effectiveness, based on scientific, technical and economic information. Innovation is crucial to a company's business strategy. They make it possible to win new markets and market segments, to reduce production costs, which creates the prerequisite for lowering prices and increasing market share.

Innovations in the company are largely based on developmental changes in production and on the market, they lead to the expansion of the production process. The term innovation can be understood as the introduction of "something new" into the current activities of the company. These are new knowledge, technologies, products, but also their various improvements and combinations.

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The Role of Consumer Feedback in Driving Innovation

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Abstract: This article focuses on the important role that consumer feedback plays in fostering innovation in business. It discusses the importance of listening to and understanding consumer views and preferences when developing new products and services. The article clearly analyses ways to effectively gather and interpret consumer feedback to improve the innovation process and ensure the success of new initiatives. It also discusses the challenges that can arise in processing and interpreting feedback. The article also highlights the benefits of actively involving consumers in the innovation process, including creating loyal customers, satisfied customers, improving competitiveness and minimizing the risk associated with new product launches. Based on a review of recent research and case studies, this article offers insights and guidance for entrepreneurs and managers seeking to effectively integrate consumer feedback into their innovation processes.

Keywords: CO-DEVELOPMENT, CONSUMER FEEDBACK, CUSTOMER, INNOVATION, MANAGEMENT

1. Introduction

The concept of feedback is found in various areas of human life, but its essence remains the same in every sphere – it provides the system with important information. Feedback serves as a pivotal instrument within behavioral data analysis, offering elucidation not merely on operational occurrences within a business framework, but also on the underlying rationales thereof. Without feedback, we would perceive business processes only subjectively, which could lead to erroneous and inaccurate decisions [1, 2]. Furthermore, it can be delineated as a form of customer communication specifically pertaining to a particular product or service offering. In the realm of traditional marketing, customers were often seen as passive consumers, merely purchasing and using products. Yet, a contemporary viewpoint has emerged, positing customers as active participants, contributing to the creation, development, and production of the products they wish to purchase and use. Innovation has evolved into a cyclical process involving interaction between customers and producers [3].

2. Consumer feedback and its processing

Manufacturers are increasingly leveraging customer feedback as a strategic tool to distinguish themselves within competitive markets while concurrently aligning with industry benchmarks. Following the introduction of novel product offerings, corporations' endeavor to actively engage their consumer base, incentivizing them to furnish invaluable perspectives, critiques, and suggestions for enhancements [4]. The notion of feedback is inherently intertwined with the construct of customer satisfaction. Milner and Furnham [5] elucidate customer satisfaction as the degree to which products and services align with the unique expectations of individual clientele, thereby underscoring the symbiotic relationship between feedback mechanisms and the attainment of consumer contentment. Consumer feedback provides information about how we are performing - whether we are meeting customer expectations or, conversely, not even meeting basic standards. Drawing upon a comprehensive review of extant literature, various methodologies have emerged for soliciting essential insights from customers. These methodologies include:

a. Questionnaire surveys

Questionnaire surveys are one of the most common methods of obtaining feedback. It is important to design the questionnaire correctly and to create questions that will offer us the best possible picture of our customers' opinions. If the questions have been asked appropriately and the sample of customers has answered truthfully, we will get an objective view of the product. Contemporary business practices tend to favor online surveys over traditional modes such as telephone or face-to-face interviews, reflecting the evolving landscape of consumer engagement in the digital era. This is mainly due to the lower cost or the independent time management of the respondent's answer. Nevertheless, incomplete questionnaire responses or ambiguous replies to open-ended queries may pose

challenges, potentially undermining the efficacy of the feedback mechanism [2, 6].

b. In-depth interviews

In-depth interviews are inductive in nature and arise from individual processes. Their goal is to define a category based on the data obtained and then analyze the relationships between the created categories. We use it if we want to find out from the customer his more detailed opinion on the given product, either independently or in connection with questionnaire surveys. It is important to properly manage the interviews and ask questions relevant to the characteristics of the respondent and their proper adaptation [2, 7].

c. Group discussions

Group discussions represent a prevalent qualitative research approach due to their cost-effectiveness and provide valuable insight into the opinion of the target group. Typically facilitated by the sponsoring company, these sessions convene a cohort of approximately eight to ten participants, comprising both internal personnel and external experts, for in-depth deliberations on the company's offerings. Such discussions extend over several hours, affording ample opportunity for comprehensive exploration of pertinent product and service-related matters. According to Isson and Harriott [2], the advantage of these sessions is the possibility of direct communication between the company and the target group. On the other hand, it is necessary to be careful with group discussions, because they do not always go in the desired direction, or a small sample that does not provide sufficient objectivity can also be portrayed as a disadvantage [7].

d. First-line feedback from employees

Employees are one of the main sources of information. Not only do they obtain information about customers, where they find out what they liked or disliked, but on the other hand they also act as a subject who can independently spot possible necessary changes in certain processes or products. They can either improve individual organizational processes and innovate products and services themselves, or they can pass on useful and valuable information to competent places. In this case, it is very important to reserve space and allow the right way for employees to express themselves, as it is the lack of an open corporate policy within the company that can act as a problem [8].

e. Direct interaction with the customer

It is directly related to the previously mentioned method and thus can be a valuable source of information. It furnishes invaluable perspectives on organizational strengths and weaknesses, encapsulating both commendations and grievances. However, the views collected need to be recorded and categorized, and consumer attitudes need to be analyzed on a regular basis. Without regular analysis, it loses its meaning [2].

f. Social media

With the invention of the internet, the digitization of information has made it easier to collect data. It has enabled the capture of word of mouth and more open communication about products, not least because of its potential anonymity. Moreover, this way of gathering information is not only affordable but also systematic and represents access to a large number of customers. However, the disadvantage of feedback via social media is the public sharing of individual opinions, which can be seen by the general public and that can be an influence factor. It is also important to properly separate relevant opinions from irrelevant or false or misleading ones. Moreover, this method can be time-consuming, given the quantity of users on social networks, and in many cases thorough selection is necessary [9].

3. Integrating consumer feedback into innovation processes

Utilizing consumer feedback is paramount in comprehending customer needs and preferences. Proactively soliciting and attentively heeding customer input empowers businesses to glean invaluable insights, which in turn can steer and refine their product innovation endeavors. Through consumer feedback, companies can pinpoint deficiencies in their offerings, grasp customer pain points, and unearth novel ways for enhancement.

Involvement of consumers can be delineated into two primary categories: consumer involvement as a source of information and consumer involvement as a co-developer. In contrast to the conventional approach of including consumers solely as information providers in new product development, engaging them as co-developers offers manifold advantages but also poses substantial challenges. Companies engage consumers in new product development to address their needs effectively and facilitate market entry. Consumer involvement in co-development facilitates the integration of fresh concepts, knowledge, and insights into their requirements. The exchange of information between consumers and companies represents a fundamental aspect of co-development [10, 11].

The consumer serves as a valuable resource, supplying information crucial for generating product development ideas. This role can manifest in several forms, including validating designs, prioritizing product features, and specifying product requirements. It is important to state that the development team need to work in alliance with marketing, technical and manufacturing expert in the company throughout the development process [11].

One frequently cited benefit is the enhancement of product quality, as consumer involvement tends to exert a positive influence on product refinement. Involving consumers in the process of developing new products fosters greater innovativeness. Nevertheless, certain studies have identified impediments that hinder companies from fully leveraging consumer engagement in new product development; these include the risk of information overload and the intricacies associated with managing new product initiatives [12, 13].

Co-development is also very neatly tied with consumer satisfaction. Findings show, that engaging in co-development enables the company to create a novel product tailored to meet the customer's requirements, consequently enhancing their satisfaction levels. As a result, customer satisfaction emerges as an outcome of this collaborative process [14]. Vazquez [15] elucidated that active consumer participation in the value creation process significantly enhances consumer satisfaction, potentially reducing time to market for products. This dynamic confers a competitive edge upon companies and augments product performance. Furthermore, in co-development, additional value or features are integrated into the product [16, 17].

Based on theoretical insights and empirical evidence, we claim that consumer involvement in new product development creates mutual benefits for both consumers and companies. From the company's standpoint, consumer engagement in the development process facilitates deeper understanding of customer preferences

and market dynamics, leading to the creation of products aligned with customer needs and expectations. Research indicates that consumer involvement accelerates the company's new product development process and mitigates the risk of product failure, consequently enhancing marketing effectiveness [15, 18].

Consumer involvement in the development process also serves as a potent marketing strategy. Engaged consumers can narrate the product's development journey to new or potential customers, effectively promoting the product and expanding its market reach. This word-of-mouth marketing can significantly influence purchase decisions and enhance overall sales performance [18].

Undoubtedly, consumer co-development presents its share of challenges, notably in the realm of integrating customer-provided information seamlessly into the development process, which can introduce complexity. From a theoretical view point, the abundance of consumer data heightens the complexity of information processing, potentially fostering miscommunication that could influence the use of consumer information [11, 19].

In table 1 we summarize the positive and negative features of using consumer co-development for innovation management, to which we have referred in this chapter.

Table 1. Positive and negative features of using consumer co-development for driving and managing innovation.

Positive features	Negative features
Influence in product quality	Information overload
Customer satisfaction	Difficulty of information processing
Reduction of the product time to market	
Increase of product performance	
Minimalization of sale and service cost	
Increase in buyer retention	
Speed up product development process	
Reduction of the risk of product failure	
Word-of-mouth marketing	

4. Implementation of consumer co-development

Theoretical insights suggest that effective new product development hinges on adept leadership, relationship management, and communication. Cultivating strong consumer relationships necessitates skillful navigation of these elements, it is very important to know how to manage the relationship through leadership and communication [20].

Trust is another very important factor or element for a successful relationship in a consumer involvement. Based on empirical findings, trust emerges through transparent discussions regarding product development, sharing comprehensive development insights, and granting customers access to the company. Trust is further fostered by the exchange of knowledge and technical expertise within development teams. In an environment characterized by openness and honesty from both company and consumer, mutual comfort is established, enabling the free exchange of viewpoints and collaborative refinement of concepts. Research indicates that trust is essential for successful consumer relationship management, and in some cases, can be cultivated through formal contracting. Consequently, trust assumes paramount importance in fostering positive consumer relationships throughout the co-development process [20, 21]. Establishing trust is instrumental in cultivating customer loyalty. Aligning with these

insights, integrating consumer relationships into the new product development framework enables companies to mitigate sales and service costs, thereby enhancing buyer retention [22].

Communication is another point that we consider as a key factor used within a co-development. Communication is a major driver during the product development process. Communicating a new concept is a major starting point for customer involvement in new product development. There is efficacy of communication through visual aids, examples, and best practices, illustrating the potential inherent in novel ideas, technologies, and products. Communication between the consumer and the company must be two ways. Effective management of the development process necessitates the establishment of an interactive dialogue among development teams, comprising both company and consumer representatives. This interactive dialogue facilitates improved communication and proper sharing of information between the teams [23, 24].

Effective communication plays a pivotal role in strengthening the bond between a company and its consumers. Conversely, miscommunication represents a potential drawback that can undermine this relationship, resulting in negative implications for both parties involved. To avoid misunderstandings during the development phase, it's advisable to clearly delineate specific details, such as the anticipated outcome of the product development, to the consumer. We advocate for utmost transparency from the company throughout the development journey, aiming to mitigate information imbalances as highlighted by Von Hippel [26].

We found, that transparency is another important concept worth considering. In simple expression, transparency means being open and honest about the development process. Establishing trust and fostering commitment from consumers are, again, integral aspects of the new product development process, as underscored by both theoretical frameworks and qualitative data. However, intentional lack of transparency by the company, aimed at safeguarding certain information, can potentially lead to project failure. Consumers inherently appreciate being valued by companies, and failure to convey this sentiment can detrimentally impact the development outcome, potentially signaling to consumers that their input is not taken seriously [25].

In Fig. 1 we graphically represent the elements that create the successful relationship and alliance between consumer and the company in driving innovation, that we have presented in this chapter.

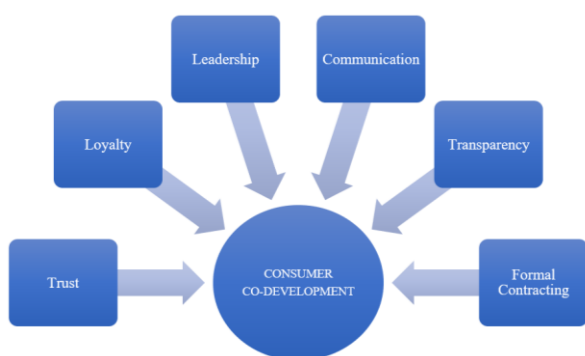


Fig. 1 Elements creating alliance in driving innovation between company and consumer.

5. Conclusion

Through a comprehensive examination of literature and empirical data, we have shown the significant influence of consumer involvement on the new product development process. Consumer involvement in new product development entails a collaborative partnership between the company and the consumer, aimed at jointly resolving challenges to generate innovative product solutions.

Based on both theoretical frameworks and empirical evidence, involving consumers in the new product development process creates superior value compared to traditional approaches. This customer-centric approach is increasingly adopted across various

industries, fostering creativity and generating impactful ideas that enhance product value. Moreover, consumer involvement fosters satisfaction by ensuring products are purposefully designed to meet customer needs. Ultimately, this collaborative process cultivates sustainable customer relationships by attentively addressing customer requirements and preferences.

Addressing customer needs and ensuring customer satisfaction are crucial for a company's long-term viability. Economically, involving consumers in product development lowers development costs while simultaneously enhancing customer satisfaction. This approach accelerates time-to-market and reduces the risk of product failure. From an economic sustainability perspective, collaborative product development proves more profitable than solitary development endeavors.

Customer relationships and satisfaction are paramount considerations in the co-development process, particularly given its inherent uncertainties. It is imperative for managers to clearly clarify the co-development plan—including roles, duration, and expectations—to involved consumers prior to start of co-development process. Additionally, fostering regular communication and providing feedback strengthens the manager-customer relationship and keeps customers informed. Ensuring that customers possess a robust level of trust and commitment is essential for successful project execution. Co-development necessitates diverse expertise to identify potential needs and glean insights from consumer experiences, behaviors, and preferences. Consequently, managers should assemble multidisciplinary teams encompassing backgrounds in engineering, marketing, finance, behavioral science, among others.

By obtaining feedback from consumers, we are able to build a comprehensive picture of the products and services we offer. But the important step is to process this feedback, i.e. to make the economic decisions of the business important enough and bring about the improvements and innovations that consumers demand. Theoretical and empirical evidence underscores the necessity for openness and flexibility in the new product development process, facilitating mutual understanding between company and consumer teams. Effective integration and implementation of novel insights are imperative for refining the overall product solution.

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Waste reduction - a factor for intelligent and sustainable growth and higher competitiveness

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Abstract: This publication analyses the process of transforming the online economy into a circular one. The focus of the analysis is on the progress of the European Union member states in reducing waste. Member States' progress towards a circular economy is slow. The circular business model should not be seen as wishful thinking, because it will be crucial for companies in the future. The circular economy is at the heart of the European Green Deal and plays a key role in decarbonisation and achieving climate neutrality by 2050 and in the fight against pollution. Circular economy means smarter use of resources. The circular economy is built using sustainable economic models based on innovation and technology to allow the repeated use of the same resources. Achieving a zero carbon footprint on the natural environment by 2050. is the top priority. This would only be possible if the world moves towards a circular economy, and this is one of the highlights of the Green Deal, while also aiming to increase the competitiveness of the economy.

Keywords: CIRCULAR ECONOMY, RESOURCES, WASTE, RECYCLING, SUSTAINABLE DEVELOPMENT

1. Introduction

The linear economy will inevitably be displaced by the alternative circular economy. A linear economy is a model of producing products from various resources that are used and then discarded. In the circular economy, after the end of the useful life of a product, it again becomes a resource for reuse. This is done by repairing it, recycling it, reusing it, etc. Our planet's resources are limited and at some point they will simply run out. This necessitates a rethinking of consumption, and the need to reorient towards a circular economy and build intelligent productions that efficiently use resources is becoming increasingly clear. The linear principle - "take, produce, use, throw away" is no longer applicable.

Accelerated global growth in commodity consumption has led to overexploitation of natural resources. The EU's goal is until 2030. to reduce waste disposal below 10% and to turn it into a resource through high-quality recycling. The goals are to do this with 65% of household waste and 75% of packaging waste. By 2030 this means 65% recycling, 25% recovery and 10% municipal waste disposal. This poses a number of challenges both to the industry and to the state and society.

2. Waste management

The EU generates about 2.5 billion tonnes of waste (about 5 tonnes per capita). The majority of these come from the construction, mining and manufacturing sectors. Household waste represents 9% of the total amount of waste generated. (Fig. 1) Construction waste includes materials scrapped during the demolition or renovation of old buildings, as well as materials scrapped during the construction of new buildings. The wastes generated in the mining and extractive industries are mostly materials treated to provide access to mineral resources, causing irreparable damage to the natural landscape, flora and fauna. In manufacturing, waste is all materials discarded during production processes. Manufacturing waste includes a wide variety of materials. Municipal waste includes both mixed municipal waste and separately collected waste. The other waste category includes materials discarded during waste processing, including during sorting and recycling. 5 tons of waste generated per capita, 4.5 tons are treated.

The main idea behind the circular economy concept is to extend the time for efficient use of products, materials and resources while minimizing waste. By using advanced technologies, they can separate and recover valuable materials from waste streams. This process of moving from a linear to a circular economy requires a high degree of responsibility and commitment both from society as a whole and from each individual. This can only be done by building a new type of public attitude and culture of responsibility towards nature and future generations.

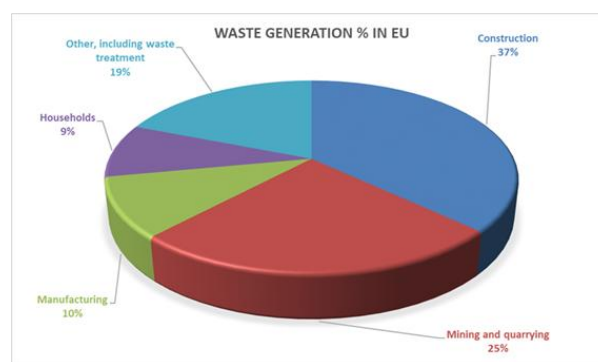


Fig. 1 Distribution of types of waste generated with the EU. Data source: EPRS, Infographics, 2018. Грешка! Источникът на препратката не е намерен.

Recycling turns waste into new resources, and in some cases it also involves generating energy from waste materials. Not all materials can be recycled to the same extent. The degree of recycling of different materials depends on their properties, wear and tear and ability to acquire new properties or regain old ones. [5].

Waste minimization can be done in three main ways: reduce, reuse and recycle. [3] Some standards developed by the International Organization for Standardization (ISO) related to recycling are widely applied in practice, such as ISO 15270:2008 [10] and ISO 14001:2015 [11]. There are also very effective good practices that are gaining more and more popularity in the context of the circular economy.

Materials that are subject to recycling are glass, paper, cardboard, metal, plastic, tires, textiles, batteries and electronics. Food and plant waste are biodegradable waste and can also be recycled through the technology of composting. [2].

The recycling of a material produces a new quantity of the same material. Some types of materials, such as metals, can be recycled many times without losing their purity and properties. [4]. Other materials lose or change properties when they are recycled. Recycling some materials is technologically difficult or too expensive compared to extracting them from natural sources. Such materials can be reused in the production or recycling of other materials. Extracting materials from end-of-life products, either because of their specific value or rarity, is also a form of recycling, such as lead from batteries and gold and silver from printed circuit boards, or because of their hazardous nature, such as the removal and reuse of mercury from thermometers, barometers or other devices containing or working with mercury or other hazardous substances. According to Eurostat data, in the period 2010 - 2022, a smooth but permanent trend towards an increase in the amount of recycled materials is outlined (Fig. 2)

Recycling requires: a source of recyclable waste, a system for collecting, sorting and processing recyclable materials from the waste stream, an enterprise that can treat and recycles them and a demand for recycled products. [2]

An important indicator of recycling efficiency is the energy intensity of the processes. In general, it takes much less energy to produce recycled materials than to produce materials from natural resources. In some cases, however, the cost of recycled materials exceeds the cost of materials produced from raw materials.

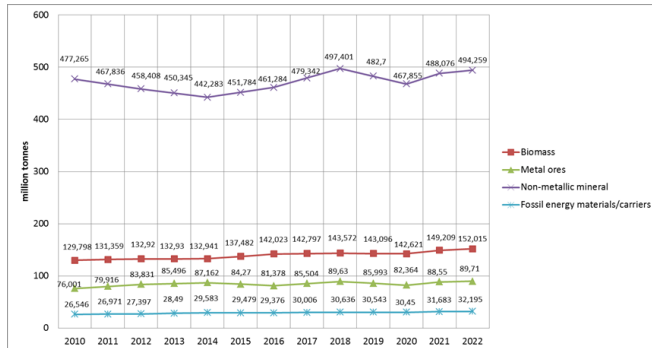


Fig. 2 Materials going through recycling in European Union for the period 2010 ÷ 2022 according to data extracted from Source: Eurostat (env_ac_mfa, env_ac_sd, env_wassd) [7]

In EU, the 'waste hierarchy' is a guiding principle for waste management. It sets a priority order for waste prevention and management options:

- Preventing the generation of waste by reducing packaging or extending the shelf life of products. Prevention is more about product design and consumption than waste management.
- Reuse. This can include repurposing items or using durable goods that have a longer life - for example reusing packaging through deposit schemes or remanufacturing electronics (telephones, decoders).
- Recycling - involves processing used materials into new products, reducing the need for raw materials and reducing the overall impact on the environment - for example, ferrous metals, non-ferrous metals (eg aluminum, copper), glass, paper and cardboard, rubber, plastic, wood and textile waste, whether hazardous or non-hazardous.
- Restore (energy). Combustion of waste in incinerators; in most cases the energy produced is used to generate electricity and/or heat (used for example in industrial processes or central heating systems).
- Disposal: Landfill.
- The polluter pays principle is one of 27 fundamental principles adopted by the Rio Declaration (1992) on which nations base their decisions and policies, taking into account the environmental consequences of socio-economic development. Adherence to this principle obliges polluters to be responsible and bear the costs associated with the environmental pollution they cause, including the costs of the measures taken to prevent, control and remedy the pollution.[9]

These principles aim to promote responsible and sustainable waste management practices and encourage people and businesses to be more mindful of their consumption and disposal habits.

The circular economy opens up opportunities for:

- Socio-economic impact;
- Cost savings for the business;
- Quality jobs;
- Climate impact.

3. Municipal waste management in Europe

Municipal waste covers waste generated from households and other sources. The overall goal is to reduce unsorted, mixed household waste, regardless of origin.

Separate collection is key to sustainable waste management and development towards a circular economy. Success requires four elements: economic incentives, enforcement, customized facilities, and engaging communication.

A zero waste idea is not possible without waste segregation. If waste is separated, it is not waste, but a resource. Waste can be separated at source – ie. the citizen sorts the waste or finally – i.e. a waste company separates the waste after it has been mixed. When the two options are compared, systems with separate collection at source not only significantly outperform mixed collection in terms of both material quality and deviation rate, but also cost less. In separate collection at source, there are ways to optimize the process and achieve the highest levels of material purity. Experience has shown that separate door-to-door collection yields much better results than separate collection in containers. European best practices in waste management use this system. (env_wasmun, 2016)

Flanders in Belgium is the region with the highest percentage of separate collection and recycling in Europe. Most collection is door-to-door, and some areas use the Pay-as-you-Throw (PAYT) system, where citizens pay according to the amount of residual waste they produce. Flanders currently separates 75% of its waste, and some municipalities recycle over 80%.

In Italy, more than 1,500 municipalities have adopted door-to-door split collection and already have over 55% source separation. 20% of them (300 municipalities) have over 80% separate collection at the source. All Italian zero-waste municipalities use the door-to-door separate collection system“.

Following the successful Italian initiative, the first door-to-door split collection in Spain takes place in Catalonia, where more than 100 municipalities currently use this system. The success encouraged other municipalities (Hernani and Oiartzun) to join the zero-waste strategy and separate waste at source, and both currently recycle more than 80% of their waste, while reducing waste generation with measures such as home composting. Currently in Spain, the separate collection rate for these municipalities with door-to-door collection is almost triple that with containers.[12]

Zero Waste practices from around the world prove the environmental and social convenience and cost-effectiveness of door-to-door separate collection. Door-to-door collection introduced in EU Member States varies from one container (residual waste collection only and relying on recyclable and bio-waste delivery systems) to six separate bins or sacks.(Fig. 3), (Table 1)

Collection type	Paper	Glass	Plastic	Metal	Bio-waste
Door-to-door (single fraction)	AT, BE, BG, CY, DE, DK, FI, HU, IT, LU, LV, NL, SI	BG, FI, LU, LV, NL, SI, MT	AT, LV, NL, DK	FI, NL, DK	AT, BE, CZ, DE, FI, EE, IT, HU, LU, NL, SI, SE, IE
Co-mingled ...plastic + metal			BE, BG, CY, DE, FR, IT, HU, LU, SI		
...3 fractions	RO, MT: paper, plastic, metal				
...all in one bin	EL, IE: paper, glass, plastic, metal				
Bring points	CZ, EE, ES, FR, HR, LT, PT, PL, SE, SK	AT, BE, DK, CY, CZ, DE, EE, ES, FR, HR, IT, HU, LT, PT, PL, RO, SE, SK	SE	AT, EE, SE	ES
Civic amenity sites	Primary collection: CZ (metal waste), SK (metal and bio-waste), LV (metal) Addition collection of all waste streams: all countries PL: rare distribution of civic amenity sites				

Fig. 3 Overview of collection systems in place in EU countries (primary systems only). [8]

Strict separate collection usually results in higher recycling rates. Among collection methods, door-to-door collection systems result in the highest rates of capture and recovery of recyclables.

Table 1: Primary waste collection systems in EU countries. (Author)

Country	Separate Door to door collection					Mixed Door to door collection					Bring points				
	Glass	Paper	Plastic	Metal	Biowaste	Glass	Paper	Plastic	Metal	Biowaste	Glass	Paper	Plastic	Metal	Biowaste
Austria	0	1	1	1	1	0	0	0	0	0	1	0	0	1	0
Belgium	0	1	0	0	1	0	0	1	1	0	1	0	0	0	0
Bulgaria	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0
Croatia	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Cyprus	0	1	0	0	0	0	0	1	1	0	1	0	0	0	0
Czech	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0
Denmark	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Estonia	0	0	0	0	1	0	0	0	0	0	1	1	0	1	0
Finland	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0
Germany	0	1	0	0	1	0	0	1	1	0	1	0	0	0	0
Greece	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
Hungary	0	1	0	0	1	0	0	1	1	0	1	0	0	0	0
Ireland	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
Italy	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0
Latvia	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Luxembourg	1	1	0	0	1	0	0	1	1	0	0	0	0	0	0
Malta	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0
Netherlands	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Portugal	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Romania	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
Slovenia	1	1	0	0	1	0	0	1	1	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Sweden	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0
Σ	7	13	4	3	12	2	4	12	12	9	18	10	6	10	2

Legend: 1 – exist; 0 – not exists

The common household waste treatment operations are illustrated on the Fig. 4. Data on the treatment of municipal waste are divided into the following categories:

- Combustion (separately with and without energy recovery);
- Landfilling;
- Recycling (except composting or fermentation);
- Composting.

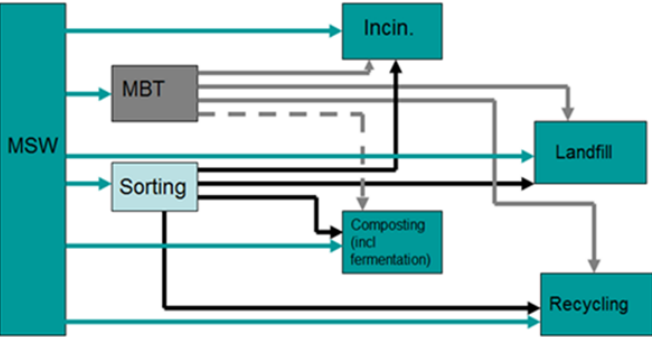


Fig. 4 Options for the treatment of household waste

When waste pretreatment operations - mechanical-biological treatment (MBT) or sorting - are carried out, their results must be allocated to one of the four types of treatment operations - incineration, landfilling, composting or recycling as it is shown on the Fig. 4.

Combustion

Incineration is the thermal treatment of waste in an incineration plant. Household waste can be burned directly or after pre-treatment. Waste incineration is often used as a quick fix to growing amounts of municipal waste and decreasing space in regional landfills. In reality, incineration does not solve municipal waste problems, but creates a number of health and environmental risks and stops the development of municipal systems for more recycling and composting. Waste-to-energy is defined as the incineration of waste to "recover energy" under an energy efficiency criterion, as well as the co-incineration of waste in power plants or industrial facilities such as cement kilns so that the resulting energy can be used to generate heat or electricity.

Landfilling

Landfilling of waste includes its storage in or on land, including in specially designed landfills, as well as temporary storage for more than one year at permanent sites. Landfills are often created in abandoned or disused quarries, mine shafts or pits. Landfilling covers both on-site disposal and off-site disposal. Municipal waste can be landfilled directly or after pre-treatment operations. The pre-treatment of waste prior to its landfill must contribute significantly to reducing the quantity or hazardous properties of the waste, to reducing the risk to human health and limiting the harmful impact on the environment caused by the disposal of the waste throughout the landfill's life cycle.

Composting

Composting and digestion are processes that subject biodegradable waste to aerobic or anaerobic decomposition. The products of these processes are compost or residue, which is used in agriculture. Municipal waste can be composted and digested directly or after pre-treatment operations.

Recycling

Recycling is a form of recovery where waste materials are processed into products, materials or substances intended for reuse. Household waste can be recycled directly or after pre-treatment.

The treatment of waste, its recovery or disposal begins with preparatory activities such as mixing, repackaging, temporary storage, etc., which change the characteristics of the waste, reduce its volume or hazardous nature, facilitate handling and increase the efficiency of its utilization.

Mechanical-biological treatment is a tool for pre-treating waste before landfill or for preparing municipal solid waste to be used as fuel. Mechanical-biological treatment plants significantly reduce moisture by extracting, reducing and stabilizing the organic content in the waste. These treatments include mechanical separation of the waste, biological treatment of the organic fraction and additional mechanical separation if necessary.

The processed waste from the mechanical-biological treatment plants is significantly reduced in weight and stabilized. Emissions from mechanically-biologically treated waste can be reduced by approximately 90–98% compared to untreated waste under landfill conditions. In some countries, mechanically-biologically treated waste is used as landfill cover if contamination is low enough, or it can be landfilled directly. The quality of treated waste is generally not acceptable for widespread use due to contaminants associated with both inert content (glass, plastic, etc.) and heavy metal content resulting from other wastes entering the waste stream such as batteries and etc. Other products are combustible fractions and recyclable materials (eg metals, plastics). Different methods of sorting and processing household waste are shown in Fig. 5 and Fig. 6.

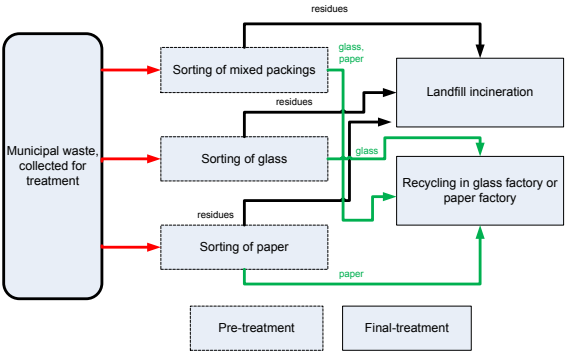


Fig. 5 Sorting and treatment of municipal waste

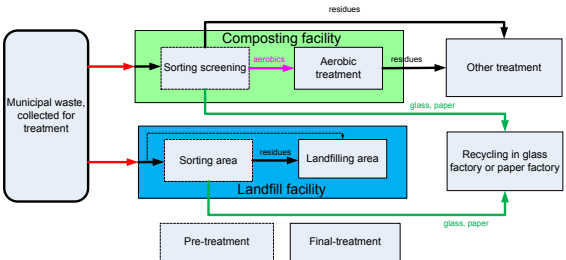


Fig. 6 Integration of pretreatment in facilities.

4. Distribution of waste treatment methods

EU member states have different approaches and practices to the treatment of household waste. Municipal waste are usually

landfilled, incinerated {in most cases with energy recovery), recycled (e.g. paper, glass or metal) or composted. Recycling and composting are generally preferred over incineration. Landfilling is the least preferred option. According to the data of EPRS [6] the share of recycling and composting among waste treatment methods varies from 67% in Slovenia to 8% in Malta (EU average is 46%); eight Member States landfill less than 5% of their municipal waste, while eight Member States landfill over 60% of their municipal waste (the EU average is 25 %). [1]

Another important indicator is the amount of household waste per capita per year. It varies from 261 kg in Romania to 777 kg in Denmark (EU average is 483 kg).

Fig. 7 ÷ 9 present summary of information on Distribution of waste treatment methods that are most often used in EU member states - Landfill, Combustion, Recycling and composting.

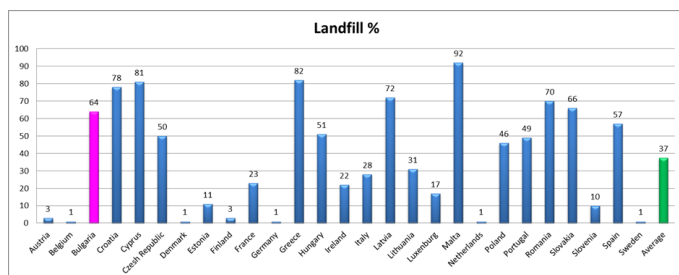


Fig.7 Breakdown of landfill method. (Author)

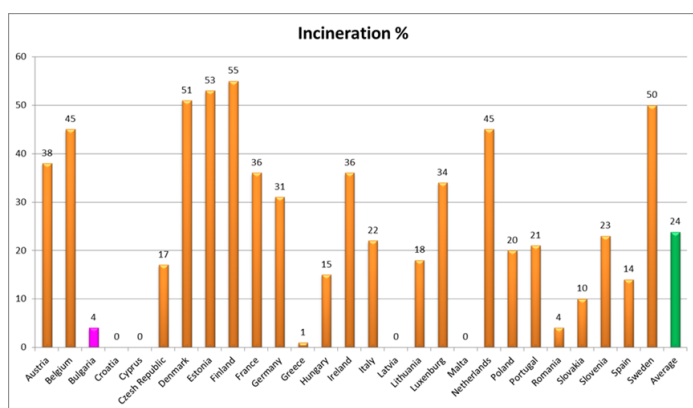


Fig.8 Breakdown of incineration method. (Author)

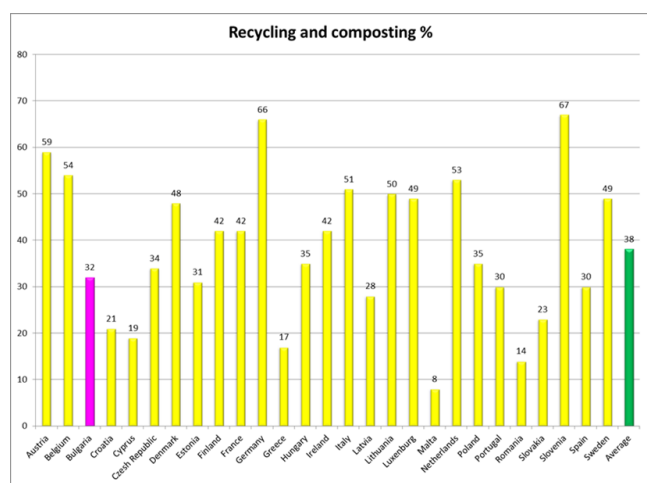


Fig.9 Breakdown of recycling and composting method. (Author)

5. Conclusions

The growing consumption of material resources continues to generate a large amount of waste. Waste is becoming an

increasingly serious problem for the planet. Waste management is a multifaceted field that will become increasingly relevant in our time and for the future. Responsibility and commitment of every single person in society is necessary. In order for this to happen, a new mindset and culture must be systematically built from an early age, so that young people can gain an understanding of recycling and be encouraged to be responsible for waste. This implies comprehensive scientific and scientific-applied research for many years to come.

Achieving sustainable development requires a balance between the economic, environmental and social aspects of human activity. Economic growth is associated with increased production, but this leads to increased energy consumption and growth in carbon emissions. That's why industries should focus on rational planning and energy efficiency. The industry as a whole needs to reorient itself from linear to circular processes that use recycled resources, reduce waste and minimize the carbon footprint on nature. Sustainable development is based on the idea and pursuit of economic growth that improves the well-being of people and society in the long term and is directly related to the need to solve global problems related to climate change, economic, social, environmental and demographic crises. Sustainable waste management is an important part of modern manufacturing processes as it helps companies achieve environmental goals and meet regulatory requirements. Scientific research shows how waste management can be used not only to achieve sustainable development, but also to address a wide range of social and environmental problems and increasingly become a factor for smart and sustainable growth and higher competitiveness.

6. References

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AI-driven strategies for category management profitability

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Abstract: Category Management (CM) is undergoing a transformation thanks to artificial intelligence (AI). AI automates tasks such as data analysis, market segmentation, and demand forecasting, which streamlines and simplifies the work of category managers. It also allows the creation of innovative strategies and campaigns that are relevant to customer needs. This paper focuses on identifying ways in which AI can help to create innovative strategies needed to optimize prices and product lines within category management with the aim to maximize profitability. The paper deals deeper with price optimization, where AI significantly impacts CM. AI analyzes price elasticity and suggests optimal prices for products, which affects the maximization of profitability. Thanks to AI, category managers no longer have to rely on manual analysis and intuition, but they can set prices with much greater accuracy and efficiency. Based on the findings and case studies in the article, the implementation of AI in CM brings companies significant benefits in terms of efficiency, innovation, and profitability. However, it requires strategic planning, investment in technology, and talented people. It is also important to be responsible and ethical when using AI to avoid negative impacts on customers and society.

Keywords: CATEGORY MANAGEMENT, UMEĽÁ INTELIGENCIA, OPTIMALIZÁCIA CIEN, ZISKOVOŠŤ, CENOVÁ ELASTICITA

1. Introduction

In the dynamic and competitive world of business, Category Management (CM) has emerged as a pivotal strategy for the success of retailers and manufacturers. CM transcends the realm of ordinary product management and focuses on strategic planning for product categories to maximize profitability and customer satisfaction.

CM is undergoing a profound transformation driven by advancements in Artificial Intelligence (AI), which opens up new possibilities for optimizing pricing, product assortments, and overall category strategy. This article explores the intersection of AI and CM and summarizes its impact on the work of category managers in the future.

This transformation presents both opportunities and challenges for category managers. They must learn to utilize AI-powered tools, interpret complex data analytics, and adapt their strategies to rapidly changing market conditions.

Traditional CM methods relied on intuition and manual data analysis, which was time-consuming and error-prone. AI introduces sophisticated algorithms and tools to process massive amounts of data from various sources, including sales, prices, inventory, marketing campaigns, and online reviews. With real-time analysis and predictive models, category managers gain deep insights into the market, customers, and competitors, enabling them to make more informed and strategic decisions.

CM is a strategic tool with significant benefits for retailers and manufacturers. Implementing CM can lead to revenue growth, increased profitability, enhanced brand image, and stronger customer loyalty. In the era of AI, CM becomes an even more powerful tool, empowering businesses to make informed and strategic decisions for sustainable growth and success.

2. The significance of pricing in CM

Category management is a strategic approach to managing product categories in retail. It aims to maximize category profitability and market share by optimizing product assortment, pricing, promotion, and distribution. Category managers collaborate with suppliers to achieve shared goals and ensure that category products meet customer needs.

Price is a crucial factor influencing product demand and category profitability. Lowering a product's price can lead to increased demand but also reduced profit margins per unit. Conversely, raising the price can decrease demand but potentially increase profit per unit.

Category managers must consider various factors when setting prices to find the optimal price that maximizes category profitability. These factors include:

1. Cost of production and distribution – Category managers must consider all costs associated with producing and distributing the product, such as materials, labor, transportation, and marketing.

2. Price elasticity of demand – This measures the extent to which product demand changes in response to price changes. Products with low price elasticity are less sensitive to price changes, while those with high elasticity are more sensitive. Understanding price elasticity allows managers to predict demand changes based on price adjustments.
3. Competition – Category managers must consider competitive product prices when setting their own. If competitors offer lower prices, customers may switch to their products. Conversely, higher competitive prices may attract customers to the company's products.
4. Customer expectations – Understanding customer price expectations is crucial for maximizing product line profitability. If a product's price is too high, customers may not buy it. Conversely, if the price is too low, they may perceive the product as low quality.

Factors affecting price elasticity of demand:

1. Product type – Basic products like bread and milk typically have low price elasticity, while luxury items like jewelry and cars often have high elasticity.
2. Availability of substitutes – If multiple product substitutes exist, demand for that product is likely more elastic. Conversely, with fewer substitutes, demand is less elastic.
3. Product importance to consumers – If a product is highly important, demand is likely less elastic. Conversely, for less important products, demand is more elastic.
4. Time horizon – Price elasticity may vary depending on the time frame. In the short term, demand may be less elastic, while in the long term, it may become more elastic [1, 7].

3. Practical applications of price elasticity in CM

Category managers can implement various pricing strategies to maximize profitability and achieve category goals by understanding price elasticity. This section delves into various pricing strategies and their practical applications in CM.

Penetration pricing involves setting a low initial price to gain rapid market penetration and acquire a large customer base. The goal is to attract a significant number of customers and establish a strong customer foundation. While initial profits may be lower, this strategy can lead to higher overall profitability in the long run if a substantial market share is achieved. This strategy is primarily suitable for new products, products with high price elasticity of demand, and products with high growth potential. Low prices not only motivate customers to buy but also stimulate demand and drive rapid sales growth.

In contrast to penetration pricing, skimming pricing involves setting a high initial price to maximize profits from products with high price elasticity of demand. The objective is to capitalize on the willingness of price-inelastic consumers to pay a premium for the product. Later, the price can be reduced to attract price-sensitive

consumers and increase overall sales volume. This strategy is primarily used for luxury products, high-value products, and products with low price elasticity of demand. Essentially, this strategy is suitable for products where demand is not significantly affected by price. Instead, price can strengthen the product's perceived value and increase its attractiveness to customers. Price-inelastic consumers are willing to pay a high price for luxury products.

Skimming pricing involves setting a high initial price for a product and gradually lowering it over time. The goal is to maximize profits from products with high price elasticity of demand in the initial phase while attracting price-sensitive consumers in later stages of the product's life cycle. Unlike the previous strategy, skimming pricing is primarily used for new products with a high degree of innovation, where demand for the product is very high in the initial market entry phase, and customers are willing to pay a high price due to the high value they perceive in the product. This type of strategy is particularly suitable for ICT products and their systematic advancement through the innovation process.

Psychological pricing utilizes various psychological factors that influence customer price perceptions to make products appear more attractive. Price determination assumes that the price will be perceived as more appealing to the customer.

One example of psychological pricing is the *"Baťa price"*, introduced by the renowned Czech entrepreneur Tomáš Baťa.

In this strategy, it is crucial that prices align with the overall pricing strategy and customer expectations. Excessive use of psychological pricing can lead to customers perceiving prices as unrealistic or manipulative (*"Baťa prices"* are becoming less effective). Therefore, it is necessary to test various psychological prices to determine the most effective ones for a given product category and target customer group.

While previous strategies focused on long-term price setting, promotional pricing involves temporarily lowering a product's price to promote the sale of specific products. The goal is to stimulate demand and increase sales in a short period. Promotional prices are often used to clear out excess inventory or introduce new models. This strategy is also applicable to seasonal products where the seller aims to increase revenue during the season. As the name suggests, promotional pricing is suitable for introducing new products to the market. To attract customer attention to new products, a *"promo"* price is set instead of or in conjunction with additional promotional materials, stimulating customers to purchase and try the new product. The most critical factor in using promotional pricing is to clearly communicate prices to customers and ensure they are time limited.

Personalized pricing involves setting product prices based on individual customer characteristics such as their purchasing habits, demographics, and interests. The goal is to maximize profit from each customer and build long-term relationships. Personalized pricing is becoming increasingly common as customer data becomes more accessible and artificial intelligence technologies advance.

This pricing strategy must adhere to data privacy regulations and protect customer privacy. It is the responsibility of every seller to ensure prices are transparent and customers understand how prices are determined. Optimal personalized pricing also involves identifying the most effective prices for specific products, product lines, and target customer groups.

This pricing strategy is most used in online environments, particularly e-commerce stores, where different product prices are displayed to different customers based on their purchase history and viewed products. The final pricing strategy discussed in the article is differentiated pricing. This strategy involves setting different prices for the same product to different customers or in different markets. The goal is to maximize profit from each sale and adapt to varying market conditions. Differentiated prices are often used based on various factors specific to a customer segment. Pricing is influenced by the customer's geographic location, with prices potentially varying depending on region, country, or even city. Local market conditions, competition, and purchasing power all

play a role in determining the appropriate price for a specific location.

Customer volume can also influence pricing. Businesses may offer discounts for larger purchases, encouraging bulk buying and increasing overall revenue. The channel through which a product is sold can also impact pricing. Online retailers may offer lower prices compared to physical stores due to lower overhead costs. Pricing strategies may evolve throughout a product's lifecycle. Initially, higher prices may be set to recoup development costs, while lower prices may be introduced later to attract a wider audience.

Businesses must ensure that differentiated pricing practices do not constitute price discrimination, which involves charging different prices based on prohibited factors like race, religion, or nationality. Clearly communicate pricing policies and the rationale behind differentiated pricing to customers to avoid misunderstandings and maintain trust. Pricing practices should be fair and non-deceptive, avoiding misleading or hidden charges that could disadvantage certain customer groups.

When implemented strategically and responsibly, differentiated pricing can be a powerful tool for businesses to maximize profitability, expand market reach, enhance customer satisfaction, and adapt to dynamic market conditions. By carefully considering customer segments, market characteristics, pricing objectives, and legal and ethical guidelines, businesses can leverage differentiated pricing to achieve their strategic goals and drive sustainable growth [2, 3].

4. Leveraging Artificial Intelligence in CM

AI has the potential to revolutionize the field of CM. AI tools and algorithms can analyze vast amounts of data on customers, products, competitors, and market trends, providing category managers with valuable insights for optimizing pricing and product assortments. This chapter delves into the intersection of AI and CM in the areas of pricing and product assortment optimization.

AI can significantly enhance pricing strategies by analyzing price elasticity. AI algorithms can scrutinize historical sales and pricing data to identify factors that influence product demand. This empowers category managers to set optimal prices that maximize profitability and cater to customer needs.

AI models can accurately predict future product demand based on various factors, including seasonal trends, marketing campaigns, and economic conditions. This enables category managers to optimize inventory levels, preventing stockouts or overstocking.

AI tools can analyze individual customer profiles and purchasing habits to offer personalized pricing. This personalized approach can boost customer satisfaction and drive sales growth.

AI algorithms can analyze sales, profitability, and margin data for individual products to identify underperforming items. This allows category managers to optimize product assortments, focusing on products with high profit potential.

AI-powered pricing automation involves dynamically adjusting prices in real-time based on various factors, such as competitor pricing, product demand, and inventory availability. This automation saves category managers time and resources while ensuring optimal pricing [4, 5].

Table 1. Practical applications of AI in CM

Company	AI applications
Amazon	Personalizes product prices for each customer based on their purchase history and preferences.
Walmart	Predicts product demand and optimizes inventory levels.
Procter & Gamble	Analyzes price elasticity and sets optimal prices for its products.
Coca-Cola	Develops personalized marketing campaigns and optimizes product distribution.
Unilever	Analyzes online reviews and customer feedback to improve products and services.

The integration of AI into CM offers a multitude of advantages, including:

1. **Enhanced Profitability** – AI empowers category managers to maximize profitability by optimizing pricing and product assortments. AI algorithms can analyze vast amounts of data to identify optimal price points and product mixes that align with customer demand and market trends, leading to increased revenue and profit margins.
2. **Elevated Customer Satisfaction** – AI enables category managers to deliver personalized experiences that enhance customer satisfaction. By analyzing customer data and purchasing patterns, AI can tailor product recommendations, pricing strategies, and marketing campaigns to individual customer preferences, fostering loyalty and satisfaction.
3. **Improved Efficiency** – AI streamlines processes and automates tasks, saving category managers time and resources. AI-powered tools can handle repetitive tasks such as data analysis, price adjustments, and inventory management, allowing category managers to focus on strategic decision-making and value-added activities.
4. **Enhanced Decision-Making** – AI provides data-driven insights that inform strategic decisions. AI algorithms can analyze vast amounts of data to identify trends, patterns, and correlations, enabling category managers to make informed decisions about pricing, product assortments, marketing strategies, and overall category management strategies.
5. **Increased Competitiveness** – AI empowers category managers to stay ahead of the competition. By leveraging AI for data analysis, pricing optimization, and personalized customer experiences, category managers can gain a competitive edge, attract and retain customers, and achieve sustainable growth [6].

5. Conclusion

Each Artificial intelligence (AI) holds immense potential to revolutionize Category Management (CM) practices in the future. As AI continues to evolve and innovate, category managers can expect to gain access to even more sophisticated tools and algorithms that empower them to achieve strategic goals.

AI is poised to enable category managers to create customized pricing offers and marketing campaigns for each customer based on their unique buying behavior, preferences, and demographics. AI models will also accurately predict product demand in real-time, allowing category managers to optimize inventory levels and minimize losses.

Dynamic pricing algorithms will adjust product prices based on various factors, such as competitor pricing, demand, and inventory availability, ensuring maximum profitability. Advanced data analytics will empower category managers to analyze vast amounts of data from diverse sources, gaining valuable insights into market trends, customer behavior, and competitive landscapes.

AI assistants will serve as intelligent partners, assisting category managers in tasks like information retrieval, data analysis, and decision-making.

The adoption of AI in CM will bring significant benefits to businesses in terms of efficiency, competitiveness, and profitability. However, it is crucial to emphasize that AI serves as a tool to augment category managers, not replace them. The human element will always play a pivotal role in strategic category management and building strong customer relationships.

AI stands as a powerful catalyst with the potential to elevate CM to new heights. By responsibly and ethically embracing AI, category managers can look forward to a future brimming with innovation, growth, and success.

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Positioning a holistic approach for integration of renewable energy powered charging stations into a nationwide electrical power distribution system

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Abstract: This paper explores various models of integrating independent Electric Vehicle Charging Stations (EVCSs) into Montenegro's electricity distribution system (EDS) and energy market. It examines different possibilities by applying a multidisciplinary approach to the EDS integration coupled with market frameworks to form a novel holistic perspective for participations and influences of various stakeholders. The primary goal is to envisage and achieve a more efficient integration of different prosumers models that own and engage independent EVCSs with photovoltaic systems into the EDS and transport infrastructure. This approach is aimed at reducing CO₂ emissions, promoting electromobility, engagement of citizens, and facilitating distributed renewable electricity generation at the point of consumption. Through the analysis of each of the three identified prosumer models, we give specifics of the integration within the grid, solar energy exploitation potentials, practical options for energy provisioning during and outside sunny periods etc. Economic, legal, and technical implications are integrated, and recommendations are provided using economic modelling and game theory formulations between the relevant actors and within regulatory provisions to optimize electric mobility in Montenegro.

Keywords: SOLAR (PV), RENEWABLE ENERGY SOURCES (RES), ELECTRICAL VEHICLES (EV), ELECTRICAL VEHICLE CHARGING STATION (EVCS), PROSUMERS, ECONOMIC MODELING

1. Introduction

Nowadays, the living world faces numerous challenges due to reliance on conventional energy sources. Namely, the emission of carbon dioxide, sulfur oxides, and nitrogen oxides caused by the excessive use of fossil fuels is threatening and increasingly pointing towards the complete degradation of the environment and living world, including humans. Pollution emitted into the atmosphere leads to the occurrence of acid rain and global warming. A true breakthrough would be achieving economic and social development without compromising short-term climate goals and contributing to global efforts to achieve the long-term goal of limiting the temperature increase to less than 2 °C [1], but preferably up to 1.5 °C.

The integration of Renewable Energy Sources (RES) into the electric power grid, with a particular emphasis on the distribution grid, is highly relevant and desirable in order to mitigate the negative impact of fossil fuel consumption. Nowadays, there are numerous types of RES (e.g. solar, wind) and their installations (e.g. wind or solar farms) with stimulating degrees of cost efficiencies and shares of energy contributions in overall power productions within a region or a distribution grid system.

Our project focuses the exploitation of RES for further electrification of green transport in Montenegro as a whole, that is, as an optional type of EVCSs across the country's transport infrastructure. This approach specifically refers to involvements of independent and geographically distributed energy producers via solar panels and their integrations in the transport network with other EVCSs via novel models configurations discussed in this paper. As part of our project, we have already conducted a complementing study on optimal distributions of EVCSs across Montenegro's cities, roads and regions taking into considerations various factors such as population and traffic densities, seasonal upsurge in demand due to tourism, availability of electric grid infrastructures etc. [2]. We highlight here that these energy producers are mainly considered to be outside the energy production system of conventional power companies, and generate solar energy subject to its natural availability. They are considered here as novel models of prosumers with charging of unowned EVs as their extended capability. Therefore, this charging would be an optional commercial activity for wider public EVs, not only for personal use.

Opening up of the energy market and transport infrastructure to nation-wide large scale involvement of independent prosumers-

based EVCSs, in addition to existing "typical" EVCSs, requires diverse multidisciplinary investigation. Some of these include: a) economic issues of divestiture of market power of the existing power companies [3] across the green transport; b) legal and regulatory aspects of involvement of novel models of prosumers in the energy system and markets; c) operational and engineering implications of integrating novel prosumer models into the existing energy system, this being the foundational topic of this paper.

Generally, prosumers are electricity consumers who produce electricity from renewable sources, consume it, store it for future needs, or distribute it further into the grid. As such they emerge as an acceptable solution in the distribution grid with various incentive for formulating different prosumer types [4]. We observe that there are variations in definitions and perspectives of how prosumers and associated configurations are defined. While some observe a prosumer setup from an engineering point of view of the necessary composition of operations and components [5], a view from European Environment Agency (EEA) [6] includes individual energy producers of, for example solar energy, but also citizen collectives, public institutions, and communities. In fact, the EEA emphasizes that prosumers' activities are not their main commercial activities. While we originate with the same view on the definition of prosumers, the addition of the exclusive EVCS-to-EV charging capability using renewable but variable solar energy, opens various technical and exploitation models for prosumers on a one-to-one energy exchange basis. Hence, in this paper, we apply the terms with this flexibility of interpretations.

The paper's sections are: Section II describes incentives for considering novel prosumer models; Section III outlines some prosumer models with charging capabilities; Section IV outlines an essential economic model setup for integrations of the prosumers into the energy market; Section V gives the concluding remarks.

2. Incentive for defining different prosumer models

The integration of prosumers into the electrical distribution grid holds significant global importance. However, indiscriminate and poorly planned intentions behind integrating such energy entities can slow down and obstruct the processes of energy transition, decarbonization, and electrification of transportation.

Namely, the aim of a prosumer is to produce electrical energy at the point of consumption, thereby reducing losses (both financial and technical), relieving the burden on transmission and distribution lines, and contributing to the overall energy production mix of a state (or system). However, if a prosumer or a cluster of prosumers

acts contrary to the design guidelines and agreed-upon principles, it can cause harm to the power system. It thus degrades its role or, worse, renders it entirely meaningless, where the prosumer becomes "damaging" and represents a hindrance to the optimal functioning of the power system.

On one hand, the technical and economic benefits of integrating RES and prosumers within the electrical grid are evident, such as relatively inexpensive electrical energy, low CO₂ emissions, and lower operational costs. However, the integration of RES also brings about a couple of challenges and problems regarding: power system management, such as reduced system inertia and stability, lower quality of electrical energy (manifesting as higher harmonics), higher short-circuit currents, variability, and unpredictability of weather conditions, and so forth [3].

In order to efficiently integrate prosumers into the electrical distribution system (EDS), it is imperative to develop appropriate models and analyze their impact to optimize production and consumption while minimizing the negative effects that prosumers may potentially cause.

The task of this paper is to analyze a specific type of prosumer, namely EVCSs symbiosis with photovoltaic panels, and to find suitable models and their configurations. In addition, we aim to position a holistic multidisciplinary analysis of the operations and functioning of such a prosumer type within the national power distribution systems and in balance with all stakeholders affected by it.

4)

PV system 500kW output power													
Slope 36 deg (optimum); Azimuth 0 deg (optimum) System losses 14%													
P(kW)													
Podgorica (BIG Fashion parking) 2020													
Time/Date	15-Jan	15-Feb	15-Mar	15-Apr	14-May	15-May	15-Jun	15-Jul	15-Aug	15-Sep	15-Oct	15-Nov	15-Dec
4:00					7.25	0.62	34.88	11.95	0.60				
5:00				74.86	48.26	13.17	118.03	9.69	61.70	25.36			
6:00		29.35	66.89	187.32	14.19	23.32	201.77	49.15	148.67	121.56	13.74	9.20	
7:00	88.00	143.63	25.09	283.06	67.06	71.21	269.33	248.93	221.61	136.07	19.95	74.33	81.12
8:00	172.48	224.32	15.63	346.16	225.04	59.34	321.24	307.19	281.59	227.96	30.02	133.22	159.61
9:00	218.69	278.87	18.36	389.81	329.90	45.74	358.23	341.33	322.36	193.08	101.71	170.07	202.82
10:00	238.74	301.86	38.58	403.56	356.92	51.44	319.40	359.48	336.43	296.17	16.70	130.85	220.31
11:00	235.36	298.34	41.85	394.05	346.72	48.26	70.55	355.92	331.13	238.84	16.31	169.68	207.53
12:00	200.27	266.06	174.57	364.02	91.83	54.79	48.56	335.87	314.06	245.79	13.61	80.75	174.42
13:00	145.22	208.43	180.03	307.80	43.45	89.60	290.08	272.23	263.63	192.89	14.75	60.77	113.28
14:00	70.65	133.12	178.27	225.55	58.61	55.66	185.25	227.10	127.55	120.91	4.99	15.53	37.93
15:00	1.51	40.81	84.74	128.15	24.05	24.13	82.82	144.57	121.11	70.44	0.66		
16:00			10.38	36.34	14.37	6.13	74.05	72.44	47.73	10.97			
17:00					2.36	0.20	9.31	20.00	7.25				
18:00													
19:00													
20:00													
Average power (kW)	171.18	192.48	75.85	261.72	135.03	45.23	194.94	226.99	214.80	208.89	25.75	105.55	113.10

Fig 1. Daily irradiance for the 15th of each month in 2020 (exception May 14th).

Date (month)	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Year(2020)
Energy (kWh)	27240.84	30700.77	48556.54	60599.17	71087.85	76208.69	81320.07	73781.98	56938	43741.93	28810.57	24306.84	623293.3
Average daily energy (kWh)	878.74	1096.46	1566.34	2019.97	2293.16	2540.29	2623.23	2380.06	1897.93	1411.03	960.35	784.09	1704.30
Average hourly power (kW)	109.84	109.65	142.39	168.33	191.10	211.69	218.60	198.34	158.16	156.78	106.71	98.01	161.04
Estimated average working hours	8	10	11	12	12	12	12	12	12	9	9	8	10.58333

Fig 2. Presentation of average values of produced energy and output power per month in 2020(500kWp), along with the estimated effective operating time of the prosumer per month.

3.1 Off-grid prosumer (EVC + PV)

The off-grid prosumer model consists of a photovoltaic system that operates independently of the EDS and as a additional specificity of this study, lacks a storage system or battery for excess electrical energy. Specifically, the only consumers would be EVs potentially connected to one of the outputs of a shared EVCSs. Although this system has certain drawbacks compared to conventional EVCSs, it still possesses significant advantages that can enable it to compete fairly in the market and play a significant role in the electrification of transportation and sustainable management of the electrical power system. Because this system is not connected to the electrical distribution system (EDS), it has no negative impact on the system. Issues such as harmonic distortion, variability, delivery of surplus electrical energy when electricity prices are low in the market, and the need for additional quantities

This is to ultimately reveal most optimal energy pricing, power divestiture and regulatory boundaries where these players would be incentivized to achieve an equilibrium contributing to overall public welfare.

3. Proposal of Three Prosumer Models (EVC + PV)

Under the concept of a prosumer, we consider EVCSs that can produce/consume and, when existent, directly provide renewable (solar) electrical energy to EV(s) having other owners with a direct commercial incentive and arrangement. EVCSs could also feed some energy it produces back to the grid subject to its overall consumption and circumstances. The profitability and commercialization potential of these solar EVCSs are affected by the variability in charging due to unpredictable occurrences and volumes. Thus, they remain seen as prosumers within the flexible boundaries of our definition but span many configuration options and commercialization potentials as discussed in the following text.

We define three types of EVCSs prosumer models and give detailed explanations in the consequent subsections:

- 1) Off-grid prosumer;
- 2) On-grid prosumer with virtual "storage" system;
- 3) On-grid prosumer without virtual "storage" system;

of electrical energy are all avoided. The cost of powering vehicles from such systems should typically be lower, as the electricity is produced on-site and directly delivered to the electric vehicle user without additional transmission or storage costs.

For the purposes of this analysis, a public parking lot in front of the BIG FASHION shopping center in Podgorica city (42°26'14.8"N, 19°14'04.5"E) was considered. A canopy with 500 kWp photovoltaic (PV) panels was modeled on a portion of the parking lot surface (~2600m²) and around 150 parking spaces, with the panels oriented at a 10° inclination and -29° azimuth-southeast using the K2 base software package. Simulation calculations were performed using the PVGIS software tool, providing actual solar irradiation data for the year 2020 on an hourly basis for each day of that year. Due to the complexity and large amount of data obtained, Грешка! Източникът на препратката не е намерен. displays

actual data for the fifteenth day of each month in 2020, while data for the month of May is also shown for the fourteenth day to provide a more realistic representation. This accounts for the fact that data from a single day may not necessarily reflect irradiation throughout the entire month, and there may be significant deviations from day to day.

Fig 2 presents average data for each month, as well as the total forecasted electricity production per month, allowing for data averaging and displaying the average power and energy expected at the output of the electric vehicle charging station.

The fundamental idea behind such a prosumer model is to provide price incentives for EV users to utilize their time spent at shopping malls, workplaces, and other locations where they plan to stay for an extended period of time to charge their vehicle batteries at slightly lower electricity prices, while simultaneously avoiding burdening the electrical distribution system and harnessing the cleanest source of electrical energy by simultaneously taking electricity at the point of production.

Specifically, this type of prosumer would ideally have 20-50 connections (parking spaces with chargers) for electric vehicles, with power evenly distributed based on the number of connected vehicles and the currently available power. The operating hours of such prosumers would be defined by weather conditions and the month of the year, with an average of 10.5833 hours per day, as shown in

Fig 2. During one working day, the average power that this prosumer could deliver would be 161.04 kW throughout all working hours, which is sufficient to charge approximately 37 average electric vehicles (with a battery capacity of 77 kWh) bringing them from 20% to 80% (in total ~46kWh) within one day, if the energy is evenly distributed.

Date (month)	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Year(2020)
Energy (kWh)	8231.7	8007.57	11248.32	12589.18	13602.36	14060.96	15245.04	14930.85	12741.06	11219.44	8297.62	7715	137889.1
Average daily energy (kWh)	265.54	285.98	362.85	419.64	438.79	468.70	491.78	481.64	424.70	361.92	276.59	248.87	377.25
Average hourly power (kW)	33.19	28.60	32.99	34.97	36.57	39.06	40.98	40.14	35.39	40.21	30.73	31.11	35.65
Estimated average working hours	8	10	11	12	12	12	12	12	12	9	9	8	10.58333

Fig 3. Presentation of average values of produced energy and output power per month in 2020(100kWp), along with the estimated effective operating time of the prosumer per month.

The average daily energy produced by such a system without predetermined system losses of 14% is 377.25 kWh, enough to supply 8.2 electric vehicles with 46 kWh of electrical energy. From the present analysis, it can be concluded that this type/model of charging station/prosumer would have the capacity to provide 46 kWh of electrical energy (~300 km range) for about 8-9 electric vehicles in one day. However, it can happen that the photovoltaic system produce more energy than needed at certain times or when no electric vehicles are connected. If that happens at that time, the system has the capability to deliver the surplus electrical energy to the electrical distribution system for its needs. In this way, the electrical distribution system plays the role of a "virtual" energy storage system, that enables the photovoltaic system to retrieve the same energy when needed, namely when electric vehicles are connected. This introduces a concept of "virtual" energy storage with financial compensation for the electrical distribution system, which in this model serves as a storage facility for surplus energy and reclaims it when needed.

This provides for regulation of the maximum power supplied and demanded in order to ensure the stability of the electrical distribution system. This also allows for a legal regulation of the billing for such activity. It is proposed that the operating hours of such charging stations be linked to the operating hours of the facility they are integrated with. In this way, the charging of electric vehicles can take place within a certain period of time, e.g. from 08:00 to 23:00. This encourages consumers to draw electricity during sunlight hours, minimizing the energy stored in virtual energy storage and consequently reducing storage costs and the burden on the electrical distribution system. Such a model would be

With appropriate software solutions, the ability to control energy distribution, and a management system, this prosumer model could provide the cheapest electricity for electric vehicle users while significantly reducing the negative effects on the EDS that could be caused by the mass integration of photovoltaic (PV) systems within the EDS. Implementing this prosumer model at production sites such as large company parking lots, public institutions, shopping centers, and similar locations is straightforward. With proper energy management, all negative aspects of this model, particularly production variability and spillage/loss of generated energy, could be overcome.

3.2 On-grid prosumer with "virtual" storage system (EVC+PV+grid storage)

Compared to the first model of charging stations for electric vehicles, the second proposed model operates under a slightly different system. In particular, this model is connected to the EDS, which earns it the designation of a "on-grid" hybrid system. However, that's not the only difference. This model has a significantly lower installed capacity of photovoltaic modules than the first model, which in this case is 100 kWp. The operating pattern is designed so that the EDS of this type of charging station guarantees a constant power of 20 kW in order to ensure users a certain level of security and reliability in the power supply. During the sunny hours and the generation of electricity by the photovoltaic system, the charging speed of the vehicles as well as the amount of energy delivered to the consumers would increase, as shown in (Fig 3). The data was obtained based on the PV Gis software package for a 100 kWp output power photovoltaic system simulated at the following location (42°26'14.8"N, 19°14'04.5"E).

suitable for restaurants, hotels, supermarkets and similar establishments with an parking area of around 500 m².

3.3 On-grid hybrid prosumer with guaranteed power (EVC+PV+grid)

The third model aims to provide safe and fast charging for electric vehicles when users need it most. The output power of such a charging station would be 100 kW at any time of the day. More specifically, this type/model of prosumer has a constant supply or guaranteed power from the electrical distribution grid of 100kW, while the installed power of photovoltaic system would be a maximum of 50kWp and anything less. The idea behind the third model comes closest to conventional charging stations, especially when drivers need them most, as these models significantly reduce the anxiety and fear of potential electric vehicle drivers of getting stranded on their journeys. This type of charging station is best suited for locations such as gas stations, farms near highways and freeways, and some locations along major roads where user convenience and satisfaction are much more important than the cost of charging the vehicle. Such a system requires a roof area of up to 250 square meters, which may consist of the roof area of the building itself and a canopy for the cars, much like today's gas stations. In this scenario, the energy generated by such a photovoltaic system with a nominal output of 50 kWp has a lower impact than the energy and power drawn from the electricity grid. However, the energy from a photovoltaic system with an average output of 17.83 kW can reduce the energy drawn from the grid during sunny hours and thus help to reduce the financial costs of the charging station. As can be seen in Fig 4, once the analysis is completed, this system primarily relies on the support it receives from the electricity distribution system to enable efficient, fast and

safe charging of electric vehicles, but it is also the heaviest burden on the system itself, as its peak load is extremely high and the variability factor changes rapidly. Therefore, the expected number of such charging stations (within the boundaries of a country) is the lowest compared to other models, and at the same time the smallest

number of parking spaces or connections for vehicles belongs to this type of charging station. Nevertheless, this model/type of charging station is extremely important at strategically vital locations to reduce the anxiety and uncertainty of drivers, especially those who use electric vehicles for intercity/interstate travel.

Date (month)	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Year(2020)
Energy (kWh)	4115.85	4003.78	5624.16	6294.59	6810.18	7030.48	7622.52	7465.43	6370.53	5609.73	4148.81	3857.51	68953.57
Average daily energy (kWh)	132.77	142.99	181.42	209.82	219.68	234.35	245.89	240.82	212.35	180.96	138.29	124.44	188.65
Average hourly power (kW)	16.60	14.30	16.49	17.48	18.31	19.53	20.49	20.07	17.70	20.11	15.37	15.55	17.83
Estimated average working hours	8	10	11	12	12	12	12	12	12	9	9	8	10.58333

Fig 4. Presentation of average values of produced energy and output power per month in 2020(50kW), along with the estimated effective operating time of the prosumer per month.

4. Economic Modeling Setup of Optimal Prosumer models

Our study aims to establish both technical and multidisciplinary foundations, including regulatory, economic, and operational aspects, for integrating prosumer models into the energy system and transport infrastructure. We can observe the market of EVCSs as a novel space for emergences of various combinations of: markets players, energy distribution, purchase models, and price creation mechanisms. Given the favourable conditions in Montenegro for a clean slate approach, we explore how prosumers can engage in the electric transport market and expand their commercialization potential beyond traditional tariff arrangements, such as feed-in tariffs. From our three examples of solar EVCSs presented earlier it can be deduced that the magnitude of energy productions can vary, and so can the ambitions for commercialization, ranging from a significant business venture to a modest supplementary source of income. Such potentials and contributions can be sporadic if based on a small and discontinuous production of solar energy, or they can be continuous in combination with regular energy supplies. Likewise, the numbers and distributions of these individually-owned, solar EVCSs [2] can be such that they can present an important element of the energy supply within the traffic infrastructure.

From a regulatory or governmental perspective, these prosumers can become significant players in the energy market. This perspective calls for a reconsideration of electricity payment models (e.g. Power Purchase Agreements) on a one-to-one retail-level basis, as well as new energy price market dynamics and a regulatory framework that can boost supply availability and expand locations. Ultimately, citizens would benefit through increased engagement of prosumers and enhanced public welfare.

To further explain the dynamics within the electric vehicle charging station (EVCS) market, we employ a theoretical game theory approach. This framework allows us to define the key players, their strategies, and utility functions, facilitating a clearer understanding of the strategic interactions and potential outcomes. By analyzing these interactions, we can identify optimal strategies and policies that promote the efficient integration of prosumer models into Montenegro's energy system.

First, we consider the role of the State/Regulator. This player is crucial in developing and enforcing regulations, promoting public welfare, balancing energy prices, and ensuring system stability. The State/Regulator's strategy involves determining optimal regulations and incentives that maximize public welfare and system stability. They must navigate the complexities of providing adequate subsidies, setting fair tariffs, and ensuring a stable energy supply while fostering an environment conducive to the growth of RES and prosumer participation. The utility function for the State/Regulator can be expressed as:

$$U_s = \alpha W_{soc} + \beta R_{reg} + \gamma S_{stab} - \tau S_{gov}$$

Where W_{soc} represents the welfare of society, R_{reg} indicates the effectiveness of regulatory policies, and S_{stab} reflects the stability of the energy system, S_{gov} cost of subsidies for installation of PVs and subsidies for EV users. The coefficients α , β , γ , and τ denote the relative importance of each factor in the overall utility.

Second, we consider the Energy Company Montenegro (ECM) and Electrical Distribution System (EDS)¹. Their primary objectives are to ensure grid stability and efficiency, manage energy supply and demand, particularly during peak and off-peak hours, and maintain profitability while balancing this with sustainable development. ECM plays a crucial role in purchasing surplus energy from prosumers and potentially "storing" energy from On-Grid Charging Stations with Virtual Storage on the grid. This storage mechanism allows ECM to utilize energy without immediate costs, though they must later return equivalent energy to the charging stations upon request.

ECM's strategy involves optimizing these interactions to maximize their utility, which includes revenues from energy sales, costs of purchasing surplus energy, and costs related to maintaining grid stability. Additionally, EPCG's preference for On-Grid Charging Stations with Virtual Storage over conventional charging stations stems from the increased flexibility and potential cost savings associated with the virtual storage model. This preference aligns with their objective to integrate more prosumers into the grid, enhancing overall system resilience and sustainability.

The utility function for ECM can be formulated as:

$$U_{ecm} = \gamma R_{energ} - \epsilon C_{buy} - \delta C_{stab} + \theta P_{strg}$$

Where R_{energ} represents the revenue from energy sales, C_{buy} costs of buying the electricity from prosumers, C_{stab} costs associated with maintaining grid stability, and P_{strg} captures the premium from providing virtual storage services.

Third, we consider the On-Grid Charging Station with Virtual Storage (PM2), as defined in the second proposed model. Their primary objective is to maximize profits from providing EV charging services. These stations offer a distinct advantage by utilizing stored surplus energy, produced from renewable sources like photovoltaic systems, to provide charging services at lower costs. The marginal cost of this stored energy is effectively zero, allowing PM2 to set their prices below the market value that conventional on-grid charging stations incur as input costs.

The PM2 also incurs costs related to the installation and maintenance of the photovoltaic systems. Additionally, they would have to pay a premium for the virtual storage service provided by EDS. Despite these costs, PM2 benefits from the added stability and reliability that comes with virtual storage, allowing them to manage energy supply more effectively and reduce fluctuations in charging availability.

The strategy for PVS involves balancing these costs with the revenue generated from EV charging services. Their utility function can be formulated as follows:

$$U_{pm2} = \eta R_{charge} + \tau S_{gov} - k C_{pinst} - \vartheta C_{cinst} - \lambda C_{maint} - \phi P_{strg} + \epsilon B_{chstab}$$

Where R_{charge} denotes the revenue from providing EV charging services, S_{gov} government subsidies for installing photovoltaic systems, C_{pinst} installation costs of the photovoltaic systems, ϑC_{cinst} installation costs of the charging infrastructure, C_{maint} maintenance costs, and P_{strg} premium paid for virtual

¹ Elektroprivreda Crne Gore AD and CEDIS in the Montenegrin system respectively

storage services, B_{chstab} overall benefit of stability and reliability of charging that comes with virtual storage. By strategically setting their prices and managing their costs, PVS can attract more customers, maximize their profits, and contribute to a more stable and sustainable energy system.

Fourth, we consider the Conventional On-Grid Charging Station (OCS). Similar to the On-Grid Charging Station with Virtual Storage, OCS benefits from a stable supply of electricity due to its connection to the grid. However, unlike PM2, the OCS does not produce its own energy and therefore incurs higher costs for purchasing electricity at market value. This reliance on external energy sources means that OCS typically has higher operational costs compared to PVS. OCS can offset these higher costs by setting higher prices for their fast-charging services, catering to EV owners who prioritize speed and convenience. Although OCS avoids the premium costs associated with virtual storage, they still face installation and maintenance expenses for their charging infrastructure. Furthermore, the high-power demand of fast chargers can negatively impact grid stability, increasing the overall costs associated with grid management for EDS.

The primary goal for OCS is profit maximization. To achieve this, they strategically set their prices to balance the higher cost of electricity with the revenue from fast charging services. Their utility function can be formulated as follows:

$$U_{ocs} = vR_{charge} + \omega S_{gov} - \sigma C_{pinst} - \pi C_{maint} - \vartheta S_{stab}$$

Where R_{charge} represents the revenue from providing fast charging services, S_{gov} government subsidies for installing photovoltaic systems, C_{pinst} installation costs of the charging infrastructure, C_{maint} maintenance costs, S_{stab} and costs related to the impact on grid stability.

Lastly, we consider the EV Owners. Their primary objectives are to minimize charging costs, ensure the availability of charging stations, and reduce range anxiety. EV Owners are faced with the decision of choosing between different types of charging stations, which offer varying trade-offs between cost and charging speed. While some EV Owners may prioritize lower costs and opt for slower charging at On-Grid Charging Stations with Virtual Storage. For the PVS, although they bear the cost of virtual storage, P_{strg} , this cost is offset by the benefits of increased stability and reliability, S_{stab} which enhance their operational efficiency and attractiveness to customers.

This structured analysis highlights the importance of coordinated policies and practices in achieving optimal outcomes for integrating prosumer models into the energy system. By identifying Nash Equilibria and Pareto Optimal outcomes, policymakers can design strategies that promote cooperation and maximize public welfare.

Conclusion

This paper presents a study of possible operational types of charging stations fully or partly powered by RES and being positioned for integration into the EDS and energy market of Montenegro. The charging stations' autonomous ownerships formulate them are prosumers. As such they pose various technical, economic, regulatory challenges in becoming parts of the energy system, transport infrastructure, and energy market within the country. The three proposed prosumer models currently would not have a decisive effect on the successful electrification of transportation. However, if conventional sources of electricity are gradually replaced with alternative "green" production capacities, there is an immediate need to plan and define new energy generation models, engage citizens, and enforce new economic models for their integration. Then, combinations of these three prosumer models in the correct proportion can relieve the EDS, reduce the highly financially demanding investments in the EDS, and provide enough electricity for all EVs. We will further look into how prosumer model selection is incentivized by price, thus enabling successful redistribution and precise management of energy and power.

(PVS), others may prioritize speed and convenience, opting for faster charging at Conventional On-Grid Charging Stations (OCS) despite higher costs.

The EV Owners' strategy involves balancing these factors to optimize their overall utility. Their utility function can be formulated as follows:

$$U_{ev} = \mu B_{choice} - \nu C_{charge} - \xi R_{anxiety} + \tau S_{gov}$$

Where B_{choice} denotes the benefit derived from having multiple charging options, C_{charge} cost of charging, which varies based on the type of charging station chosen, $R_{anxiety}$ range anxiety and S_{gov} government subsidies EV driver receive for purchasing of EVs, which is influenced by the vicinity of charging stations.

By modelling the cooperation and non-cooperation between the State/Regulator and EPCG, we can analyze the effects on the utilities of PVS, OCS, and EV Owners. This approach demonstrates how cooperative behavior can lead to improved outcomes for all stakeholders by enhancing stability, reducing costs to EV drivers, and increasing overall welfare.

In the cooperative scenario (CC), the State/Regulator provides subsidies, EPCG purchases surplus energy from regular prosumers, and provides virtual storage. Although the State/Regulator incurs a cost represented by S_{gov} , this cost is justified because $\tau S_{gov} < \alpha W_{soc}$, indicating that the welfare gain for society outweighs the cost of subsidies.

For the PVS, the installation cost C_{pinst} is effectively reduced by the subsidy S_{gov} , making it more competitive in the market. This reduction in initial costs allows PVS to offer lower prices for charging, attracting more customers. Additionally, EV owners benefit from reduced costs when purchasing vehicles, thanks to the subsidy τS_{gov} , and they also enjoy lower prices for charging from PVS while still having the option of fast charging from OCS.

When EPCG cooperates, they incur the cost of purchasing surplus energy, C_{buy} , but this cost is mitigated by the premium P_{strg} , they receive for providing virtual storage. Furthermore, the overall benefit of improved grid stability, C_{stab} , adds to their utility, making cooperation advantageous.

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Non-detonating chemical mixture for non-invasive methods of rock breaking

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Abstract: Within the Innovation Project of the Ministry of Science and Technological Development of the Republic of Serbia, researchers of Blasting Center at the University of Belgrade - Faculty of Mining and Geology have developed several different non-detonating chemical mixtures for non-invasive methods of rock breaking. Laboratory and polygon tests gave the satisfactory results and knowledge enough to start the practical experiments in the field. The basis of this innovation is a theoretical assumption that certain chemical mixtures release a large quantity of gases during combustion. If these gases are found in the enclosed space a growing pressure on the walls of the chamber in which combustion takes place will be resulted. If this space is a borehole with good stemming, the rising pressure should be sufficient to break the rock material in which the borehole was drilled. Chemical mixtures developed through the research do not detonate. They represent the generators of borehole pressure made up of oxidants and fuels and the modifiers to adjust the speed of combustion and ignition temperatures. Rock breaking occurs because of progressive increase in pressure. Non-detonating chemical mixtures can be applied in road and railroad construction, demolition works, secondary breaking, rock breaking for foundation, trenching and similar civil construction operations especially in urban areas as well as quarrying of dimension stones. In other words, for different methods of rock breaking where negative effects of blasting should be avoided.

Keywords: NON-DETONATING, CHEMICAL MIXTURE, ROCK BREAKING, BOREHOLE PRESSURE

1. Introduction

Regarding the method of decomposition, except for black powder, which is classified as deflagrating explosive, all commercial explosives are decomposed by detonation. Deflagrating explosives have a relatively low decomposition rate because the activation energy is transferred from layer to layer by heat transfer. Detonation is the process of explosive decomposition, where the energy required to activate the explosive molecules is transferred from layer to layer by means of a shock wave, which moves through the explosive material at supersonic speed. During the detonation of explosives, there is a sudden release of energy, which is partly spent on breakage the rock mass, moving the broken rock, heating the immediate rock environment and on other useless effects of explosive energy such as seismic waves. The energy of seismic waves induced by blasting manifests itself in the form of ground vibration. Another negative effect of every blast are: air blast, toxic fumes, and flyrock. For this reason, it is necessary to strictly define safety zones to protect the immediate surroundings of the blast field from these negative effects when planning blasting especially in urban areas [1].

During the construction of buildings in urban areas, in some cases there is a need to remove large quantities of solid rock mass that cannot be excavated by machinery. For smaller quantities, the problem can be solved by hydraulic jackhammers mounted on the excavator. However, when larger volumes of rock mass are involved, the use of explosives is necessary.

In cases where there are facilities declared as cultural heritage, industrial and other objects that are very sensitive to ground vibration, blasting using commercial explosives may be prohibited. Despite this, the need to remove a certain solid rock mass still exists.

During building demolition in urban areas, certain parts of the structures, which are usually concrete or reinforced concrete, are blasted. In that case, the problem of negative effects of blasting is even more pronounced, so the procedure and calculation are even more complex [2].

The use of explosives is limited during the extraction of dimension stone blocks. Contour blasting methods using small-diameter explosive charges or a detonating cord are most often used to cut off primary blocks from the remaining rock mass. The parameters of contour blasting must be strictly defined so that the explosive energy would be used only for cutting the block and not for crushing the rock mass. The procedure is similar when the primary block is split into commercial blocks.

During production blasting in surface mines, depending on the quality of the blasting, the blasted rock mass may contain a smaller

or larger percentage of oversized fragments of rock mass called boulders that must be subsequently crushed. A high percentage of boulders worsens the technical and economic indicators of surface mining, reduces the performance of loading and transport machinery, and increases the unit cost of the product.

The tendency in the world today is to find new solutions that can be applied to break solid rock masses, and which will be an adequate replacement for commercial explosives in sensitive areas. The reason for this is the problems related to blasting in urban areas, in road and railroad construction, demolition works, secondary breaking, rock breakage for foundation, trenching, stabilization of slopes and similar civil construction operations especially in urban areas as well as quarrying of dimension stones. In all the cases mentioned, there is a problem of removing solid rock mass or concrete structures in an efficient way, while protecting the environment. Except where prohibited or restricted, blasting remains the cheapest method of efficiently removing large volumes of solid rock mass. However, the problem of the negative effects of blasting remains.

The negative effects of blasting have influenced the researchers to work on improving new chemical mixtures that could be an adequate replacement for explosives. These are mainly different compositions that develop borehole pressure without the detonation process and which are placed in a previously drilled series of boreholes (in a case of the extraction of primary blocks of dimension stone, splitting the primary block of dimension stone into commercial blocks as well as cutting off a rock mass during slope stabilization as a substitute for contour blasting methods) or according to a pre-calculated pattern of bore holes (in a case of the building demolition, secondary breaking, rock breakage for foundation, trenching and similar civil construction operations especially in urban areas, etc.). When the stress overcomes the tensile strength of the rock, cracks appear along the predisposed direction and the rock is broken.

One of the mixtures that are used as a substitute for explosives for the generation of borehole pressure is expansive mortar. Expansive mortars do not detonate. Although there are several well-known manufacturers of expansive mortars, they are mostly chemical agents with similar characteristics. The expansive mortars are mixed with water in a certain ratio according to the recommendation of the manufacturer. When the mixture is obtained, it is poured into the boreholes. Expansive mortar in the boreholes expands, developing a pressure force in the range of 7-8 kN/cm², which is much more than the required force for splitting the rock mass. The speed of expansion directly depends on the temperature of the rock mass.

Expansive mortars have the following advantages: the rock mass splitting process takes place without detonation and

explosions. Rock splitting is done without noise, dust, and toxic fumes. Expansive mixtures do not cause ground vibration, flyrock and excessive damage to the surrounding rock mass. They are clean ecological products and very acceptable from an environmental point of view. Storage and transport are not dangerous for the environment.

One of the well-known expansive mortars on the market is DEXPAN [3]. DEXPAN is used for controlled demolition of buildings, especially in urban areas, minor construction works, such as trenching and the extraction of blocks of dimension stone: granite, marble, limestone, and onyx. DEXPAN [3] is a mixture of powdery consistency which, expanding inside the boreholes, develops a pressure of 1241 bar, enabling the cutting the dimension stone blocks safely, without noise, vibration, and dust. Handling the DEXPAN mixture does not require special permits and certificates, as is the case with explosives, does not require the employment of a specially trained operator, as well as special regulations for safe storage, transport, and maintenance, because it is not categorized like explosive.

Cardox [4] non-detonating expansive system is another alternative to classic explosives. The Cardox system [4] has several different tubes for specific applications. The tubes are filled with liquid carbon dioxide (the same as a fire extinguisher). After activating the chemical heater with a small electrical charge, liquid carbon dioxide is converted into gas. This conversion expands the volume of CO₂ and increases the pressure inside the tube until it causes the disc at the end of the tube to burst. Then the release of CO₂ occurs - now 660 times greater than the original volume - through a special discharge nozzle, which creates a force, at pressures of up to 3000 bar. The whole process takes place in milliseconds. Since it does not detonate, the Cardox system is suitable for use in sensitive areas, for controlled demolition of reinforced concrete, tunneling, shafts, and underwater demolition. It does not create air blast, vibrations, dust, or harmful gases, so it is suitable for use in urban areas and in populated areas where blasting by conventional methods is prohibited. The Cardox system is also widely used for the exploitation of ore, as well as dimension stone blocks [5].

Within the Innovation Project of the Ministry of Science and Technological Development of the Republic of Serbia [6], researchers of Blasting Center at the University of Belgrade - Faculty of Mining and Geology have developed several different non-detonating chemical mixtures for non-invasive methods of rock breaking. Chemical mixtures do not detonate. They represent the generators of borehole pressure made up of oxidants and fuels and the modifiers to adjust the speed of combustion and ignition temperatures. The gases increase the borehole pressure and cause stresses that should overcome the tensile strength of the rock and cause rock breaking. The laboratory and field tests were consistent with research of foreign Companies that dealing with this problem for several years.

2. The characteristics of developed non-detonating chemical mixtures

The basis of this innovation is a theoretical assumption that certain chemical mixtures release a large quantity of gases during combustion. If these gases are found in the enclosed space a growing pressure on the walls of the chamber in which combustion takes place will result. If this space is a borehole with good stemming, the rising pressure should be sufficient to break the rock material in which the borehole was drilled. Chemical mixtures developed through the research do not detonate. They represent the generators of borehole pressure made up of oxidants and fuels and the modifiers to adjust the speed of combustion and ignition temperatures. Rock breaking occurs because of a progressive increase in pressure [2,6].

Developed non-detonating chemical mixtures are pyrotechnic compositions whose energy potential is lower than that of black

powder. The process of developing the non-detonating chemical mixtures has started from the concept that new compositions should have the characteristics of „benumbed“ black powder in order to keep the rate of decomposition by deflagration even in the conditions of confined charging [2,6].

These generators of borehole pressure represent a wide range of mixtures made up of oxidants and fuels containing modifiers to adjust the speed of combustion and ignition temperatures. Compositions combust during the activation on the open with the speed of 2-5 cm/s, while in the closed space a significant acceleration of combustion is taking place, but still below the explosive one. Thereby it comes to a sudden jump in pressure, leading to an increase in combustion rate in such a way that there are at least two decomposition rates until the final decomposition of the mixture. All compositions have powdery consistency with the cartridge bulk density of 0.85 to 1.1 kg/dm³. Commercial explosives detonate at a speed of 2000-6000 m/s, while the decomposition velocity of these mixtures should be set at 180 - 300 m/s. Combustion rate is lower than of black powder and conventional fuels [2,6].

Gas pressure grows exponentially during the several tens of milliseconds until they overcome the rock tensile strength, which is 10-20% of the compressive strength of rocks. Depending on the composition of the mixture it is possible to achieve borehole pressures at the initial speed of decomposition of 34, 68, 102 and 136 MPa when it comes to jump of combustion rate in the function of lnP, which gives a new pressure jump before the final decomposition of the mixture. Thus, mixture achieves at least two speeds in the combustion process. Gas pressure of powdered redox mixtures is aimed primarily at the bottom part of the borehole. Powdered redox compositions for this purpose after ignition burn at the subsonic speed, even at higher pressure up to 276 bar, while with the use of explosives a supersonic shock wave is created at normal atmospheric pressure.

2.1 The modifiers

In these compositions a decomposition rate and pressures of released gases in the borehole can be controlled to achieve stresses in rock mass slightly greater than the rock tensile strength. All this can be achieved by modifying the basic redox composition.

These modifiers are combustion catalysts such as metal oxides and organometallic compounds. Compounds that promote the reaction rate and the amount of released gases are also in use, because they also participate in the creation of gaseous products and thus increase the gas volume of mixtures. Besides these compounds, substances that contribute to the release of heat may also be used, although they do not release gaseous products alone. The released heat helps the reaction rate at which emission of gases occurs and affects the increase in pressure because with the heat the volume of released gases increases, too. For this purpose, various metal powders can be used such as: Al, Mg, FeSi, paying special attention to safety in the work [2,6].

2.2 Charging the cartridges with non-detonating chemical mixtures

The best effects are achieved by direct loading of boreholes with non-detonating chemical mixtures but it is often impossible in real conditions of application, so it is provided that the mixture is transported in form of cartridges. The cartridge should be made of flexible plastic material in order not to relieve until the reactive mixture is completely deflagrated after initiation. The possibility of deformation of 10 - 20% of cartridge is preferred before it bursts, and the diameter of the cartridge should be as close to the diameter of drilled hole.

Elasticity of the cartridge is achieved by choosing the material that can withstand plastic deformation, at least until the expansion of the cartridge on the borehole wall. In the case that the diameter of the cartridge is 30 to 33 mm, plastic cartridge in the radial direction

should withstand the increase of the diameter on 35 to 38 mm before it expands.

During the research cartridges of high-density polyethylene, with the outer diameter of 25 mm, inner of 20 mm, wall thickness 2.5 mm and length 150 mm were used. Different types of mixtures were examined in terms of composition, powdered consistency, combustion time, the degree of coat deformation. For the initiation of the mixtures, various systems that were available were applied. At the same time, several redox compositions with increased density, using a natural binder for thickening the mixtures were also made and tested [2,6].

Stemming the bore holes was carried out with well compressed mixed clay - sandy material. It must be taken that stemming is not burden in the geometry but should be for a minimum of 50% higher than burden and the distance between bore holes. To determine the parameters of blasting the same amount of non-detonating chemical mixture per m^3 is recommended as in the case with conventional explosives 290-600 g/m^3 . Stemming must be well done to withstand the pressure of released gases and direct them to the walls of the bore holes, where there is a breaking of the rock material due to tension stresses. In this case, the detonation does not occur as well as the formation of shock waves as in case during the use of commercial explosives.



Fig. 1 Charging the cartridges with non-detonating chemical mixture [2,6]



Fig. 2 Cartridges charged with non-detonating chemical mixture [2,6]

2.3 Initiation of the non-detonating chemical mixtures

Initiation of non-detonating chemical mixtures was done with electrical fuse heads or NONEL shock tubes. Figure 3 shows preparing the initiation of cartridge with NONEL shock tube while Figure 4 shows preparing the initiation of cartridge with electrical fuse head.

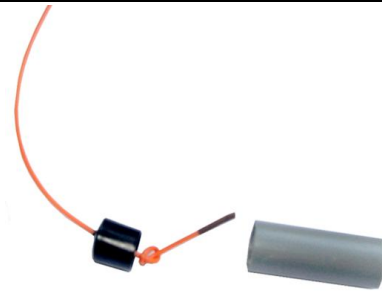


Fig. 3 The initiation of cartridge with NONEL shock tube [2,6]

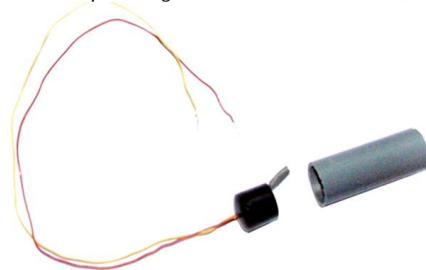


Fig. 4 The initiation of cartridge with electrical fuse head [2,6]

Non-detonating chemical mixture had different sensitivity to the initial impulse. Most sensitive are ignited with spark generated in standard NONEL shock tube (20 mg/m reactive mixture) while those less sensitive required a stronger initial impulse.

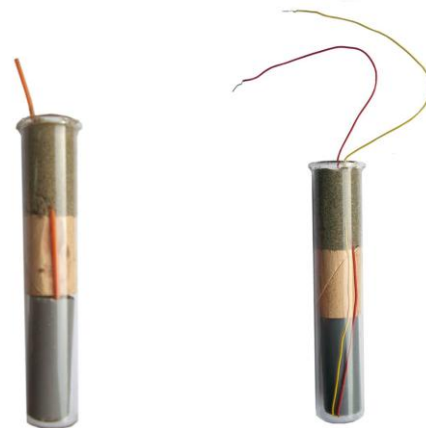


Fig. 5 Initiation of charges of non-detonating chemical mixtures with NONEL shock tube (left) and electrical fuse head (right) [2,6]

2.4 Polygon tests of non-detonating chemical mixture

Polygon tests of non-detonating chemical mixtures were carried out at the granite quarry. The tests consisted of cutting off a granite block using non-detonating chemical mixtures. A borehole with a diameter of 32 mm was drilled into the granite block, in which the cartridge with a diameter of 25 mm was placed. The cartridge was charged with a non-detonating chemical mixture. Initiation of the charge of non-detonating chemical mixture was done with an electrical fuse head [2,6].

The results of testing are satisfactory. As shown in Figure 6, cutting of the granite block was achieved by increasing the pressure of the gases produced by the combustion of non-detonating chemical mixture. The pressure of released gases in the borehole creates stresses in the rock mass slightly higher than the rock tensile strength, which is 10-20% of compressive strength and causes rock breaking without a shock wave.

After the fracture of rock mass, the stress decreases due to a sudden drop in the pressure of generated gases, thus avoiding excessive flyrock of rock pieces. As shown in Figure 6, after the fracture of rock mass, gaseous products of the combustion of non-

detonating chemical mixture exit through the newly formed cracks, which causes the pressure of gases to decrease intensely, and the gas mixture begins to decompose by burning. The results of polygon tests of non-detonating chemical mixture are shown in Figure 6.



Fig. 6 The results of polygon test of non-detonating chemical mixture [2,6]

3. Application of non-detonating chemical mixture

Non-detonating chemical mixture as borehole pressure generators, can be widely used as a replacement for commercial explosives when it is necessary to break the rock or concrete structures non-invasively, in sensitive and urban areas, such as:

- road and railroad construction,
- demolition works,
- secondary breaking,
- rock breakage for foundation,
- trenching,
- stabilization of slopes and similar civil construction operations especially in urban areas,
- quarrying of dimension stones block etc.

The main difference between the effects of explosives and non-detonating chemical mixtures is that in the case of non-detonating chemical mixture the energy is transferred to the rock mass by increasing the pressure of released gases without shock waves. In just a few milliseconds gas pressure exceeds the tension strength of rocks and splits or breaks the rock depending on the non-invasive method of rock breaking. Stress waves rapidly decrease after rock breaking which is of great importance for the reduction of ground vibration, flyrock and possible damage of the surrounding rock mass.

Ground vibration is many times less than that caused by commercial explosives, and safety zone against flyrock does not exceed 30-35m. The air overpressure is 6-10 times lower than during blasting using explosives. An essential condition for successful application of non-detonating chemical mixture is that the cartridge must fit well with the wall of the borehole, because the smallest gap affects the reduction of the effect due to drop of the released gas pressure. Cartridge should have such a diameter that can be inserted into the bore hole without compression, and at the same time the gap between the cartridge and the borehole wall should be as small as possible.

4. Conclusion

After completion of laboratory and polygon testing, the basis for successful IN SITU implementation of non-detonating chemical mixture was created. The final adjustment of compositions remains, in terms of the optimization of charging and initiation pattern in specific types of rock regarding the type of non-invasive methods of rock breaking.

The best results are achieved if non-detonating chemical mixture is used in compact rock mass, because in bore holes with intensive system of joints, there are two reasons for the reduction of effect of non-detonating chemical mixture [2,6]:

1. expiration of products of decomposition through joints and thereby the inability of directing the released energy,
2. inability to create the optimal pressure and force necessary to break the rock because of conditions in which the reaction itself takes place.

For these reasons, the retention of the released gases in the cartridge is a necessary precondition for effective application of these mixtures until obtaining the optimum pressure.

Further research is moving towards finding adequate rates of decomposition of non-detonating chemical mixtures, achieving optimal bore hole pressures with the absence of detonation, controlling ground vibration, toxic fumes, flyrock, etc. A special problem is the precision of the initiation of non-detonating chemical mixtures, which is required, for example, when cutting the rock material.

5. Acknowledgement

The authors of the Paper express special gratitude to the late Prof. DSc Dragan Petrović, who made a major contribution to the development of a new type of non-detonating chemical mixture.

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The effect of applying a conversion layer by phosphating on the roughness relief of the steel surface

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Abstract: The contribution is focused on the analysis of the surface roughness after applying the conversion layer using phosphating. In the experiment, uncoated deep-drawn steel DC 04 was used as the base material. During the application of the conversion layer, changes in surface roughness were studied with respect to the phosphating time, which was 3, 5 and 10 minutes. The achieved results provide information for other technological operations such as creating joints by gluing, where the correct anchoring of the glue is important for sufficient adhesion to the surface.

Keywords: STEEL SURFACE, PHOSPHATING, ROUGHNESS, CONVERSION LAYER

1. Introduction

The protection of metal products against environmental influences can be ensured in various ways, from the most common of which are material selection, corrosive environment treatment and the use of protective coatings.

Material selection is the simplest method. However, this requires a deep, comprehensive knowledge of materials and the relationship between the material and the specific corrosive environment. In addition to technical suitability, the proposed material should also demonstrate the economic viability of the choice.

Corrosive environment treatment is often used in the field of temporary protection of products in storage and transport. Protective coatings are mainly used in the protection of carbon steels against atmospheric influences. These include organic coatings (coatings), metal coatings (zinc, aluminium and alloy) and combination coatings (metal coating combined with coating). In the field of corrosion protection of surfaces of engineering products, bridges and steel structures, the application of coatings and coatings is the dominant method of surface treatment. [1-7]

In anti-corrosion protection of cars, the method of protection with metal coatings is very widespread. An important criterion for these coatings is the thickness of the film and its porosity. The service life of the coating increases with its thickness and at the same time the number of corrosion-significant pores decreases. If we achieve a non-porous coating, the anti-corrosion protection of the coating is then equal to the resistance of the metal that was used for the coating.

The work deals with surface treatment of metal materials by conversion coatings, more precisely by phosphating. This is a widespread method in technical practice, mainly in the automotive industry, due to its wide applicability given the current availability and reliability of coatings. Phosphate layers are applied to metals to improve corrosion resistance due to their relatively high electrical resistance. Their other role is to support the adhesion of organic coatings or other adhesives. The conversion coating has the ability to adhere excellently to the treated metal and resists solubility in water or other solvents. Subsequently applied coatings are characterized by excellent adhesion to the material.

In general, three types of phosphating can be applied, iron, zinc and manganese. The uniqueness of these species is characterized by the crystals that form in each of them. Manganese phosphating is generally considered to be highly resistant in corrosion protection. Iron phosphating is more stable than zinc phosphating at higher pressures and temperatures. [8-12]

The paper deals with zinc phosphating applied to uncoated deep-drawn steel with different applied phosphating times. The latter causes changes on the surface of the material, which are also manifested by changes in roughness.

2. Materials and methods

2.1 Used basic material

DC04 steel (designation of samples DC) is an uncoated deep-drawn steel, particularly suitable for demanding external and internal parts in car bodies, or for other extrusions. The chemical composition of the materials is in Table 1.

Table 1: Chemical composition of used steel DC

Material	C	Mn	P	S
DC	0,04%	0,25%	0,01%	0,01%

2.2 Pre-treatment of the surface

The surface of the test samples of DC steels was without any surface treatments. The tested samples of both materials were classified into two categories:

- Surfaces without further treatment – a steel sample is used for testing in the state in which it was delivered from the manufacturer. The sheet surface was preserved by electrostatic oiling with an intensity of 0,5 – 2,5 g.m⁻², which protects it from corrosion.
- Surfaces with the addition of a conversion layer of zinc phosphate - during the phosphating process, small crystals form on the surface of the material, creating a phosphate layer that serves as protection against corrosion or as a base layer to improve adhesion when applying additional layers and when gluing.

A total of 4 types of samples were used for the experiment. Samples DC 0 were samples, the surface of which was not treated with a zinc phosphate conversion layer. The other samples used in the experiment were treated with a layer of zinc phosphate with different immersion times of the sample in the phosphating bath, namely 3, 5 and 10 minutes.

For the phosphating of the samples, the technology of phosphating with Pragofos, manufactured by Pragochema s.r.o., applied by immersion, was used. Before applying the phosphate layer after the application of the degreaser Pragolod 57 N, the rinse in the bath was diluted with the activating rinse Pragofos 1007 at a concentration of 0,3% at room temperature with a mixing time of 3 minutes. DC type steel samples were subsequently phosphated in a Pragofos 1501 bath at a temperature of 60°C for 3, 5 and 10 minutes.

2.3 Roughness measurement methodology

Surface roughness of the produced samples was evaluated according to ISO 21920 by the contact method using a stylus profilometer SurfTest SJ-201, Mitutoyo, Tokyo, Japan. This standard defines roughness parameters based on the deviation from

the mean line for the primary profile. The measurement parameters used were as follows:

- a measured profile: R,
- a filter: GAUSS,
- a sampling length $\lambda_c = 0,8$ mm,
- a number of sampling lengths $N = 5$,
- an evaluation length $l_n = 4$ mm,

In order to obtain as much information as possible about the produced surfaces in individual positions, the surface roughness was evaluated using a set of several parameters:

- the arithmetical mean deviation of the assessed profile (Ra),
- the maximum height of profile on the basic length (Rz),
- the mean width of the profile element on the sampling length (RSm),
- the mean number of peaks per centimeter (R_{Pc}),

2.4 Methodology of statistical analysis of surface microgeometry

The measured data were subjected to the statistical analysis using Statistica software using a non-parametric Kruskal - Wallis test. The Kruskal - Wallis nonparametric test was used to compare positions on the building platform for each roughness parameter evaluated. The test that compares more than two groups, whether population comes from the same distribution.

3. Results

By measuring the selected roughness parameters on the DC material, the values shown in Table 2 were achieved.

Table 2. The mean and standard deviation of roughness parameters

Sample	Measured values of roughness parameters			
	Ra [μm]	Rz [μm]	R _{Pc} [1/mm]	RSm [μm]
DC 0	1,04 ± 0,10	5,43 ± 0,49	44,78 ± 7,80	230 ± 39
DC 3	1,05 ± 0,11	5,28 ± 0,37	47,17 ± 6,72	216 ± 34
DC 5	1,00 ± 0,12	5,35 ± 0,47	47,54 ± 9,87	218 ± 41
DC 10	0,96 ± 0,10	5,21 ± 0,57	56,57 ± 12,85	186 ± 46

In the attached profilograms of individual surfaces of materials Fig. 1a – Fig. 1d we recorded a change in the surface roughness of tested materials.

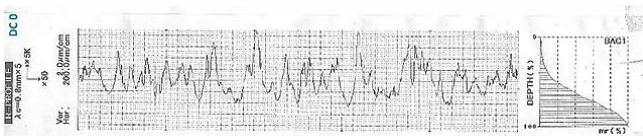


Fig. 1a Profilogram + Firest-Abbot curve for the sample DC 0

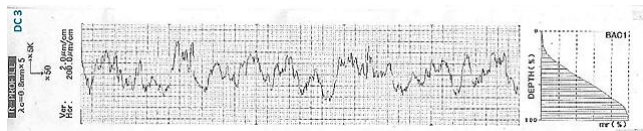


Fig. 1b Profilogram + Firest-Abbot curve for the sample DC 3



Fig. 1c Profilogram + Firest-Abbot curve for the sample DC 5

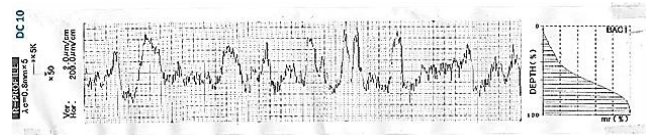


Fig. 1d Profilogram + Firest-Abbot curve for the sample DC 10

From the measured values of the roughness parameter Ra, it can be concluded that it is relatively stable on the base material as well as on the applied pretreatments.

Differences were noted in R_{Sm} and R_{Pc} parameters. Zinc phosphate consists of multiple crystals of insoluble phosphates, which gained their size on the surface during the application of the phosphating process, thereby achieving an increase in the density of the projections. If there is an increase in the density of protrusions per cm of length, it means that there is a prerequisite for an increase in the contact area between the treated surfaces, which is advantageous in the case of using such surfaces to create adhesive joints.

The average density of protrusions of the R_{Pc} surface increased the most in the DC material pretreated with zinc phosphate compared to the original surface of the material at a phosphating time of 10 min. Compared to a process lasting 5 min. this difference is relatively small (9 protrusions per cm⁻¹) and therefore it is possible to recommend the application of a phosphate layer on the surface for 5 minutes with the DC material. Applying this conversion layer for a period of 10 (with a minimal difference in the number of protrusions compared to 5 min.) is neither suitable (higher operating costs) nor efficient from the point of view of the economy of the process.

SEM appearance of the base material and pretreatment samples are in Fig. 2.

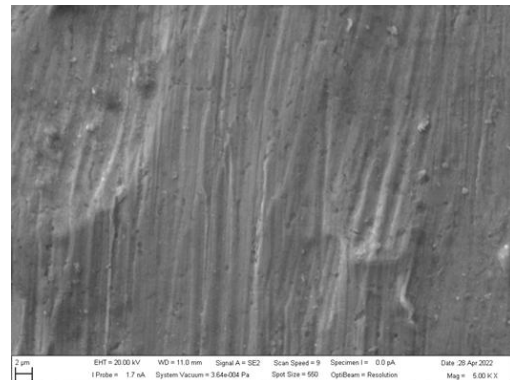


Fig. 2a DC 0 sample surface

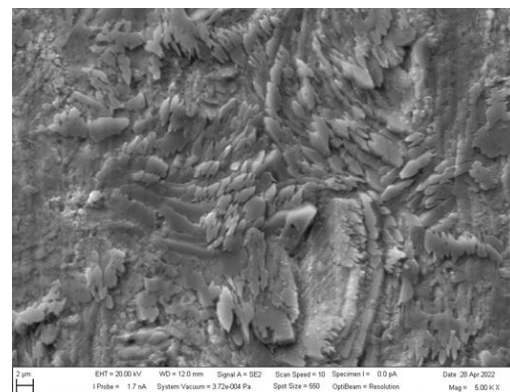


Fig. 2b DC 3 sample surface

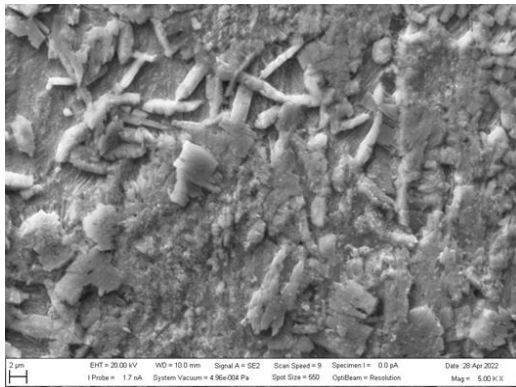


Fig. 2c DC 5 sample surface

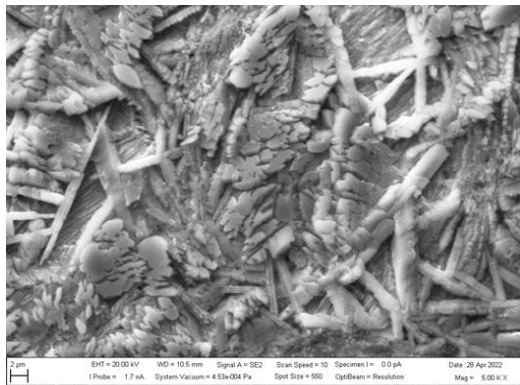


Fig. 2d DC 10 sample surface

Results of statistical evaluation for parameter Ra

The homogeneity condition for the Ra parameter values at different phosphating application times was verified by Levene's test. The value of p was as follows: DC (p = 0.5682 > 0.05) and this means that the null hypothesis of equality of variances is not rejected at the significance level of 0.05. The condition of homogeneity is fulfilled. A graphical comparison of the phosphating time for the parameter Ra is in Fig. 2.

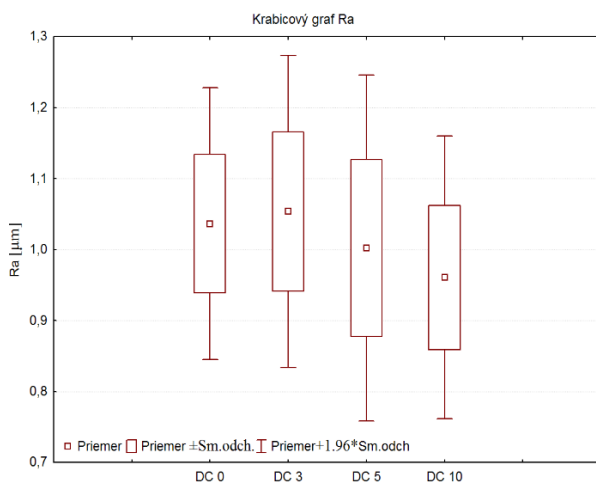


Fig. 2 Comparison of phosphating time for parameter Ra

The result of the one-factor variance analysis is $0.0011 < 0.05$, i.e. the null hypothesis is rejected at the level of significance, i.e. there is a statistically significant difference between the individual mean values of the Ra parameter at different phosphating times.

This means that the time of phosphating has an influence on the value of the Ra parameter.

Given that the null hypothesis of equality of means was rejected at the 0.05 significance level, post-hoc analysis subsequently identified pairs with a statistically significant difference (Table 3). Statistically significant differences were noted between groups DC 0 - DC 10, DC 3 - DC 10.

Table 3. Post-hoc analysis – parameter Ra

Ra - DC	Tukey HSD test			
	DC 0	DC 3	DC 5	DC 10
DC 0	-	0,8936	0,4991	0,0106
DC 3	0,8936	-	0,1501	0,0008
DC 5	0,4991	0,1501	-	0,326
DC 10	0,0106	0,0008	0,326	-

4. Conclusions

Based on the experimental measurements, it can be concluded that:

- using different application times when applying a phosphate conversion layer on uncoated deep-drawn steel creates a surface with a different appearance and different roughness values

- measurements of the roughness parameters at all applied times showed that the value of the parameters Ra and Rz after surface treatment by phosphating does not change significantly, the differences were manifested in the parameters RSm and R_{Pc}.

- the statistical evaluation showed that the phosphating time has a slight effect on the value of the Ra parameter.

Acknowledgement

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Exergy analysis of a two-cylinder steam turbine from combined cycle power plant at three operating regimes

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Abstract: This paper presents an exergy analysis of a two-cylinder low power steam turbine from combined cycle power plant at three operating regimes. The highest mechanical power produced in the whole turbine is 6807.24 kW in Operating regime 1. Cylinders of the observed turbine did not have the same operation dynamics in relation to produced mechanical power in all operating regimes. In each operating regime High Pressure Cylinder (HPC) has lower exergy destruction and higher exergy efficiency in comparison to Low Pressure Cylinder (LPC) due to the influence of wet steam which expands through the last LPC stages (water droplets in wet steam increases LPC exergy destruction and decreases LPC exergy efficiency). Whole turbine exergy efficiency is between 51.62% (in Operating regime 2) and 64.98% (in Operating regime 1). This range of exergy efficiencies can be expected for a low power steam turbine. An increase in the ambient temperature decreases exergy efficiency of the whole turbine and both turbine cylinders, regardless of the observed operating regime. The exergy efficiency of the LPC is low in all operating regimes, so any improvements should be based on this cylinder first.

KEYWORDS: EXERGY ANALYSIS, TWO-CYLINDER STEAM TURBINE, COMBINED CYCLE POWER PLANT, VARIOUS OPERATING REGIMES

1. Introduction

Steam turbines are nowadays constituent components of many power plants worldwide: conventional [1], nuclear [2, 3], cogeneration [4], marine [5, 6] and various others. In addition, steam turbines can also be found in the combined cycle power plants where steam is produced by using combustion gases from gas turbine or more of them [7, 8]. Utilizing heat from gas turbine(s) combustion gases in combined cycle power plants results in very high plant overall efficiency [9].

Medium and high power steam turbines are composed of several cylinders [10, 11], while low power steam turbines can also be composed of one cylinder only [12, 13]. Each turbine cylinder is usually composed of several turbine stages [14]. Steam turbine cylinders can be single flow and dual flow cylinders, while dual flow cylinders can be symmetrical and dissymmetrical [15-17].

In this paper is analyzed, from the exergy viewpoint, a two-cylinder low power steam turbine which operates in a combined cycle power plant. Whole turbine and both of her cylinders are analyzed in three operating regimes. It should be highlighted that for the observed low power steam turbine and her cylinders can be expected much lower exergy efficiencies in comparison to medium and high power steam turbines [18]. According to the obtained exergy analysis results, it will be presented guidelines for possible improvement of the observed turbine and her cylinders.

2. Description and operating characteristics of the analyzed steam turbine and her cylinders

The analyzed steam turbine is a constituent component of a combined cycle power plant [19]. General scheme of the observed steam turbine, along with operating points required for the exergy analysis at all loads are presented in Fig. 1.

The observed steam turbine is composed of two cylinders: High Pressure Cylinder (HPC) and Low Pressure Cylinder (LPC) connected to the same shaft which drives an Electric Generator (EG). HPC get steam from Heat Recovery Steam Generator (HRSG). The whole steam mass flow rate from HRSG expands through HPC (which means that HPC did not possess any steam extraction). A certain steam mass flow rate is taken between turbine cylinders and delivered to Deaerator (operating point 3, Fig. 1). As can be seen from Fig. 1, analyzed steam turbine did not possess steam re-heater between cylinders [20]. Whole steam mass flow rate which enters in the LPC (operating point 4, Fig. 1) expands through it, which means that also LPC did not possess any steam extraction). After LPC, the remaining steam mass flow rate is delivered to the Main condenser for condensation. Both cylinders of the analyzed steam turbine are single flow cylinders which means that steam expands in one direction from the cylinder inlet until the cylinder outlet.

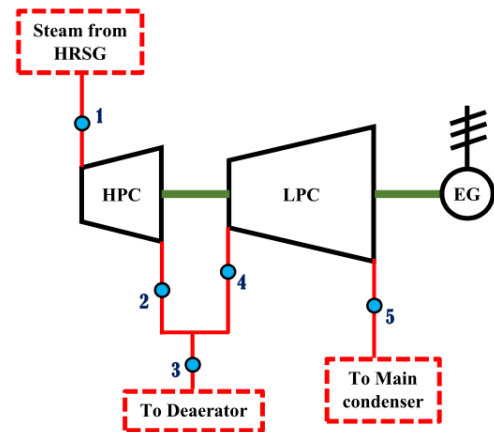


Fig. 1. General scheme of the analyzed steam turbine along with operating points necessary for the exergy analysis

Unlike isentropic analysis [21], exergy analysis of any steam turbine and her cylinders is based on the real (polytropic) steam expansion process only (along with fluid exergy flows at each cylinder inlet, outlet and in steam extractions if the extractions exist). Real (polytropic) steam expansion process through both cylinders of the analyzed turbine is presented in Fig. 2. General steam expansion process presented in Fig. 2 is valid for all three observed steam turbine operating regimes.

Fig. 2 shows that HPC operates by using superheated steam only, while the LPC partially operates by using superheated steam and partially by using wet steam (wet steam operation is evident at the last few LPC stages, under the saturation line). The operating points of real (polytropic) steam expansion process presented in Fig. 2 are marked in accordance to operating points from Fig. 1.

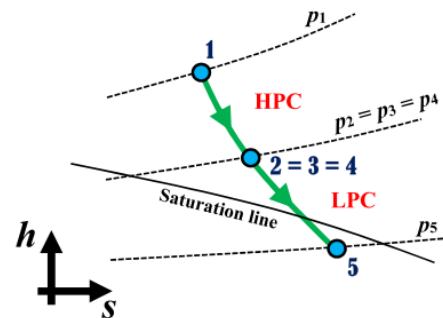


Fig. 2. Specific enthalpy/specific entropy (h/s) diagram of real (polytropic) steam expansion process throughout the analyzed turbine

3. Equations for the exergy analysis

Unlike isentropic or energy analyses, exergy analysis takes into consideration the parameters of the ambient (ambient pressure and temperature) in which observed component and component parts operate [22]. Exergy analysis enables change in the ambient parameters (especially the change in the ambient temperature) to observe the influence of such change on component and component parts exergy destructions and efficiencies [23]. Therefore, in any exergy analysis the base ambient state must be defined.

3.1. Overall exergy equations and balances

The overall exergy balance equation for any component (or component part) at steady state is [24]:

$$\dot{X} - P = \sum \dot{E}x_{out} - \sum \dot{E}x_{in} + \dot{E}x_D. \quad (1)$$

In the above overall exergy balance equation, P is real (polytropic) mechanical power, index in denotes input (inlet), index out denotes output (outlet) and index D denotes destruction. $\dot{E}x$ is a fluid total exergy flow which can be defined by the equation [25]:

$$\dot{E}x = \dot{m} \cdot \varepsilon, \quad (2)$$

while the exergy transfer by heat at the temperature T ($\dot{X}$) is defined by the equation [25]:

$$\dot{X} = \sum (1 - \frac{T_0}{T}) \cdot \dot{Q}. \quad (3)$$

In the above two equations (Eq. 2 and Eq. 3), T is a temperature, $\dot{Q}$ is the energy transfer by heat, $\dot{m}$ is fluid mass flow rate, index 0 denotes the base ambient state, while ε is fluid specific exergy which is defined, according to the literature [26], by an equation:

$$\varepsilon = (h - h_0) - T_0 \cdot (s - s_0), \quad (4)$$

where h is fluid specific enthalpy and s is fluid specific entropy. Always valid mass flow rate balance for any component (or component part) is:

$$\sum \dot{m}_{in} = \sum \dot{m}_{out}. \quad (5)$$

3.2. Equations for the exergy analysis of whole observed steam turbine and her cylinders

Equations for the exergy analysis of each cylinder (HPC and LPC) and whole observed steam turbine are defined according to the recommendations from the literature [27, 28]. Exergy analysis equations presented in this Subsection remain always the same, regardless of the observed operating regime. The indexes used in the equations are related to operating points from Fig. 1 and Fig. 2. Index WT denotes the Whole Turbine.

Real (polytropic) mechanical power

$$P_{HPC} = \dot{m}_1 \cdot (h_1 - h_2), \quad (6)$$

$$P_{LPC} = \dot{m}_4 \cdot (h_4 - h_5), \quad (7)$$

$$P_{WT} = P_{HPC} + P_{LPC}. \quad (8)$$

Exergy inlet

$$\dot{E}x_{in,HPC} = \dot{m}_1 \cdot \varepsilon_1, \quad (9)$$

$$\dot{E}x_{in,LPC} = \dot{m}_4 \cdot \varepsilon_4, \quad (10)$$

$$\dot{E}x_{in,WT} = \dot{m}_1 \cdot \varepsilon_1. \quad (11)$$

Exergy outlet

$$\dot{E}x_{out,HPC} = \dot{m}_2 \cdot \varepsilon_2 + P_{HPC}, \quad (12)$$

$$\dot{E}x_{out,LPC} = \dot{m}_5 \cdot \varepsilon_5 + P_{LPC}, \quad (13)$$

$$\dot{E}x_{out,WT} = \dot{m}_3 \cdot \varepsilon_3 + \dot{m}_5 \cdot \varepsilon_5 + P_{WT}. \quad (14)$$

Exergy destruction

$$\dot{E}x_{D,HPC} = \dot{E}x_{in,HPC} - \dot{E}x_{out,HPC}, \quad (15)$$

$$\dot{E}x_{D,LPC} = \dot{E}x_{in,LPC} - \dot{E}x_{out,LPC}, \quad (16)$$

$$\dot{E}x_{D,WT} = \dot{E}x_{in,WT} - \dot{E}x_{out,WT} = \dot{E}x_{D,HPC} + \dot{E}x_{D,LPC}. \quad (17)$$

Exergy efficiency

$$\eta_{ex,HPC} = \frac{P_{HPC}}{\dot{E}x_{in,HPC} - \dot{E}x_{out,HPC} + P_{HPC}} = \frac{P_{HPC}}{\dot{E}x_{D,HPC} + P_{HPC}}, \quad (18)$$

$$\eta_{ex,LPC} = \frac{P_{LPC}}{\dot{E}x_{in,LPC} - \dot{E}x_{out,LPC} + P_{LPC}} = \frac{P_{LPC}}{\dot{E}x_{D,LPC} + P_{LPC}}, \quad (19)$$

$$\eta_{ex,WT} = \frac{P_{WT}}{\dot{E}x_{in,WT} - \dot{E}x_{out,WT} + P_{WT}} = \frac{P_{WT}}{\dot{E}x_{D,WT} + P_{WT}}. \quad (20)$$

4. Steam operating parameters required for the exergy analysis at three operating regimes

Steam operating parameters of the analyzed steam turbine and her cylinders, at each operating regime, are found in the literature [19]. In the mentioned literature are found steam temperature, pressure and mass flow rate in each operating point and in each operating regime, other steam operating parameters are calculated by using NIST-Refprop 9.0 software [29].

The base ambient state is defined by the ambient temperature of 298.15 K and by the ambient pressure of 1 bar.

Steam operating parameters required for the whole observed turbine and her cylinders exergy analysis in Operating regime 1 are presented in Table 1, in Operating regime 2 steam operating parameters are presented in Table 2, while in Operating regime 3 steam operating parameters are presented in Table 3. From Table 1, Table 2 and Table 3 can be clearly seen that in different observed operating regimes the dominant change in each operating point is related to the change of steam temperature and steam mass flow rate.

Table 1. Steam operating parameters in Operating regime 1

Operating regime 1						
O. P.*	Temp. (K)	Pressure (bar)	Mass flow rate (kg/s)	Specific enthalpy (kJ/kg)	Specific entropy (kJ/kg·K)	Specific exergy (kJ/kg)**
1	673.15	95.0	13.94	3108.2	6.2504	1249.30
2	453.03	10.0	13.94	2777.1	6.5850	818.35
3	453.03	10.0	1.04	2777.1	6.5850	818.35
4	453.03	10.0	12.90	2777.1	6.5850	818.35
5	372.76	1.0	12.90	2607.2	7.1772	471.91

* O. P. = Operating Point (according to Fig. 1)

** Specific exergy at the base ambient state

Table 2. Steam operating parameters in Operating regime 2

Operating regime 2						
O. P.*	Temp. (K)	Pressure (bar)	Mass flow rate (kg/s)	Specific enthalpy (kJ/kg)	Specific entropy (kJ/kg·K)	Specific exergy (kJ/kg)**
1	628.15	95.0	6.33	2959.7	6.0218	1168.90
2	453.03	10.0	6.33	2777.1	6.5850	818.35
3	453.03	10.0	0.40	2777.1	6.5850	818.35
4	453.03	10.0	5.93	2777.1	6.5850	818.35
5	395.08	0.6	5.93	2561.1	7.2757	396.45

* O. P. = Operating Point (according to Fig. 1)

** Specific exergy at the base ambient state

Table 3. Steam operating parameters in Operating regime 3

Operating regime 3						
O. P.*	Temp. (K)	Pressure (bar)	Mass flow rate (kg/s)	Specific enthalpy (kJ/kg)	Specific entropy (kJ/kg·K)	Specific exergy (kJ/kg)**
1	653.15	95.0	9.71	3045.8	6.1562	1214.90
2	453.03	10.0	9.71	2777.1	6.5850	818.35
3	453.03	10.0	0.59	2777.1	6.5850	818.35
4	453.03	10.0	9.12	2777.1	6.5850	818.35
5	318.96	0.1	9.12	2488.2	7.8488	152.61

* O. P. = Operating Point (according to Fig. 1)

** Specific exergy at the base ambient state

5. Exergy analysis results and discussion

Real (polytropic) produced mechanical power in each cylinder and whole turbine for three observed operating regimes is presented in Fig. 3. Fig. 3 confirms that the observed steam turbine is a low power turbine, because the highest mechanical power produced in the whole turbine is 6807.24 kW in Operating regime 1. In Operating regime 2 whole turbine produces the lowest mechanical power equal to 2436.74 kW only.

It is also evident that cylinders of the observed turbine did not have the same operation dynamics in relation to produced mechanical power in all operating regimes. HPC produces the highest mechanical power in Operating regime 1 (equal to 4615.53 kW), while the LPC produces the highest mechanical power in Operating regime 3 (equal to 2634.77 kW). The only similarity between HPC and the LPC is that both cylinders produce the lowest mechanical power in Operating regime 2.

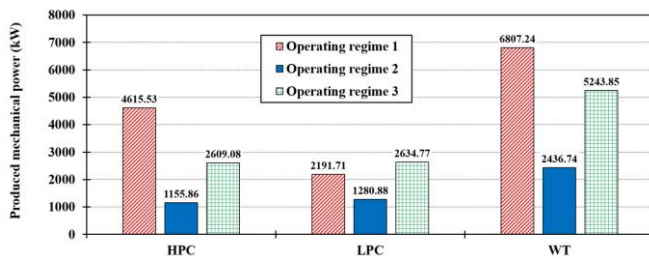


Fig. 3. Produced mechanical power in each cylinder and whole turbine for three observed operating regimes

Exergy destruction of the whole turbine and each of her cylinders at all three observed operating regimes is presented in Fig. 4.

The lowest exergy destruction in each cylinder and whole turbine is obtained in the Operating regime 2 in which whole turbine and each cylinder produce the lowest mechanical power, Fig. 3 and Fig. 4. Observation of the cylinders leads to conclusion that in each operating regime HPC has lower exergy destruction in comparison to LPC what can be explained by the influence of wet steam which expands through the last LPC stages (wet steam increases LPC exergy destruction).

Whole turbine has the highest exergy destruction in Operating regime 3 (equal to 4678.20 kW) and the lowest exergy destruction in Operating regime 2 (equal to 2284.11 kW).

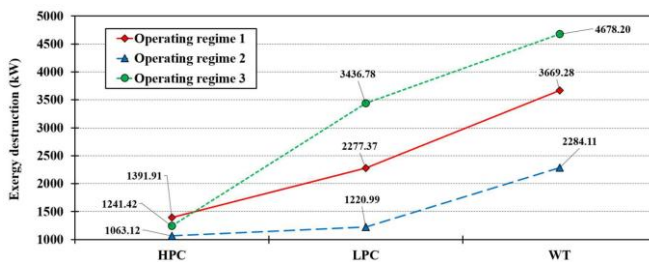


Fig. 4. Exergy destruction in each cylinder and whole turbine for three observed operating regimes

Exergy efficiency of the whole observed turbine and her cylinders at all three operating regimes is presented in Fig. 5.

Observing both cylinders, it can be concluded that HPC has higher exergy efficiency in comparison to the LPC in all operating regimes. This result related to the cylinders is expected due to much lower HPC exergy destruction in comparison to LPC, Fig. 4 and Fig. 5. The highest HPC exergy efficiency is obtained in Operating regime 1 (equal to 76.83%), while LPC has the highest exergy efficiency in Operating regime 2 (equal to 51.20%).

Whole observed turbine exergy efficiency is between 51.62% (in Operating regime 2) and 64.98% (in Operating regime 1). According to the literature, this range of exergy efficiencies can be expected for low power steam turbines [30, 31]. However, it should be highlighted that obtained exergy efficiencies (for the whole

turbine and each cylinder) are notably lower in comparison to medium and high power steam turbines from various power plants [32].

Finally, it can be concluded that exergy efficiency of LPC in all operating regimes is low and it surely can be improved.

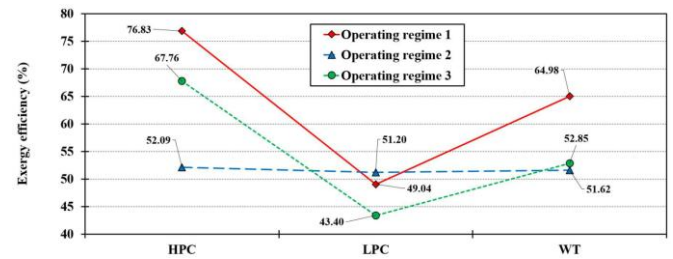


Fig. 5. Exergy efficiency in each cylinder and whole turbine for three observed operating regimes

As stated before, exergy analysis is dependable on the ambient parameters. In this paper is performed an analysis related to the ambient temperature change and its influence on the steam turbine exergy efficiency. In Fig. 6 is presented exergy efficiency of the whole turbine during the ambient temperature change for all three observed operating regimes. However, it should be highlighted that the same conclusions related to the ambient temperature change of the whole turbine are also valid for each cylinder (HPC and LPC).

From Fig. 6 is clear that an increase in the ambient temperature decreases exergy efficiency of the whole turbine, regardless of the observed operating regime (what is also valid for both turbine cylinders).

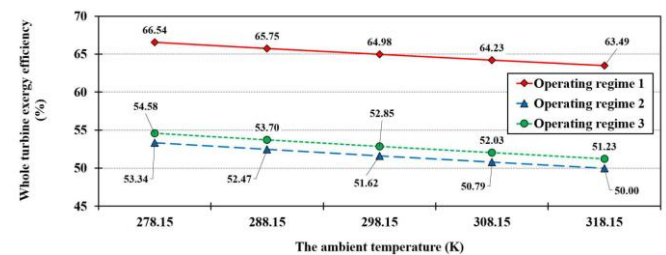


Fig. 6. Exergy efficiency of the whole turbine during the ambient temperature change for three observed operating regimes

Further analyses of the observed steam turbine and her cylinders can and will be based on the usage of many conventional [33] and artificial intelligence [34, 35] methods and processes. Results obtained in this analysis at all operating regimes will be used as a baseline in further analyses.

6. Conclusions

In this paper is performed exergy analysis of a two-cylinder low power steam turbine from combined cycle power plant at three operating regimes. The most important conclusions are:

- The highest mechanical power produced in the whole turbine is 6807.24 kW in Operating regime 1.
- Cylinders of the observed turbine did not have the same operation dynamics in relation to produced mechanical power in all operating regimes.
- In each operating regime HPC has lower exergy destruction and higher exergy efficiency in comparison to LPC what can be explained by the influence of wet steam which expands through the last LPC stages (water droplets increases LPC exergy destruction and decreases LPC exergy efficiency).
- Whole observed turbine exergy efficiency is between 51.62% (in Operating regime 2) and 64.98% (in Operating regime 1). This range of exergy efficiencies, according to the literature, can be expected for a low power steam turbine.
- Analysis shows that exergy efficiency of LPC is low in all operating regimes, so any improvements should be based on this cylinder first.

- An increase in the ambient temperature decreases exergy efficiency of the whole turbine and both turbine cylinders, regardless of the observed operating regime.

7. Acknowledgment

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Vanadium Unveiled: Exploring Jordanian Rock Phosphate and the Crucial Role of Vanadium Technologies in Shaping a Sustainable Energy Future

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Abstract: Vanadium, a vital element for the advancement of clean energy technologies, holds the potential to revolutionize the energy landscape. This study investigates the distribution of vanadium within Jordan huge rock phosphate deposits, exploring its implications for sustainable energy transitions. Utilizing advanced analytical techniques, including X-ray fluorescence spectroscopy and scanning electron microscopy, were scrutinized the intricate geochemical characteristics of these deposits. The concentrations of Vanadium in different samples of Jordanian rock phosphate, encompassing Al-bied, Al-Hasa, and Eshidiya (A1, A2, A3, S1, and S2), as well as phosphoric acid, were analyzed. The Vanadium concentrations observed were 181 mgkg⁻¹, 204 mgkg⁻¹, 107 mgkg⁻¹, 117 mgkg⁻¹, 55 mgkg⁻¹, 237 mgkg⁻¹, and 291 mgkg⁻¹, and 135 mgkg⁻¹, respectively. The findings unveil promising concentrations of vanadium within Jordanian rock phosphate, positioning the country as a potential key player in the global supply chain of this critical metal. By elucidating the abundance and distribution of vanadium in Jordan rock phosphate, this research not only contributes to the understanding of vanadium fate and distribution but also underscores the imperative of sustainable resource utilization in advancing towards a cleaner and more resilient energy future.

KEYWORDS: VANADIUM, JORDAN, ROCK PHOSPHATE, CLEAN ENERGY, SUSTAINABLE RESOURCE UTILIZATION, RENEWABLE ENERGY SOURCE

Introduction

Vanadium is present in over 50 different minerals and is the 22nd most abundant element in the Earth's crust [1]. Vanadium is a relatively abundant trace element and occurs in a large number of minerals and deposits. Vanadium is not only produced from primary resources, but is also obtained from secondary production, or processing of steelmaking slag, oil and coal residues, spent catalysts and uranium co-products (Table 1). Characteristics of vanadium in secondary resources are completely different and depend on the sources [2]; the average concentration of vanadium varies in different sources. The majority of vanadium is produced as a co-product from slag, given its high affinity for oxygen and tendency to report in the oxide phase during the smelting for production of steel. Of the remainder, in 2015 approximately 18% was produced from primary vanadium ores and 11% from secondary sources [3]. Vanadium significantly increases strength and improves toughness and ductility of carbon steels, which are used for constructing high-rise buildings, bridges, and pipelines [4], making of ceramics, glasses, and pigments; and in vanadium redox-flow batteries (VRBs) for large-scale storage of electricity. World vanadium resources in 2012 were estimated to be 63 million metric tons, which include about 14 million metric tons of reserves. The majority of the vanadium produced in 2012 was from China, Russia, and South Africa [5]. Countries such as China, South Africa, and Russia are the largest world producers of ferrovanadium and its toxic oxides while about 40 other countries contribute smaller quantities in different forms for global consumption [6].

Table 1. General resources of vanadium production [7].

Recourse Type	Resources Name	V2O5 Content (%)
Primary	Natural ore	1.2-81
	Vanadium-bearing titanomagnetite	0.39-3.21
	Stone coal	0.13-1.2
Secondary	Ferrophosphorus	3-11%
	Fly ash	2.5-40%
	Vanadium-bearing uranium ore	0.25-2%
	Spent catalysts	0.5-30%
	Bayer red mud	0.18-0.7%
Co-product	Vanadium slag	6-24%

The global supply of vanadium originates from primary sources such as ore feedstock, concentrates, metallurgical slags, and petroleum residues. Vanadium-bearing host minerals consist of carnotite, mottramite, patronite, roscobelite, and vanadinite. Deposits

of titaniferous magnetite, uraniferous sandstone, bauxite, phosphate rock, crude oils, oil shale and tar sands host vanadium [8, 9, 10].

Vanadium is used in metal alloys with iron to produce high-strength steels, which have a wide range of uses, including structural applications such as reinforcing bars in building and construction, gas and oil pipelines, tool steel, the manufacturing of axles and crankshafts for the motor vehicle industry, and in jet engines for the aircraft industry. Other applications such as catalysts, biological applications and fuel cells have increased the importance of vanadium recently [11,12].

Today over 85% of the world production of vanadium is consumed in carbon and stainless steel production, as an alloying agent to produce ferro-vanadium. Vanadium is employed for the manufacture of a variety of vanadium compounds, many of which in turn are employed to prepare catalysts such as hydrocarbon oxidation catalysts and catalysts for the manufacture of sulphuric acid [13].

Vanadium may be used for mass storage redox batteries. The only really good long-term, cost-effective solution for mass storage energy is vanadium mass-storage batteries. The vanadium redox flow battery is a type of rechargeable flow battery that employs vanadium ions in different oxidation states to store chemical potential energy [14].

Vanadium in rock phosphates

Most phosphate rock contains metal compounds in varying amounts, and in many cases these metal compounds are dissolved from the phosphate rock and appear in the wet process acid as contaminants. Phosphate rocks have long been known to contain variable amounts of heavy metals such as V. The variation depends on the source and method of processing [15].

Vanadium may substitute as vanadate for the phosphate group [16]. Anomalous concentration of V and its correlation with P₂O₅ in phosphorite were attributed to substitution of V in apatite. Vanadium is enriched in phosphorites where it substitutes easily for P, reaching sometimes a higher concentration [17].

Extraction of Vanadium

Many methods had been reported for the extraction and quantifying of vanadium in different sources Vanadium production varies between different resources and processing plants, there are a few common features. The process used will vary depending on the nature of the ore. Most vanadium is produced from titanomagnetite ores, either directly or from the slag generated by the smelting of titanomagnetite ores. For this reason, Table 2. shows this review of the extraction of Vanadium from different sources.

Table 2. Extraction of Vanadium from different sources.

Vanadium source	Extraction Methods	material	result	Ref
Industrial Low concentration (1-7M) Phosphoric acid	Solvent Extraction Trioctylmethylammonium Chloride (TOMAC)	1. Trioctylmethylammonium chloride (TOMAC), 1. phosphoric acid (H ₃ PO ₄)(1-6M) 2. ammonium metavanadate (NH ₄ VO ₃), 3. potassium dihydrogen phosphate (KH ₂ PO ₄), 4. nitric acid (HNO ₃), isodecanol and n-heptane. Reagents were prepared by dissolving a given weight of the sample in aqueous acid in a volumetric flask.	TOMAC is highly efficient to produce V	[18]
Idaho Phosphorite Ores	Roasting and leaching	Roasting with or without salt, followed by leaching; and leaching under pressure.	Extractions of 91 to 99 pct of the V ₂ O ₅	[19]
Industrial Low concentration (1-7M) Phosphoric acid	Liquid-liquid extraction	1. LIX 860 - I(5-dodecylsalicylaldoxime, HL) 2. Organic solutions 3. Aqueous solutions of V(V) from NH ₄ VO ₃ (Merck p.a.) and V(IV) from VOSO ₄ . 5H ₂ O 4. H ₃ PO ₄ (1M-7M)	Need further investigation	[20]
Phosphoric acid (wet process)	oxidation and reduction	(i) adsorbing an anionic pentavalent complex of vanadium, derived from the wet process phosphoric acid, onto an anion exchange resin or into an organic layer; and (ii) reducing the vanadium complex to trivalent and/or tetravalent vanadium so as to selectively strip vanadium from the anion exchange resin.	NO RESULT ADOPTED	[21]
SPENT CATALYST	Leaching by acid , oxidation and precipitation	sulphuric acid 50% v/v, nitric acid 65% wt., a mixture of sulphuric acid 50% v/v and nitric acid 65% wt. 2:1 and a mixture of sulphuric acid 50% v/v, nitric acid 65% wt., hydrofluoric acid 40% wt. and perchloric acid 70% wt.	Vanadium pentoxide can be recovered with the efficiency of 70%	[22]
Fly ash	Leaching by acid	1. 1g/l NaClO as an oxidative agent 2. 87.5 g/L H ₂ SO ₄ , 15 g/L HF and a liquid/solid ratio of 4 mL/g 3. TEMP 95°C	Extraction 85.1%	[23]
Stone coal	Leaching by acid	1. 1M H ₂ SO ₄ 2. liquid/solid ratio of 333.34 G/L 3. TEMP 95°C	Extraction 85 %	[24]
Steel Slag	Leaching by sodium hydroxide	1. 0.4M NaOH 2. liquid/solid ratio of 500 G/L 3. TEMP 240°C	Extraction 90%	[25]
Calcium vanadate	Leaching kinetics	1. 1.5M Na ₂ CO ₃ 2. liquid/solid ratio of 40 G/L 3. TEMP 80°C	Extraction 95%	[26]

Methods and Techniques

Chemical Analysis

Acid digestions were carried out on eight composite samples in triplicate. In Teflon beakers, 0.2 g of composite samples were placed, followed by the addition of 3 ml of concentrated HCl to initiate the reaction. Subsequently, 2 ml of concentrated HNO₃, 1 ml of HClO₄, and 2 ml of HF were sequentially added. The samples were then dried on a hotplate at 110°C. An additional 1 ml of concentrated HNO₃ was added, and the sample was dried once more. After cooling, dried samples were removed from the hotplate, and 19 ml of 1% HNO₃ was added. The solution was heated in an oven at 100°C for 30 minutes. The concentrations of V₅₊ were determined using ICP-MS.

Sequential Chemical Extraction

In this investigation, we introduced an initial water-soluble phase extraction step alongside the five extraction stages outlined by Tessier et al. (1979). These six extraction procedures utilize specific reagents to identify the relative concentrations of uranium and select trace metals across distinct fractions: (1) water-soluble; (2) exchangeable; (3) carbonate; (4) Mn-iron oxide; (5) organic matter; and (6) residual. The choice of extraction method depends on factors such as deposit grade, size, location, and geological composition, with a focus on maximizing ore recovery while adhering to economic considerations. We analyzed a total of eight representative samples using sequential extraction, and the extracted fractions were subsequently analyzed via ICP-MS to quantify V and other trace metals.

Results and Discussions

Table 3 illustrates the concentrations of Vanadium in various samples of Jordanian rock phosphate including Al-bied, Al-Hasa, and Eshidiya (A1, A2, A3, S1, and S2), and phosphoric acid. The Vanadium concentrations observed were 181 mgkg⁻¹, 204 mgkg⁻¹, 107 mgkg⁻¹, 117 mgkg⁻¹, 55 mgkg⁻¹, 237 mgkg⁻¹, and 291 mgkg⁻¹, and 135 mgkg⁻¹, respectively. Table 4 demonstrates that Eshidiya Jordan rock phosphate exhibits relatively higher Vanadium enrichment compared to its abundance in global phosphorites.

Sequential Extraction

The concentration of V₅₊ in the four samples under scrutiny ranged from 120 mgkg⁻¹ to 321 mgkg⁻¹. Notably, all four samples contained water-soluble V₅₊ (>0.5%). Predominantly, the highest quantities of V₅₊ from all four samples were extracted during the "residue" and "organic" extraction steps, with the "exchangeable" extraction step following suit. The proportion of V₅₊ extracted in the residue (using all five extraction steps) from the Al-Abied and Al-Hasa samples was notably lower (~52%) compared to that extracted from the two Eshidiya samples (75%), likely attributed to V₅₊ entering the apatite structure. Similarly, the percentage of V extracted in the organic (using all five extraction steps) from the Al-Abied and Al-Hasa samples was relatively comparable (30%) to that from the two Eshidiya samples (20%), indicating a substantial association of V₅₊ with organic matter. This association can be attributed to the reducing conditions induced by organic matter,

rather than implying V5+ containment within the organic matter itself.

Table 2. Average Vanadium (mgkg⁻¹) in phosphate rocks from Al-bied mines, Al-Hasa mines, and Eshidiya mines.

Mines	V ppm
Eshydia bed A1	107
Eshydia bed A2	117
Eshydia bed A3	55
Eshidiya-S1	237
Eshidiya-S2	291
Al-Hasa	204
Al-Abiad	183
Phosphoric Acid	135

Table 3. Average vanadium concentrations in various phosphate rocks and in the average continental crustal Abundances [27]

COUNTRIES	V (PPM)
Average World Phosphates	130
Morocco Phosphate	87
Egypt Phosphate	79
USA Phosphate	82
Crustal Abundances	97

Conclusions

The analysis revealed varying concentrations of V5+ in the four examined samples, ranging from 120 mgkg⁻¹ to 321 mgkg⁻¹. A modified six-step sequential extraction method was employed to fractionate uranium and trace metals, including V5+, in phosphate rock samples sourced from different locations in Jordan. The highest quantities of V5+ were predominantly extracted during the residue and organic steps, particularly notable in the two Eshidiya samples, where extraction percentages were 67%, 91%, 76%, and 75% respectively. Across all five extraction steps, 75% of V5+ was extracted from the Eshidiya samples, with an apparent mobility of 1.42%. These findings highlight significant concentrations of vanadium in Jordanian rock phosphate, suggesting the country's potential role in the global vanadium supply chain. This research not only enhances regional geological understanding but also emphasizes the importance of sustainable resource management for a cleaner and more resilient energy future.

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