

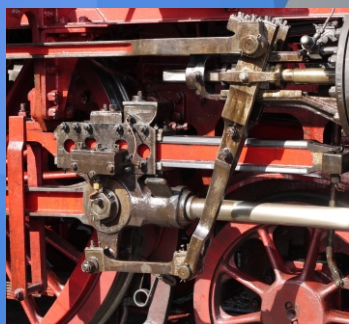
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Sustainable hybrid energy production system

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Abstract: Solar energy has a drawback when it works individually, because it could not produce electrical energy in rainy and cloudy seasons, and during the night time. Wind energy is not constant and it varies from zero to storm force. This means that wind turbines do not produce the same amount of electricity all the time. Therefore, the need to overcome these drawbacks could be by combining two energy resources so that any one source fails the other source will keep generating electricity. In this study, a designed prototype that combines two energy resources wind and solar energy will be constructed and tested. The design will supply the sustainable energy resources without damaging the nature and gives uninterrupted power. Also it works during day time and produce DC power by the solar PV cell which is stored in the battery bank through a hybrid controller, which maximizes charging current and prevents excessive discharge/overcharge. The Wind turbine generator will generate power when wind speed exceeds cut-in speed; wind power is also stored in the battery bank through hybrid controller. Energy stored in the battery is drawn by electrical loads through the inverter, which converts DC into AC power. The inverter has in-built protection for short-circuit, reverse polarity, low battery voltage and over load. The battery bank is sizing to feed loads up to five hours, during non-sun/wind days. The designed prototype has proved to work efficiently for a sustainable electricity supply for 24 hours, the results of this work give an incentive to proceed with building and using such sustainable power generation systems (hybrid) that have proven to be efficient and economically feasible to use for continuous energy generation which is suitable for urban, rural and isolated areas.

KEYWORDS: SOLAR ENERGY, WIND ENERGY, BATTERY BANK AND CONVERTER

Introduction:

Humans have an insatiable thirst for energy, but the population will increase rapidly with the continuous increasing in energy demand. Global electric power has now reached 15 terawatts (the equivalent of 150 billion 100W light bulbs) and assuming an increase in population to 9 billion and continuation of the current growth rate in energy demand, this would increase to 100 terawatts by 2050 [1 and 2]. Even if we take on more sustainable approaches in the future and conserve energy to the best of our ability, we would still require 30-40 terawatts of electrical power capacity by 2050. Since the industrial revolution, our entire infrastructure and economy has been built upon cheap and easily available fossil fuels, such as coal, natural gas and oil, so that these are now the most essential resources for humankind. These fossil fuels are being rapidly consumed – an approximate 2 trillion barrels of oil were consumed over the last 100 years and another trillion is likely to be consumed in the next 30 years, nature took millions of years to produce this amount of oil. Current predictions state that coal reserves will be depleted in 250 years, oil in 40 years and gas in 70 [3 and 4]. This means that we are in an energy crisis, and the implementation of renewable energy solutions can help solve this predicament. Renewable energies refer to energies derived from sources that are a constant factor for humans on earth, and these sources include the sun, wind, biomass, the ocean, hydro power and geothermal. However, the move towards renewable energies needs to be done quickly. Although the depleting fossil fuels will not affect us for a few decades at least, governments of countries have an increasing incentive to diversify their energy sources [5 and 6]. Investing in renewable energy on the national and global scale is advisable for the following reasons [7].

- Energy security
- Escalating costs of conventional energies
- Less price volatility and competitive market
- Stimulation of economy and creation of jobs – investing in renewable energies will create a renewable energy industry which will stimulate the economy [8]
- Environmental concerns – burning of fossil fuels leads to the release of carbon dioxide gas into the acreage havoc in many parts of the world [9]
- Depleting resources

Motivation of the Study: Jordan is a non-oil-producing country and imports 96% of the energy used. As a consequence, energy imports accounts for roughly 22% of the GDP (Gross domestic product). The population's growth rate is high; about 2.3% per year. This causes the demand on energy sources, mainly oil products to increase rapidly. Implementation of renewable energy resources such as solar and wind energy, will lead to economic, social and environmental benefits [9].

Objectives: The main aim of this study is to design and implement a prototype of a solar-wind hybrid energy system. While the sub-objectives are:-

- Calculate the wind power generation for the case study
- Calculate the solar power generation for the case study
- Calculate the total storage of combined power that generated from the system
- Design a suitable combined system to give a sustainable energy for 24 hour

Methodology: In order to achieve the overall objectives of the research, the following approach is adopted in the current research.

- Literature survey: Reviewing the collection of research publications related to the present research problem, in order to understand and evaluate of the current state of the research
- Theoretical analysis of the proposed designed system
- Analysis the data that will be collected
- Modeling and simulation of the designed controller for hybrid energy system

The Proposed Hybrid System in Present Work: In recent years, hybrid technology has been developed and upgraded its role in renewable energy sources due to its benefits [10]. It produces autonomous power production which is un-challenged, and now days many houses in rural and urban areas use hybrid systems. Many isolated islands try to adopt this kind of technology because of the benefits which can be obtained in comparison with a single renewable system. In present work this system will be designed based upon a wind ducted turbine and photovoltaic (PV) panels, as shown in figure (1). This specific hybrid system presents many benefits; specifically, the assessment for a wind/solar hybrid system which is focused on the wind and solar potential of the region.

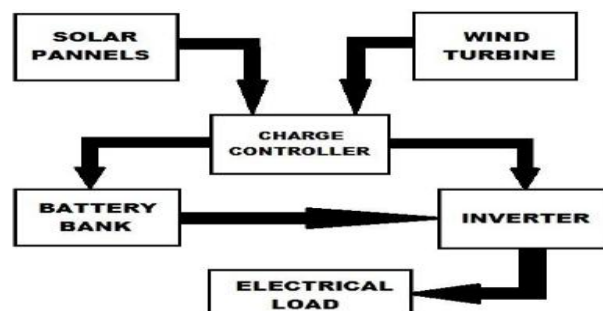


Figure -1: Operation Diagram of a Hybrid System for PV and Wind Turbine

The system can be operated during the day using the energy from the sun and after the sun has set it can utilize the potential wind energy to continue its function. For this reason, wind and solar systems work well together in a hybrid system and they provide a more consistent year-round output than either wind-only or PV-only systems. Moreover with the use of the appropriate auxiliary systems like batteries can store energy which will be useful in compensating electrical demands used by the building for periods where there is no sun or wind. Finally, it is economically sound and advantageous to use non finite resources, i.e. solar and wind (hybrid). The investment financially and environmentally in modern technologies will win through the generations to come in the fight for energy efficiency and effectiveness.

Wind Turbine Power Generation: Wind turbine (WT) power is used to convert kinetic energy into electrical energy through the use of a generator. As wind conditions vary, the electrical energy created from the generator needs to be converted for usability. A rectifier, inverter, transformer and filter are needed within the wind turbine for utility-grade AC power to be transmitted over long distances. A transformer is usually installed at the bottom of the tower to provide voltage conversion from the low voltage generated by the wind turbine, to medium/high voltage for transmission [11].

Rectifier and Inverter: The rectifier and inverter are key components in the wind turbine system. The rectifier converts noisy AC power to DC power, while the inverter converts DC power to clean and reliable AC power. The switching of these devices is usually controlled by a DSP-embedded controller via a fiber optic link, to provide efficient and reliable switching control with high galvanic isolation capability

Power Outputs: The mechanical power extracted from the wind can be calculated by the following equation [11]:-

$$P_{mec} = \frac{1}{2} \rho_{air} A_r C_p V^3 \eta \quad \dots\dots\dots (3)$$

Where

P_{mec} : Mechanical power on the shaft of the turbine,

ρ_{air} : Air density,

C_p : Power coefficient,

A_r : Area swept by the rotor,

V : wind speed.

η : Mechanical efficiency of wind turbine.

Wind turbines are also classified by the amount of power that they can generate, and are directly correlated to the physical size of the turbine (larger wind turbines produce more energy). The three types of turbines in terms of power output levels are: utility, industrial, and residential- scaled wind turbines. Table-1 displays the average size range and uses for each of the three scales of turbine [12].

Table -1: Wind Turbine Classifications [12]

Scale	Average Output Range	Uses
Utility	900 kW - 2 MW	•Generate bulk energy for sale in power markets •Commonly used in "wind farms"
Industrial	50 kW - 250 kW	•Remote grid production •Reduce consumption of higher cost grid power •May be sold if permitted by state regulations
Residential	400 W to 50 kW	•Remote power •Battery charging •Net-metering type generation

Wind Speed and Effect of Height: Wind speed varies with height at ground level (zero meters) the speed is low and turbulent and at some higher altitude (say, 100 m) it is faster and smoother, this is due to friction as wind passes across the earth's surface. Whilst the nature of surface varies, it is common practice to use an empirical

relationship between height and speed. The standard height for meteorological observation wind speed data is 10 m. This type of data is the most readily available, as the power generated is proportional to the velocity cubed, there is an advantage to be gained by locating the turbine on some form of tower, typically in the range 10 to 120 m high. The effect of height is shown in the figure (2)

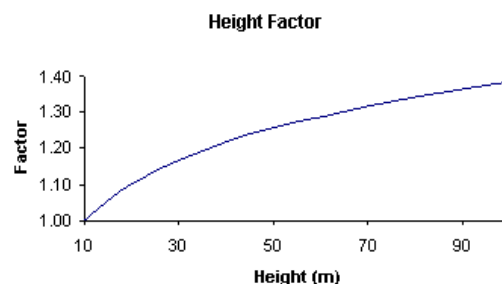


Figure -2: The effect of height and speed factor [13]

While, figure (3) illustrates the increase in wind speed with height in the context of rated output.

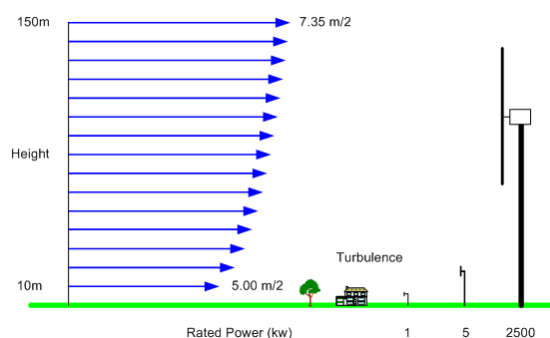


Figure -3: Wind Speed with Height [13]

The sample calculation assumes that the turbine is mounted on a 30-meter tower, thus if the Rayleigh wind speed is 5 m/sec at 10 m, this can be expected to increase by a factor of 1.17, allowing a value of 5.85 to be used for the estimate, giving a 60% increase in output [13]

Wind Speed - Operating Range: At very low speeds (say less than 2 m/sec) the turbine will not rotate at all whilst at high speeds (say greater than 25 m/s) it is necessary to limit or stop the turbine to prevent damage from over-speeding [14]

Pitch Regulated and Stalls Regulated Wind Energy: Turbines are designed to withstand extreme winds statically. This means that they can survive a storm, but only when they are not spinning. They are not designed for extreme rotational torques or speeds. At very large aerodynamic torques or rotational speeds, the forces on the blades and other parts of the turbine are enormous and it will literally tear the turbine apart. This is why they are always designed with a cut-out speed above which breaks will slow the turbine to a halt. These control strategies can broadly be classified as pitch-regulated and stall-regulated, respectively. Pitch-regulated wind turbine have an active control system that can vary the pitch angle (turn the blade around its own axis) of the turbine blades to decrease the torque produced by the blades in a fixed-speed turbine and to decrease the rotational speed in variable-speed turbines. This will slow down the turbine's rotational speed or the torque transferred to the shaft so that the rotational speed or the torque is kept constant below a set threshold. Figure (4) shows the pitch-regulated turbine is represented by the red curve [13]

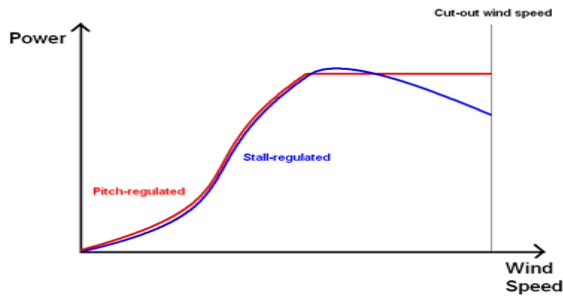


Figure -4: Pitch-regulated and Stall-regulated Wind Turbine [13]

Stall-regulated wind turbine, on the other hand, have their blades designed so that when wind speeds are high, the rotational speed or the aerodynamic torque, and thus the power production, decreases with increasing wind speed above a certain value (usually not the same as the rated wind speed). The benefit of stall-regulation over pitch-regulation is limited the capital cost of the turbine, as well as lower maintenance associated with more moving parts [14].

System Design and Data Collection: The present work system design will be performed by the following main steps: -

- (a) Design of Combined Energy System: The proposed design of the combined energy system which will be used in this work as follows:
 - (1) Data Required for Solar System:
 - Monthly averaged insolation incident on horizontal surface ($\text{kWh/m}^2/\text{day}$)
 - Solar power that can be generated from the panel
 - (2) Data Required for Wind System:
 - Hourly wind speed (m/sec)
 - Wind power that can be generated from the wind turbine

(3) Technical Part
Technical components of the prototype are as shown in the figure (5)

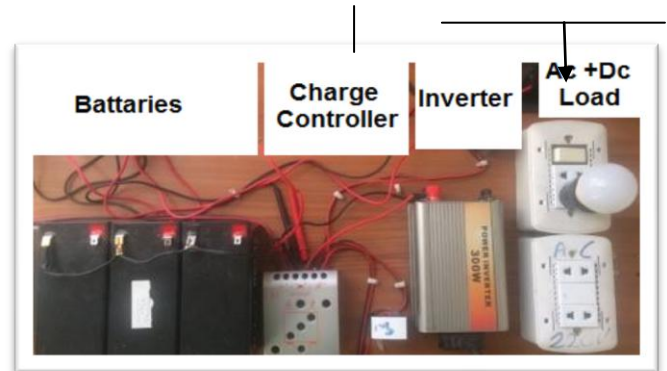
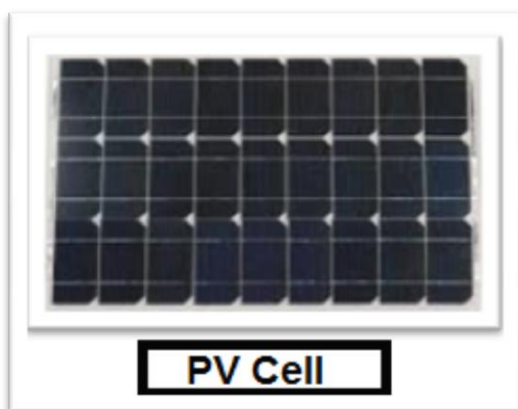


Figure-5: Prototype of Combined Energy Resources

(b) Calculations of the Design: During day time, DC power generated by the solar PV array is stored in the battery bank through hybrid controller, which maximizes charging current and prevents excessive discharge/overcharge. Wind turbine generator will be started generating power when wind speed exceeds cut-in speed of the minimum wind turbine (above 2.7m/s). The wind turbine is self-regulated type with protection for over speed. Energy stored in the battery will be consumed by electrical loads through the inverter, which convert DC into AC power. The inverter has in-built protection for short-circuit, reverse polarity, low battery voltage and over load. The battery bank is sizing to feed loads up to two hours per day, during non-sun/wind days. The designed calculations will be performed by the following main steps (figure-6):

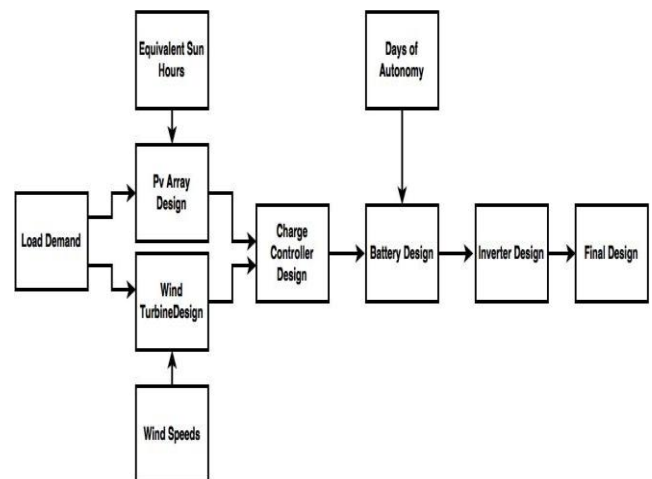


Figure -6: Step by Step Designing of the Hybrid System

Step- One: Calculation of the Load Demand

Calculating power consumption demands and total Watt-hours per day for some appliances for example to verify the present design used as shown in table (2).

Table 2: The Load Demand for the Hybrid System for the Case Study

Appliance type	Quantity	Power per item (W_{DC}, W_{AC})	Total Power (W_{DC}, W_{AC})	Time of Use (h/day)	Total Energy (Wh/day)
AC Light	1	5	5	2	10
DC Light	1	9	9	2	18
AC Small TV	1	10	10	2	20
AC Small Camera	1	16	16	2	32
Total		40			80

Step -Two: Calculation of the Minimum Powers that PV and Wind Turbine Expected to deliver from the load demand which was calculated in table (2) will calculate:

(1) Outputs Energy of PV and Wind turbine:

The DC loads as calculated above = 18 watt

The AC loads as calculated above = 62 watt

(2) After it passes through the inverter where the efficiency is 90 % as in figure-, the AC load will be:-

$$P_1 = \frac{P_{AC}}{\eta_{inv}} \dots \dots \dots (4)$$

$$\rightarrow = \frac{62}{0.9} = 68.89 \text{ W h/day}$$

(3) Minimum outputs energy of PV and Wind turbine after the power passes through charge controller and the battery where the efficiency is 85% as in figure (7):

$$P_2 = \frac{(P_1 + P_{DC})}{\eta_{cc}} \dots \dots \dots (5)$$

$$= \frac{(68.89 + 18)}{0.85} = 102.2 \text{ W h/day}$$

- If it is assumed that general losses that may occur in the system will be 10% when considering the worst situations (cable losses, attachments, development current), the total power needed per day can be expressed by the equation (Yousif. 2012)

$$P_{Load} = P_2 \times 1.1 \dots \dots \dots (6)$$

$$\rightarrow 112.42 \text{ Wh/day}$$

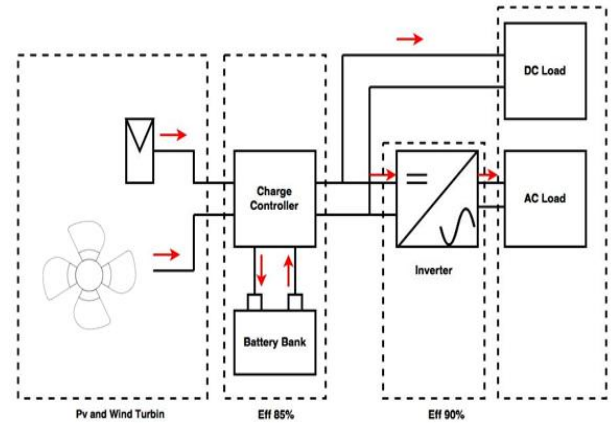


Figure-7: The Energy Conversion for the Study

Step -Three: Solar Panel Sizing: Solar panel is used to convert solar radiation to the electrical energy. The physical of PV cell is very similar to that of the classical diode with a PN junction (a boundary or interface between two types of semiconductor material, p-type and type, inside a single crystal of semiconductor) formed by semiconductor material. When the junction absorbs light, the energy of absorbed photon is transferred to the electron-proton system of the material, creating charge carriers that are separated at the junction. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field, and circulate as current through an external circuit. Solar array or panel is a group of a several modules electrically connected in series parallel combination to generate the required current and voltage. Solar panels are the medium to convert solar power into the electrical power.

(1) **Radiation in Mutah University Site:**

The system has been designed on the basis of the solar data available for the selected area that is south Jordan and for more accurate working Mutah University has been selected as a more specific location and all the calculations are based on Mutah University, as shown in figure (8) shows monthly averaged insolation a horizontal surface.

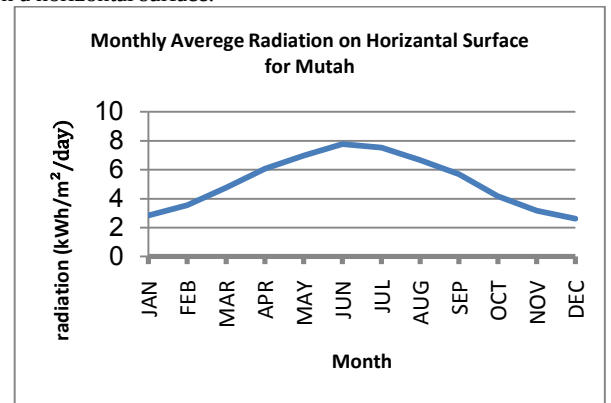


Figure -8: Monthly Average Radiation on a Horizontal Surface (kWh/m²/day) (NASA)

(2) **Calculating Equivalent Sun Hours:** The peak sun hours per day (PSH) is the number of hours per day of solar irradiation > 1000 Wh/m² for Jordan the PSH is 5.7 h/day.

(3) **Calculating Size of PV Panel:** To find the number of panels that the system need, and connection between them to cover the load demand.

$$\text{Minimum PV Power} = \frac{\text{Total Energy Demand}}{\text{Equivalent Sun Hours}} \dots\dots (7)$$

$$\rightarrow W_p = \frac{112.42}{5.7} = 19.72 \text{ w}$$

$$\text{Number of Panels} = \frac{\text{MinimumPv Power}}{\text{Power output of Pv}} \dots\dots\dots (8)$$

So, the number of panels = $\frac{19.72}{50} = 0.39 \approx 1$ panel as shown in figure (9), the specification of the panels is shown in figure (10)

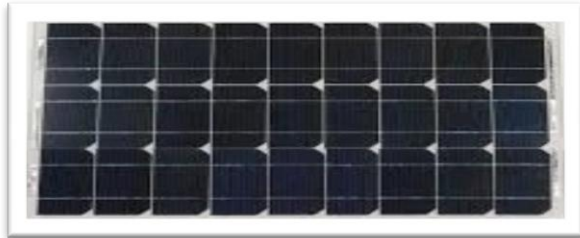


Figure-9: Project PV Panel

Solar Module			
Solar Module Type: PVM-50			
Maximum Power	(Pmax):	50	WP
Voltage at Pmax	(Vmp):	18	V
Current at Pmax	(Imp):	2.78	A
Open-Circuit Voltage	(Voc):	21.6	V
Short-Circuit Current	(Isc):	3.1	A
Power Tolerance: +/- 3%	Size:	630mmx540mmx18mm	
Weight: 3.6 Kg	Cells:	36pcs,125x62.5,mono-crystalline silicon	
Max System Operating Voltage: 1000 V Standard Test Condition: 1000W/m ² , AM1.5, 25°C			

Figure-10: PV Panel specifications

Step –Four: Wind Turbine Sizing: Modeling is a basic tool for analysis, such as optimization, project, and design and control, a mathematical model of wind turbine is essential in the understanding of the behavior of the wind turbine over its region of operation; Modeling enables control of wind turbines performance.

(1) **Calculations of Wind Speeds:** The system has been designed on the basis of the wind data available for the selected area that is south Jordan as shown in figure (11). For more accurate working Mutah University has been selected as a more specific location and the following calculation are based on Mutah, the data has been acquired on the basis of following details

- Site: Mutah University
- Latitude: 31°5'33" N
- Longitude: 35°41'40" E
- Elevation:820 m

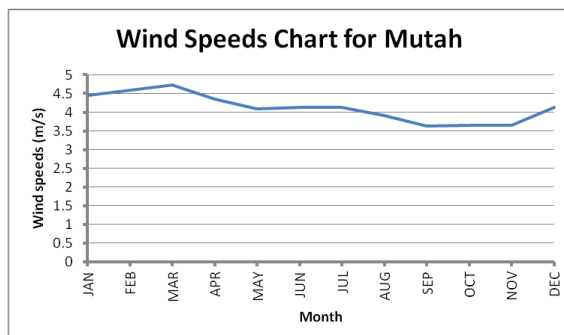


Figure-11: Wind Speeds Chart for Mutah University at 10 m (NASA)

So, the annual average wind speed value was calculated as 4.12 m/s.

(2) Calculating the Size of Wind Turbine

Energy needed = **112.42 Wh/day**, annual average wind speed = 4.12 m/s.

From the following equation [15]:

$$\text{Power (W)} = 0.5 \times C_p \times \eta \times \rho_{\text{air}} \times A \times V^3 \dots\dots\dots (9)$$

Where;

C_p : Rotor efficiency; but $C_p = 0.45$ is often used in this type of calculations;

η : Efficiency of driven machinery;

A: Swept rotor area (m²),

ρ_{air} : Air density

V: Wind speed (m/s)

$$\text{So, the turbine radius, } R = \sqrt{\frac{2 \times P}{C_p \times \rho \times \pi \times V^3}} \rightarrow \frac{2 \times 112.42}{0.45 \times 1.123 \times \pi \times (4.12)^3} =$$

1.4 m

In this work prototype is going to use a small wind turbine as shown in figure (12) with area equals 962 cm², so, R = 17.4 cm, because it is not possible to use a turbine with 1.4 m radius in a small prototype.

(3) Calculating Turbine Revolutions

From equation [15]:

$$\text{Revolutions (rpm)} = \frac{V \times \text{TSR} \times 60}{6.28 \times R} \dots\dots\dots (10)$$

Where;

TSR: Tip Speed Ratio,

R: Radius of rotor,

So, the calculated revolution RPM = 720 at average wind speed = 4.12 m/s.



Figure-12: The Project Wind Turbine

(4) Calculating the Tip Speed Ratio

The Tip Speed Ratio (TSR) is an extremely important factor in wind turbine design. TSR refers to the ratio between the wind speed and the speed of the tips of the wind turbine blades, so, from the equation (Ashish, 2015):

$$\text{Blade Tip Speed} = \frac{\text{RPM} \times \pi \times R}{T(\text{time})} \dots\dots\dots (11)$$

$$\rightarrow \text{Blade Tip Speed} = \frac{720 \times \pi \times 0.174}{60} = 6.56 \text{ m/s}$$

$$\text{TSR} (\lambda) = \frac{\text{Tip Speed of Blade}}{\text{Wind Speed}} \dots\dots\dots (12)$$

$$\rightarrow \text{TSR} (\lambda) = \frac{6.56}{2} = 3.28$$

The tip speed ratio is very important factor in the different formulas of blade design

Wind turbines must be designed with optimal tip speed ratios to get the maximum amount of power from the wind, for optimum Tip Speed Ratio and maximum power output, this formula has been empirically proven:

$$\lambda = \frac{4\pi}{n} \dots\dots\dots (13)$$

n: number of blades

$$\rightarrow \text{Optimal tip speed ratio} = \frac{4 \times \pi}{3} = 4.1$$

Step –Five: Charge Controller Sizing: Charge controller has a basic function which is to control the source for active or inactive; it simultaneously charges battery and also gives power to the load. The controller has an over-charge protection, short-circuit protection, pole confusion protection and automatic dump-load function. Also its function is to vary the power as per the load demand. It adds both powers so that the load demand can fulfill, and when power is not generating it should extract power from battery and gives it to the load. Figure (13-a) shows the charge controller which will be used in the prototype of this study. The charge controller depends on the specification of PV and figure (13-b) shows its specifications.



Figure 13-a: Project Charge Controller



Figure 13-b: Specifications of the Charge Controller.

Step –Six: Battery Bank Sizing: The battery bank size per the load requirement should be chosen s to fulfill the requirements of the required load and to calculate the battery bank size needs to have following data:

- (1) Total daily use in watt-hour (W h).
- (2) Total back up time of the battery

To increase the battery bank size must connect cell in series so that will get the larger battery bank size. Also should calculating the minimum capacity of the battery bank, because the capacity of the battery affected by number of days and the losses.

$$\text{Total amp/day} = \frac{\text{Watt-Hours per day} \times \text{battery loss factor}}{\text{system voltag}} \dots\dots\dots (14)$$

$$\rightarrow \frac{103.27 \times 1.2}{12} = 10.33 \text{ Ah / day}$$

$$\text{Number of Battery needed} = \frac{\text{Total Amp day}}{\text{Battery Amp rating}} \dots\dots\dots (15)$$

$$\rightarrow \frac{10.33}{7} = 1.48 \approx 2$$

In present prototype will going to use three batteries to storage more loads, the specifications of the battery which will be used in this study is shown in the figure (14).



Figure 14: Specifications of the Battery

Step –Seven: The Inverter Sizing: Greater rating inverter than the desired rating must be chosen, the pure sign wave inverter is recommended in order to prolong the lifespan of the inverter. The inverter is needed to convert DC power into AC power because the load working on the AC supply. The input voltage, the output voltage, the frequency, and the overall power handling depends on the design of the specific device or the circuitry. The inverter does not produce any power but the power is provided by the DC source. Calculating minimum nominal power rating of the inverter is as following:

$$\begin{aligned} \text{Minimum Nominal Power Rating:} \\ &= \frac{\text{Total Power Demand for AC Loads}}{\text{Inverter Efficiency}} \dots\dots\dots (16) \\ &\rightarrow \frac{31}{0.9} = 34.4 \text{ Watt} \end{aligned}$$

But in present work prototype 300-watt inverter will be chosen for more loads in future

Results and Discussion: Sample of three days' analysis and discussion will be taken:

- (a) **Results of the first day:** Figures-15, 16 and 17 (Solar, Wind, and both) show that the total daily power production from PV cell is 180.63 W/day and the wind power is 13.221 W/day. So, the combined system capacity is able to generate 193.851 W/day or 8.077W h/day. Also, can see in table (3), that the hourly electricity production from wind turbine is variable through 24 hours, the power production results of the systems

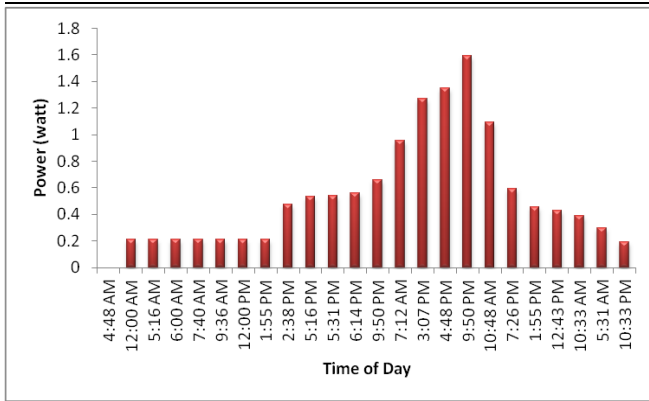


Figure-15: Daily Average Electricity Production from the Wind System of the first day

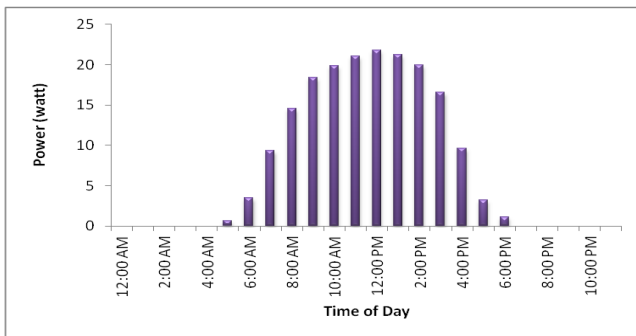


Figure -16: Daily Average Electricity Production from the PV System of the first day

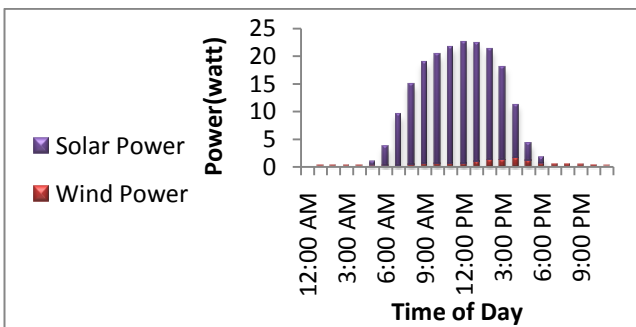


Figure -17: Daily Average Electricity Production from the combined (Hybrid) Wind and PV System of the first day

(b) Results of the second day: Also figures- 18,19 and 20 (Solar, Wind, and both) show that the total daily power production from PV cell is 211.08 W/day and the wind power is 18.688 W/day. So, the combined system capacity is to generate 229.768/day or 9.573W h/day

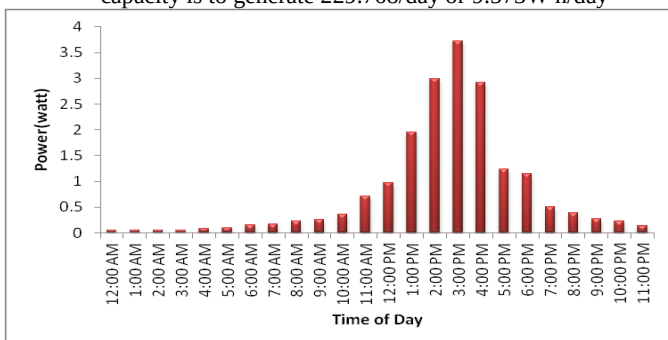


Figure-18: Daily Average Electricity Production from the Wind System of the second day

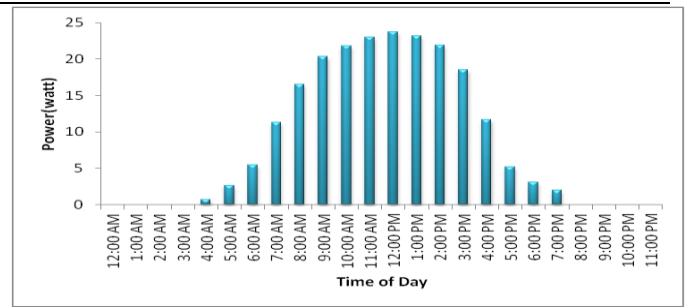


Figure -19: Daily Average Electricity Production from the PV System of the second day

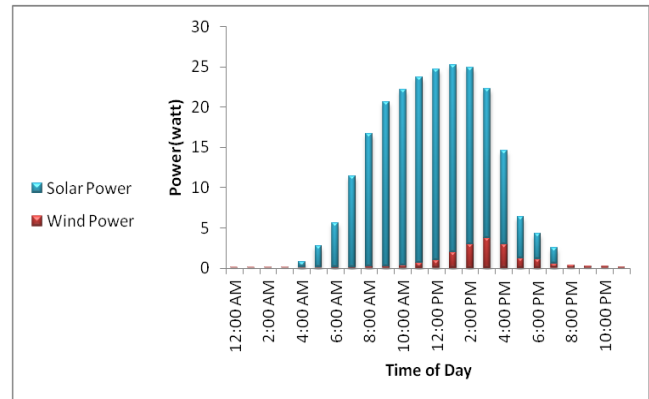


Figure -20: Daily Average Electricity Production from the Hybrid Wind-PV System of the second day

(c) Results of the third day: From figures -21, 22 and 23 (Solar, Wind, and both) can see that the total daily power production from PV cell is 197.34 W/day and the wind power is 14.598 W/day. So, the combined system capacity is able to generate 211.938 W/day or 9.83W h/day. The power production results of solar

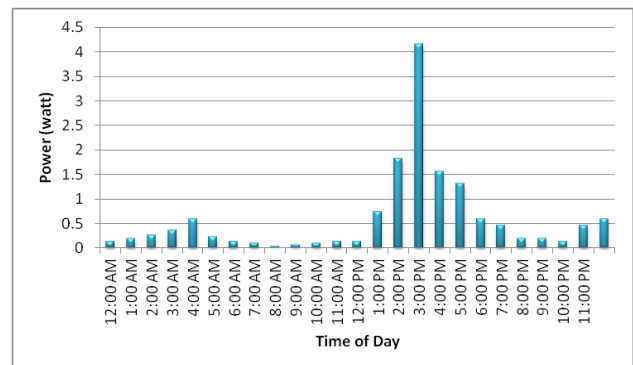


Figure-21: Daily Average Electricity Production from the Wind System of the third day

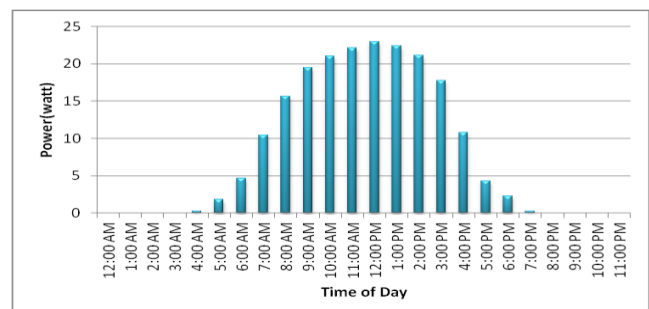


Figure -22: Daily Average Electricity Production from the PV System of the third day

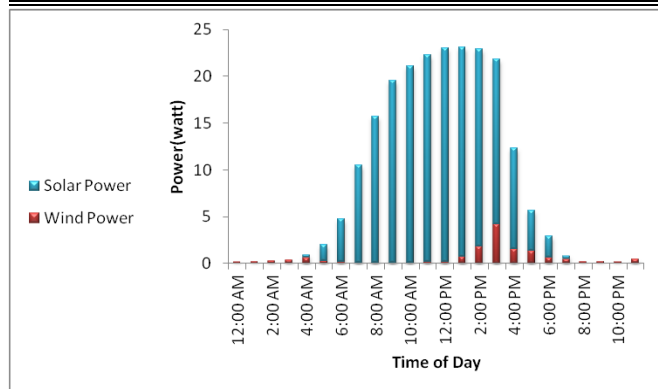


Figure -23: Daily Average Electricity Production from the Hybrid Wind-PV system of the third day

Wind power generation shown in figures (15), (18) and (21) demonstrates a continuous power production during the day with high values at night, while figures (16), (19) and (22) depict that highest solar electricity generation levels occur between 05:00 M and 18:00 PM. The combination of both power generations are shown in figures (17), (20) and (23). In these figures it can be observed that PV energy has a dominant contribution in the hybrid energy model from 04:00 AM to 18:00 M, which means when the sun existing, while the wind power is continuous during the whole day variable values depending on wind speed and giving uninterrupted power to supply the loads.

Conclusions: Through this work an insight into the energy situation and renewable energy potential has economically feasible power generation potential of wind and solar energy. The design of hybrid prototype for solar and wind energy has proved its effectiveness by installation of 50 watt PV panel and one 25-watt wind turbine which can supply a power for example is of 40-watt load which is efficient to operate TV, Camera, DC Light, and AC Light in effective way for 24 hours. The results of this work give an incentive to proceed with building and using such sustainable power generation systems (hybrid) that have proven to be efficient and economically feasible to use for continuous energy generation.

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Methods of artificial intelligence for cyber-physical systems

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Abstract: *Cyber-physical systems (CPS) are the core of the Fourth industrial revolution and the Industry 4.0 initiative. They are facing many challenges, addressing them requires attracting and using new methods and techniques from the field of artificial intelligence and big data to make intelligent decisions and perform effective data analysis. The paper presents an analyze of the current trends and challenges in the development of cyber-physical systems and the ever-increasing interest in the methods and approaches of artificial intelligence and its application in the life cycle phases of design, analysis, implementation and maintenance of CPS. There are two aspects that are the focus of attention and analysis: (1) the computing by intelligence and (2) the computing for intelligence. Finally some ideas for using different methods and approaches of artificial intelligence for achieving interoperability and autonomy of CPS are proposed.*

Keywords: CYBER-PHYSICAL SYSTEM, INDUSTRY 4.0, ARTIFICIAL INTELLIGENCE, METHODS, ONTOLOGY, AGENTS

1. Introduction

The evolution of personal computers into smart devices and their miniaturization, as well as the unstoppable development of the Internet and technologies related to it, led to the strengthening of the tendency to provide IT services and infrastructure through intelligent networks (computing clouds) and the construction of a world surrounded by ubiquitous computer calculations. The development of embedded systems and the achievement of their autonomy, as well as their wireless connection with each other and with the Internet, brought the physical world closer to the virtual in the form of so-called cyber-physical systems. The new Internet protocol IPv6, introduced in 2012, made possible the creation of the Internet of Things and services.

The initiative "Industry 4.0" has a huge potential, which allows creating wider opportunities to satisfy individual customer requirements, achieving greater flexibility of manufacturing and enterprise systems, enhancing the potential for optimal decision-making and increasing productivity and efficiency of the resources used or planned, as well as arising the prerequisites for creating value through new services. The concepts of Industry 4.0 initiative and that of digital transformation have also been transferred to a number of non-industrial and public sectors, contributing to increasing their efficiency and sustainability. The Industry 4.0 Working Group [1] argues that at the core of the fourth industrial revolution and the Industry 4.0 initiative are cyber-physical systems. In [2], eight technology clusters with the greatest contribution and importance to the development of Industry 4.0 are defined. The cluster on Industrial Internet of Things (IIoT) that includes the IIoT-related technologies and Cyber-Physical Systems (CPS) is the largest cluster, forming the core of Industry 4.0.

Cyber-physical systems (CPS) are physical and engineering systems whose operation is monitored, coordinated, controlled and integrated by a computing and communication core [3]. They are unique in that components can be distributed both spatially and temporally, and include complex networks of controllers with real-time feedback and communication. The structural and behavioural complexity of cyber-physical systems poses major challenges to the methods and environments for their design and analysis. It is necessary to develop the theoretical foundations of CPS, as well as to create software platforms with appropriately defined levels of abstraction, architecture, languages for modelling different aspects of CPS and transformations between these models. All this requires the development and application of modern methods and technologies aimed at integrated access to distributed information and data from sources that grow in number, type and complexity every day. Data from distributed information sources are in different formats, which makes it technically difficult to access and use the information offered in terms of interoperability between different hardware and software technologies.

Addressing many important challenges to CPS require attracting and using new methods and techniques from the field of artificial intelligence and big data to make intelligent decisions and perform effective data analysis based on large amount of data and efficient and intensive computations, as well as integration with other powerful computing systems, including cloud and fog applications. All these technical challenges in the design and analysis of CPS arise from the need to build a bridge between the sequential semantics and the parallel physical world and connect them to the solution of different types of engineering tasks.

The main purpose of the paper is to analyze the current trends in the development of cyber-physical systems as the core of the Industry 4.0 initiative and the ever-increasing interest in the methods and approaches of artificial intelligence and its application in the life cycle phases of design, analysis, implementation and maintenance of CPS. There are two aspects that are the focus of attention: (1) the computing by intelligence and (2) the computing for intelligence, as they are defined in [4].

The paper is presented in four parts. After the Introduction, the second part of the paper presents the basic characteristics and challenges to the CPS. The third part is dedicated to a modern look at artificial intelligence methods and their importance for solving various tasks in the field of cyber-physical systems and the Industry 4.0 initiative. Special attention in the fourth part is given to some of the most attractive methods of artificial intelligence in solving interoperability problems and the approach to creating autonomous systems using intelligent agents and multi-agent systems. Finally, some conclusions reflecting the results of the analysis are presented.

2. Basic characteristics and challenges to the CPS

2.1. Basic architecture and characteristics of CPS

The impact of CPS is revolutionary and pervasive, as argued by the CPS Public Working Group at NIST [5], as the development of these systems is associated with the emergence of autonomous vehicles, smart grids, smart cities and homes, robots, smart medical devices, telemedicine, Internet of Things (IoT) and more. Some of the main non-functional properties distinguishing CPS are: real-time, configurability, scalability, context awareness, interoperability, resilience and security. Synergies between cyber and physical systems can be at both the Nano level and the "system of systems" level. However science is still indebted to CPS, the lack of theoretical basis and methodologies creates barriers that can hinder the adoption, commercialization and market success of new applications of CPS [6]. The basic architecture of CPS is shown in Fig.1, including the both parts Cyber and Physical, connected through sensors, actuators and Network. The basic operations of Cyber part are computing, communication and control,

In [7], a very detailed analysis of the CPS characteristics is presented. The authors define 19 most cited lower-order

characteristics of CPS, which are aggregated in the following eight clusters:

- Cluster 1: Complexity/heterogeneity/encapsulation;
- Cluster 2: Interoperability, connectivity, communication, networking capability
- Cluster 3: Service orientation,
- Cluster 4: Modularity, autonomy, self-capabilities, decentralization;
- Cluster 5: Virtualization, real-time capability;
- Cluster 6: Computational capability;
- Cluster 7: Cooperation, collaboration;
- Cluster 8: Dynamic reconfigurability, adaptability.

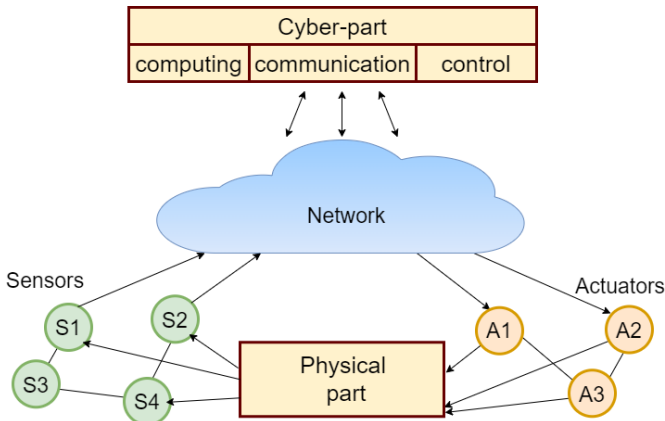


Fig.1: Basic architecture of CPS

2.2. Basic challenges to the CPS

The technical challenges to CPS are discussed in [8] and summarized in Fig.2. Cyber-physical systems include a large number of sensors, actuators and computing devices that exchange diverse data presented in different formats and temporal sequences. This requires new approaches providing the opportunity to work with a dynamically changing network topology of the system (1). The distributed nature of the physical system structure, computation, and communications creates major challenges in operational performance and ensuring safe system operation, security, and resilience in the face of environmental impact, component and system failures, and unregulated actions and cyber-attacks (2). Especially important challenge is the development of methods that integrate the discrete dynamics of the computing part with the continuous dynamics of the physical part and the stochastic nature of communications, which must be expanded to cover a wider context. The emphasis on these approaches is on the communication between the different components of the system. Methods are needed that combine systems with continuous dynamics with those of a discrete-event nature. Different time scales and dimensionality must also be taken into account (3). The emphasis on the approaches connected to the challenge (4) - networked control is on the communication between the different components of the system. There are two main approaches for data acquisition from the physical part of the CPS: timed driven and event driven sampling. The latter approach requires continuous monitoring of the physical system. There is a compromise approach, the so-called self-triggering approach that is related to the determination of safe intervals during which the physical system is not observed and the time when the data is collected. The main obstacles in the development of networked control for CPS are the event- and time-driven computing, the transmission failures, the varying time-delays, and also system reconfigurations. Particular attention is also paid to methods of addressing the effect of delayed network signals, such as scheduling or stability analysis methods. The next important challenge is sensor and sensor-actuator networks and their inclusion in the design process (5). The reliability, safety and security of the CPS largely depend on the quality and accuracy of the software components, which must undergo verification, validation and testing throughout the design

stages (6). This requires both the development of new verification and validation methods and the use of new software models (software development life cycle models). The joint design of control and planning systems (7) is a widely researched multidisciplinary task whose successful solution in CPS is complicated by the networked nature of CPS, network time delays, and system-wide robustness issues. Programming abstractions should be used at different levels covering different aspects of the designed system (8). Meta-level CPS architectures must be complete. The development of the new paradigm should follow the principle: "Globally - virtual, locally - physical" (9).



Fig.2: Basic challenges to the CPS

3. Short analysis of the methods of Artificial Intelligence

3.1. Computing by intelligence

Artificial intelligence is being used more and more and has an increasingly tangible impact in different areas of industry and society. The successful solution of many different tasks and problems related to the achievement of the goals of the Industry 4.0 initiative and guaranteeing high added value is thanks to the application of the latest methods and achievements in the field of artificial intelligence. More and more often, the enterprises and factories of the future are associated with the development of artificial intelligence and are mentioned with terms such as: smart factory, smart grids, cognitive enterprises or intelligent manufacturing. What all these paradigms have in common is that they are all based on a new principle of integration of the physical and cyber parts, through a comprehensive and complete design, development and evolution of the knowledge of the cyber-physical system of systems and the integration of artificial intelligence into the various technologies used.

Biologically embodied intelligence is presented in the machine through the generic intelligence that is composed of Data Intelligence, Perceptual Intelligence, Cognitive Intelligence and Autonomous Intelligence [4]. All these intelligent abilities are part of computing by Intelligence as shown in Fig.3. Data intelligence includes the computer's ability to formalize, express, calculate, remember, and store data rapidly. The most important and popular Data Intelligence methods are Artificial Neural Networks (ANN), evolutionary computing and fuzzy systems. Computational models have a high degree of complexity and can refer to various areas: digital, analog, hybrid, discrete-event, graphs, etc. Great successes have been achieved in the field of neural networks, such as the emergence of so-called convolutional neural networks (CNN) and reinforcement neural network (RNN), which open the way to processing big data and improving the accuracy of classification, identification and prediction tasks. Development in the field of neural networks is also a catalyst for success in the field of machine learning, where deep learning and deep reinforcement learning are successfully developed. Gaining popularity and wide scientific interest in the 1980s, Lotfi Zadeh fuzzy systems are particularly

applicable in areas where sufficient data is lacking, such as: signal and image processing, control, identification, and decision making. The third group of methods, including evolutionary calculations and programming, as well as genetic methods and algorithms, are primarily related to solving optimization tasks.

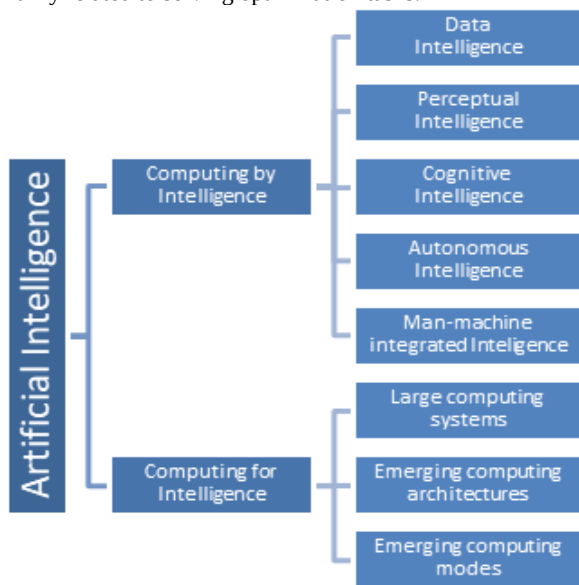


Fig.3: Classifications of methods in Artificial Intelligence [4]

Perceptual intelligence refers to receiving information such as voice, images and video through various sensors and I/O devices. It can also include multi-modal perception, signal extraction, selection and processing, data fusion based on different sensors for vision, hearing, smelling, tasting. The use of recognition and machine learning methods has led to significant advances in voice and image recognition. Another important direction is the development and use of intelligent sensors, of particular value being sensors with the ability to be self-aware and respond to remedy situations.

Cognitive intelligence refers to a machine's ability to understand and reason, think and explain. It requires understanding the relationship between data and analyzing the logic of structured data. The main directions in which cognitive intelligence is developing are natural language processing (machine translators, text generators, etc.), causal inference (a conceptual network of causal events for extracting causal relationships from text) and reasoning on knowledge (knowledge acquisition, representation, storage, modeling, integration, understanding, and management). Knowledge reasoning may be based on knowledge graphs, logical rules, graph-structure, or neural-network-based reasoning.

Autonomous intelligence refers to the ability of a machine to acquire a self-governing ego and consciousness. It develops in three directions: transfer learning, meta-learning and autonomous learning. Transfer learning is based on accumulating experience from past data, and for this purpose, machine learning methods are applied. Meta-Learning supports machine learning based on the use of meta-knowledge, finding application in the absence of sufficient training data and in self-learning conditions. Successfully copes in the cases of similar, homogeneous tasks, transferring the learned. Autonomous learning also includes models of the external open world. From the indicated methods, it can be seen that quite often combinations of different types of intelligence are used, especially in cases of solving more complex tasks.

Despite advances in machine intelligence, many complex scenarios and tasks require the use of human intelligence and other computational methods such as statistical ones. The possibilities for this are through human-computer interaction, human-machine integration, and brain computer interface.

3.2. Computing for intelligence

Although the major advances in development of machine intelligence algorithms and tools, the computing power remains a

bottleneck for intelligent computing. An opportunity to deal with this problem is the introduction of distributed structures and calculations, such as: federated learning, Large Computing Systems as High-Performance Computing or Edge, Fog, and Cloud Computing. The use of emerging computing architectures as accelerators and in-memory computing results in efficient power consumption, cheaper hardware, and an easier debugging process. Another possibility to deal with the complexity of calculations is the introduction of new Emerging Computing Modes as Quantum Computing, Neuromorphic Computing, Photonic Computing and Biocomputing. The characteristic of all these innovative solutions is that they use the algorithms and methods of artificial intelligence to varying degrees.

4. SOME IDEAS OF USING ARTIFICIAL INTELLIGENCE FOR CPS

4.1. Ontological approach for interoperability

Achieving interoperability through the use of semantic technologies can be represented as a sequence of three main processes: converting data from heterogeneous sources (relational databases, XML, tables, documents), processing integrated models (unification, editing and logical analysis) and information extraction (conversion, visualization). During the three stages, different methods are used to control the data being integrated, to sort the data, to reject duplicates, to extract information, to perform logical analysis and verification.

The integration can be done in different ways, going through different stages, using different languages, technologies and mechanisms. Ontology-based integration covers processes similar to ETL transformations: (E) xtracte from a data source, (T) transform into an RDF model (target ontology), and (L) oad e into ontological data stores. The main difference is that in the ontology-based integration, both structured and unstructured data can be used, and the semantics in the ontology can be set in the transformation process, or subsequently in the processing of the ontology model through the operations on ontologies: merging, mapping, alignment, integration. The reference ontology can be used as the target ontology. The transformation is repeated, when the data changes. Fig.4 illustrates an ontology integration method representing the integration of results obtained in the technology space (TP) of "BNF", which by means of "Scheme 1" and "Scheme 2" are stored in the TP of "RDB" as a database, which in turn have dynamic correspondences with "Local Ontology 1" and "Local Ontology 2", respectively. These two ontologies can be mapped to each other based on the existing reference ontology.

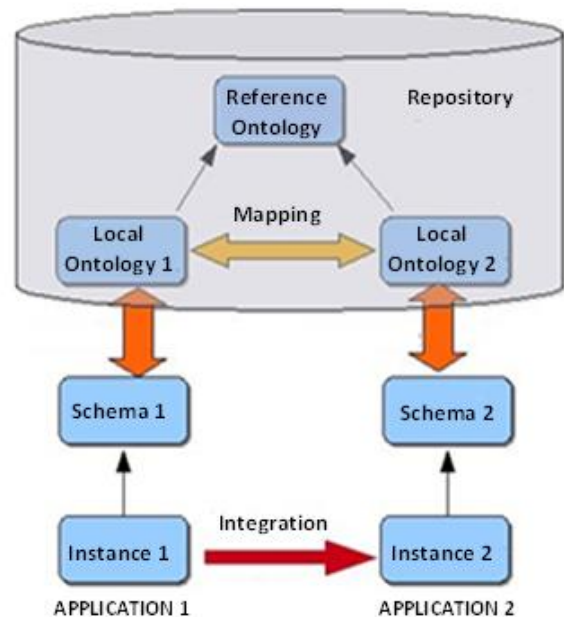


Fig.4: An example of ontological integration

4.2. Multi-agent systems

CPS development is much more than the union of computational and physical systems, and to apply CPS principles to new applications, new methods and tools are needed. CPSs integrate computational, network, and physical dynamics, featuring a high degree of heterogeneity and parallelism. As a result, software design techniques are insufficient. New approaches, methods, algorithms, and techniques are needed to support the CPS analysis and design process using execution platforms based on different software architectures.

In [9], three types of software architecture categories are defined and analyzed: component-based, service-oriented, and agent-based. The analysis shows that the agent-based approach has greater advantages in ensuring the autonomy of CPS objects, while the service-oriented approach is more suitable for achieving their interoperability. The advantages of agent-based architecture in terms of non-functional properties, especially in terms of configurability and reliability, make this approach highly suitable for the field of CPS. Other non-functional properties such as scalability, security and context awareness can be improved using the combination with knowledge-based approaches.

The concepts of CPS are closely related to agent-based systems, due to their main properties such as: autonomy, sociality, reactivity, proactivity and mobility. Different approaches and methods are used to ensure the useful characteristics of agents in different application areas, such as modeling, monitoring, control, diagnostics, etc. An important conclusion to be drawn from the analysis of the approach is that the results are more successful when the agent-based approach is combined with other approaches, methods and tools, such as model-driven development.

To achieve these features, the agent functions are divided into 4 sub-functions: Monitoring, Analysis, Planning and Execution (MAPE), which share knowledge, as shown in Fig.5. They underlie the architectural aspects of autonomous systems and obey an intelligent control loop known as MAPE-K (K is for Knowledge) [10]. This cycle is similar to and inspired by the general agent model proposed by Russell and Norvig [11], where an intelligent agent perceives its environment through sensors and uses these perceptions to define actions (effectors) to be performed on the environment.

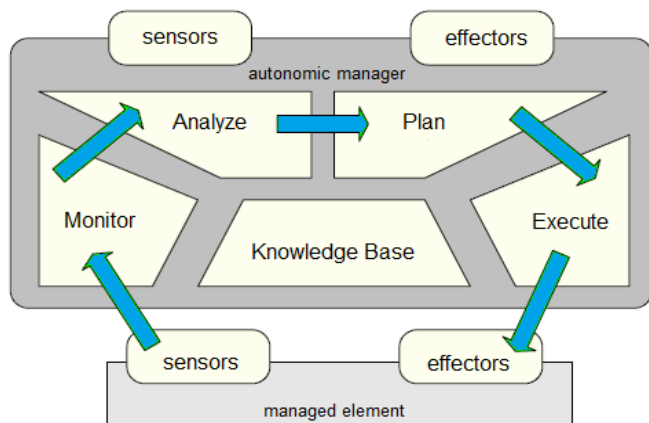


Fig.5: MAPE-K control loop, according [10]

5. CONCLUSIONS

Based on the CPS analysis and the presented classification of artificial intelligence methods in the two aspects (1) calculations with intelligence and (2) calculations for intelligence, the following main conclusions can be drawn:

- The stormy invasion of artificial intelligence methods in the field of CPS and IIoT requires changes in the 5-layer reference architecture of CPS, due to the inclusion of intelligent and cognitive methods in all layers of the architecture;

- As the requirements for CPS increase in terms of security, safety, reliability and resilience, changes are required in the life cycle models of these systems, including the introduction of risk assessment where possible.
- Advances in the field of artificial intelligence and especially in the field of Data Intelligence and in particular the high degree of applicability of convolutional neural networks and related deep learning opens the doors to address the challenges of CPS, such as those related to their modeling, diagnostics and maintenance, or regarding their cyber security.
- The idea of achieving interoperability enables the achievement of vertical and horizontal integration, based on different actions between local ontologies and the use of a reference one.
- The idea of using multi-agent systems as an approach to achieving autonomy and self-organization of the CPS allows the use of intelligent adaptive and predictive technical systems with self-X functions and cognitive information processing in continuous interaction with the environment, the Industry 4.0 initiative implies the integration of cyber-physical systems (CPS), the Internet of Things (IoT) and cloud computing, leading to what is called the "smart factory".

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Development of ceria-based catalysts for safety production and storage of hydrogen

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Abstract: This study is aimed at the development of active and selective ceria-based catalysts for hydrogen production by methanol decomposition. The effect of ceria modification with different metal oxides and development of mesoporous texture of the composites were illustrated. The microstructure of the obtained catalysts was studied in details by different physicochemical techniques, such as nitrogen physisorption, XRD, HRTEM, SEM, various spectroscopic methods and TPR with hydrogen. The bi-metallic spinel oxides revealed promising potential for the synthesis of more active and selective catalysts. The catalyst formula was optimized using mesoporous ceria doped with iron oxide as catalyst support and deposition of nickel oxide nanoparticles on it.

Keywords: HYDROGEN PRODUCTION; CERIA-BASED CATALYSTS; METHANOL DECOMPOSITION

1. Introduction

The high energy vector of hydrogen and the practically zero carbon target during the application identify hydrogen as promising alternative fuel in the near future [1,2]. However, the development of the hydrogen-based economy requires fast and efficient solving of the problems related to the low-cost and safety production and storage of hydrogen, without significant changes of the existing infrastructure, especially in case of the mobile and portable installations. Liquid organic compounds could be appropriate hydrogen carrier if they are abundant and cheap enough and also possess sufficient H/C balance. Methanol has been considered as one of the most suitable candidates, even more, it could be produced from diverse sources, including biomass and every waste which could be converted to syngas [3,4].

Among the various technologies for reverse hydrogen release from methanol, the catalytic methanol decomposition seems to be most effective because of easy operation and possibility for energy saving [5,6]. A crucial point of this technology is the efficiency of the catalysts. The intensive study in this aspect reveals that the behavior of the catalysts could be improved if they are produced in nanoscale and by development of porous texture, which ensure high active surface area. The optimization of the bi-functional acid-base and redox properties of the catalysts and the initialization of a synergistic activity between the distinct components in them is also needed. Ceria is one of the most promising candidates of catalyst or catalyst support because it possesses high surface acidity and significant oxygen storage capacity, related to the easy reversible Ce^{3+} - Ce^{4+} transitions [7,8]. It has been reported that the catalytic properties of ceria could be improved via development of mesoporous texture, using hydrothermal preparation procedure in presence of appropriate organic template, and/or by doping it with metal oxides [9,10].

This study is focused at the evolution of ceria - based catalysts for methanol decomposition by modification of ceria with diverse mono-and binary metal oxides. The samples were characterized in details by different physicochemical techniques, such as nitrogen-physisorption, XRD, SEM, HRTEM, various spectroscopic analyses and temperature-programmed reduction with hydrogen. The relation between the microstructure and the optimal formula of the catalysts was clarified as well.

2. Materials and Methods

2.1. Materials

Nanosized mesoporous ceria was synthesized by template assisted hydrothermal technique using aqueous solutions of CeCl_4 as a precursor and N-hexadecyl-N,N,N-trimethyl ammonium bromide (CTAB) as a template according to the procedure described in [11]. After the precipitation of the obtained mixture with 25% solution of ammonia, the sludge was subjected to treatment at 373 K for 24 h in a closed container. The produced solid was calcined at 773 K for 10 h in air.

Aqueous solutions of copper, chromium, iron, zinc and nickel nitrates were used for the modification of thus prepared ceria support by incipient wetness impregnation technique. After drying at room temperature, the solid product was subjected to calcination at 773 K for 4 h. For all modifications, the overall amount of metal was 8 wt.%. The monometallic materials were denoted as MCe (M=Cu, Fe, Cr or Ni). For the preparation of binary spinel oxide modifications of ceria, the Cu/Cr and Cr/Fe molar ratio was fixed as 1:2 and the obtained samples were denoted as CuCrCe and FeCrCe, respectively. The ratio between the metals in the ternary CuZnFeCe modification was Cu:Zn=1 and (Cu+Zn)/Fe=1:2, respectively. Alternatively, bi-metallic 1Fe9Ce and 5Fe5Ce mesoporous oxides with Fe/Ce molar ratio of 1:9 and 5:5, respectively, were obtained by hydrothermal technique, following the procedure, reported in [11]. The corresponding Ni5Fe5Fe modification was obtained by incipient wetness impregnation technique, as described above. The Ni content in it was 8 wt.%.

2.2. Methods

Nitrogen physisorption measurements were performed on a Beckman Coulter SA 3100 apparatus. A Bruker D8 Advance diffractometer with Cu K α radiation and a LynxEye detector with constant step of 0.02° 2 θ and counting time of 17.5 s per step was applied for the powder X-ray diffraction analyses. The SEM investigation was carried out on a FEI Nova NanoSEM450. A FEI Talos F200X transmission electron microscope was applied for the HRTEM analyses. UV-Vis measurements were done on a Jasco V-650 UV-Vis spectrophotometer. Raman spectra were collected on a DXR Raman microscope (Thermo Fischer Scientific, Inc., Waltham, MA) equipped with 532 nm laser. The XPS measurements were carried out on a AXIS Supra electron spectrometer (Kratos Analytical Ltd.) using monochromatic AlK α radiation with a photon energy of 1486.6 eV. The Mössbauer spectra at room temperature (RT) were recorded by Wissel (Wissenschaftliche Elektronik GmbH, Germany) electromechanical spectrometer working in a constant acceleration mode. A $^{57}\text{Co}/\text{Rh}$ (activity ≈ 10 mCi) source and α Fe standard were used. The spectra were fitted using CONFIT2000 software.

The TPR/TG (temperature-programmed reduction/thermo-gravimetric) analyses were performed on a Setaram TG92 instrument in a flow of 50% H_2 in Ar with heating rate of 5 K.min $^{-1}$.

2.3. Catalytic tests

The catalytic tests were carried out in a flow type fixed-bed reactor (55 mg of catalyst). Methanol (1.57 kPa) was introduced into the reactor from a saturator, thermo-stated at 273 K using argon as a carrier gas (50 cm ^{3} .min $^{-1}$). Step-wise increase of the temperature in the reactor was done up to 773 K keeping the heating rate of 2K/min.

On-line gas chromatographic analyses were performed on a SCION 456-GC apparatus equipped with flame ionization and thermoconductivity detectors using PORAPAC-Q column.

3. Results and Discussion

2.1. Monometallic ceria promoted composites

The texture of the parent ceria and its monometallic modifications was studied by low-temperature nitrogen physisorption. The physisorption isotherms (Fig. 1) characterize with a hysteresis loop between 0.7-0.9 relative pressure and strong increase of the adsorption above it, which is typical of materials with interparticle meso-macroporous texture.

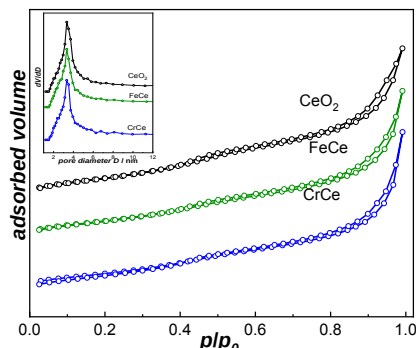


Fig. 1 Nitrogen physisorption isotherms and pore size distribution (inset) for selected samples.

The parent ceria possesses about $100 \text{ m}^2\text{g}^{-1}$ surface area and $0.2 \text{ cm}^3\text{g}^{-1}$ total pore volume. These parameters decrease of about 10-20% during its modification with different metal oxides. The preservation of the shape of the physisorption isotherms for all modifications (Fig. 1) indicates that the observed effects are predominantly related to partial pore blocking due to the deposition of metal oxide nanoparticles in the pores of the ceria support, without significant structural collapse with it.

SEM and HRTEM techniques were used for the visualization of morphology of the obtained composites (Fig. 2).

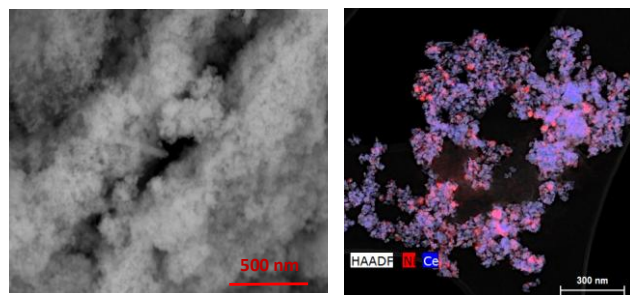


Fig. 2 SEM (left) and HRTEM (right) images of NiCe composite.

It was well-illustrated that the ceria matrix possesses granular structure of spherical-like nanoparticles. According to the XRD measurements, the average crystallite size was about 11 nm. In the case of the metal oxide modifications, HRTEM images (Fig.2,right) demonstrate presence of metal oxide particles with average size of about 5-10 nm, which are almost homogeneously spreaded within the ceria matrix. This morphology ensures close contact between the ceria support and the loaded metal oxide particles, which could affect the electron transfer between them, initiating synergistic support-metal oxide activity as well.

Fig. 3a demonstrates methanol decomposition activity of pure ceria and its monocomponent modifications with the temperature increase in the range of 520-770 K. Ceria support exhibits very low catalytic activity. Here, methanol decomposition is initiated just above 700 K and up to 20% selectivity to CO, due to the formation of methane and CO_2 as by-products, is detected (Fig.3b). The shift of the conversion curves to lower temperatures for the metal-modified materials indicates improvement of the catalytic activity (Fig. 3a). CO selectivity increase is also demonstrated in this case (Fig. 3b).

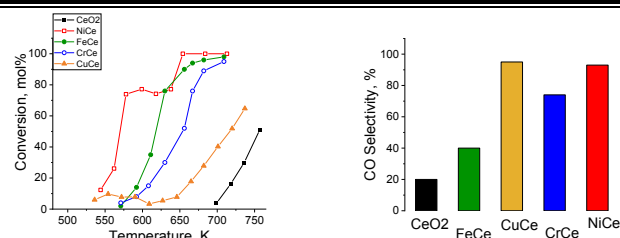


Fig. 3 Methanol conversion vs temperature (left) and CO selectivity (right) for the monocomponent CeO_2 modifications.

The modification of ceria with copper is less effective with respect to the development of active catalysts, despite the improved CO selectivity. Just the opposite, significantly higher catalytic activity and lower selectivity in methanol decomposition to CO is demonstrated for the iron- and chromium containing samples. Excellent catalytic behavior, even at relatively low temperatures, is observed for NiCe. However, the complex shape of the conversion curve with the temperature increase indicates significant changes with the catalyst. The additional TPR-TG study clearly demonstrates reduction transformations of the active NiO particles by the reaction medium.

2.2. Spinel oxide ceria promoted composites

In order to improve the behaviour of the Cu and Fe-containing catalyst, binary metal oxide modifications were also produced. Cr was added as a second metal, due to the possibility to obtain binary CuCr and FeCr metal oxides with spinel structure. The superior magnetic, optic and catalytic properties of the spinel materials have been well-demonstrated [12]. They are probably related to their unequal structure, consisted of metal and oxygen ions, arranged with different symmetry in two sub-lattices.

The samples were studied under the conditions of thermo-programmed reduction (TPR) with hydrogen (Fig. 4).

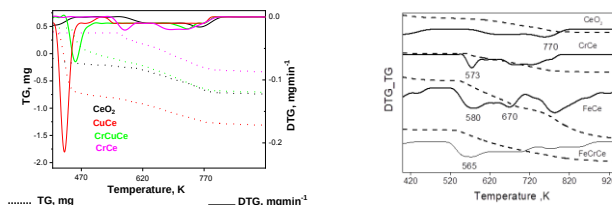


Fig. 4 TPR-TG and TPR-DTG profiles for CuCrCe (left) and FeCrCe (right) composites. For comparison, monocomponent Fe, Cu and Cr modifications of ceria are also presented.

The TPR profiles of the individual Cu, Cr and Fe-containing samples significantly change after their combination in the binary materials. This evidences strong interaction between the distinct oxide components, most probably included in the spinel structure.

In order to characterize the changes with the iron components in the binary materials, Moessbauer spectroscopy was also applied. The Moessbauer parameters: isomer shift (IS), quadruple splitting (QS), hyperfine field (H_{eff}) and full width of half-maxima (FWHM) as well as the relative part of each component (G), elucidated by the least squares fitting of a set of discrete Lorentzian line shapes, are listed in Table 1.

The Moessbauer spectra of the mono-component FeCe is well fitted with sextet and doublet parts. The Moessbauer parameters of the sextets (S_x) are typical of Fe_2O_3 with average crystallite size above 10-12 nm. The parameters of the doublet part correspond to Fe^{3+} ions from the "core" and the "shell" of finely dispersed (below 10-12 nm) particles with superparamagnetic behavior (SPM).

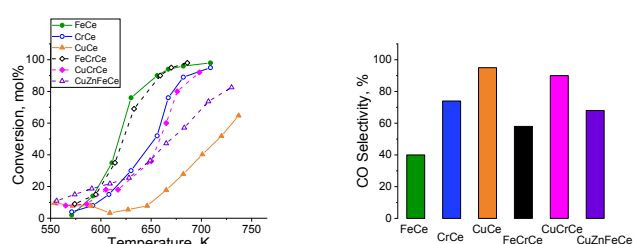
Doping FeCe with Cr provides disappearance of the sextets in the spectra. The core/shell ratio of the doublets is close to 1, which indicates significant increase in the iron dispersion.

Table 1. Moessbauer parameters of FeCe and FeCrCe materials

Sample	Components	IS, mm/s	QS, mm/s	H _{eff} , T	FWHM, mm/s	G, %
FeCe	Sx - Fe ³⁺ , γ-Fe ₂ O ₃	0.34	0.00	49.8	0.64	47
	Db1 - Fe ³⁺ , SPM Fe ₂ O ₃ core	0.36	0.69	-	0.44	27
	Db2 - Fe ³⁺ , SPM Fe ₂ O ₃ shell	0.36	1.15	-	0.51	26
FeCrCe	Db1 - Fe ³⁺ , SPM Fe ₂ O ₃ core	0.35	0.73	-	0.56	46
	Db2 - Fe ³⁺ , SPM Fe ₂ O ₃ shell	0.37	1.17	-	0.52	54

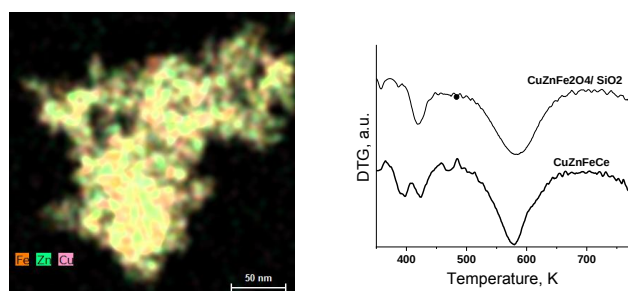
The increase in the FWHM values for FeCrCe evidences change in the environment of the iron ions, most probably due to the interaction with the situated nearby chromium ions.

In Fig.5 the catalytic behavior of all mono- and bi-component Cu, Cr and Fe containing samples in methanol decomposition is compared.

**Fig. 5** Methanol conversion vs temperature (left) and CO selectivity (right) for the mono- and bi-component Cu and Fe modifications of CeO₂.

The methanol conversion is strongly improved for the CuCrCe composites with respect to the corresponding ingredients, without significant changes in the CO selectivity. The catalytic activity of FeCrCe is similar to that one of FeCe, despite the lower content of iron in the former. Here, simultaneous increase of the CO selectivity is also detected. Considering the Moessbauer results (Table 1), these observations could be related to the stabilization of iron and copper species in highly dispersed state. Their catalytic behaviour is also affected by the easier reduction transformations of the iron and suppressed reduction transitions in the copper species under the reduction reaction medium (Fig.4).

The evolution of the Cu- and Fe-ceria modifications after doping with zinc oxide, was followed in the obtained ternary CuZnFeCe composites. The XRD results show co-existence of cerianite and ferrite phases with average crystallite size of 22 and 16 nm, respectively. The TEM images (Fig.6, left) demonstrate high dispersion and close contact between the distinct metal oxide species.

**Fig. 6** TEM image of CuZnFeCe composite (left) and TPR of CeO₂ and SiO₂-supported CuZnFe (right).

The TPR profiles (Fig. 6, right) show reduction transformations with the ferrite phase in the 400-650 K range. Note, that the TPR

effects of CuZnFeCe are narrower and shifted to lower temperature in comparison with the similar CuZnFe modification of the inert silica support. This suggests complex influence of the ceria support on the loaded spinel particles, which probably improves not only their dispersion, but also the electron transfer from the support to the loaded spinel oxide particles.

The ternary CuZnFeCe composite demonstrates higher catalytic activity, but about 25% lower CO selectivity as compared to the single CuCe modification (Fig.5). In comparison with FeCe, the CuZnFeCe sample possesses much lower catalytic activity, but about double higher CO selectivity.

Thus, the spinel oxides provide good opportunity for the improvement of the ceria catalytic behaviour in methanol decomposition and the catalyst formula could be optimized by simple variation of the spinel oxide composition.

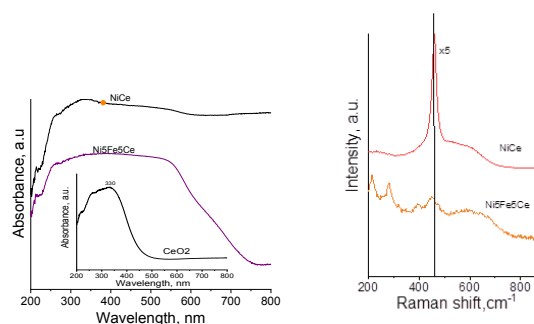
2.3. Nickel and iron ceria promoted composites: Effect of the preparation procedure.

The preparation procedure is a powerful strategy for the regulation of catalyst behavior. In this study, FeCe and 1Fe9Ce materials with similar Fe content were prepared by traditional incipient wetness impregnation and template assisted hydrothermal technique, respectively. The XRD study (Table 2) demonstrates higher dispersion of the samples, prepared by the addition of iron during the hydrothermal treatment. For this sample, a slightly higher BET surface area and pore volume is registered (Table 2), which evidences lower effect of pore blocking. Using similar hydrothermal technique, the 5-fold increase of the iron content in the sample (5Fe5Ce) provides a significant decrease in the BET surface area and pore volume combined with a segregation of hematite phase with average crystallite size of about 42 nm (Table 2). For both 1FeCe and 5Fe5Ce samples a deviation in the ceria unit cell parameters is observed which indicates that the hydrothermal procedure facilitates partial insertion of Fe³⁺ ions in the ceria lattice.

Table 2. XRD and N₂ physisorption data for Fe and Ni decorated CeO₂.

Sample	Phase composition	Unit cell parameters (Å)	Crystallite size, nm	BET, m ² /g	Pore volume, m ³ /g
CeO ₂	CeO ₂	5.4126(5)	18	105	0.22
FeCe	CeO ₂	5.4126(5)	18	90	0.19
1Fe9Ce	CeO ₂	5.3948(8)	11	99	0.25
5Fe5Ce	CeO ₂	5.374(1) a=5.044(1) c=13.78(4)	8 42(3)	68	0.37
NiCe	CeO ₂ NiO	5.4119(4) 4.184(1)	19(18) 15	41	0.16
Ni5Fe5Ce	CeO ₂ Fe ₂ O ₃ NiO	5.375(1) 5.046(1) 13.781(4) 4.190(3)	9(8) 48(42) 13	58	0.27

The modification of ceria with Ni and Fe provides significant change in the optical properties, which is well-illustrated by the changes in the absorption features in the UV-Vis spectra (Fig. 7).

**Fig. 7** UV-Vis (left) and Raman (right) spectra of NiCe and Ni5Fe5Ce composites.

This could be assigned to significant changes in the environment of the cerium ions due to the situated nearby Fe³⁺ and

Ni²⁺ ions and related with them, oxygen defects. The Raman spectra (Fig.7) display strong decrease in the intensity of the typical of ceria Raman shifts, especially in case of the Fe-doped materials. This indicates changing in the ceria microstructure due to the incorporation of Fe³⁺ and/or Ni²⁺ ions in it.

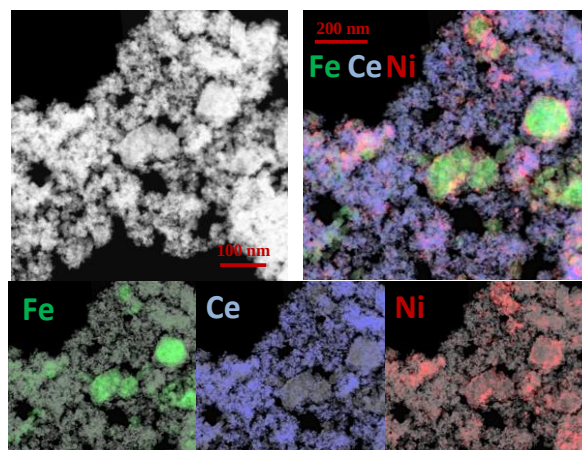


Fig. 8 TEM image of Ni5Fe5Ce composite.

TEM images of Ni5Fe5Ce is presented in Fig. 8. It is well visible that the Fe particles are finely dispersed within the whole CeO₂ matrix. Only small number of larger Fe-containing aggregates could be distinguished, which is in accordance with the XRD study (see above). The Ni-containing particles, which are also with very high dispersity, seems to be in close contact both with ceria and iron-containing species.

More information for the surface distribution of all elements in various composites was obtained by XPS technique (Table 3).

Table 3. Data from the XPS analyses for the selected Ni and Fe decorated CeO₂.

Samples	O 1s, at %	Fe 3p, at %	Ni 3p, at %	Ce 3d, at %	Ce ³⁺ %
CeO ₂	79.5	-	-	20.5	22.6
NiCe	80.8	0.0	6.5	12.7	8.0
1Fe9Ce	59.4	8.2	-	32.4	34.3
5Fe5Ce	63.1	11.7	-	25.2	27.7
Ni5Fe5Ce	77.0	4.5	3.1	15.4	15.0

Co-existence of Fe³⁺, Ni²⁺, Ce⁴⁺ and Ce³⁺- containing phases is detected. The presence of significant amount of cerium in lower oxidative state evidences formation of defects in the ceria lattice, most probably related to the replacement of Ce⁴⁺ ions by Fe³⁺ and/or Ni²⁺ ones. This ensures higher concentration of the latter on the surface as compared to the expected nominal ones. Note, that the Ni/Fe ratio is about 1.5, which is close to the theoretic ratio in the Ni ferrite. These results could be an indication for the preferable location of the Ni ions around the Fe-containing species, most probably on the Fe-Ce interface.

The catalytic behavior of the samples is illustrated in Fig. 9. All modifications exhibit higher catalytic activity and CO selectivity as compared to the pure ceria support. Among the mono-component iron modifications, the impregnation technique facilitates the formation of more active, but less selective to CO samples. Obviously, the higher extent of insertion of Fe³⁺ ions in the ceria matrix, which is achieved by the hydrothermal preparation technique, forms lower number, but highly active in methanol dehydrogenation to CO catalytic sites. The segregation of larger hematite particles, which is facilitated with the increase in the Fe/Ce

ratio (sample 5Fe5Ce), improves the catalytic activity, but decreases the selectivity to CO.

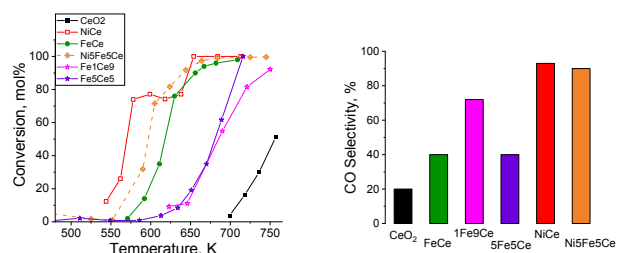


Fig. 9 Methanol conversion and CO selectivity for Ni and Fe-decorated CeO₂.

As demonstrated above, NiCe modification demonstrates superior catalytic activity and CO selectivity at lower temperatures, but the catalyst significantly loses its activity above 570 K, most probably due to the reduction and segregation of the active Ni-species by the influence of the reaction medium. This disadvantage is overcome by Fe-doping of ceria during the hydrothermal procedure (sample Ni5Fe5Ce). It seems that the localization of Ni²⁺ ions in the vicinity of the Ce/Fe interface stabilizes them in highly dispersed state and probably provokes the activity of mixed Ni-Fe-Ce redox pairs.

4. Conclusions

The catalytic activity and selectivity of mesoporous CeO₂, prepared by template assisted hydrothermal technique, in methanol decomposition could be significantly increased after modification with Cu, Fe, Ni or Cr oxides by simple incipient wetness impregnation procedure. The catalytic behaviour of these composites could be improved by development of binary oxides with a spinel structure. The Ni modification of ceria provides superior catalytic activity in selective decomposition of methanol to CO and the catalyst stability could be improved by preliminary doping of ceria with iron oxide using hydrothermal preparation procedure.

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Energy utilization of high-water content biomass in albanian rural areas

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Abstract: The use of renewable sources for energy purposes is very important from the global environmental perspective. Biomass is part of this group of fuels. This article focuses on the characteristics of wet biomass, a typical fuel source in the Albanian rural areas and not only. Thus, the most significant factor of biomass combustion is its moisture content in natural conditions. This property significantly influences the burning quality of biomass. Drying of this fuel using conventional methods or energy intensity processes aims to decrease the moisture content in biomass and meantime increase of its calorific value. The techniques of drying wet biomass vary significantly. Energy utilization of wet biomass is the main goal of this paper, considering it an important fuel source especially during winter season in Albanian rural areas. The variation of heating value to moisture content and other significant parameters have been investigated.

Keywords: MOISTURE, BIOMASS, ENERGY, HEATING VALUE.

1. Introduction

Naturally, biomass is one of the oldest resources that man has used to meet his needs [1]. Likewise, the technology of converting this fuel into useful energy is one of the most well-known and studied, but improvements and increased efficiency bring new challenges in this field as well [2]. Albania is situated in the Mediterranean with relatively small arable land [3]. Thus, the biomass resources of the country are limited. It is known that the main sources of biomass are forest waste, agricultural waste derived from processes, animal waste, urban waste, as well as energy crops [4]. The studies on the use and exploitation of biomass in general and fuel wood in particular in Albania were limited. In the cases where they have been carried out, they were partial, without taking into account the demographic developments, ownership changes, economic and political changes that our country experienced during the recent years [5]. In Table 1 is presented the biomass potential in the country. Firewood (biomass) represents about 52% of the renewable share in the Albanian energy consumption, where the other 48 % is electricity. It is widely known that the Albanian electricity production is largely based on hydropower [6]. The use of firewood is mostly dominant in rural areas of the country. In recent years the institutions have initiated actions in controlling the unlimited cuts of forests [7]. Although the situation has changed there is still poor progress in full control of the country's forest by legal authorities. Thus, except firewood other biomass resources have been used for heating purposes or processes requiring heat. Herbs, agriculture crops, olive mill waste, medicinal herbs etc., have been seen as a useful energy source. These typical biomass sources are commonly found in natural condition, and their energy utilization requires pre-processing such as drying, which results in cost increase for the end consumer. Therefore, the investigation of wet biomass parameters, such as moisture content, calorific values, ash content is seen as highly important in this article.

Table 1. Biomass energy potential in Albania [8]

Biomass	Theoretical potential (ktoe)	Share in national energy balance (%)	Technical potential (heat ktoe)	Technical potential (electricity ktoe)
Forest	263.6	1.07	234.4	70.3
Agriculture	1521.1	6.17	979.8	293.9
Urban Waste	1576.4	6.39	1276	382.8
Waste from trees	168.1	0.68	142.9	42.9
Livestock waste	585.25	2.37	521.6	156.5
Energy crops	62.3	0.25	57.1	17.13
Total	4176	16.9 %	3212	936.6

2. Energy utilization of wet biomass

Moisture content has a significant influence in the energy utilization of biomass [9]. Thus, in normal conditions the moisture content can vary from 15% found in dry straw up to 80% in wood or other products such as agricultural waste or various residues [10]. High water content will negatively affect in the calorific value. The dependency of moisture content and calorific value is given according to [11] by the relation (1) where the increase of water content causes the decrease of calorific value.

$$H_u = H_h - 2453 \cdot (W_r + 9 \cdot H_r) \quad [\text{kJ/kg}] \quad (1)$$

From the moisture content point of view wood chips are considered relatively in high water content. However, in rural areas where the consumption of fuel wood is very high and the storage infrastructure is poor, it is expected that the water content of biomass for fuel purposes to reach higher values. Some agriculture waste result in high water content where from the analysis the below results were taken.

Moisture	$W^r = 79,7 \%$
Ash	$A^r = 1,21 \%$
Volatile matter	$h^r = 19,09 \%$
Calorific value	$H_u = 1,46 \text{ MJ/kg}$

Wet biomass is commonly found in many sectors in Albania. Particularly the olive processing industry, medicinal herbs sector, has shown key potential in biomass production for energy purposes. Thus, in recent years the olive processing industry has reached a significant increase. The amount of olive mill waste resulting from the respective companies operating in the market has significantly increased the capacities of wet biomass production. Currently for the drying of wet olive mill waste is used open sun drying process resulting in less cost for the end consumers. However, the increase of the demand for this product will lead to more energy intensity processes in this sector. A view of fresh wet olive mill waste is given in Figure 1.



Fig.1 Typical wet olive mill waste in Berat, Albania.

The moisture content of around 80% is related to the low calorific value of 1.46 MJ/kg, practically excludes the possibility of stand-alone burning.

Table 2. Chemical properties of different biomass type

Chemical Analysis			Wood chips	Straw	Herbs
Parameter	Unit		Typical	Typical	Typical
Moisture	W_r	%	20-60	7,7-23	10.5-21
Ash	A_d	%	0.3-6	2-7	3.8-8
Volatile matter	h_d	%	70-85	75-81	74-82
Calorific Value	$MJ.kg^{-1}$		5.9-15.1	11.8-16.1	11.1-15.2

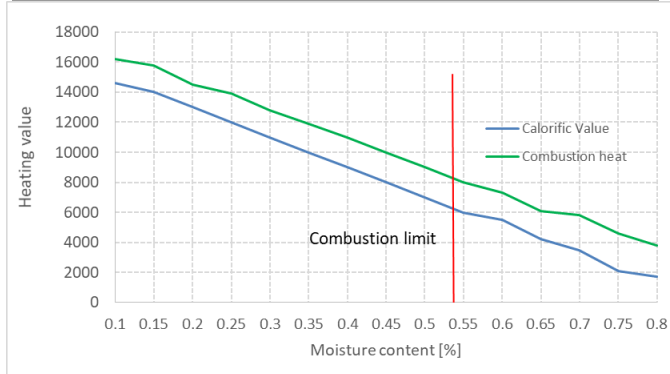


Fig. 2 Relation of calorific value and heat of combustion to moisture content

The reason for that is, of course, the large amount of heat needed for the evaporation of moisture from the biomass before ignition and also the large amount of water vapor in the combustion gases that are released in this case. Both of these influence on the temperature reduction in the combustion chamber below the permissible limit, which is necessary to ensure continuous combustion. The influence of the moisture content on the calorific power for wet biomass is presented in Figure 2.

At a moisture content of 55%, the calorific value is slightly above the limit of 6 MJ/kg, which can be estimated as the possible limit of the single burning of this biomass in the relevant energy technologies. From the graph, it is clear that with the decrease of water content, it is possible to obtain fuel with more calorific value, that is, better quality, regardless of the improvement of ignition and stability during its combustion process.

When the moisture drops below 35%, the biomass will have a calorific value similar to lignite coal, but with the advantage that it releases less SO_2 and ash residue. Fig. 3 shows the influence of moisture content on biomass for the theoretical flame temperature. Its calculation was carried out for excess amount of air $\alpha=1.3$, for different preheating of air. From the figure it is clearly shown that it is not possible to use biomass with high humidity for combustion, because the flame temperature is too low. For temperatures up to 600°C, flame ignition will most likely not occur. For slightly higher temperatures, up to 1000°C, the combustion would be very unstable and with a high CO content in the combustion gases.

From the graph, it is clear that with the decrease in humidity, it is possible to obtain fuel with more calorific power, that is, better quality, regardless of the improvement of ignition and stability during combustion. When the humidity drops below 35%, the biomass will correspond a calorific value similar to lignite, but with the advantage that it releases less SO_2 and ash residue.

Only after decreasing the flame temperature to approximately 1100 to 1200 °C, we can expect a stable combustion and almost perfect continuation of the burning mass. This adiabatic flame temperature corresponds to a moisture content of about 55%, which is consistent with experiences of burning wet fuels. The situation can be improved if we preheat the air to higher temperatures. Moisture content significantly affects the volume of combustion gases during biomass combustion. Figure 4 shows the dependence of the volume of combustion gases and water vapor in them, in relation to the water content of the biomass we are studying. Meanwhile, the

volume of gases released during the burning of 1 kg of biomass decreases with increasing moisture, while the volume of water vapor in it increases. It is interesting to compare the volume of combustion gases for 1 MJ of calorific value. To achieve the required thermal power in the heat generator, it is important to add another amount of heat to the fuel. The quantity of this amount of heat depends on the efficiency of the heat generator, which varies slightly with the characteristics of the fuel, in this case the biomass. The relation of flue gas volume to water content if shown in Fig.4.

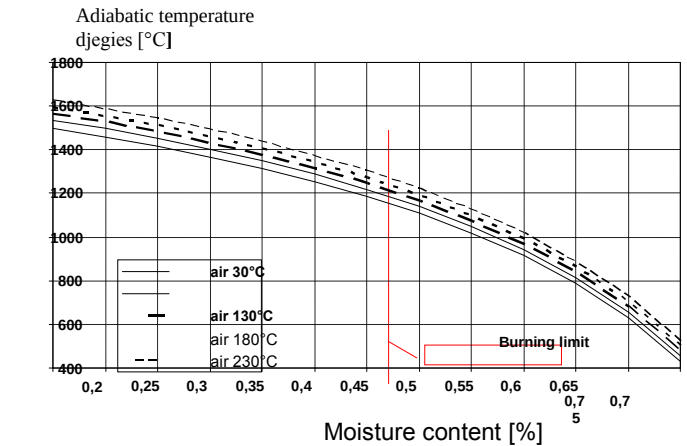


Fig.3 Adiabatic temperature variation to moisture content and air temperature

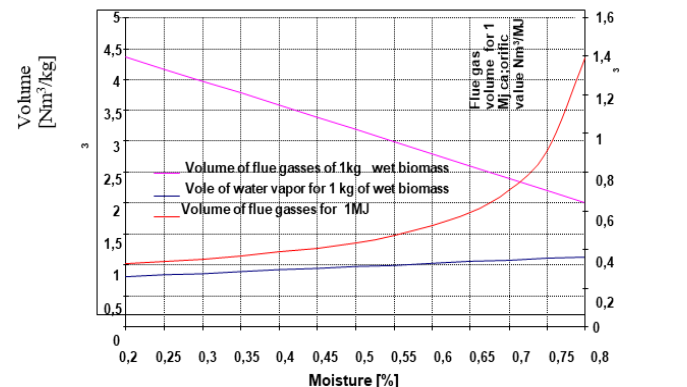


Fig.4 Volume of flue gases and water vapor to moisture content of biomass

Having this into consideration comes out that heat generators which burn drier biomass will release less combustion gases, so this heat generator will be smaller than those that burn wetter biomass. The graph in Figure 5 is presented the variation of water vapor saturation temperature in flue gases to moisture content of wet biomass. The excess amount of air is estimated $\alpha=1.3$.

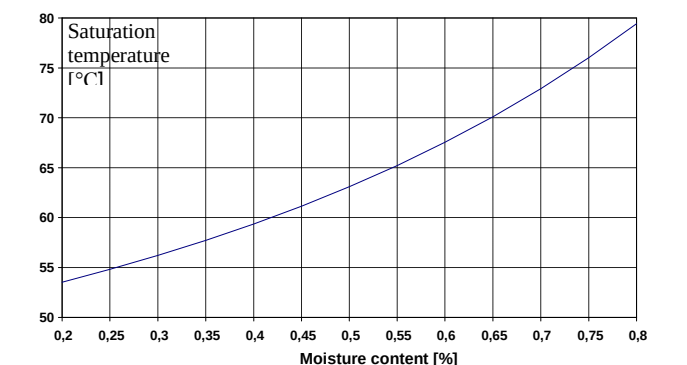


Fig.5 Saturation temperature variation to moisture content of wet biomass.

Another important aspect related to the moisture content in the biomass is the influence on the dew point temperature of the combustion gases. The temperature of the dew point of the gases corresponds to the saturated state of the vapors, thus the beginning of the condensation of water vapor in the combustion gases. Its scale is proportional to the content of water vapor in the gases, that is, the moisture content of the fuel. This is mainly divided by the temperature of saturated water vapor that responds to the partial pressure, although its real value is greater due to the presence of solids, mainly SO₂ gases in the combustion gases. In Figure 2 is shown the relationship between water vapor saturation temperature and biomass moisture (fuel), the actual dew point temperature would be 10 to 15 °C higher. Having into consideration that we do not want condensation on the end surface of the generator, we choose the temperature of the exhaust gases from the heat generator with a certain margin above the dew point temperature. From the above it follows that the cooling of the combustion gases and the use of heat in the dry biomass can be better than in the wetter biomass.

The content of combustion gases and the amount of water vapor in them affects the change in dew point temperature and losses in the heat generator chimney. The heat losses in the chimney, or in other words the apparent heat losses of the combustion gases, are the most important losses in the generator and significantly determine its performance. The method of their calculation is not the same. In order to express this the relation (2) is used in this case, where:

Z_m - the mechanical losses from unburned mass;

h_{gdj} is the enthalpy of flue gasses during the temperature t_0 , and air excess α_0 , after the heat generator;

h_{air} - is the outdoor air enthalpy;

$$Z_O = (1 - Z_m) \cdot \frac{h_{fg}^{t_0, \alpha_0} - \alpha_{fg} \cdot h_{air}}{Q_n} \quad (2)$$

In Figure 6, is presented the relation between chimney losses to moisture content of the biomass. In order to estimate the other losses value is shown the relation with generator efficiency.

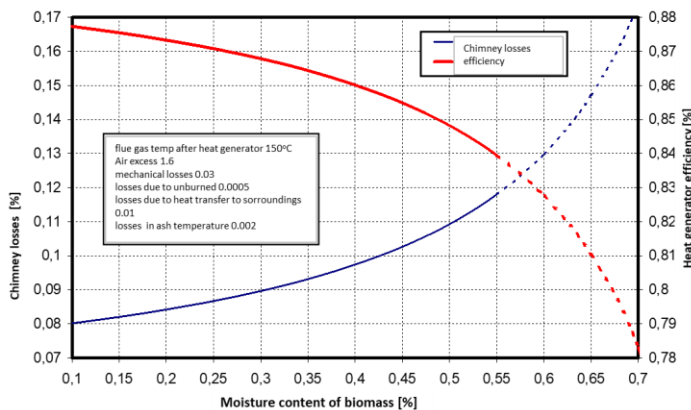


Fig. 6 The relation between chimney losses, heat generator efficiency to moisture content of biomass

From the graph above, it can be observed that for the same values of combustion gases and excess air, the efficiency of the generator progressively deteriorates with the increase of moisture content of the biomass product. The decline may reach several percent. The graph also shows the imaginary burning limit of biomass with 55% moisture content.

3. Drying of wet biomass

In order to utilize the wet biomass energetically it is necessary moisture must be removed before entering the heat generator. This can be achieved in two ways:

- Mechanical drainage;
- Drying, or the combination of these two methods.

Mechanical drainage of biomass can be carried out in many ways. The most widespread of them is mechanical pressing and centrifuge applying the centrifugal force on it. From the literature review it is obtained that the use of quality biomass presses leads to a moisture content of about 65%. These devices are of course expensive and the removal of moisture is found energetically difficult. The main reason why this high-water content biomass cannot be drained further is that the water is bound in the cells, where it can be released after the destruction of their walls. The drying of biomass in convective dryers utilizing hot air or combustion gases from different processes represents the most widespread method in the drying industry today. During the production of sawdust "pellets" or "briquettes" with this method, pre-heating is performed before the pressing process. Hot air-drying method has the advantage that the air holds more water than the combustion gases which are saturated with vapors from the combustion process. On the other hand, it is necessary to heat the air for drying in a special combustion gas-air heat exchanger or in steam heaters, which complicates and increases the cost of this method. Most industrial drying applications use combustion gases.

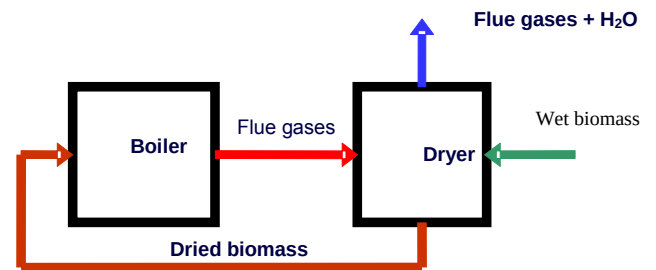


Fig. 7 Principle of open convective dryer for wet biomass

Drying of biomass with extraneous flue gases obtained by burning e.g. gas only for drying purposes is already well studied. Therefore, the attention will be focused primarily on convective drying with flue gases obtained by burning pre-heated biomass in a boiler that would produce steam for energy purposes. This variant corresponds to the common way of preparing fuel for combustion by drying its own flue gases in the so-called open circuit, where the dryer is integrated as part of the combustion equipment and partial or full flow of flue gas generated in the boiler by burning pre-heated biomass. The diagram is shown schematically in Fig. 7. The designation of the drying circuit as open means that the gases referred to as edges are removed from the dryer to the atmosphere and do not pass through the boiler. This has a favorable effect on the temperature in the hearth and the total volume of the generated flue gas will be smaller, however, the separation of the flight of solid fuel particles from the dryer must be addressed. The temperature of the drying biomass can be slightly high due to the high-water content in the material. It is important to observe the condition that the temperature of the drying medium behind the dryer (e.g. in the chimney) lies above the dew point temperature with a margin. The low temperature would lead to the condensation of water vapor on the cooler walls of the channels or in the chimney. In general, it can be said that the greater the drying and the smaller the flow of the drying medium, the higher the temperature will be needed after the drying process and also before the drying process. Experience with biomass drying shows that when drying to a moisture content lower than 30%, the temperature of the drying medium at the entrance to the dryer must be taken into account and chosen so that charring does not occur, i.e. partial gasification of biomass. If we were to answer the question of the drying temperature of raw wet biomass with the above-defined input moisture by the own flue gas, the following facts should be stated:

- The heat used in the boiler when burning wet biomass, regardless of their degree of drying, will be approximately constant and will depend only on the temperature of the flue gas behind the boiler or for dryness and excess air in the outgoing flue gas (relative to the minimum amount of combustion air).
- The flue gas temperature after drying will be the same in all cases, because the flue gas after drying will always have a humidity determined by the moisture of the wet biomass used. The dew point temperature of the flue gas will therefore be unchanged.
- A better drying scale will contribute to an increase in the temperature in the combustion chamber, which will simultaneously increase the temperature potential of the heat released in the boiler and thus improve the conditions for its use (smaller heat exchange surfaces for the same output), and also improve the conditions for ignition and burning of biomass in generally.
- A higher degree of drying will require a larger amount of heat for drying, i.e. a higher temperature of the flue gas taken from the boiler to the dryer. With a high initial moisture content of the biomass and extensive drying, this temperature may exceed the technically acceptable limit from the point of view of the safe operation of the dryer. This problem can be partially solved by recirculating the cold flue gas taken after the dryer to its inlet.

4. Conclusions

The promotion of renewable energy in Albania in recent has known significant progress, which includes various initiatives from high penetration of solar photovoltaic system, high efficiency cogeneration, energy efficiency in building, etc. Nevertheless, the country remains a large consumer of biomass for heating purposes. More than 50% of the population is using wood as fuel to meet their demand in winter period. This has created very strong relations between the community and the forests. For many years forests have been the main source of firewood causing unlimited use and degradation in specific areas. Therefore, wet biomass properties such as moisture content influence on calorific value was investigated in this paper. The results obtained demonstrate a combustion limit up to 55% moisture content in biomass. Another interesting result was the variation of chimney losses and efficiency compared to moisture content on biomass. The results obtained show significant drop on combustion efficiency with the increase of water content in biomass. The topic might be developed further in specific types of biomasses with high interest for the Albanian rural communities, especially in wood burning regions such as Korça. Investigation of firewood properties in non-conventional technology might be of great interest considering the energy efficiency of combustion techniques and environmental impact in this region where the intensity of biomass burning is very high. However, this issue might be the task for another study in near future.

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Industry 4.0 and the necessity of a new quality human capital

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Abstract: Humanity enters Industry 4.0. It is characterized by the emergence of numerous innovative technologies that should be produced in "smart" factories. However, this presents the entire Western world with a problem. Talking about the industry for machines, we immediately talk about machine engineers who power this industry. However, in the West, the crisis with this type of personnel is severe because of our previous ideology – "Knowledge Economy" which diverted many of the finest young people towards social science specialties and above all, those related to economics and management. Therefore, the West, is tasked with creating a new quality industry for machines without the engineering personnel to secure this process. This report presents a new approach to bring back the previous and well-deserved prestige of the all-important engineering profession through a fourth and final engineering wave in the development of a holistic business model ontology, a wave that will also generate a new quality of systemic economic engineers – the necessary engineering capital for realizing Industry 4.0.

Keywords: PRESTIGE, ENGINEERING WAVE, ENGINEERING KNOWLEDGE, DISRUPTIVE INNOVATION

1. Introduction

For us, engineers, it is a well-known fact that the world we live in would not be as we know it today without the enormous advances of the industry for machines^{1,2}. It is perfectly clear that today, the industry for machines represents the basis for the operation and development of all other industries. If some unknown force suddenly wiped out all machines in our contemporary world, this would lead to a devastating calamity comparable to a nuclear war.

The fact is that the modern world owes its level of development precisely to the industry for machines. But it would be impossible to establish, maintain, or develop the industry for machines without the existence of a huge multitude of engineers. This status of the industry for machines as leading in the development of all other industries means that engineering positions must be of the highest level of importance and be desired by the most qualified young people in the modern world.

And while this was the case for the majority of the 20th century, in the 21st century this significance and hence prestige have been questioned. The technical universities in the Western world find it increasingly difficult to fill their student quotas, while the industry has been experiencing "acute hunger" for engineering personnel. At the same time, we observe huge growth in all kinds of socio-scientific professionals and, above all, professional economists.

With this concept paper, we will briefly outline the causes of the shocking loss of prestige of the engineering education, but most importantly, we will present a concept for a Fourth engineering wave in the development of the fundamental scientific knowledge of economy, which aims first, to reorient the population back towards the engineering profession and second, create a new generation of machine engineers called systemic economic engineering – the new quality human capital necessary for Industry 4.0 to become a reality.

2. The past, the present and the fourth engineering wave

The state of the engineering education at the beginning of the 20th century and the three engineering waves in the development of the fundamental scientific knowledge of economy

By 1903 the United States of America and Europe were producing thousands of engineers per year, compared to the insignificant number of business personnel (about 30 people) [1, 2]. The engineering profession was particularly celebrated during that period due to the fact that most Western countries were in the process of industrialization, with the U.S.A. at the forefront of this process. Many famous engineers stood behind the industrialization of that time. But optimizing the management of all these enterprises for machines required the development of a new type of knowledge to complement the technical skills of engineers. A necessity emerged for knowledge of the principle set up and way of functioning of the enterprise for machines, which would derive universal approaches to management. Such knowledge — towards the end of the 19th century — was absent. The realization of the absence of such understanding gave rise to the *First engineering wave* in the development of the fundamental scientific knowledge of economy³.

This wave is associated with the names of the engineers Henry Towne and Frederick Taylor, two prominent members of the American Society of Mechanical Engineers (ASME). Henry Towne reached the conclusion and declared in his work "The Engineer as Economist" (1886) that "(Shop management) should come from those whose training and experience has given them an understanding of both sides (viz.: the mechanical and the clerical)... **for the reasons above indicated, particularly from mechanical engineers.**" [3] The First engineering wave creates, develops, and disseminates knowledge of operational modeling of the production processes in an enterprise.

The First engineering wave is followed by another two. The Second engineering wave of development of the fundamental scientific knowledge of economy covers the 1930s, 40s, and 50s. It involves the creation, development, and dissemination of knowledge of production management focused on quality. It is associated with the names of the US engineers Walter Shewhart, William Deming, and Joseph Juran.

By 1950, the number of engineering graduates compared to business and economy graduates was almost equal, but still in favor of the engineers. Dozens of people were fighting for a single place

¹ **Machine** is a broad term – an object that transforms one kind of energy into another. This includes all electrical, automotive, aerospace, etc. machines as well as the machines that are used to manufacture all other machines.

² **Industry for machines** - the multitude of enterprises providing machines and spare parts to all industries as well as the multitude of enterprises providing services for those machines.

³ The knowledge about management of the enterprise processes is fundamental for the knowledge about management of the enterprise economy.

in the technical universities, and the West held a "comfortable" leadership position in a geopolitical plan.

The Third engineering wave covers the 1970s, 80s, and 90s. It involves the generation, development, and dissemination of knowledge of computer-integrated modeling of the sales processes, manufacturing processes, and manufacturing supply processes.

The key concepts for this knowledge are MRP I (Material Requirements Planning) and MRP II (Manufacturing Resource Planning). MRP I refers to knowledge of computer-integrated modeling of the sales processes, manufacturing processes, and manufacturing supply processes without taking into account the production capacity of the enterprise. MRP II refers to the same type of knowledge; however, it also takes into consideration the production capacity. The Third engineering wave of development of the fundamental scientific knowledge of economy stems from the work of two IBM engineers – Joseph Orlicky and Oliver Wight.

The purpose of all three engineering waves was to address the deficit of knowledge of the management of the economy of the enterprise for machines. Even though they provided extremely useful practical solutions, they had not reached a holistic knowledge of management; holistic knowledge, which consisted of unified theory and terminology about the principle set up and way of functioning of the enterprise for machines. It is not clear why American engineers abandoned that goal. The emergence of ERP, the successor of MRP, should have been a step in this direction, but by that time the positions of "ideologues" who affected the direction of development had become the representatives of the different economic schools. They integrate various "business" modules to the classic MRP system. However, this approach leads to the significant departure of the functional constructs of all modern ERP systems from the cognitive universalism, which is inherent in the functional construct of every pure, application-free MRP system.

Nevertheless, it is precisely the three engineering waves and the serious achievements of engineers that gave rise to the United States as a world economic power, as well as the "economic miracle" of Japan after World War II.

The state of the engineering education today

In recent years, we have observed a huge "outflow" of students from technical universities in the West. An outflow, that is paradoxical, as it is the engineering profession that allowed the Western world to become a world leader. For technical universities, it has become increasingly difficult to fill their quotas of engineering majors due to a lack of candidates. According to data for 2020 at the Technical University of Sofia, the enrolled number of students is only 50 % of the university's total capacity, even though the entry requirements are as low as possible (admission in the program is dependent upon a matriculation exam in Bulgarian language). [4] This is not an isolated case and unfortunately, it is not only happening in Bulgaria. It is a fact throughout the Western world. Even technical universities in countries with rich manufacturing history, such as Austria and Germany, cannot fill their universities' capacities. Why do we say the Western world? Because in the East - China, Japan, and South Korea - the situation is rather different, as shown in Figure 1.

Meanwhile, the Western industry is experiencing an "acute hunger" for engineers and technical specialists. Therefore, we need to ask the question "*Which majors related to the management of the real industry do students pursue?*" The answer is the disciplines related to economic science - *Economics, Business and Management, Entrepreneurship*, etc.

In the United States during the 2018-2019 academic year, 426,000 undergraduates graduated with a Business and Economics major, and only 190,000 undergraduates graduated with an Engineering major. In the EU, the situation is no different: 459,000 graduates with a Business and Economics major and 280,000 with an Engineering major [5] [6]. The quality of incoming students in the engineering majors is also questionable. In 2004, for every 100

applicants, only 20 were admitted to the TU-Sofia, while in 2021, there was no competition whatsoever [7]. And as we know, quality is found in the competition. As of today, in the Western world, the number of undergraduates in business and economics disciplines has increased by a factor of 10 since 1950 and engineering only by a factor of 3. Perhaps the Western world's loss of leadership in the global economy to the advantage of China is not accidental either.

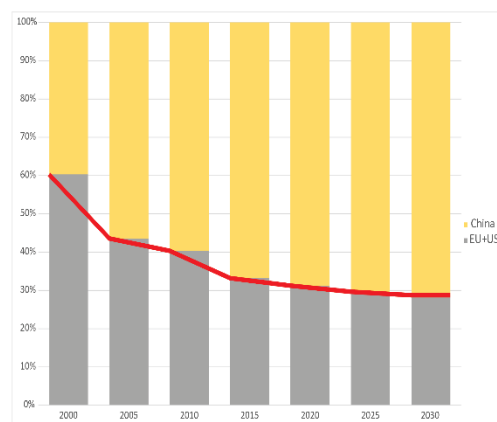


Figure 1. The trend of development of engineering personnel in the Western world and China.

Causes of the loss of prestige in the engineering education

The reasons for the loss of interest in the engineering field to the benefit of the economic field are numerous. The very word "Management" in the Business Management degrees gives the impression that it provides students with high-quality management skills and abilities. Indeed, it is a fact that an economics degree is required to undertake a managerial position. Another reason is the fact that an engineering degree is much more difficult to complete than an economics degree since economic science lacks uniform theory, terminology, and systematic upgrade of knowledge.

However, there are also more global reasons, such as the political ideology of the *knowledge economy* adopted by the West between 2000-2010. According to the Lisbon Strategy, the countries in the West should "*get rid of the outdated manufacturing and to focus on innovation*," and above all, focus on the services sector – financial services, legal services, and consulting services for "effective management of the economy". Thus, candidates began to shift from engineering professions to a range of social science professions, especially professional economics, and we can observe this decline as shown in Figure 1.

This is all the more unwise because by giving up the industry for machines and the development of numerous and capable engineering professionals, Europe and the United States are voluntarily giving up their geopolitical leadership position. Furthermore, it is becoming more and more evident how they are losing their advantage in innovation and even worse - becoming extremely dependent on China's industry for machines. A fact that was made clear during the "COVID 19" crisis. What does the future hold? The cultivation of countless social scientists and, above all, professional economists at the expense of engineering specialists will lead the Western world to the inability to maintain and develop its current industry for machines, which would eventually lead to industrial collapse. But why can't we rely on modern economists to create, develop, and disseminate practically effective scientific knowledge for the management of the existing industry for machines?

Our in-depth studies of the numerous parts of the modern fundamental scientific knowledge of economy show that the most significant ones (from a practical point of view) are: knowledge of accounting, knowledge of productivity and quality management,

and knowledge of production planning and control by utilizing the MRP algorithm. The first was the work of a monk, and the other three were the work of American engineers. Among these, and all other parts of the fundamental scientific knowledge of economy, there is a lack of unified theory and terminology that would allow graduates of this field to speak a common managerial language. For comparison, the state of medical science was similar before the introduction of the systemic anatomical and physiological model of the human body. This means that in the age of digital information technology, the fundamental scientific knowledge of economy is still at a scholastic level of development, compared to the level of development of the fundamental scientific knowledge of medicine. A fact that is reflected in numerous quotations from the great engineers before us:

Henry Towne, 1886: *"(Management of works as a science) is unorganized, is almost without literature, has no organ or medium for the interchange of experience, and is*

without association or organization of any kind."

Oliver White, 1981: *"...but where in our manufacturing economy is a school on how to run a manufacturing business in all of its facets? What about the subject of manufacturing itself? ... There is not even a well-defined body of practical knowledge on the subject. There are virtually no college textbooks that address the subject from a practical viewpoint."* [8]

What about today? Our survey of economics students from business universities has shown that even when allowed to use specialized literature economics students are incapable of providing a uniform explanation of the objective meaning of terms such as *economy and economic science, goods and service*, or explain the principle setup and way of functioning of an enterprise for machines. One disregarded reason for youth unemployment lies precisely in the fact that our educational system produces graduates who are incapable of meeting the demands of the labor market, both in terms of professional orientation and in terms of the quality of their preparation.

Today we are witnessing how after enrolling in economics and business majors, Europe's youth with the greatest potential do not receive practically useful knowledge for managing the real industry. It turns out that the European educational system has been turned into a machine for intellectual and professional distortion of its most valuable human resources. It sounds absurd, but this is a fact. A fact, which presents a grave issue for the future of the European world.

A concept for a Fourth engineering wave in the development of fundamental scientific knowledge of economy

Today we live in the age of the so-called "Industry 4.0". An age when many new technologies are expected to emerge and be produced in "smart factories". This poses a serious problem for the entire Western world, namely that modern economics education does not provide practically useful knowledge for re-engineering already existing enterprises, or for creating entirely new ones. At the same time, a huge number of young people are directed precisely towards an education in economics in search of this kind of knowledge. Unfortunately, it is not possible to rely on the elder generation that created the vast industry for machines of the West, as these people are either retired or no longer among the living. The currently existing huge shortage of engineers and technical specialists is of no help either. Thus, the Western world is faced with the task of creating an industry for machines of a higher quality without the know-how for this process and without sufficient engineering personnel to fulfill it. This is a prerequisite for a huge division between the West and countries like China – where the specific knowledge is also missing, but their enormous engineering armies and models derived from practice, which they duplicate with phenomenal speed have already earned them the title of "new technological leader".

This means that we, the engineers, especially those at the head of the engineering organizations of our Western World, need to take cardinal measures responsibly and quickly in order to return the interest, and hence the prestige, in the engineering education and to direct more and more young people back towards it [9]. This can be realized through a Fourth engineering wave in the development of fundamental scientific knowledge of economy. A wave that would complete the work of all the great engineers before us and would consist of the creation, development, and above all, dissemination of a new class of digital technologies for managerial modeling of the economy of the enterprise for machines. Technologies whose functional construction includes knowledge of a holistic business model ontology based on the economy of these enterprises, which describes their basic structure and way of functioning as a systemic object and subject.

3. The holistic business model ontology based on the enterprise for machines and what's to come

Is it possible to create a holistic business model ontology based on the enterprise for machines?

Perhaps we also would not have arrived at the concept of a Fourth engineering wave if we were not convinced that such a model really exists. One such model, the only one we are aware of, is the result of more than 20 years of efforts by the Bulgarian Institute for Systemic Economic Engineering (ISEE). During all those years, the main goal of ISEE was to prove to the world that a new generation of holistic ERP systems can be created. ERP systems that are currently available on the market (without exception) are built on the basis of a fragmented (scholastic) fundamental scientific knowledge of economy – knowledge that we have repeatedly found to have large functional gaps.

In this regard, the new ERP systems are completely different. Their engineering design is based upon a holistic fundamental scientific knowledge of economy, which provides a clear understanding of the principle set up and way of functioning of each enterprise for machines as a systemic object and subject. This knowledge is available in the form of hundreds of pages of theory and terminology. This difference opens up the possibility for the new ERP systems to entirely outperform the systems that are currently available on the market. This superiority is clearly observed through a direct comparison between the current prototype of the new holistic ERP system created by ISEE and all currently-available ERP systems. All developments made by ISEE were subjected to practical testing in functioning enterprises for machines.

A number of scientific discoveries were made as a result of the testing activity, two of which have the most significance. Both are defined as "cognitive engineering platforms" for understanding of the enterprise of machines as a systemic object and a systemic subject simultaneously. The first cognitive platform provides knowledge for the understanding of an enterprise for machines in its capacity as a systemic object, which exists as a result of the synergy of five functional systems. The visual representation of the cognitive platform created by ISEE for the understanding of an enterprise for machines as a systemic object has the form of a cross and is called the "Industrial Cross" (Figure 2) [10].

The second cognitive platform provides knowledge for the understanding of an enterprise for machines in its capacity as a systemic subject. Within the second cognitive platform, the enterprise for machines is considered as a complete subject, characterized by an inherent, hierarchical system of five types of knowledge, including a system of responsibilities for continuing its own existence. The visual representation of the cognitive platform created by ISEE for the understanding of an enterprise for machines as a systemic subject has the form of a tree and is called "The Tree of Industrial Cognition". The knowledge of the holistic business model ontology is extremely extensive and is not within the scope of the current paper. It is presented in the book "Business Model Ontology: The Basis for Digital Reform of Economic Science".

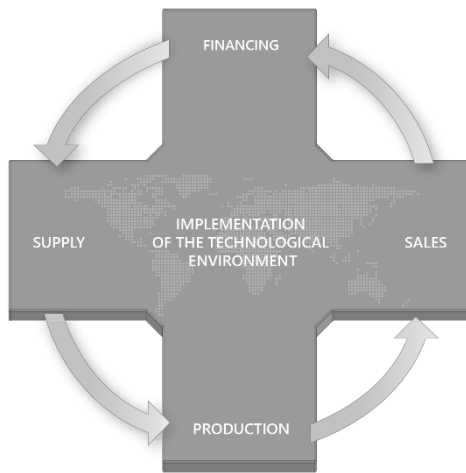


Figure 2. The Industrial Cross

Results of the implementation of the holistic ERP system, bearer of a holistic business model ontology, within enterprises for machines

The developed knowledge of the holistic business model ontology and the holistic ERP system built on its basis have been applied and experimented within mid- and large sized enterprises for machines in Bulgaria and Russia. Once the engineering staff mastered the knowledge and application of the ERP system, they were able to carry out activities within their enterprises at a significantly lower cost of resources and within a shorter period of time than the much more experienced international consultants. Some of the experiments included:

- Large-scale re-engineering of an enterprise for hydraulic cylinders, consisting of more than 500 workers. During the re-engineering process, more than 70% of all workplaces were restructured and relocated. Notably, this process was completed without any suspension or even delay of the production processes.
- Assimilation and modernization of the constructive and technological documentation of axial piston hydraulic pumps and motors and their subsequent implementation in production, technology which had previously never been produced in the Balkan Peninsula. The results of this experiment are spectacular: five young machine engineers, who did not have any prior experience in plant design but were very well versed in the ISEE ERP system, managed to design, build, and ensure the operation of the extensions of the technological environment of two plants. They accomplished all this for the same amount of time and money that foreign consulting companies required to simply update the product documentation.

These, as well as other such results, have proven that after only several months of study of the holistic business model ontology, engineers with no substantial experience in managing enterprises can achieve practical results that even the most renowned professional economists cannot accomplish⁴.

Potential outcomes of the Fourth engineering wave in the development of fundamental scientific knowledge of economy

We will try to briefly present the potential effect of the theoretical and practical study of knowledge of the functional construct of the holistic ERP systems and its impact on Industry 4.0.

The people who should consider this knowledge to be of the highest priority and should study this knowledge are engineers, and more precisely machine engineers⁵, as the real professionals who

create, develop, and manage the industry for machines. This view is in complete agreement with the concept of "The Engineer as Economist" – an idea born in the late 19th century that led to the three engineering waves in the development of the fundamental scientific knowledge of economy, but which has remained incomplete to this day.

The only viable chance for realizing "Industry 4.0 is through the realization of a Fourth engineering wave in the development of the fundamental scientific knowledge of economy. This wave will lead to the finalization of the work of the American engineers, Henry Towne and Frederick Taylor. A finalization, crowned by the emergence of a new generation of machine engineers, which we define as "systemic economic engineers" [11].

A *systemic economic engineer* is any professional machine engineer who, as a result of purposeful education, has acquired fundamental and specialized engineering knowledge in a certain field of the industry for machines, and has also acquired theoretical and practical knowledge of the new class of holistic ERP systems. The *systemic economic engineer* - as a result of several months of theoretical and practical study of the functional construct of the holistic ERP system - forms a cognitive potential for managerial modeling of the economy of the enterprises for machines, which is far superior to the one possessed by even the most renowned professional industrial economists. A superiority, which is expressed in the conscious understanding and application of:

- (1) knowledge of the principle set up and way of functioning of the enterprise for machines as a systemic object and subject;
- (2) practical knowledge for development of highly effective strategies for future economic development of the enterprise for machines with a focus on anticipating the development of its innovation potential;
- (3) practical knowledge for the development of highly effective programs for training, retraining, and motivation of the staff of an enterprise for machines – programs that aim toward the realization of the strategies for future economic development of the enterprise for machines;
- (4) practical knowledge for auditing enterprises for machines in order to assess the current and future development of their economy and to generate ideas to increase the effectiveness of this development;
- (5) conceptual knowledge for the creation and development of a truly effective accounting model of the economy of the enterprises for machines;
- (6) knowledge for the management of the cost and quality of a product and the ability to conduct a technological analysis of the process of creating the goods and services sold, while offering different options for implementing this process;
- (7) practical knowledge for the development and management of projects for implementation of systems for lean manufacturing (Single-Minute Exchange of Die – SMED) of goods and services sold by the enterprises for machines;
- (8) practical knowledge for the planning and management of the execution of engineering and reengineering of enterprises for machines or large parts of them.

4. Conclusion

The Fourth engineering wave in the development of the fundamental scientific knowledge of economy will lead to the emergence of a new generation of machine engineers – *systemic economic engineers* who represent the new quality human capital necessary for the successful realization of "Industry 4.0".

It is the managerial advantages of the new knowledge of a holistic business model ontology that will bestow huge prestige to

involves the design, production, and exploitation of all types of machines. "Machine engineer" is the umbrella term that unites all those engineers dealing with machines, which include: mechanical, electrical, computer, automotive, aerospace, hydraulic, etc., engineers.

⁴ The experiments and some of the results are presented at <https://isee.bg/en/>.

⁵ **Machine Engineer** – a practitioner of machine engineering. Machine engineering is the branch of engineering that

the engineering profession, which will naturally attract the young people who want to engage in industrial management. The emergence of *systemic economic engineers* and the shift of the human capital of the Western world back to engineering, the natural environment for cultivating quality executives for the industry for machines, will bring our Western world back to its morally responsible, creative foundations of the early and mid-20th century. The same foundations that made the Western world the technological and economical leader of the whole world.

The success of "Industry 4.0" relies on the successful dissemination of the new quality knowledge for managerial modeling of the economy of the enterprise for machines. This dissemination should first be extended to all technical universities, and subsequently, the knowledge of a holistic business model ontology should become a standard for enterprise management. A standard controlled by the best technical universities of our world.

The responsibility to make all this happen rests upon us, the engineers, and the engineering organizations concerned about both the future of our profession, as well as the future of our world.

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Forms of eco-innovation transfer in industrial enterprises

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Abstract: After the adoption of the European Green Pact aimed at achieving the sustainability of the Union's economy, industrial enterprises are faced with the challenge of creating and implementing eco-innovations aimed at achieving the goals set in the Pact. Considering that the innovation activity is a complex, expensive and risky process, for a large part of the enterprises there is the possibility of taking advantage of the possibilities of technological transfer of eco-innovations. The purpose of this report is to present the essence, characteristics and main forms of transfer of eco-innovations. The results show that the development and implementation of eco-innovations can be a complex, expensive and risky process that requires knowledge, effort and many activities that are beyond the power of every enterprise. This necessitates cooperation as a form of reducing costs and achieving a better economic effect.

Keywords: ECO-INNOVATION; TECHNOLOGY TRANSFER; GREEN ECONOMY; INDUSTRIAL ENTERPRISES

1. Introduction

In response to the challenges related to the climate and the environment, on 04.03.2020, the European Commission officially presented the European Green Pact, to achieve the sustainability of the Union economy [1]. This is the new growth strategy which aims to transform the EU into a fair and prosperous society with a modern, resource-efficient and competitive economy in which there are no net greenhouse gas emissions in 2050 and economic growth does not depend on the use of resources [2].

The strategic elements of the Green Pact are presented in fig. 1.

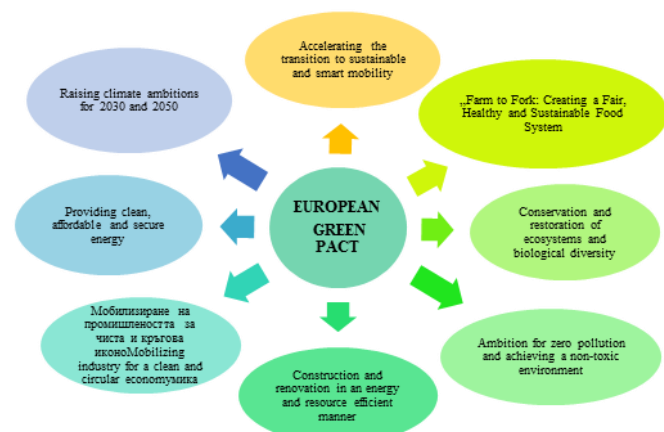


Fig. 1. Strategic elements of the European Green Pact

The conditions for achieving the goals set in the European Green Pact are:

- Provision of "green" financing and investments. The realization of the objectives defined in the European Green Deal require significant investments. According to the Commission, Achieving the current climate and energy targets for the period up to 2030 alone will require €260 billion of additional investment per year (i.e. around 1.5% of GDP in 2018) This flow of investment will need to remain constant over time. The scale of the investment challenge requires mobilizing both the public and private sectors.

- Greening of national budgets. Greater use of green budgeting tools will help redirect public investment, consumption and taxation towards environmental priorities and eliminate harmful subsidies. Mobilization of scientific research and promotion of innovation;

- Development of new technologies, sustainable solutions and revolutionary innovations. To maintain its competitive edge in cleantech, the EU needs to significantly increase the large-scale deployment of new technologies across sectors within the Single Market by building new innovative value chains [3].

- Activation of education and training. Schools, training institutions and universities are in a position to prepare students,

parents and the wider community with the changes necessary for a successful transition [4].

The concept of eco-innovation was first mentioned in the scientific literature by Fussler and James (1996). They consider eco-innovation as "new products and processes that provide value to customers and businesses but significantly reduce environmental policy"[1]. Klemmer's definition is similar, according to which: "Eco-innovations are all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which develop new ideas, behavior, products and processes, apply or introduce them and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets" [2].

By achieving the main goal - reducing the harmful impact on the environment, eco-innovations make significant progress towards the realization of the sustainable development of modern society, more efficient and responsible use of natural resources and achieving economic, ecological and social impact [3].

In the nature of the innovation process lies the created as a result of creative activity products to have a practical focus and be applicable in the organization that creates them, or in the activity of another business entity [5]. Usually, the results of the research and development carried out are used to product and process development in fulfillment of the company's innovation strategy [6].

In addition, in support of long-term growth goals, they can become object of purchase and sale in the direction of companies from the same or other industries. In this case the two parties: the owner of an intellectual product and the buyer of certain rights on its use, enter into interaction within the national or the international market of scientific and technological products [7]. The process by which technology, knowledge and/or information developed into one organization, within one area or to achieve some goals assimilated and used by another organization, in another area or for the achievement of other purposes is defined as technology transfer [8].

2. Research

The implementation of the strategic elements of the European Green Pact requires the development and implementation of eco-innovations .

According to the Environmental Technology Action Plan (ETAP), eco-innovation is defined as "the production, application or operation of a good, service, production process, organizational structure or management or business method that is new to the firm or user and which leads throughout its life cycle to a reduction of environmental risk, pollution and negative impacts of resource use (including energy use) compared to the relevant alternative" [9].

The development and implementation of eco-innovations can be a complex, expensive and risky process that requires knowledge, effort and many activities that are beyond the power of every enterprise. This necessitates cooperation as a form of reducing costs and achieving a better economic effect [10].

The cooperation of organizations in modern conditions is a powerful factor for accelerating the technological level and innovation processes [11]. The need for cooperation is constantly increasing. The reasons for this are various:

- The innovation process requires large costs and there is a tendency towards their increase;
- The contraction of the market cycle of the products necessitates the need for their more frequent renewal;
- The lengthening of the cycle for the creation of new products and the complexity of the necessary research works increase the costs of implementation;
- The innovation process requires a material and information base, research and technological knowledge, current costs.

In this regard, various forms of transfer of foreign experience and technical achievements or own corporate strengths and capabilities can be used for the realization of eco-innovations [12].

- ❖ *The realization of eco-innovations with one's own forces is reduced to the implementation of the following tasks:*
 - modification of manufactured products;
 - partial improvement of the technologies used;
 - mastering the production of new products;
 - renovation of equipment;
 - introduction of innovations in marketing (market innovations);
 - introduction of innovations in management, production and labor organization;
 - legal protection of the objects of intellectual property of enterprises - inventions, utility models, industrial design, trademarks;
 - providing licenses for inventions, utility models and industrial designs owned by enterprises;
 - provision of free licenses (know-how contracts).

Each industrial enterprise forms its own eco-innovation goals – strategic, tactical or operational and builds the corresponding investment programs and projects for their realization [13]. The business plan is the main document that defines the main directions for planning alternative eco-investment projects in the enterprise's activities in the short-term and long-term perspective [14].

- ❖ *Implementation of eco-innovations through the transfer of foreign experience and technical achievements.*

The transfer of foreign expertise and technical achievements is usually seen as technology transfer or technological transfer [15]. In essence, transfer is an intermediary organizational-management activity for the selection, transfer and adaptation of scientific and applied results and new technologies from scientific structures to business organizations (vertical transfer). In practice, there is also the spread of already implemented technologies in other companies and spheres of social practice (horizontal transfer) [16]. Between the two fields (scientific and economic) there are significant substantive differences that place numerous barriers to the transfer of knowledge from one field to the other, but what they have in common is that they represent the material expression mainly of human intellectual capital [17].

The transfer of eco-innovations through foreign experience and technical achievements can take place in different forms, presented in fig. 2.

Forms of transfer of foreign experience and technical achievements of eco-innovations include:

- *Transfer of technology.* This form refers to transfer of technology in its non-materialized form through various types of contracts and agreements, contracts for "know-how", "show-how", franchising. It is applied by industrial enterprises that do not have the opportunity to carry out relevant scientific research on their own. Of particular importance is the presence of a built-up scientific and scientific-technical potential in the

enterprise to "take over" these technologies and bring them to their industrial application.

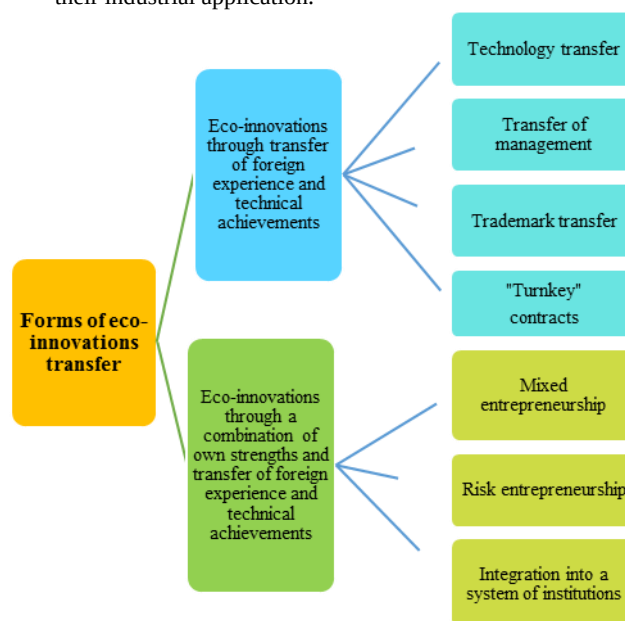


Fig. 2. Forms for the transfer of eco-innovations

- *Transfer of management.* The transfer of management is carried out through a management contract (management contract) of a national or mixed company by the foreign company (team). In some management contracts, the manager company not only manages the finances, production and marketing of the product, but also conducts the relevant administrative and personnel policy [18]. In such cases, we speak of a full management contract. In practice, there are also incomplete forms such as "consulting contracts", which can be in the field of commercial and industrial activity; on the problems of industrial production itself (industrial consultations); on engineering and technical issues (engineering consultations); on the organization of the placement (marketing consultations), on management issues (managerial consultations)[19].
- *Transfer of trademark.* The trademark recognized by the buyer is associated with quality, secured markets, strict compliance with company standards and efficient control over the entire technological process [20]. The transfer of a trademark can be carried out in two ways:
 - By concluding a franchise agreement;
 - Through its direct purchase.

"Branded" franchising means that the franchisor company provides the franchisor person not only with the right to manufacture by using the trademark, but at the same time provides the company's "know-how" and experience, company culture and strategy, quality control methods and company management [21].

- *Turnkey contracts.* Turnkey contracts are a non-equity form of investment that allows the national production base to be expanded and renewed entirely through foreign capital [22]. After the construction of the sites, they become the full property of the local contractor. The foreign contractor company usually undertakes all types of engineering-consultative services (choice of the optimal project or the design itself), performs the full cycle of construction and installation works, supplies and adjusts the equipment, prepares it for operation and makes the trial run of the production facilities [23]. After handing over the object to the local contractor, the foreign contractor bears no responsibility for the further work of the object, which necessitates that turnkey contracts be supplemented by other types of contracts. It should be noted that the imposition of additional conditions

during the construction of "turnkey" objects significantly increases their value, and this may create additional financial difficulties for the contracting authority.

The forms of transfer of eco-innovations through a combination of own forces with the transfer of foreign experience and technical achievements refer to:

- **Mixed entrepreneurship.** This is the most common form. In practice, it manifests itself in the creation of joint ventures (Joint Ventures) between two or more countries. In developing countries, the creation of joint ventures is encouraged, as through them not only investments can be attracted, but also access to new technology, management, etc. It is done through:
 - license agreement between the patent, license, trademark owner company and the buyer company;
 - union of two or more enterprises to build a structure for joint research, most often of an applied nature.

Common forms are – joint (mixed) enterprises, inclusion in a subcontractor chain, trade in knowledge-absorbing products, operational leasing, limited venture capital investment, engineering, joint scientific and technical research by two or more companies [24].

- **Venture entrepreneurship.** As a form of investment, it appears in practice in the form of special companies of the so-called. "venture" capital (venture capital firm). It is also found in the literature as an "associated" form of capital investment. The purpose of venture entrepreneurship is to invest in industries and industries where venture innovation and even scientific research are carried out. They mainly deal with risky productions. This form is specific, it has some features of the shareholder form, but differs in the distribution of the profit, with the largest share of the profit going to the shareholder with the smallest capital share. In this method of profit sharing, the large "associate" participants in the form of financial institutions pay the risk to the founders of the venture capital firm, since they risk their entire fortune. The associated form of capital investment in venture entrepreneurship can grow into a traditional shareholding form in the event that the venture (venture) is successful.

- **Transfer of eco-innovations through integration into a system of institutions.** The connection between scientific research, training and business is achieved through various forms on the basis of two-element and three-element integration. A wide variety of connections between science, education and production shows that innovation is the basis of progress, and enterprises more quickly and easily deal with emerging crises and achieve better results when science, education and production are chained together in international, national and regional aspect.

3. Methods, research and discussions

The methods used to achieve the objectives of the study are as follows: methods of description, comparison, analysis and synthesis, method of grouping, tabular and a graphic method, a survey method.

Main sources of information are statistics published by National Statistic institute (NSI); European and national strategic documents; analytical materials of The European Commission and the World Bank; research and development of scientific institutions; results of a survey carried out in industrial enterprises of the territory of the Republic of Bulgaria. Industrial enterprises from the sectors of the economy requiring the transfer of eco-innovations are summarized in fig. 3. Sectors requiring the transfer of eco-innovations for transformation include energy, construction, sustainable transport and water, waste and land management. The eco-innovations implemented can be seen in the start-up industries of renewable energy sources such as solar, wind and geothermal energy. These renewable energies can be used to support green buildings and sustainable transport to make them more efficient and greener. Water and waste management is carried out through eco-innovations related to water purification and recycling. Land management in the green economy can be transformed through

green innovation for habitat restoration, national parks, nature reserves and forest restoration efforts, etc. A study of the investments made by the country's industrial enterprises in eco-innovations related to environmental protection and restoration in the period 2010-2021 is presented in fig. 4.



Fig. 3. Sectors for transformation through eco-innovation
Source: Own calculations

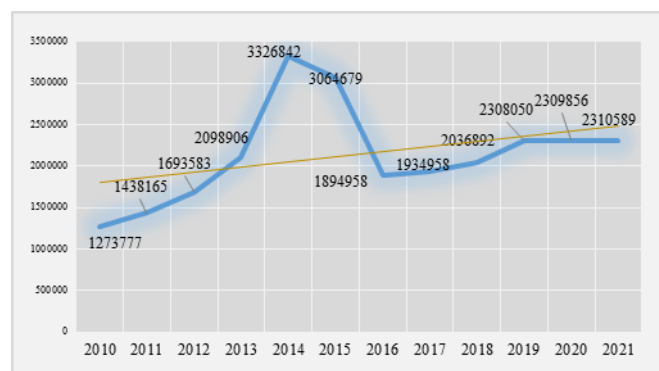


Fig.4. Changes in the total costs in the country for environmental protection and restoration , Source: Own calculations

The trend shows an increase in spending, as by 2022, it represents 1.9% of the total gross domestic product.

The distribution of the available long-lasting material assets with ecological purpose by ecological directions in the country by 2022 is presented in Fig. 5.

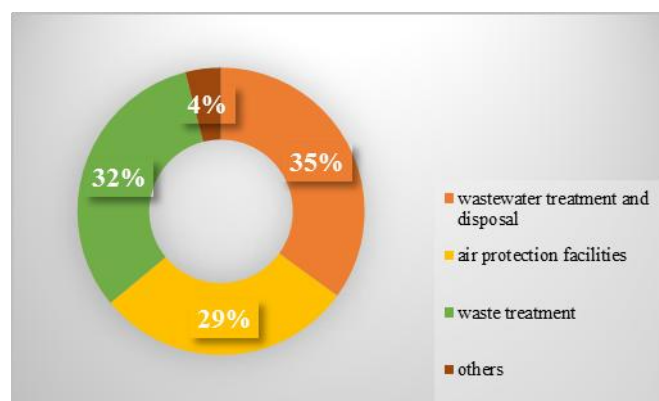


Fig.5. Investments in DMA for eco-innovations by directions
Source: Own calculations

The largest share is occupied by investments for DMA in the waste water direction (35%), followed by investments for DMA in the direction of waste treatment (32%) and investments in DMA for air protection (29%).

In fig. 6, in a percentage ratio, are summarized the costs of industrial enterprises for the transfer of eco-innovations in separate ecological directions in Bulgaria in the period 2010-2021.

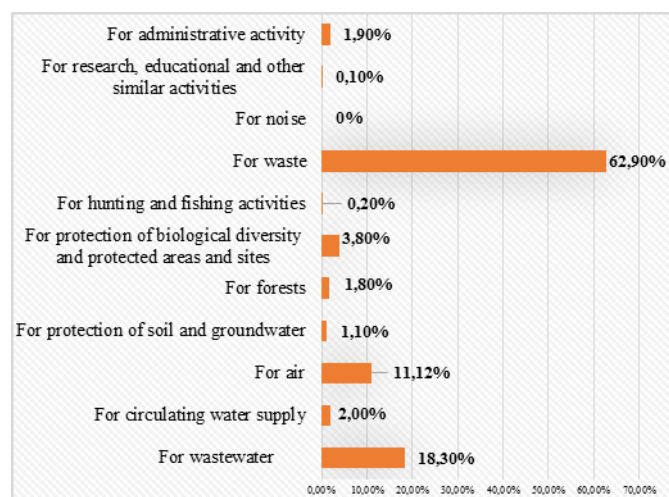


Fig. 6. Costs for the transfer of eco-innovations in eco-directions in Bulgaria for the period 2010-2021 (in %)

Source: NSI, own calculations

The data show that the largest investments of industrial enterprises for the considered period are related to eco-projects in the field of waste management (63.2%), soil protection (18.3%), water (18.3%), the air (11.7%). The least investments have been made in noise reduction, forest protection, and biodiversity in protected territories and areas. The low share of investments in research and development activity means that Bulgarian industrial enterprises rely mainly on the transfer of eco-innovations.

4. Conclusion

Innovations are of vital importance for the success of industrial enterprises in Bulgaria. Businesses need not only product or process innovation, but also innovation in the way business is run, building partnerships, winning over consumers and ensuring sustainable development. It is not enough to use innovation only to develop a new product or reduce production costs, it is necessary to apply new methods to gain prestige and trust of society. For the purposes of research, the theoretical statements related to innovation activity and efficiency have been examined. Definitions of eco-innovations have been studied and a connection between eco-innovation activity and the increase in the efficiency of industrial enterprises has been substantiated. In this context, the present work considers eco-innovation activity as a means of increasing the efficiency, competitiveness, innovation and adaptability of enterprises. Bulgarian industrial enterprises still lack the entrepreneurial innovation culture and the understanding that it is necessary to invest in human capital, which is key to the creation of R&D and the increase of economic results and efficiency. It is necessary to invest in technological development and concentrate efforts in R&D to achieve higher eco-innovation activity, efficiency and competitiveness. The main goal has been achieved, namely – to examine the state of the eco-innovation activity of industrial enterprises and how it affects the efficiency of their activity and technological transfer in the conditions of a turbulent business environment and transit to a circular economy.

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Post-crisis development of recreation areas

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Abstract: *The main issues considered in this article: the development of recreational areas during the period of overcoming the consequences of the war on the example of Ukraine; the importance and content of pre-project studies regarding the implementation of programs and projects of recreational development of territories; the need to use methods of analysis and comparison when researching the experience of successful countries in the field of recreational development, in particular Southern Europe; attraction of investments, loans, budgetary and extra-budgetary funds for the innovative development of recreational areas; improvement of tax legislation with the aim of providing temporary preferences to recreational areas for the implementation of necessary programs and projects.*

KEYWORDS: RECREATION AREAS, PRE-PROJECT PLANS OF TERRITORY RESEARCH, TAX PREFERENCES, INNOVATIVE DEVELOPMENT

1. Introduction

The development of recreational areas is important for every person and for society as a whole. Such development depends on many factors. The development of recreational areas and relevant facilities is of particular importance in post-crisis periods, when a large number of people need to restore their physical strength and psychological state. That is why, when studying the process of development of recreational areas, it is necessary, first of all, to pay attention to the peculiarities of people's condition and behavior, to their requests for recreation, reactions to the services provided. Secondly, from the position of service providers, it is necessary to respond in a timely manner to the requested types of services and the forms of their provision. It is necessary to develop the infrastructure of recreational areas in accordance with the expansion of the range of services. Expansion may require new construction, renovation of existing facilities, retraining and increased staffing. The entire development complex of recreational areas is a set of sociological studies, the development and implementation of projects for the development of the material and technical base, the formation of financial plans and the conclusion of the necessary agreements for the performance of the necessary works with specialized enterprises and institutions.

Analysis and comparison should be important methods of researching the problems of the development of recreational areas. It is necessary to analyze the activities of those countries where recreational areas have acquired such importance that they have become the main donors of the budgets not only of individual regions, but also of the state as a whole. At the same time, the comparison should find not only certain common features of the economic activity of recreational areas. Differences between countries, their socio-economic level, people's mentality, their willingness to accept people, both internally organized tourists and foreigners, are of great importance.

2. Preconditions and means for resolving the problem

The solution to the problem of the development of recreational areas is determined by certain ascending prerequisites and the composition of the appropriate necessary means.

The ascending prerequisites for the development of recreational areas include: 1) composition and content of people's needs for recreational services; 2) cost of relaxation services; 3) social assessment of recreational opportunities.

The means of solving the problems of the development of recreational areas are: 1/ correct assessment of the state and development prospects; 2/ development of the program, project and pre-project plan; 3/ assessment of opportunities and activation of the potential of all types of development resources.

Regarding the composition and content of the needs of people who apply for recreational services, the following can be

noted. Depending on the socio-economic development of the country, its citizens may or may not have the opportunity to rest outside of working hours. The world practice of leading countries has long recognized the need for employee relaxation. Relaxation is a complex process that requires a change of environment in the broadest sense. For a short rest, it is sometimes quite enough to visit a theater, cinema, club, sports ground. As for the cost of such a short vacation, it is quite affordable if you have to move far away from your home.

Instead, a long period of rest requires the availability of recreational infrastructure. Because of this, there is a problem with the cost of relaxation services, the sufficiency of funds for moving and staying in the desired place of rest. Of course, in different countries, the assessment of the sufficiency of funds for such a dynamic rest (that is, with a significant number of crossings by different vehicles) differs. For example, Ukrainian citizens do not have the opportunity to rest for a long time due to lack of funds.

The social assessment of recreational opportunities is of great importance, which significantly affects people's choice of territory, as well as post-rest feelings: satisfaction, or even disappointment. In addition to the value assessment, traditions and social assessments should also be taken into account. Traditions can be based on purely climatic considerations, and social evaluations are related to the attitude of the environment of a particular person to whether the vacation was spent in prestigious places.

At the same time, the requirements for recreation infrastructure are individual. It can be argued that the infrastructure should correspond to the declared content of the services. People should be able to choose from a sufficient number of sanatorium-treatment and rest facilities in those regions that are traditionally considered recreational, where there is clean air, clean water, perhaps natural mineralized springs, thermal waters, enough sunny days, or ski slopes, etc. Also, the choice depends on the time of year planned for rest. Even in those cases where recreation even looks like a sporty, consists in tourist crossings, appropriate routes, recreation centers, places of safe parking should be equipped. The specified conditions and requirements require systematic development in accordance with changes in public views, in achieving a certain level of well-being of people.

To determine the composition of means of development of recreational areas, the correct assessment of the state and development prospects is of great importance. Firstly, their ascending position is important for the development of recreational areas. In some cases, the territories have long been recreational with relevant facilities, services, personnel and service traditions. In other territories, the development of recreation business and the development of recreational infrastructure are beginning. Secondly, both in the first and in the second cases, development should involve innovative changes that meet the requirements of modern

society and modern man. This means that, under any circumstances, a person, being on rest, should not voluntarily lose the usual amenities: communication with the outside world, comfortable conditions in the apartment, the opportunity to receive transport services, medical consultation at any time or help.

In Ukraine, all such conditions were foreseen in previous years, and the development of appropriate institutions in villages and towns took place. Such projects were implemented on the shores of the Black and Azov seas, in Volyn, where there are a number of lakes, in Prykarpattia and Transcarpathia. Unfortunately, many such institutions, especially in the East and South of the country, were destroyed. That is, it is necessary to develop or restore such objects, which requires significant financial resources. At the same time, the question arises of the recovery of the country's economy as a whole. It will be necessary to rebuild the production base, which should provide Ukrainians with jobs. Yes, recreational infrastructure also creates a certain number of jobs. Such a structure of the economy was not characteristic of Ukraine in previous decades. However, the restructuring of the economy in the post-war period may involve a change in the structure of economic activity and a possible increase in the share of enterprises and institutions specifically related to the provision of people's recreational needs.

The need to develop a program, project and pre-project plan should be emphasized separately. This is an important means, since the formation and implementation of programs and projects for the structural restructuring of the economy and giving it a greater recreational orientation is possible only on the basis of accordingly developed plans. Such work plans must contain a number of studies on the assessment of the state of territories and objects of recreational use and are of a pre-project nature. The pre-project nature of the plan means that it precedes the development of the proposed project or program for the development of the recreational territory, is drawn up at the pre-project stage. Based on it, a project or program is already being developed.

Of course, there may be a different composition of territories and parameters for evaluation. 3 If there is a large share of recreational areas in the state, as well as a high or medium level of development of recreational areas, the smallest number of parameters can be selected for evaluation. Instead, with a small number of recreational areas and a low level of their development, a significant number of calculations are required for the creation of appropriate institutions and enterprises. Of particular note are situations where, for various reasons (whether earthquake, tsunami or major floods, or war), the loss of recreational infrastructure facilities has occurred. Under such circumstances, there is a need not so much for renewal as for the reconstruction of recreational areas and destroyed objects.

The pre-project stage is extremely important. After all, it is necessary to clearly identify the resources that are necessary to implement the restructuring of the region's economy in order not only to rebuild destroyed enterprises, but also to determine the profile of their activities. As an example, we can take Ukraine, in which there was a situation of the destruction of many enterprises, the loss of certain industries, the death of a large number of able-bodied people of various professions and specialties. Of course, the question arises regarding the possibility of restoring the production potential, the structure of industrial production that existed before the war. The pre-project study itself should answer such a question. Ukrainian entrepreneurs have already gained experience in the development of recreation sectors. Although this sector of the national economy was not sufficiently developed. Therefore, in the future, the question arises only about the availability of the appropriate potential for the development of recreational areas, filling them with recreational facilities and necessary related enterprises to ensure full-scale and large-scale service for vacationers.

It is impossible to implement any project without appropriate **assessment of opportunities and activation of the potential of all types of development resources**. Ukraine has sufficient natural and human potential for such development. In other words, in the future,

the country's economy should be based not only on the mining, metallurgical, and chemical industries, but also on the recreational sector and the development of tourism. These areas of economic activity should become leading in the national economy. Such development should be based on all-season resorts, recreation centers in mountainous areas, seaside towns, green tourism estates, and other such facilities. Along with the development of recreational facilities, it is necessary to develop related enterprises to provide vacationers with food products and means for effective and interesting recreation.

Pre-project studies should take into account the real situation in different territories. Under normal circumstances, in particular in peacetime, it is quite likely to bring all resources in line with the needs of the economy and society. That is, it is possible to use budget financing if the central and local authorities are interested. Accordingly, funds from the state budget will be used, and funds from the local budget may be sufficient. Special trust funds can also be used. Provided a stable situation that guarantees minimization of risks, we can hope to attract credit resources, and possibly at the expense of investors. Such a development of events is possible, provided not only a peaceful stable state in the country, but also with some accumulated and working capital, assets in working order. Yes, it is possible that these assets (meaning fixed assets such as buildings, structures, equipment) are somewhat worn out. Instead, the task of development is their renewal, replacement with innovative means of production, transition to new materials, and so on. A significant factor can be the presence of qualified personnel. New technologies require some retraining, but we can talk about the presence of people who are already carriers of a certain technological culture. In this case, there is no need to explain to workers, engineers, agronomists, animal technicians the basics of industrial or agricultural production. At the same time, it is the presence of a certain production team that can guarantee the receipt of investments, loans for the successful implementation of an innovative project.

Another situation is when, as a result of the war, enterprises are destroyed, fixed assets are destroyed, looted, workers are killed - carriers of the same technological culture, without which the development of new technologies is not only difficult, but almost impossible. Training and gaining some experience in working with machines, tools, devices require considerable time. Especially in modern computerized systems, when not only engineers, but also workers must have sufficient knowledge not only of materials science, the peculiarities of processing metal and non-metal workpieces, assembly operations and quality control, as well as possess the skills of setting up, adjusting, and repairing machine tools, devices, apparatus, machines and mechanisms. In the same way, specialists should be involved in agricultural production, for whom there are no secrets in crop production or livestock production, in the logistics of agricultural products. These are problematic upward conditions concerning human potential and its material and technical support.

Speaking of human resources, the human potential of each enterprise should also be understood the need to preserve, and under crisis circumstances, the formation of a new production team. This means the need to take into account the peculiarities of the psychological compatibility of the persons who will make up the teams, sites, workshops and enterprise as a whole. Aspects of the compatibility of people who have to cooperate effectively have long been studied, including by Nobel Prize laureates [1]. For this, the management has developed the necessary recommendations. It is well known that the adaptation of each individual employee to the requirements of a particular team sometimes does not go as quickly as you want. As a result, labor productivity, product quality, and the company's profitability suffer. Adaptation in a team that is already functioning is a rather difficult issue. Instead, the formation of a new team is an even more complicated process. Meeting people, establishing cooperative relations between them, appointing formal leaders and identifying informal leaders is a compromise and long-term process. A process that is filled with many small and large conflicts.

Instead, the implementation of all programs, projects, and plans requires a financial base, investments, and loans. Internal financial resources, budgetary and extra-budgetary funds are also important. As for own budget funds, which are formed at the expense of taxes, it is necessary to use the experience of such countries in which the tourism business is one of the key sources of revenue in their budgets. In particular, the experience of Albania, Bulgaria, Greece, Croatia, which is closer to us, can be useful. At least in the post-war period, recreational areas can act as certain "locomotives" of economic progress. It is necessary to study the experience of these and other countries to ensure rapid and innovative development of recreational areas. It is necessary to revise the tax system in such a way that it helps the development of the specified sphere of activity, encourages entrepreneurs to invest in relevant institutions, to attract Ukrainians and foreigners to rest in Ukraine, and accordingly to fill local budgets with funds. The granting of preferences should, of course, be temporary, until the relevant institutions and related enterprises stabilize their activities at a level sufficient for effective profitable operation.

The issue of attracting funds is even more complicated. Investors and lenders are dealing with extremely important and at the same time most vulnerable resources. It is generally accepted that funds are needed to implement any program or project. In the economic sphere, where it is necessary to acquire licenses for the relevant activity, for the production of products or services, to purchase equipment, equipment, raw materials, materials, tools, to pay for labor, funds are the first necessary prerequisite. The lack of necessary financial resources immediately endangers any promising idea. There are not many free funds in the world. This is evidenced by a number of publications. Some emphasize a significant number of countries seeking investment [2]. Others talk about the best countries for investment, in particular by leading the world rankings [3]. At the same time, the owners of financial resources should receive extremely reliable guarantees in their effective use and receiving a certain benefit from it. Lenders must be sure of repayment and payment of loans. Investors usually seek not only dividends on their invested capital, but also a return equal to their investment. Owners of funds do not want to take risks, as is commonly known. Instead, new publications appear in accordance with current conditions in the financial markets [4]. The International Monetary Fund systematically monitors the state of financial markets and identifies problem areas [5]. At the same time, the time dimension of the return of credit and invested funds is also important. This is emphasized by financial funds that provide their resources for various needs in the form of grants and in other forms [6].

Separately, it should be emphasized, what level the program or project is being implemented. The sources of funds depend significantly on whether the program is nationwide or whether the project is implemented at the local government level. Of course, it is desirable to invest in programs that are national in scope. Sometimes investors seek to obtain government guarantees in what is to be created. After all, foreign companies may not know the peculiarities of the functioning of national legislative norms. This requires appropriate consultants - specialists of economic and legal profile with perfect knowledge of Ukrainian economic realities. The same can be said about regional projects. After all, different tax conditions may exist for different regions, including those established by local authorities and management. There may also be local regulations limiting economic activity in various territories, such as national parks, nature reserves, sanctuaries. And it is necessary to recognize the special attractiveness of these natural zones for people and, accordingly, for recreational establishments. There are also features in the field of environmental legislation and its compliance in some territories.

B Taking into account these prerequisites and means of realization of recreational development are serious factors in organizing such types of business that fill the recreational sphere.

3. Solution of the examined problem

We study the problems of development of recreational territories on the example of Ukraine. It is this example that is marginal in terms of the conditions that have developed as a result of the war. Therefore, this example may contain the maximum number of requirements and means for solving the problem under investigation. The limits of one article do not allow a detailed consideration of all aspects. Instead, the specific and most important directions of the development of recreational areas, the use of some means of solving problems in the post-crisis (post-war) period are determined in general.

Consideration of the problem of the development of the country and its territories in the period after the end of the war is extremely relevant for Ukraine today. Discussions are already taking place and the directions of economic activity are being determined in order to solve such complex issues among Ukrainian specialists [7]. The international community is also exploring the possibilities and determining specific measures to help Ukraine restore its economic potential [8]. Power structures also take care of these problems, in particular, the National Council for the Recovery of Ukraine from the Consequences of the War was created [9].

An important aspect of economic recovery in the period after any crisis, and even more so after a war, is the determination of strategic directions of development. One of these strategic directions is considered by state leaders to abandon the raw material economy [10]. The need to ensure this type of development of the Ukrainian economy has been recognized for a long time, even before the war. On the other hand, regarding the implementation of such ideas, during the thirty years of the existence of the Ukrainian state, there was no political will and desire of certain oligarchic circles. The concentration of key, including financial, resources in the hands of oligarchs interested in trade in raw materials did not allow the authority to change the nature of the domestic economy.

The Government of Ukraine is aware of the potential risks that have arisen as a result of the war. However, these risks are exacerbated by external influences, which, in particular, the World Bank warns about. The authors of the report "Global Economic Prospects" from the World Bank emphasize such changes in the world economy that will negatively affect not only low-income countries, but also middle-income countries [11]. Special attention is paid to the impact of the war against Ukraine. After all, after the negative impact of the COVID-19 pandemic, which led to lockdowns and a reduction in the volume of world trade, the said war caused a series of measures that strengthened the negative trend. This primarily refers to the markets of hydrocarbons and food. That is why the authors of the report consider it necessary to influence the situation by market means, not to apply measures to regulate economic processes by the governments of countries. At the same time, the need to strengthen the role of local authorities and management in stimulating the economy of individual regions is emphasized.

Considering the problem of economic development of Ukraine in the post-war period, the following can be noted. It is now clear that the government should differentiate its efforts in relation to different areas. After all, the aggressor completely destroys individual settlements and enterprises. Because of this, it will be necessary to carry out complete reconstruction of social and economic infrastructure in some cities and villages, and to carry out partial restoration of infrastructure facilities in some settlements. Instead, the losses caused in industry, agriculture, on transport highways will require a radical restructuring of the country's economy. After all, the disappearance of certain enterprises causes the destruction of economic ties, the disappearance of suppliers and the possibility of carrying out usual production activities. In particular, in Ukraine, this applies to such industries as metallurgical, chemical, metalworking and, accordingly, mining, mechanical engineering and instrument engineering.

The traditional specialization of territories is changing, as it is already happening. The surviving industrial enterprises from the eastern regions that were attacked are moving to the western

regions, which were recently mostly recreational and had prospects for development in this direction. Of course, the global and regional (especially Eastern European) division of labor will have an impact on the specialization of territories and the country as a whole. Whether it will be necessary to return to the types of economic activity that have been traditional in previous decades, will be decided in view of the prospects of cooperation with the countries of the European Union, the countries of North America, Asia and Africa, which were traditional trading partners of Ukraine. At the same time, it is worth strengthening the recreational opportunities of those Ukrainian territories where appropriate enterprises have already been created, taking into account the available natural resources and climatic conditions.

4. Results and discussion

The results achieved in the development of recreational areas and the creation of appropriate enterprises should certainly not be lost. First, it is important for Ukrainians, especially those who do not have high incomes. Secondly, the development of recreational areas meets the requirements of ecological development of regions and the state. Thirdly, such conditions can be attractive for foreign tourists who appreciate the opportunities for a good and fairly budget-friendly rest.

Provision of the specified direction of socio-economic and ecological oriented development requires financial support of appropriate measures. It is well known that ecological measures (preservation of mountain and forest areas, water bodies - lakes, rivers) require a lot of funds and do not bring large profits. This, in the post-war reconstruction of the country, requires a revision of the state's tax policy.

In previous years, the tax policy of the state was given a lot of attention, both practitioners and scientists [12]. New economic circumstances require greater attention to regional finances and, accordingly, differentiation of taxation conditions by region. In particular, this is important taking into account the above-mentioned considerations regarding recreational areas, parallel innovative development in them both of sanatorium-treatment profiles, and of industrial enterprises relocated from other regions. There is already a scientific work on the budgeting of territorial communities [13]. Instead, it is necessary to develop research in this direction, taking into account the need to overcome the consequences of the war.

5. Conclusion

The development of recreational areas in Ukraine in the process of overcoming the consequences of the war requires significant efforts. One of the directions that should contribute to this process is the improvement of the taxation system. The entire complex of tax instruments should be used to attract investments, loans, and perhaps most importantly, budget funds. At the same time, budget funds should contribute to the innovative development of recreational areas not so much as budget expenditures, but as a part of potential budget revenues, which, as a result of the benefits granted to the territories, would be used for the implementation of relevant target programs.

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NoSQL database for air quality prediction

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Abstract: The increasing application of NoSQL database technology and the neural networks raises the question of how compatible and applicable are the NoSQL databases to the neural network prediction models. This paper examines the applicability of a traditional relational database for storing air quality data and compares it to a NoSQL database performing the same functions. The possibility of the NoSQL database to feed a neural network model for predicting the atmospheric air quality is evaluated. The tendencies in the data are studied, and some solutions for improving the air quality are proposed. An analysis and a comparison of the performance of both relational SQL and NoSQL database systems by using real-world data for the Air Quality Index in the city of London is assessed and their performance is compared. Bivariate analysis on the data in order to assess the quality of the neural network forecast is performed.

Keywords: AIR QUALITY INDEX, NEURAL NETWORKS, NOSQL, PEARSON COEFFICIENT

1. Introduction

Recently, the document-based databases (NoSQL) are gaining more and more popularity. What they have in common is that the data is stored in the form of a table that is not fully normalized, and the level of normalization in the tables depends on the complexity of the data to be processed. Unlike relational databases (SQL based), which are organized around the concept for a table for each object in the information system. The various objects are connected to each other through relations (a relational tables for many-to-many relationships or index columns in the other cases). In the document [1] the applicability of the Cassandra NoSQL data base management system is considered. The latest releases of some NoSQL systems (Cassandra) use the so-called CQL (Cassandra Query Language), which resembles SQL in the way the queries are structured, as well as in the way the tables are defined (METADATA). For the most modern applications, Apache Cassandra is considered a good choice in the application and web services development environments.

It offers many advantages, including easy data portability on a global scale and outstanding performance. Today, Apache Cassandra is amongst the most popular NoSQL database management systems. It is used for online retail applications, for internet portals, for time series databases, for mobile applications, for internet banking.

The development of the right data model is critical to achieving a good application performance and future scalability. Creating the right data model is important for any application, but its importance increases when it comes to applications that require minimal latency, minimal blocking, and global scalability.

An application must be able to work both with thousands of records and several hundred concurrent users, and even when the number of records and users is in the millions or even billions figures. At the same time, the target is to minimize the waiting time.

Regardless of whether a SQL or NoSQL database management system is used, if the data model is not developed correctly or does not fit the underlying architecture of the chosen database, it can lead to performance degradation, long query wait times, data loss or corruption. It may be necessary to change the data model (migration) after the application is created and deployed, but this could prove to be an expensive and complex operation. Therefore, it is a good idea to select a proven methodology for designing a scalable, extensible and easy-to-maintain data model during the development process.

2. Differences between Cassandra and the relational databases

Most professionals are familiar with the relational databases such as Oracle, MySQL, SQLite, PostgreSQL. Before moving on to the data modeling with NoSQL, it is a good idea to pay attention to some differences between NoSQL-based and relational databases. Relational databases prioritize the data size minimization over the

response time – a piece of information exists at only one place in the database (this is guaranteed by the Normalization rules, 1st, 2nd, 3rd, 4th Normal forms), but when retrieving data (SELECT statement) many joins (JOIN operations) have to be done. This results in slow execution of even trivial-to-fetch queries. NoSQL systems, on the other hand, prioritize the execution time for the retrieval query, and for this purpose, a given information is presented in several places in the database, and they are not so well normalized. On the other hand, the requests to update data (UPDATE, INSERT statements) are executed much faster on a relational databases, since a given information needs to be updated at only one place, unlike the NoSQL-based ones. In general, it can be concluded that with the traditional databases, normalization is highly recommended, while with NoSQL databases, the lack of normalization can be a sign that a good data model has been created. Researchers who came to similar conclusions are [2].

When creating a data model with the traditional databases, the approach is to take the initial data, then the work that is done is in the direction to define and decompose granular groups of objects that have common characteristics, and subsequently a separate table with the characteristics of the object is created. Relations between individual objects are defined by relations (1-1, 1-many, many-many). After that, when the application runs, the individual objects (tables) are combined into larger tables, and each of them contains information about several objects at once achieved through joins (JOIN operators). These combined tables are called lookups, or retrieval queries. They are the product of objects decomposed into separate tables, which are combined in order to extract common information about the relationship between several objects. An example of this is a database for books. One object is obviously a Book (with attributes Title, Price, ISBN, and Number of Pages). The other object could be Author (with characteristics First Name, Middle Name, Last Name, and Date of Birth). When implementing this model through the relational model, it represents a many-to-many relationship. This type of relationship also requires an additional table BooksFromAuthor. After that, by means of 2 JOIN operators, a reference such as Titles of books written by a certain author can be retrieved, which is a product that represents a table, and it is obtained by combining data from the tables Book and Author and BooksFromAuthor. While the organization of the data in this way saves space (there are no duplications in the Authors nor in the Books tables), data extraction is done by the computationally expensive join operator JOIN, applied twice in combination with the GROUP_CONCAT function, or its analogue (if the DBMS is different from MySQL), making it twice as slow.

From the point of view of the implementation of such a data model by means of NoSQL DBMS, the opposite approach is applied - First, the joins that are needed are defined, in this case a reference such as Titles of books written by an author, their price and ISBN number. A table is then created in the database for each such a join.

The arrangement made in this way can be realized by making a table BooksByAuthor, in which the first column is the name of the

book, and the second - a list of the names of the authors. In this scenario, in order to change the name of one of the authors, the entire record that contains the list of the names of all authors must be changed. This can lead to creating a source code of the information system that is difficult to write and maintain in the future. Fortunately, Cassandra CQL provides an easy way to modify a list of values. For example, a user can update the record for the book "The Last Thing He Told Me: A Novel" and add author "Laura Dave" in case the author is omitted as follows:

```
UPDATE BooksByAuthor SET Authors = Authors + {,Laura Dave'}
WHERE ISBN = ,978-1501171345';
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Here the ISBN field is used as a natural key, but the table index could be used instead.

Separately, the Author and Book tables will exist so that all author names and all book names can be looked up. Obviously, when changing the author's name, it must be changed in the Author table as well as in the BooksByAuthor table that is, in 2 places, which leads to slower execution of UPDATE, INSERT and DELETE requests. In some information systems, some of the characteristics of objects in the data change very rarely or never (the Author of a book does not change because it is already printed), but at a minimum such information systems must support the ability to edit the data (for example incorrect initial entry and subsequent need for editing). NoSQL DBMS rely on exactly this, as well as on the optimization, if necessary, to retrieve the data with a JOIN request from the table, so that they are executed faster.

On the other hand, a NoSQL data model can also be implemented entirely through a relational DBMS, adding loosely normalized tables to the model to serve as the basis for frequently executed retrieval queries. The opposite - implementing a relational model using Cassandra is not possible because Cassandra does not support the JOIN operator and is not optimized to support the relational model.

3. Air quality reporting system

The GAIA air quality monitoring stations use high-tech laser particle detection sensors to measure the PM2.5 pollution, one of the most harmful air pollutants in real-time. They are very easy to set up and only require a WIFI access point and a USB power supply. Once connected, the air pollution levels are monitored and reported instantly in real-time on an Internet-based mapping application.

Regarding the system, the relational data model could look like this:

```
CREATE TABLE SENSOR (STATION_INDEX INTEGER,
SENSOR_DESCRIPTION TEXT (35), SENSOR_LONGITUDE FLOAT,
SENSOR_LATITUDE FLOAT, LAST_UPDATE_TIME TIMESTAMP);
CREATE TABLE READINGS (STATION_INDEX INT, PARAMETER TEXT
(35), VALUE INT, DATETIME TIMESTAMP);
CREATE TABLE HISTORY (STATION_INDEX INT, PARAMETER TEXT
(35), VALUE INT, DAY DATE);
CREATE TABLE FORECAST (STATION_INDEX INT, PARAMETER TEXT
(35), VALUE INT, DAY DATE);
```

The PARAMETER field can have one of the following values: PM25, O3, NO2, CO2, SO2, TEMPERATURE, RH, PRESSURE, HUMIDITY, WIND_SPEED, WIND_DIRECTION.

This database model is fed with standard real CSV (Comma Separated Values) format from the <https://www.londonair.org.uk> web service. They can easily be imported into the data model constructed this way, and are compatible with it.

In [3] is investigated the applicability of the NoSQL databases in the research of Air Quality Index, by using MongoDB. On the other hand, in the document [4] several steps that lead to the construction of a NoSQL data model are outlined. These are: Step 1: Build the

application workflow; Step 2: Model the requests required by the application; Step 3: Create the tables; Step 4: Create the primary key; Step 5: Effective use of basic data types.

Step 1. The main screens of the application must be identified, as well as the data that is required for each screen.

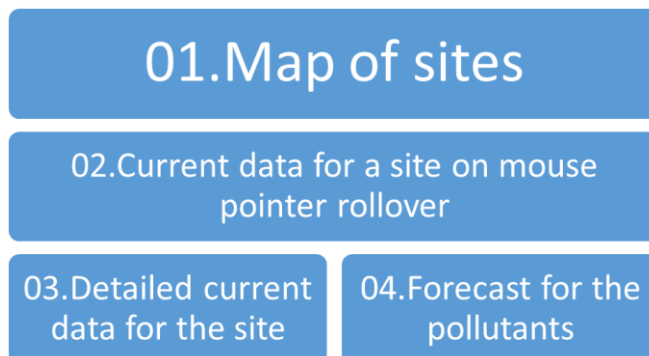


Figure 1. Data, required by each application screen

The sequence of the workflow steps is important because it helps to determine what data is available and required for each screen. For example, before the detailed information about a station can be displayed (User Step 03 above), a station identifier (StationIndex) is required. Likewise, to display a forecast for a station (User Step 04), its ID is required.

Step 2. A diagram of the interrelationships in the application is prepared, and at this step the attention could be returned back to the previous Figure 1 to correct it.

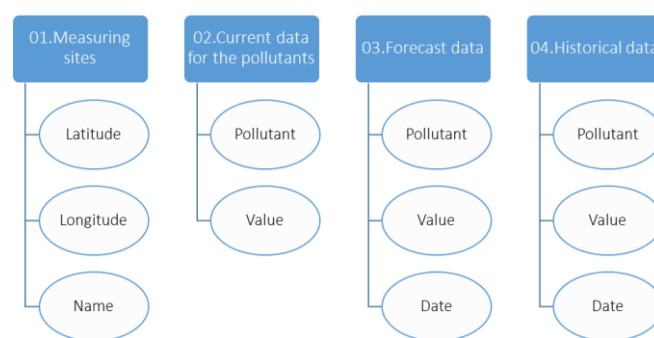


Figure 2: User steps and modeling of the requests when working with the application.

Step 3. Create the tables. The next step is to structure the tables to support the required queries of the application.

Tables are designed to match the individual views /screens/ of the application. In general, the application has the following screens:

Initially, a world map is loaded, with POI (Point of Interest) markers marking the various measuring stations around the world. To be fed with data, this screen needs only one table that contains the coordinates of all the measurement points, as well as a key to the table with the data of all measurements for a given point.

If the table is called StationCoordinates, then it will have the columns StationIndex, Latitude, Longitude, StationName.

Another screen with data appears when the mouse cursor is positioned over a measuring station. Then a request is sent to the database to load the data for the measuring station in question. The table that supports this screen should contain the data for the current values of the indicators and should have columns: index of the measuring station - StationIndex, AQI name, forecast for the next 3 days of the AQI indicator. Historical data for indicators PM25, PM10, NO2, SO2, CO, for the last 12 months, can be stored in the LastYear table with columns StationIndex, Indicator, Date, Value,

and retrieved with a separate query to the database when the screen loads.

It is beyond doubt that all air quality sensors (AQS) around the world generate a huge amount of relatively well-structured information, over large periods of time. Therefore, when working with a lot of data, the advantages of one or the other technology will become even more obvious. From this point of view, it is of interest to build a relational and NoSQL model of the data and to compare their performance in different scenarios - writing, editing and extracting data.

4. Forecast

Contamination prediction is of particular importance to the users of such a system. It is needed by the citizens who are interested, as well as by the state administration, which could introduce social incentives, for example, higher parking fees in the polluted areas, or a cheaper or even free ticket for the public transport in a case of a bad trend. The accumulated information can help in making such a forecast. The aim is to test how well it is possible to predict days with poor air quality indicators. On colder days, the burning of solid fuel sources can be expected to increase, and combined with a lack of wind, can lead to smog in a given area. Unfortunately, the cleanliness of the air also depends to a large extent on the weather forecast. The region that is studied also has an impact, as forecasts may differ for different regions. The area for which the research is being done is the center of the city of London in Great Britain, because the indicators of air pollution have been measured and recorded there for a long time, and also the information is freely available. Other researchers are also examining data about this city [5], [6]. For such a forecast, also the statistical methods can be used (linear regression, following the example of scientists [7]), as well as neural networks (time series of indicators, as the following researchers have done [8], [9] and [10]). Statistical data for past periods as input parameters of the model could be accepted – what air pollution was in the past when the conditions were similar, and their development over time.

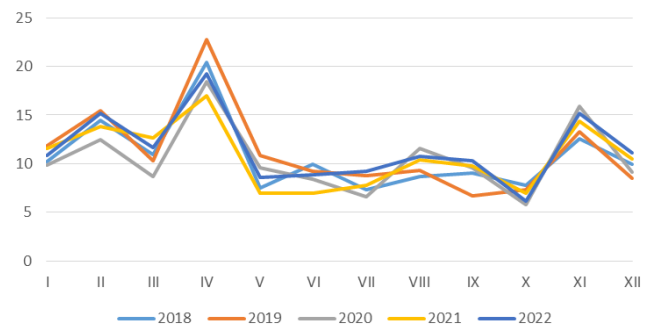
The aim is to extract some general trend in the data by which to impose restrictions on the population, which could be ban on cars, high bills for heating during the dirty period, a ban on burning coal, high electricity bills, an increase in the excise duty on fuels, stoppage of warm water, etc. as this could lead to an improvement in the air quality during the period in question.

Table 1 contains monthly average data for PM 2.5 in (ug/m3) taken from [11] for the period 2018-2021. In the last column, the values of this indicator for the year 2022 are predicted by the means of a neural network with a radial basis function. The error obtained during the preparation of the forecast is within 1.51%. The error is calculated in percentage as a deviation when comparing the forecast for 2022 with the actual data from it.

Month	Year				
	2018	2019	2020	2021	2022-forecast
I	10.23	11.81	9.89	11.52	10.83
II	14.42	15.41	12.47	13.83	15.21
III	10.95	10.32	8.68	12.62	11.64
IV	20.38	22.74	18.41	17.02	19.25
V	7.54	10.84	9.55	6.93	8.55
VI	9.98	9.26	8.40	6.99	8.85
VII	7.31	8.76	6.64	7.78	9.23
VIII	8.65	9.27	11.52	10.43	10.73
IX	9.02	6.71	9.54	9.73	10.31
X	7.81	7.35	5.74	6.93	6.18
XI	12.58	13.28	15.9	14.33	15.21
XII	9.95	8.46	9.15	10.45	11.13

Table 1. Average data for the period 2018-2021 and the forecast for the 2022 for the air pollution indicator PM 2.5

Forecast for the 2022



Graph 1. Forecast for PM2.5 for the 2022

The graph shows that, in general, the air pollution with PM 2.5 particles reaches its highest value in the month of April, from May to October it moves in more moderate limits, and then during the cold winter months it starts to increase until the month of April.

The authors [12] also investigated the prediction of air pollution by regression analysis. The bivariate analysis (correlation matrix) with the Pearson's coefficient allows to evaluate both the prediction obtained and the interrelationships between the data [13]. In general, it can be concluded that every year the trend of PM 2.5 particle pollution is uniform, which is repeated every year. That is, to a certain extent, we can talk about the predictability of the pollution in question.

Year	2018	2019	2020	2021	2022
2018	1.000	0.934	0.852	0.881	0.931
2019	0.934	1.000	0.853	0.806	0.885
2020	0.852	0.853	1.000	0.860	0.926
2021	0.881	0.806	0.860	1.000	0.954
2022	0.931	0.885	0.926	0.954	1.000

Table 2. Correlation matrix with the Pearson coefficient.

Table 2 shows that there is a high degree of correlation both between the individual variables used for forecasting /the data for the years 2018-2021/, and between them and the forecast for 2022 prepared by the neural network.

5. Conclusion

The authors [14] investigate the performance of different DBMS when running on devices with reduced power consumption and large amounts of data. For these devices, the speed is critical because the devices in question have limited resources. To evaluate the performance of the different data management systems, the neural network prediction process was run twice, in one case using the Python Datastax driver to connect to the Cassandra database, and in the second case using the MySQL Connector driver to connect to MySQL. In both cases, the time to prepare the forecast was recorded, and in the first case it was prepared in 4704 milliseconds, and in the second in 3987 milliseconds. The data was extracted raw from the database and averaged at runtime to get a better idea of which of the two systems would be faster at the extraction itself. The data covers a 4-year interval and is only for the PM2.5 metric measured every 15 minutes, or about 143,080 records that include date, time, and metric value. Keras library was used for preparing the neural network forecast.

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Influence of the COVID-19 pandemic on the distribution of teleworking in Bulgaria – social, occupational, and sectoral dimensions

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Abstract: The outbreak of COVID-19 pandemic and the related containment measures had a significant influence on the Bulgarian labour market. Economic activities where it was difficult to apply flexible regimes of work allowing the physical absence of the employee from the location of production or service provision were hit particularly high. Therefore, it is interesting from the research point of view to analyse the influence of the COVID-19 pandemics on the changes in the distribution of the remote work not only with a view of its coverage and frequency of application, but mainly in terms of its social, occupational, and sectoral characteristics. Such an analysis would contribute to better understating of the readiness of the Bulgarian labour market to implement the flexible regimes of work mediated by information and communication technologies. The analysis is based on the 10th round of the European Social Survey for Bulgaria.

Keywords: REMOTE WORK, TELEWORK, DIGITALISATION OF WORK, COVID-19, EUROPEAN SOCIAL SURVEY

1. Introduction

For many years, technologies and their impact on work, employment, and labour markets have attracted the attention of sociology. Currently, the research focus is on the transformative role of the digital, microchip or computer-assisted technologies which widespread use in all economic sectors is as an attempt to push production beyond the limits shaped by the industrial era mass-production technologies. This trend is often called “digitalisation”.

According to Eurofound, the impacts of digitalisation on work will be channelled by three phenomena with enormous economic, social and policy implications: 1) automation of work; 2) digitisation of production processes, and 3) establishment of platforms – digital networks facilitating labour market interactions [1]. In his famous book *The Fourth Industrial Revolution*, Klaus Schwab, the founder of the World Economic Forum, uses the term *human cloud* to describe metaphorically the platform work. This witty analogy to cloud computing technologies emphasises that the digitalisation has made it possible to bring together workers from all geographical locations to carry out common assignments or projects. In 2016, when *The Fourth Industrial Revolution* was published, Schwab was certain that this was a part of an ongoing “flexible work revolution” [2].

In this context, sociologists agree that digitalisation of work, among its other hypothesised effects such as job cuts and modified skill requirements, is most likely to transform existing jobs rather than create new ones [3]. Therefore, it is essential to track the changes in working conditions imposed by digital technologies.

COVID-19 pandemic has given rise to new causes of uncertainty. Employment in many economic sectors was severely affected and containment measures enforced by public authorities created a different context of the social reproduction of ‘worker-employer’ and ‘worker-worker’ relations. As a result, digitalisation has gained pace and the use of some flexible forms of employment such as teleworking and working from home become more common. At EU-level, in 2021 more than 20% of all employees worked from home for some time while in many countries (Denmark, Belgium, Ireland, Finland, Luxembourg, Sweden, and Netherlands) the share of employees having some spells of teleworking reached or even exceeded 40% [4]. However, the manifestation of this trend was uneven across sectors and occupations. It has once again magnified the importance of the concept of *teleworkability* [5] meaning that the effects of digitalisation on spatial division of labour could be modified by the technical aspects of job-related tasks in each economic sector.

Existing studies of the Bulgarian labour market show similar picture. Even before COVID-19 pandemic, the incidence of teleworking was low [4] which can be explained not only by the job characteristics but also by many other variables such as digital competences, access to Internet at home, computer- or mobile

device availability, family situation, income level, etc. [6]. Studies present different scenarios about the future of work in technological era; however, it is still unclear how Bulgarian firms will adapt to the upcoming structural shifts [7].

Therefore, it can be concluded that available evidence about the influence of the COVID-19 pandemic on work and working conditions in Bulgaria is still in a fragmentary state. This paper does not have an ambition to solve this problem but rather to contribute to enriching the existing body of knowledge by exploring the social, occupational, and sectoral dimensions of teleworking, which is only one of the many aspects of the digitalisation of work. In that regard, the choice of topic just highlights the need for further research.

2. Methods and data

This paper employs the definition of *teleworking* presented in Sostero et al. [5]. It is a sub-category of the broader concept of *remote work* where work is carried out at a place which is different from the usual place of work. It can be either the home of the worker or another place. A distinctive characteristic of teleworking is the mediating role of electronic devices. In contrast, working from home does not imply the presence of another (usual) place of work and although electronic devices may be used in some cases, it is a different concept from teleworking. Finally, teleworking is often used to describe a specific form of work organization applicable to dependent workers, i.e., employees, while working from home (regardless of the means and tools) can be performed by both dependent and independent workers (self-employed).

In this regard, the paper seeks to answer the question of how (i) the prevalence of teleworking and (ii) the profile of workers performing teleworking have changed due to COVID-19 pandemic.

Analysis is based on data for Bulgaria from the 10th round of the European Social Survey, edition 1.3 data set [9]. Data has been collected by the Institute of Philosophy and Sociology at the Bulgarian Academy of Sciences between 28.06.2021 and 30.9.2021. The number of valid respondents is 2720.

For the purposes of this analysis, a sub-sample of 1199 respondents is created. Following the definition of *teleworking*, the sub-sample consists of respondents with a status of dependent workers (employees) in the last 7 days prior the moment of data collection.

It is also assumed that employees who report some periods of remote working but at the same time declare that they do not have online or mobile communication with the people who they work with, do not telework. Therefore, remote working and teleworking are not considered synonyms.

3. Results

Data from the European Social Survey shows that 73.4% of all employees report that they do not work remotely compared to only 26.6% who do. The share of employees who report some periods of

remote working but do not have online or mobile communication with people who they work with, is very low – only 0.5% of total number of employees.

Work from home or place of choice, how often

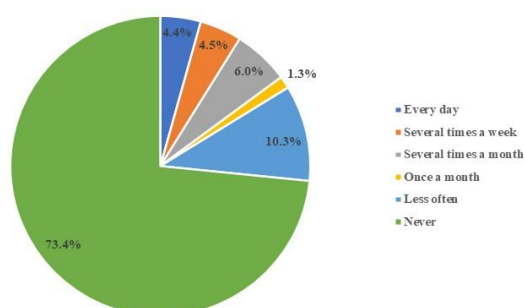


Fig. 1 Prevalence of teleworking in Bulgaria

In that regard it could be concluded that 26.1% of all workers have some experience of teleworking. Among them, 4.4% do telework every day.

How has the COVID-19 pandemic changed the prevalence of remote working? Approximately 7 out of 10 workers report that they cannot work from home or from another place of choice.

Teleworking from home or place of choice, how often compared with before COVID-19

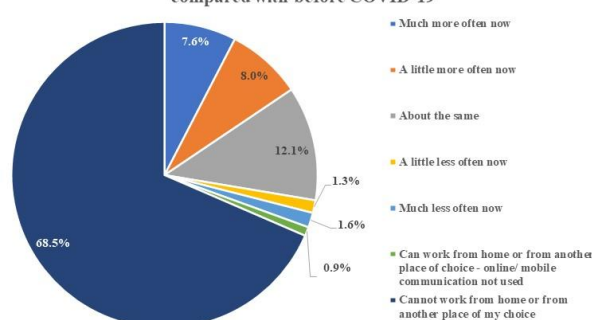


Fig. 2 Prevalence of teleworking compared with before COVID-19

Among the others, 30.5% report experience of teleworking, with 15.6% reporting more frequent digital contacts with colleagues since the coronavirus outbreak, less than 2.9% report a decline, and 12.1% do not report any changes.

It is interesting, however, to investigate to what extent the observed variability of working arrangements could be attributed to COVID-19.

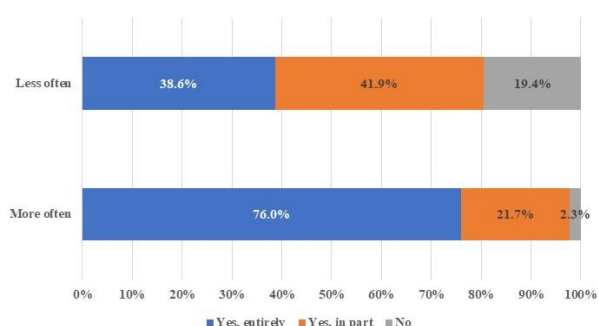


Fig. 3 Changes in incidence of teleworking due to COVID-19

In that regard, it should be noted that almost 98% of respondents reporting that teleworking has become a more frequent

feature of their working conditions since the start of COVID-19 pandemic (15.6% of the workers) tend to explain this shift in whole or in part with the coronavirus outbreak. This explanation is valid for approximately 80% of respondents reporting a lower frequency of teleworking (2.9% of the workers). So, it could be concluded that COVID-19 has brought observable changes in the frequency of teleworking among those who already had some experience of teleworking. Nevertheless, the share of workers having observed any changes remains rather low – 18.5%.

The most important question, however, remains unanswered. It is related to the profile of workers who work remotely.

Sectoral distribution of teleworking

The sectoral distribution of teleworking shows that more than 90% of all workers reporting some periods of teleworking are concentrated in 20 economic activities. It seems that more than one third of these employees work in sectors where the state is the biggest employer (education; public administration and defence; compulsory social security). On the other hand, almost all workers in ICT-intensive activities (computer programming, consultancy and related activities; information service activities; programming and broadcasting activities) and activities where work is performed predominantly in an office (for example real estate; other professional, scientific and technical activities; architectural and engineering activities; technical testing and analysis) report that they had some period of teleworking.

Table 1: Sectoral distribution of employees who report at least some period of teleworking

Economic activity	% of total
Education	23.2%
Public administration and defence; compulsory social security	13.5%
Retail trade, except of motor vehicles and motorcycles	12.3%
Computer programming, consultancy and related activities	6.4%
Legal and accounting activities	6.0%
Land transport and transport via pipelines	4.2%
Human health activities	4.0%
Information service activities	2.7%
Financial service activities, except insurance and pension funding	2.4%
Construction of buildings	2.2%
Insurance, reinsurance and pension funding, except compulsory social security	2.2%
Manufacture of fabricated metal products, except machinery and equipment	1.8%
Advertising and market research	1.5%
Scientific research and development	1.5%
Real estate activities	1.5%
Manufacture of wearing apparel	1.2%
Electricity, gas, steam and air conditioning supply	1.1%
Social work activities without accommodation	1.1%
Programming and broadcasting activities	1.1%
Manufacture of food products	0.7%
Repair and installation of machinery and equipment	0.7%
Postal and courier activities	0.7%
Publishing activities	0.7%
Other (19 activities)	7.0%
No workers reported teleworking (32 activities)	0.0%

Occupational distribution

Approximately 4 out of 10 workers who report at least some periods of teleworking represent the occupational group of *Professionals*. The other three groups having the biggest share of the total number of employees who telework are *Clerical support workers* (18.5%), *Technicians and associate professionals* (15.8%)

and *Managers* (12.5%). It is evident that these are occupations having higher qualification and skill requirements.

Table 2: Occupational distribution of employees who report at least some period of teleworking

Occupational status	% within group	% of total
Armed forces	0.0%	0.0%
Managers	54.8%	12.5%
Professionals	66.5%	43.2%
Technicians and associate professionals	37.4%	15.8%
Clerical support workers	44.6%	18.5%
Service and sales workers	9.7%	5.2%
Skilled agricultural, forestry and fishery workers	32.6%	0.4%
Craft and related trades workers	4.7%	1.9%
Plant and machine operators, and assemblers	5.2%	1.8%
Elementary occupations	2.2%	0.7%
Armed forces	0.0%	0.0%

Socio-demographic distribution

To understand better which other factors except sectoral and occupational status influence the prevalence of teleworking, a binary logistic regression in SPSS is used. The sample includes 973 employees who reported that they were able to use online or mobile communication tools to interact with people who they worked with. Among them, 29.6% had some experience of teleworking and 70.4% - did not. The following variables are included in the model:

Table 2: Sectoral distribution of employees who report at least some period of teleworking

Predictor variable	Categories
1. Education	Basic of lower, including without education; Secondary education; Post-secondary and higher education (reference category)
2. Region	Sofia – capital (reference category); The six NUTS level 3 regions with the largest population (Sofia – district; Plovdiv; Varna; Burgas; Stara Zagora; Blagoevgrad); Other NUTS level 3 regions.
3. Type of organisation	Public organisation; Private organisation (reference category).

The model was statistically better than the baseline at explaining the probability someone to have some experience of teleworking [$\chi^2(1) = 207.148$; $p = 0.000$; $p < 0.001$; $R^2 = 0.192$ (Cox-Snell), 0.273 (Nagelkerke)]. The model correctly predicted the experience of teleworking of 72.9% of respondents including 78.2% of respondents without experience of teleworking and 60.1% of those who have. The results also suggest that people with post-secondary or higher education are much more likely to telework. The probability for people with secondary ($\exp(\beta) = 0.147$, Sig. = 0.000) or less than secondary education ($\exp(\beta) = 0.053$, Sig. = 0.000) is very low. Compared to employees living in Sofia (capital), for workers living in one of the top six, in terms of their population size, NUTS 3 regions it is less likely to telework ($\exp(\beta) = 0.519$, Sig. = 0.001). The same could be concluded for workers living in smaller NUTS 3 regions ($\exp(\beta) = 0.524$, Sig. = 0.001). Furthermore, the probability that people working in public organisations (central administration, public financed educational or health organisation, etc.) have some experience of teleworking is significantly, almost 60%, higher ($\exp(\beta) = 1.586$, Sig. = 0.005) compared to private firm workers.

4. Conclusion

The results from the 10th wave of the European Social Survey show a worrying picture. On the one hand, the prevalence of teleworking in Bulgaria remains low despite the impact of COVID-19. This suggests that many Bulgarian employers are unwilling or unable to provide opportunities for flexible working arrangements, both with a view to protecting workers' health and maximising efficiency. On the other hand, there are some signs that differences in the prevalence of teleworking could reinforce existing divisions between public and private sectors, between high and low ICT-intensive industries, and between higher and lower skilled employees. Therefore, further research into the implications of this *flexible work revolution*, as Klaus Schwab named it, on the workers' wellbeing and quality of life, is more than necessary as many of the driving causes of these changes remain insufficiently explained.

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The impact of digitization on health and safety at work

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Abstract: The advent of technologies such as artificial intelligence, big data, collaborative robotics, the Internet of Things, algorithms and digital work platforms and at the same time a significant increase in the number of people working remotely brings opportunities as well as new challenges and risks in the field of health and safety. Addressing challenges and risks and maximizing opportunities depend on how technologies are used, managed and regulated in the context of social, political and economic trends [1]. This post describes digitization and its use in the field of safety.

Keywords: DIGITALIZATION, SAFETY, INDUSTRY 4.0

1. Introduction

The digitalization and automation of production and logistics technologies as part of Industry 4.0 bring a number of positive aspects to enterprises. They create conditions for expanding production capacities, asserting themselves in the competitive environment by increasing productivity and quality of manufactured products, new opportunities, and new customers, replacing humans in hazardous operations and events [1]. The introduction of modern technologies into education primarily requires the required infrastructure of the school, teachers who have the necessary digital competences and digital materials and concepts that will be used in teaching.

2. Industry 4.0

As Madsen [2] clearly summarized in his article, the concepts of modern management have evolved significantly in the last few years (e.g., Agile Management, Big Data analysis, Customer Relationship Management). As he said, I4.0 can be understood as a highly normative management concept that improves the performance of the organization, respectively: flexibility, productivity, and quality of processes or production. The versatility of this concept is that it includes many partial management concepts, such as the Internet of Things (IoT), Big Data, and digitalization, see Fig.1 [2,3,4].

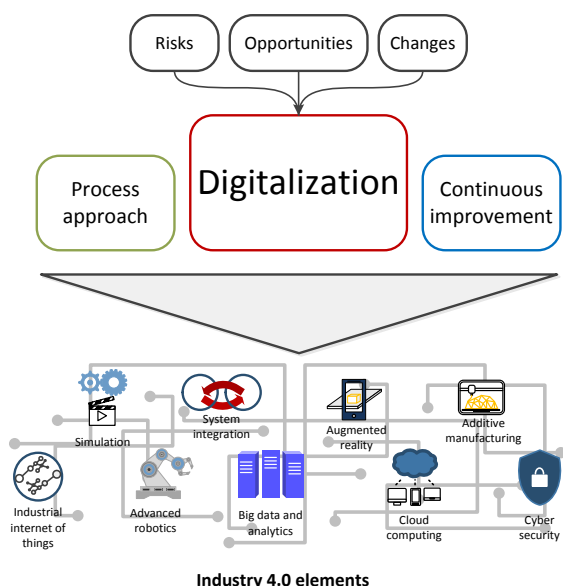


Fig. 1 The relationship between Industry 4.0 and digitalization.

Digitalization in all areas of life (Industry 4.0) has now become a trend, but also a necessity for obtaining information, storing and processing it so that it is the basis for correct decision-making. It is interesting that in Industry 4.0, the management of a manufacturing organization in particular is understood mainly as the implementation of 9 basic pillars representing modern technologies

(technological pillars), see Fig. 2. These technologies make it possible to process data from the design of the product to its delivery to the customer, even allowing to track its entire life cycle in a given market environment.

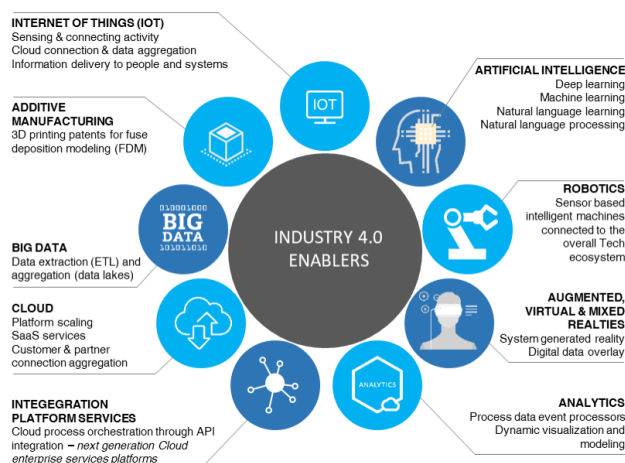


Fig. 1 Pillars of Industry 4.0 [5].

In recent years, the development of digital technologies has had a major impact on the economy, the functioning of companies and also on safety. Industry 4.0 has brought about a revolution through a high degree of automation and digitization of work activities. This has a significant impact on the competitive struggle not only on the part of companies, but also on the competition on the part of individual countries, which must make significant changes in preparation for the transformation of companies. The new transformation is based on new technological procedures, which are made possible by digitization processes. These changes have direct impacts on the operation of new intelligent operations. They must incorporate into their functioning:

- interoperability of machines and equipment,
- transparency of information,
- technical support of cyber systems,
- decentralized decision-making processes,
- virtualization,
- the ability to make changes in operation in real time,
- modularity and flexibility of processes [6].

Building upon its foresight study on digitalisation and OSH, EU-OSHA is running an 'OSH overview' research project (2020-2023) to provide in-depth information for policy, prevention and practice in relation to the challenges and opportunities of digitalisation in the context of OSH. [7].

Five priority areas give structure to the campaign:

1. Digital platform work.
2. Advanced robotics and artificial intelligence.
3. Remote work.
4. Smart digital systems.
5. Worker management through artificial intelligence [7].

3. Digital transformation

Digitization in the enterprise, see Fig. 3, is considered the first stage of digitalization of information and data. At this level, it does not affect business processes, it only provides information. *Digitalization* is associated with the introduction of new digital technologies into life. It is focused on the implementation of digital technologies in business processes [8]. From the point of view of the company, it means the digitalization of a certain specific area, process, or the creation of a digital workplace. The pursuit of such a workplace is also the support of new technologies among employees, which includes mobile devices, social cooperation, various communication and management platforms. *Digital transformation* is a complex and extensive process in which existing or even new business processes are either digitally modified to effectively meet changing business and market demands. It follows that digital transformation requires a significant re-engineering of processes to become digital and re-engineering of customer experiences to match the digital environment. *Digital business models* are based on a radical rethinking of the way a business interacts with its customers, which brings a fundamental change in performance.

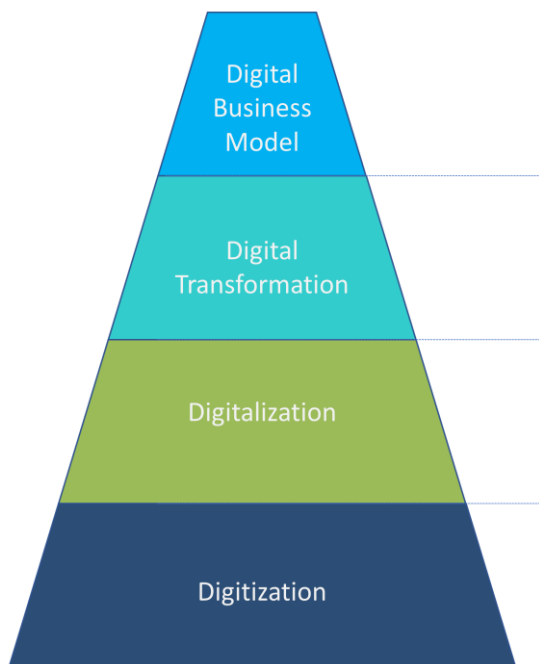


Fig. 3 Degrees of digitization in the company [8].

The new digital business model brings the linking of processes that are comprehensively digitized from the beginning to the end outputs [8].

4. Augmented and virtual reality in the field of safety

Augmented and virtual reality, which is part of the pillars of Industry 4.0, allows you to simulate any situation without any safety or financial risks.

Based on Garzon's analysis of its development, three generations of augmented reality (AR) applications in education are defined (see Figure 2). The first generation covers the period from 1995 to 2009 and could be described as hardware-based AR, as the delivery technology was the protagonist of the AR experience. The second generation covers the period from 2010 to 2019 and could be described as application-based AR, as the AR experience focused on AR applications rather than AR hardware. Finally, the third generation runs from 2020 onward and seems to be characterized by dedicated AR devices such as smartglasses and Web-based AR [9].

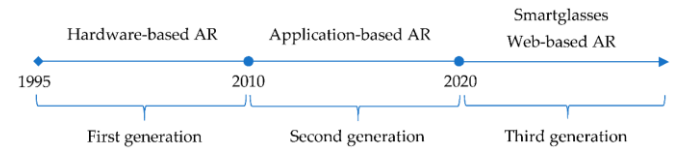


Fig. 3 Three generations of AR in education [9]

Augmented reality applications are a combination of digital and visual content into an individual's real environment. This combination of information can be used in many ways in the field of security. New combinations of simultaneously used technical devices, e.g. mobile phone, tablet, etc., also offer new possibilities in the field of security in the form of training for businesses. In essence, all the mentioned procedures can be represented as a combination of the real world and a model represented in various forms, from text to metadata [10]. Having immediate access to the necessary information right on the spot is very advantageous and thanks to this, AR finds application in industrial production as well.

Virtual reality (VR) technologies bring several possibilities of use in the field of security:

1. crisis situations that cannot be simulated in any way until they actually happen,
2. preparing employees for any risky activities,
3. consistent formation of correct habits that can lead to a reduction of risks in real operation,
4. employee training, which brings countless benefits that put this technology at the forefront of the ways in which training can be done. Among the most fundamental ones is, for example, the complete autonomy of training, in other words, the employee can learn and develop anywhere and at any time, moreover, there is no need for the presence of any other person, everything will be taught by a specialized VR application.

Another advantage of using VR compared to conventional training methods is that it can ensure the attention of the user, who performs the tasks in the training scenario completely naturally and subconsciously, so he remembers much more information. An indisputable advantage is also the fact that the VR application can monitor the user's behavior in detail, his strengths and weaknesses, according to which the training lessons can be modified, repeated, etc. [11].

The use of virtual and augmented reality has key impacts in the field of occupational health and safety:

- Increasing the quality and effectiveness of training and training of the OSH legislation,
- Freeing human resource capacities and reducing the burden on experienced workers through the automation of training and training, remote monitoring and control of the correctness of execution,
- Possibility of remote/contactless training and training,

- High added value of the project (influence of training in practice/efficiency) and at the same time easy accessibility for users [11].

5. Conclusion

The 4.0 industrial revolution is characterized by automation and digitization in various sectors, not excluding the field of education. Currently, digital technologies have an increasing impact on safety and health protection at work. Online OSH training tailored to your needs or classic training with new interactive elements, 3D technologies, virtual reality, and other elements can be combined for training. Of course, the expertise and experience of the trainer is important. And it is the same with other tools, the main competent creative team is always to clearly define the requirements, the target group and what the goal is, so that the use of new modern technologies is effective and contributes to safety and health protection at work and the prevention of occupational and occupational diseases accident.

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