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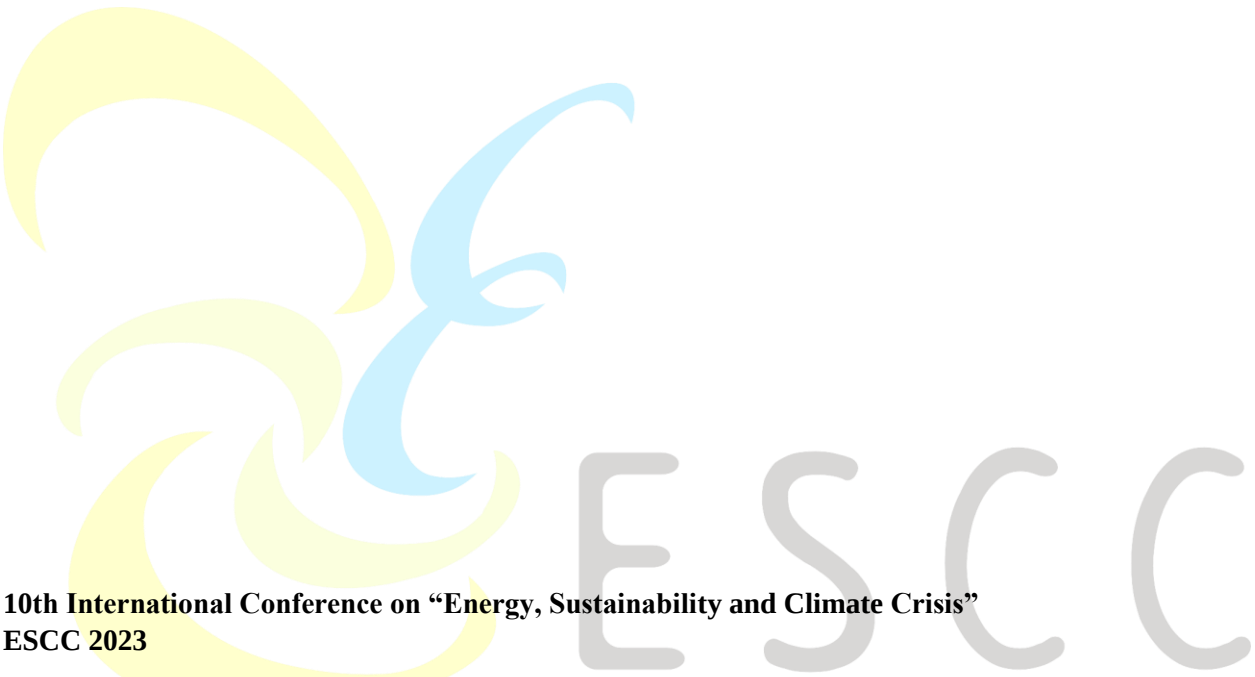

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Green Digital Transformation in Manufacturing

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Abstract
Digitization research describes the regulations on information systems since the late 1990's. With the digital explosion of streaming, the way data is shared, produced, and communicated to its owners has changed dramatically. An important research area analyzes the optimization of digital technologies to increase investment innovation performance or measurement results. With the use of DT (digital technology) in manufacturing, traditional industry exists today as a process with smart technologies. The biggest difference between traditional production systems and the production systems of the future is the digital transformations experienced in robots, unmanned factories, autonomous systems, big data, IoT (internet of things) patients. Along with these developments, investment also contributes to green. Times are used in the manufacturing process in modern business models. These models can be listed as artificial intelligence, smart factory / laboratory, military factory of the future, electronic business, digital business, electronic manufacturing system and web systems. Concepts such as modern production process Approaches, just-in-time production, rapid manufacturing, holonic manufacturing, green manufacturing, lean manufacturing, cloud-based manufacturing systems are new concepts based on the literature. While producing by carrying out the digital transformation and green manufacturing process together, it was also used for even lower energy consumption. The growth of the economies and the increase in competition are due to production, especially the production of "value". The most strategic and non-critical one to play a role in this process is the "Digital Transformation", which has emerged with the adaptation of the advances in information technologies to the manufacturing and business world. Therefore, I will examine the green and digital output AHP, TOPSIS and VIKOR methods in the manufacturing sector, with the direction taken from TEKNOROT OTOMOTİV ÜRÜNLERİ SAN.VE TİC.A.Ş, which is a good example of digital transformation.

1. Introduction

With the rapid technological developments, international competition, the importance of efficiency and quality, the spread of information technology, computer-based production and design techniques, etc. The development of innovations has put the classical industrial relations system in search of restructuring. [1]

In terms of working history, the oldest change has been experienced with the industrial revolution. With this change, while production took place in factories with the help of machines transferred by steam power, the value and importance of work gained a positive meaning incomparable to previous societies. The current level of the manufacturing sector and its competitive advantage is an important element among the indicators of the technological development and welfare level of the countries [2]. Stable growth in the economies of Western countries started to slow down after the 1970s. While the crises experienced with the oil shocks, the unions were seen as faulty and the increase in unemployment with inflation, the employee-employer relationship in the working life deteriorated over time. Information technologies that

emerged since the 1970s not only developed the automation of production systems, but also paved the way for digitalization. Thus, the new process that started with digitization and progressed with the transition to systems that connect the physical world to the virtual computing world with the help of sensors, that is, cyber-physical systems that took their place in the literature as industry 4.0 in 2000, initiated the digital transformation. This transformation emerges as a set of values consisting of IoT (Internet of Things), AI (Artificial Intelligence) and CPS (Cyber-Physical Systems), which play a major role in the formation of smart factory systems.

Green manufacturing encompasses production systems that have low environmental impact, have the highest efficiency, contain very low or zero waste, and do not pollute the environment. With this definition, green production recycling can be considered within the framework of activities that have the prevention or reduction of waste and environmental pollution and green product design. Green product design is the process of producing products whose effects on the environment are minimized through their design, composition and use throughout their life cycle. It is to emphasize that it can create a competitive advantage by reducing negative environmental effects and increasing productivity. Thus, it is aimed to spread green manufacturing practices in the manufacturing industry of our country.[3]

It is thought that this study is needed due to insufficient information and resources about green and digital transformation in our country. The digital transformation created by the digitization and digitization process and the green digital transformation in manufacturing will be evaluated with the AHP (Analytical Hierarchy Process), TOPSIS method and VIKOR method within the framework of the Industry 4.0 phenomenon. As a result of this evaluation study, it aims to show which criteria should be given more importance to those working in the manufacturing sector and to show the importance degrees of alternatives that are important for businesses aiming to switch to digital transformation in manufacturing.

As carbon dioxide emissions increase from year to year, countries around the world have agreed to reduce their greenhouse gases. Green development is the key to achieving carbon peak and carbon neutrality, as well as the key to improved production, livable life and beautiful ecology. [4] The green development of the manufacturing industry has formed a consensus that also needs its high-quality development [5]. Under the background of peak carbon and neutral carbon, low carbon and energy saving are the general trends of manufacturing improvement and transformation, and also the inevitable result of high-quality development of the manufacturing industry[6]. How to achieve green and low-carbon development while reducing costs and increasing efficiency in the manufacturing industry has become the focus of business survival and competitiveness. "Green + smart" is an important link to improve the competitiveness of digital green manufacturing enterprises [7]. The empowerment of digital technology is key to accelerating the greening and intellectualization of the manufacturing industry[8].

Currently, digital technology is penetrating widely in production and life, and the digital economy is booming. Digital industrialization and industrial digitization are accelerating. The deep integration of the digital economy and the real economy has become an important way to promote the green and high-quality development of the manufacturing mode of production [9] On the one hand, the digital economy not only effectively improves the production process and improves the efficiency of equipment operation, but also improves the accuracy of production process management. Production efficiency, energy savings and emission reduction are improved through smart collaborative management [10] On the other hand, the digital economy can effectively optimize the resource allocation model. Digital infrastructure in industrial internet, big data, artificial intelligence and other fields can realize the integration and sharing of various resource elements in different industries and businesses. Resource allocation efficiency helps to be further improved through digital technology [11]. In addition, the main production factor of the digital economy is data. Data features high efficiency, cleanliness, low cost and repeatability [12]. Therefore, the traditional

industrial structure and ecosystem can only be optimized when the data elements are used well to accelerate the deep integration of the digital economy with the real economy.

Digital Transformation (DT) refers to the idea of new products or services driven by an increasing number of innovations and use of digital technologies. This move towards products is due to the fact that DT must be driven by a broad business strategy [13]. The purpose of DT is limited to a group or business area as it works for the entire company [14]. The potential of digital technologies enables the development of new sustainable business models that still need to gain legitimacy to be adopted [15].

A company seeking good economic performance must meet the economic, environmental and social requirements of its performance[16]. Sustainability in the environmental context is included in the strategy of companies in order to minimize their environmental impacts, provide commercial benefits, and increase their performance and competitiveness in the market in which they operate [17].

To summarize, current studies focus on green innovation assessment and high-quality development of the manufacturing industry. There is little research on the convergence of green transformation and digital transformation. There is a lack of research on the effective integration of green and numbers. Relevant index systems and evaluation methods of digital green transformation in the manufacturing industry are explained systematically. There is a lack of research on macro policies and micro countermeasures based on improving the level of development of the regional green digital transformation. Therefore, in this study, the development path of digital green transformation in the manufacturing industry will be analyzed. An evaluation index system of the green digital transformation level will be established. In theory, this study will establish the research perspective and method of green digital transformation assessment in the manufacturing sector.

2. Literature Review

Since there is not much research on green digital transformation in manufacturing, generally dealt with academic sources [18-26]. The sources in the literature, which was inspired by the determination of the criteria in this research are indicated in Table 1.

Table 1 – Literature Review Table

	METHOD	CONTRIBUTION	CRITERIA
Savastano, M., Amendola, C., Bellini, F., & D'Ascenzo, F. (2019). Contextual impacts on industrial processes brought by the digital transformation of manufacturing: A systematic review. Sustainability, 11(3), 891	Innovation Management, Operations Management and Information systems	Conceptualization, MS; Data optimization, MS; Official analysis, MS; Research, MS; Methodology, MS; Project management, FD; Resources, CA	Technology/Process Type,Country/Regional Context,Focus/Main Topic,Field/Research Area,Sector/Industry/Company Size,
Xue, L., Zhang, Q., Zhang, X., & Li, C. (2022). Can digital transformation promote green technology innovation?. Sustainability, 14 (12), 7497.	Variable Selection	Conceptualization, LX and QZ; data optimization, QZ; formal analysis	Green technology innovation Degree of digital transformation Financing constraints Government subsidy Business age

Yin, S., Zhang, N., Ullah, K., & Gao, S. (2022). Enhancing digital innovation for the sustainable transformation of manufacturing industry: a pressure-state-response system framework to perceptions of digital green innovation and its performance for green and intelligent manufacturing. Systems, 10(3), 72.	AHP method	Conceptualization, SY and NZ; methodology, SY; software, SG; verification, SY and NZ; writing—original drafting, SY; writing—reviewing and editing,	Pressure system(PC),State system(SC),Response system(RC)
YANKIN, F. B. (2019). DİJİTAL DÖNÜŞÜM SÜRECİNDE ÇALIŞMA YAŞAMI. Trakya Üniversitesi İktisadi ve İdari Bilimler Fakültesi E-Dergi, 7(2), 1-38.	Empirical Analysis	Cloud computing applications, within the company and between companies. Because it is web-based compared to traditional methods. It makes significant contributions to the profitability of companies by increasing productivity.	Fiber Infrastructure (Spine + Access), High Speed Broadband Internet Number of Subscribers
YALÇINER, D., & TAŞKIN, D. H. (2019). İmalat Bilişim Sistemleri: Dijital Dönüşümde Temel Anahtar. Ankara: Iksad Publications.	Analytical Hierarchy Process (AHP)	According to the results of this study, new developments for Industry 4.0 It is necessary to give importance to vocational education in accordance with technologies and It has been stated that the demand for skilled labor will increase.	Hardware cost capital Software cost capital Project maintenance cost Current maintenance cost Education cost Installation cost Data transfer cost Labor savings Subcontracting savings
Etyemez, A., & Güngör, F. (2018, November). Dijital Dönüşüm Ve Makine İmalat Sektöründe Olası Etkileri. In 6th International Symposium on Innovative Technologies in Engineering and Science (pp. 9-11).	Create a poll	Which jobs and tasks will decrease with digital transformation in the machinery manufacturers sector, which new jobs and It has been researched that professions will come to the fore	Gender, age, education level, position at work, Industry 4.0 knowledge, business about how many years it has been operating, the number of employees and its technologies.
Feroz, A. K., Zo, H., & Chiravuri, A. (2021). Digital transformation and environmental sustainability: A review and research agenda. Sustainability, 13(3), 1530.	Systematic literature review (SLR)	Conceptualization, and Formal analysis, Methodology, Validation	Social, mobile, analytics cloud and Internet of Things, artificial intelligence and digital technologies involved and their disruptions in environmental sustainability
Wang, H., Cao, W., & Wang, F. (2022). Digital Transformation and Manufacturing Firm	Text Analysis Method	Conceptualization, methodology, software, verification, formal	Company size The nature of the property Financial leverage

Performance: Evidence from China. Sustainability, 14(16), 10212.		analysis, WC; investigation, HW; resources, data remediation, authoring—original drafting, HW; writing—analyzing, editing, visualizing	Enterprise value Market value book-to-invoice ratio Inventory turnover rate Earnings Volatility
Costa, I., Riccotta, R., Montini, P., Stefani, E., de Souza Goes, R., Gaspar, M. A., ... & Larieira, C. L. C. (2022). The Degree of Contribution of Digital Transformation Technology on Company Sustainability Areas. Sustainability, 14(1), 462.	Systematic Literature Review -PRISMA Method	Conceptualization, IC and AAF; SLR, PM, ES and RL; Data optimization, PM and RR; Official analysis, IC and ES; Financing acquisition, IC; Investigation, RR and IC; Methodology, FSM;,	Conceptualization, IC and AAF; SLR, PM, ES and RL; Data optimization, PM and RR; Official analysis, IC and ES; Financing acquisition, IC; Investigation, RR and IC; Methodology, FSM; Project management, IC; Resources, IC; Supervision, IC; Verification, CM, MAG

3. Method

Analytical Hierarchy Process

The Analytical Hierarchy Process was first mentioned by the Myers and Alpert duo in 1968, and in 1977, Professor Thomas Lorie Saaty at the Wharton School of Business was developed as a model and made available for decision-making processes [20]. In the 1970s, Saaty worked in the US Department of Defense on complex problems such as planning unexpected problems, examining the distribution of stocks in the electricity industry in order to contribute to increasing the welfare of the society, the Middle East Problem, the development of the transportation system for Sudan. Saaty, who has made many theoretical contributions to the field of operations research and mathematics, has developed the AHP method, which is one of the modern decision support methods, the importance of which has increased in recent years and its use has become widespread in every field. AHP is an approach where knowledge, experience, personal thoughts and preliminary opinions are applied logically as a result of creating a decision hierarchy. The main problems encountered in multi-criteria decision making problems are to determine weight, importance and order in order to be able to choose among many alternatives by considering more than one criterion. AHP is an effective MCDM method to solve this problem. In AHP, both subjective and objective thoughts of decision makers can be included in the decision process. For this reason, AHP is a mathematical method that takes into account the priorities of the group and the individual, and evaluates qualitative and quantitative variables together in decision-making. This makes AHP more powerful than other decision-making methods.

TOPSIS Model

The TOPSIS method, which can be defined as multidimensional weighting with ideal points, is a method that helps decision makers in making the optimal choice and ranking among many alternatives. TOPSIS method, developed by Hwang and Yoon in 1981, is frequently used in multi-criteria decision making methods [21].

VIKOR Model

VIKOR stands for VIseKriterijumsa Optimizacija I Kompromisno Resenje. In the case of conflicting criteria, it provides ranking and optimal selection among the alternatives. In the VIKOR method, an aggregation function that considers the 'ideal proximity' is used for the measurement of closeness to the ideal solution and linear normalization is applied for the criteria [22].

Findings and Discussion

The first step in the green digital transformation solution process in manufacturing is to determine the main criteria and sub-criteria that are considered to be used in the solution. Therefore, at the design stage of the decision hierarchy, the most time and effort is to determine how these criteria will be measured and what kind of indicators will be used. In order to provide benefits such as solving problems, making decisions, improving performance and encouraging with the measurements made, a relationship should be established between the indicators and the strategy of the company studied. Otherwise, the relationship between the metrics and the business would not be established. Our second step in measurements is to decide on the important criterion. The really important constraints between economic and time constraints are a very difficult process in terms of personal considerations [23]. In the selection of the criteria to be selected in the measurements, alternative scenarios should be considered and other situations such as tactics, plans and project activities should be considered during the planning phase[24]. In the company that has an important place in the manufacturing sector, it is envisaged that green digital transformation in manufacturing will be decided by using AHP, TOPSIS and VIKOR methods. The criteria in the literature created the Decision Hierarchy criteria to be used for green digital transformation in manufacturing.

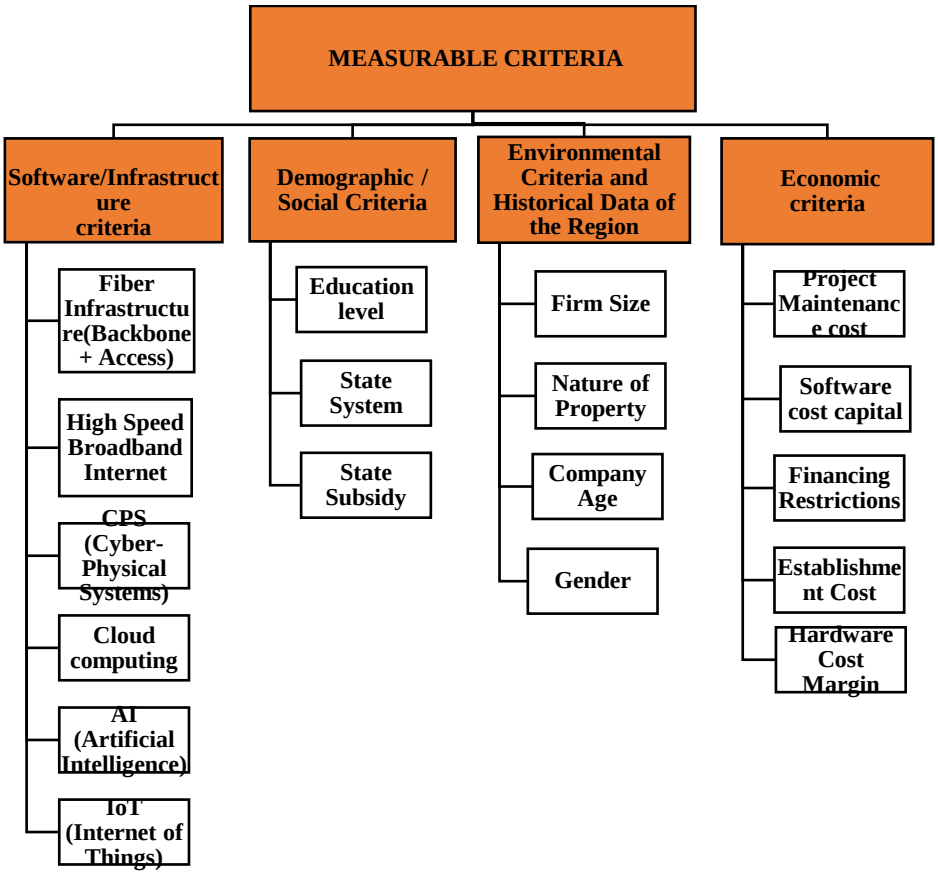

Fig. 1.Decision Hierarchy

Solution with AHP Method

In our study of comparing the importance levels of the criteria in Green Digital Transformation in Manufacturing, the AHP (Analytical Hierarchy Process) method was used to compare the main criteria with each other with the help of the binary decision matrix, and in the second step, pairwise comparisons were made at the sub-criteria level. In order to compare the priority data obtained, the application was continued with the AHP method. Excel program was used for this method. The data obtained by 3 experts for the main criteria were created.

CR (consistency ratio) values were verified. The next step is to calculate the comparison matrices as normalized comparison matrix and priority vectors for each matrix.

Table 2 - Software/Infrastructure Criteria Normalized Comparison Matrix.

Software/Infrastructure Criteria							
DECISION CRITERIA	**Fiber Infrastructure (Backbone + Access)**	**High Speed Broadband Internet**	**CPS (Cyber-Physical Systems)**	**Cloud Computing**	**AI (Artificial Intelligence)**	**IoT (Internet of Things)**	**Priority Vector**
Fiber Infrastructure(Backbone + Access)	0,479	0,645	0,389	0,283	0,256	0,224	**0,379**
High Speed Broadband Internet	0,149	0,201	0,440	0,256	0,263	0,199	**0,251**
CPS (Cyber-Physical Systems)	0,157	0,058	0,127	0,371	0,232	0,175	**0,187**
Cloud Computing	0,122	0,057	0,025	0,072	0,199	0,155	**0,105**
AI (Artificial Intelligence)	0,093	0,039	0,019	0,018	0,050	0,247	**0,078**
IoT (Internet of Things)	0,093	0,044	0,023	0,020	0,006	0,044	**0,038**

In Table 2, the normalized encounter matrix was obtained by dividing the numbers in each cell by the totals of the columns. Then, the priority vector was obtained by taking the average of each line.

Table 3 - Demographic / Social Criteria Normalized Comparison Matrix.

Demographic / Social Criteria				
DECISION CRITERIA	**Education level**	**State System**	**State Subsidy**	**Priority Vector**
Education level	0,701	0,835	0,321	**0,619**
State System	0,122	0,145	0,598	**0,288**

State Subsidy	0,176	0,020	0,081	**0,092**

In Table 3, the normalized encounter matrix was obtained by dividing the numbers in each cell by the totals of the columns. Then, the priority vector was obtained by taking the average of each line.

Table 4 - Environmental Criteria and B.G. Data from N.K.M. and Priority Vector.

Environmental Criteria and Historical Data of the Region					
DECISION CRITERIA	**Firm Size**	**Nature of Property**	**Company Age**	**Gender**	**Priority Vector**
Firm Size	0,664	0,831	0,620	0,386	**0,625**
Nature of Property	0,098	0,122	0,253	0,345	**0,204**
Company Age	0,106	0,020	0,099	0,192	**0,104**
Gender	0,132	0,027	0,028	0,077	**0,066**

In Table 4, the normalized encounter matrix was obtained by dividing the numbers in each cell by the totals of the columns. Then, the priority vector was obtained by taking the average of each line.

Table 5 - Economic Criteria N. K. M. and Priority Vector.

Economic Criteria						
DECISION CRITERIA	**Project Maintenance Cost**	**Software Cost Capital**	**Financing Restrictions**	**Establishment Cost**	**Hardware Cost Capital**	**Priority Vector**
Project Maintenance Cost	0,550	0,635	0,479	0,325	0,244	**0,447**
Software Cost Capital	0,183	0,249	0,439	0,383	0,319	**0,315**
Financing Restrictions	0,072	0,028	0,063	0,223	0,174	**0,112**
Establishment Cost	0,104	0,030	0,007	0,062	0,189	**0,078**
Hardware Cost Capital	0,090	0,058	0,012	0,008	0,074	**0,048**

In Table 5, the normalized encounter matrix was obtained by dividing the numbers in each cell by the totals of the columns. Then, the priority vector was obtained by taking the average of each row. Then we compare our software/infrastructure main criteria. It is aimed to get the result from there by multiplying the matrix with the priority vectors of the main criteria.

Table 6 - Software/Infrastructure Criteria Eigenvalue calculation.

DECISION CRITERIA	**Fiber Infrastructure(Backbone + Access)**	**High Speed Broadband Internet**	**CPS (Cyber-Physical Systems)**	**Cloud computing**	**AI (Artificial Intelligence)**	**IoT (Internet of Things)**	x	**Eigenvector**	=	**Eigen value**
Fiber Infrastructure(Backbone + Access)	1	3,21415	3,05214	3,914867641	5,1299	5,1299		0,379		2,763446576

High Speed Broadband Internet	0,311124247	1	3,45545	3,547841711	5,2776	4,5448		0,251	1,971390501
CPS (Cyber-Physical Systems)	0,327638968	0,289397908	1	5,129927784	4,6542	4		0,187	1,437458162
Cloud computing	0,255436477	0,281861504	0,194934516	1	3,9791	3,5569		0,105	0,754866385
AI (Artificial Intelligence)	0,194934516	0,194934516	0,146970379	0,251315814	1	5,6548		0,078	0,471516603
IoT (Internet of Things)	0,194934516	0,220030837	0,178780707	0,281144222	0,1208	1		0,038	0,239900521

In Table 6, Software/Infrastructure criteria and eigenvectors were multiplied by matrix and eigenvalue was calculated. In Table 7, the matrix multiplication of the Demographic / Social Criteria and the eigenvectors was performed and the eigenvalues were calculated.

Table 7 - Demographic / Social Criteria Eigenvalue calculation.

Demographic / Social Criteria					
DECISION CRITERIA	**Education level**	**State System**	**State Subsidy**	**Eigenvector**	**Eigenvalue**
Education level	1	5,738793548	3,979057208	0,619	2,64187578
State System	0,174252653	1	7,398636223	0,288	1,07890381
State Subsidy	0,251315814	0,135160044	1	0,092	0,28687162

In Table 8, Matrix multiplication of Software/Infrastructure criteria and eigenvectors was done and eigenvalue calculation was made.

Table 8 - Environmental Criteria and Historical Data of the Region Eigenvalue calculation.

Environmental Criteria and Historical Data of the Region								
DECISION CRITERIA	**Firm Size**	**Nature of Property**	**Company Age**	**Gender**		**Eigenvector**		**Eigenvalue**
Firm Size	1	6,804092116	6,240251469	5,013297935	x	**0,625**	=	2,998534
Nature of Property	0,146970379	1	2,54668	4,481404747		**0,204**		0,858371
Company Age	0,160249952	0,159812706	1	2,496		**0,104**		0,402255
Gender	0,199469494	0,223144317	0,281144222	1		**0,066**		0,265775

Table 9 - Economic Criteria Eigenvalue calculation.

Economic Criteria								
DECISION CRITERIA	**Project Maintenance Cost**	**Software Cost Capital**	**Financing Restrictions**	**Establishment Cost**	**Hardware Cost Capital**		**Eigenvector**		**Eigenvalue**
Project Maintenance Cost	1	2,548256	7,611662611	5,277632088	3,31151	x	**0,447**	=	2,674195
Software Cost Capital	0,333333333	1	6,975418475	6,21545	4,326748711		**0,315**		1,940741
Financing Restrictions	0,131377342	0,111111111	1	3,621	2,35546		**0,112**		0,603432

Establishment Cost	0,189478915	0,120820041	0,111111111	1	2,5646		**0,078**	0,337618
Hardware Cost Capital	0,164414138	0,231120425	0,189478915	0,135160044	1		**0,048**	0,226361

In Table 9, the matrix multiplication of the Software/Infrastructure criteria and the eigenvectors was done and the eigenvalue calculation was made for all our criteria.

Solution with TOPSIS Method

In our Green Digital Transformation in Manufacturing study, the Software/Infrastructure main criterion of the priority vector was found in the comparison table of the main criteria previously made with the AHP method, and we calculated the priority vectors of these criteria in Table 8. We need alternatives for the solution made by the Topsis method. In Table 10, which we have created as a result of the research conducted in the literature, the alternative table has been decided by experts in their fields.

Table 10 - TOPSIS decision matrix.

Priority Vector	0,463208	0,23326	0,1756	0,086	0,041	0,034
	Fiber Infrastructure(Backbone + Access)	**High Speed Broadband Internet**	**CPS (Cyber-Physical Systems) Cloud Computing**	**Cloud Computing**	**AI (Artificial Intelligence)**	**IoT (Internet of Things)**
Digital Transformation Degree	8	8	8	5	7	7
Green Technology Innovation	6	3	2	5	5	4
Government Incentive	7	6	6	2	4	3

Obtaining the distance values from the ideal and negative ideal points and then calculating the Ci values are calculated in Table 11.

Table 11. Distance to ideal and negative ideal points and Ci values.

	Si+	Si-	Ci	Order
Digital Transformation Degree	0,076	0,153	0,668	1
Green Technology Innovation	0,149	0,084	0,36	3
Government Incentive	0,077	0,1	0,567	2

Ci value close to 1 indicates that the decision point is close to the absolute ideal solution point. As seen in Table 11, the most optimal decision alternative is Digital Transformation Degree.

Optimal ranking: **Degree of Digital Transformation >Government Incentive >Green Technology Innovation**

According to the execution obtained by Multi-Criteria Decision-Making Methods-Topsis Method, it is envisaged to start with Green Technology Innovation for the green digital progress and software/infrastructure main criterion in manufacturing.

Solution with the VIKOR Method

We have calculated the reward vectors for our Software/Infrastructure Criteria. For the comparison in the AHP method, in the Green Digital Transformation alternatives research method in manufacturing, then we need the optimal ranking by comparing the closeness values to the ideal alternative with the Vikor method for our criterion alternatives, which it is examined in the Topsis method.

Table 12 - Best (f_1^*) and worst (f_j^-) values.

	Fiber Infrastructure(Backbone + Access)	High Speed Broadband Internet	CPS (Cyber-Physical Systems)	Cloud computing	AI (Artificial Intelligence)	IoT (Internet of Things)
Digital Transformation Degree	8	8	8	5	7	7
Green Technology Innovation	6	3	2	5	5	4
	7	6	6	2	4	3
f_1^* Government Incenti	8	8	8	8	7	7
f_j^-	6	3	2	2	4	3

In our next step, Si and Ri values for each of our alternatives were calculated in Table 13.

Table 13. Si and Ri values.

	Fiber Infrastructure(Backbone + Access)	High Speed Broadband Internet	CPS (Cyber-Physical Systems)	Cloud computing	AI (Artificial Intelligence)	IoT (Internet of Things)	S_i	R_i
Digital Transformation Degree	0,00	0,00	0,00	0,04	0,00	0,00	0,04	0,04
Green Technology Innovation	0,46	0,23	0,18	0,09	0,03	0,03	1,01	0,46
Government Incentive	0,23	0,09	0,06	0,03	0,04	0,03	0,49	0,23

In the next step, the Qi values for each i alternative are calculated in Table 14. The Qi values are then ordered from smallest to largest.

Table 14 - Qi values.

	S_i	R_i	Q_i	Sıralama
Digital Transformation Degree	0,05	0,05	0	1
Green Technology Innovation	0,99	0,46	1	3
Government Incentive	0,39	0,13	0,282519	2
S*R*	0,05	0,05		
S-R-	0,99	0,46		

The closer the calculated Qi values are to 0, the closer they are to the optimal solution point.

Optimal Solution: Degree of Digital Transformation>Government Incentive > Green Technology Innovation

According to the result obtained with the Multi-Criteria Decision Making Methods-VIKOR Method, it is envisaged to start the Digital Transformation Degree for the green digital transformation, software/infrastructure main criterion in manufacturing.

1. CONCLUSIONS AND RECOMMENDATIONS

The digital transformation planned in Industry 4.0 aims to move away from the understanding of people working like machines and to make machines work smartly. Green digital transformation in the manufacturing industry also aims to manufacture old-fashioned production efficiently, safely, sustainably and more conveniently. DTs are also known to convert carbon gases into usable plastics and fuels in the automotive factory. TEKNOROT, which works to find digital solutions to produce lower energy and more efficiency by producing, optimizes it using data analytics, internet of things (IoT) and smart algorithms technologies, and it is seen that it reduces the energy it uses while producing a product.

Today, making a decision in our daily life and working life is a troublesome and difficult process. It is normal for decision makers to make decisions based on their private lives and experiences. Therefore, they are faced with some kind of difficulties in the decision-making process. MCDM methods play a major role in decision making. These MCDM methods are both subjective and when choosing for large firms or communities, as in green digital transformation work in manufacturing; It is aimed to minimize the risk factor, to eliminate the uncertainty during the selection, to make the correct decisions and to reach effective decisions.

In this study, AHP, TOPSIS and VIKOR methods, which are among the MCDM methods, were used as a decision-making method for the evaluation of criteria and alternatives that are important in green digital transformation in manufacturing by taking the opinions of experts working in Teknorot, which produces automotive sub-industry products. The reason why many decision making methods are used in the study is that while the Topsis method applies normalization for vectors, the Vikor method applies linear normalization. In addition, Topsis evaluates the closest and farthest point to the ideal solution within the

alternatives, but the Vikor method makes a ratio of positive and negative solutions was deemed appropriate [25].

In the study, after various foreign articles in the applications and the guidance of the decision makers, the decision criteria and alternatives that are considered important in the manufacturing sector were determined. Then, decision matrices were created from the sub-criteria, and experts who were interested in green digital transformation in manufacturing were evaluated between 1-9. The priority vector (importance weight) of each criterion was calculated with the AHP method. It has been revealed that the highest criterion in the criterion weight is the software/infrastructure and then the demographic/social main criteria. The priority vector (importance weight) of each calculated criterion is used in TOPSIS and VIKOR methods. The factors that affect the transition to green digital transformation in our company, which produces TOPSIS and VIKOR methods for automotive supply industry products, have been determined by experts as the degree of digital transformation, green technology innovation and government incentives. As a result of the evaluation made with the TOPSIS method, one of the MCDM methods, it has resulted in the Digital Transformation Degree > Government Incentive > Green Technology Innovation ranking. As a result of the evaluation of the alternatives made in the VIKOR method, it is listed as Digital Transformation Degree > Government Incentive > Green Technology Innovation.

In the process of evaluating the necessary alternatives for digital transformation with the Topsis and VIKOR methods, the optimal rankings came out as Digital Transformation Degree > Government Incentive > Green Technology Innovation and can be evaluated by experts.

Looking at some of the articles in the literature using similar MCDM methods, Azadnia et al. (2013) in a study in which MCDM methods were applied, environmental criteria took the first place and then took place in economic and social criteria [26]. When we look at many leading studies like this, it is obvious that environmental criteria have been a leading criterion recently. But when domestic studies are done like in this study, the leading criterion has been economic criteria.

The thought derived from the evaluation made has been tried to reduce the environmental damage caused by industrial production in the leading countries in the world, but unfortunately it is observed that our country should not think about the economic sense. Increasing government incentives in order to ensure digital transformation and increase green innovation in Industry 4.0 will not only increase its contribution to our country both environmentally and economically, but will also provide a serious opportunity for our country to increase its place in the industry.

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Complex Case Study on Waste Collection Routing Problem: Barriers, Critical Parameters and Size Reduction Techniques

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Keywords: Waste Collection; Case Study; Route Collection Schedule; Routing Problem

The identification of critical parameters of waste collection at the municipal level is an important task. For the area of changes and designs of collection systems (design and modification of routes, choice of the vehicle fleet, collection plan, etc.), no procedures would include a whole range of operating conditions and parameters. Many barriers must be surmounted concerning the planning of waste collection plans. A presented comprehensive approach combines models, pre-processing phases, and data analysis for complex solutions to the routing problem. It includes a statistical evaluation of input data, heuristic features, and size reduction approaches. The preparation and analysis of input data focused mainly on the transport infrastructure, service time and quantity estimates, and pairing containers to the network, which also reduces the task size.
Furthermore, a procedure for compliance with the rules of the road was designed using a penalty function. An algorithm for defining imaginary edges was implemented, allowing distinguishing the collection frequency on selected network segments. Input parameters related to operating time and fullness of collection containers significantly influence the task results. A great benefit is an algorithm generating the initialization solution from historical routes. Results are presented through the visualization in maps and by quantitative evaluation of designed solutions. The solution can serve not only to improve the current operational routes but also to reallocate days of collection. Decision-making about route schedules substantially influences the expenses of technical services. The proposed approach is also valid for generating route schedules for newly separated waste types.

Mathematical Model Proposal and Cost Optimization in the Creation of an Emission Reduction Roadmap for the Industrial Enterprise in Turkey

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Keywords: Emission; Emission Reduction Roadmap; CEPA; Pinch Analysis; Emission Constraint; Process Integration; ETS; NPV; MILP

Self-protection of companies against financial sanctions (e.g. possible TR ETS) is through creating an individual emission reduction roadmap. In this study, it is aimed to propose a mathematical model to be used in determining the green transformation roadmap that an industrial organization will implement in line with its emission reduction target. The enterprise-specific (microscale) mathematical model created using the carbon emission pinch analysis (CEPA) methodology includes a system-wide emission constraint. This constraint is the company's emission reduction target. The objective function of the mathematical model is to maximize the net present value of the system by considering the environmental and financial effects. Seven different green transformation proposals are included in the mathematical model. These proposals are; rooftop solar power plant, ground mounted solar power plant, wind power plant, heat pump, waste heat recovery system, biomass power plant (2 options). Technical, regulation and emission constraints were added to the mathematical model. TR ETS carbon price estimation was carried out as a separate study and three different scenarios were created assuming that free allocation would be 90% in Scenario 1, 80% in Senario 2 and 70% in Scenario 3 in 2030. TR ETS carbon price estimates for the years 2023-2032 have been calculated. The TR ETS carbon price has been determined as 72 -75 €/t-CO2e in 2023 and 135 €/t-CO2e in 2032. In the case study, six different scenarios were created and optimized with the help of mathematical model. The three emission target scenarios are 30%, 42% and 60%, and versions of these scenarios with and without carbon pricing. While the mathematical model prioritizes investment proposals according to payback periods in optimization, it also evaluates the environmental impact of investment proposals. One of the results of the case study is that the aggressiveness of the emissions target, regardless of carbon pricing, has a positive impact on cash flows and NPV. When 30% and 60% emission reduction scenarios are compared, with 30% target increasing, the system NPV values of the scenarios increase by 70.7% without carbon pricing and increase by 70.9% with carbon pricing. According to the scenario results, the increase in the emission reduction rate decreases the IRR rate of the system in scenarios with no carbon pricing. However, in scenarios with carbon pricing, the system IRR increases when the emission reduction rate becomes aggressive. The combination of investment proposals in the optimization results varies depending on whether there is carbon pricing or not. Shortly, it has been determined that if TR ETS applies carbon pricing, it is more feasible for the company to invest in scope 1 emission reduction technologies in its green transformation roadmap. The results of this study show that the emissions trading system provides a driving force for industrial enterprises to set emissions reduction targets. In the mathematical model proposed in this study, determining the emission constraint for the whole system and working specifically for the micro-scale enterprise show that the CEPA method can be improved.

Material Living Conditions over Time by Gender Across Europe: A Window Data Envelopment Analysis Perspective

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Keywords: Material Living Conditions; Data Envelopment Analysis; Window Data Envelopment Analysis Approach; Slack Based Measure

This paper proposes the use of data envelopment analysis (DEA) to create a composite index of material living conditions (MLCs). A window Slack-Based Measure (SBM) data envelopment analysis (DEA) model was used for the first time to examine the adjustments needed for countries to enhance their MLCs for both men and women over time. Our findings indicate that the risk of poverty reduction required for women to improve MLCs is consistently higher than for men. Additionally, the required reduction of this indicator to enhance MLCs becomes more significant after 2010-2012 and decreases consistently after 2014-2016 until 2018-2020 for both men and women. The necessary adjustment for overcrowded housing is not gendered and the required reduction of this indicator decreases for both men and women after 2015-2017 until 2018-2020. The study also revealed that the required reduction in severe material deprivation is always greater for women than for men throughout the entire analysis period. In general, men consistently showed higher performance levels than women for MLCs across all windows.

Design and Optimization of Membrane-based Carbon Capture System

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Keywords: Carbon Dioxide Capture; Membrane Separation; Mathematical Programming; Energy Optimization

The challenge of reducing CO2 emissions is becoming increasingly important for our society. The combustion of fossil fuels in power plants, transportation, and industrial processes is one of the main sources of CO2 emissions. To reduce these emissions, the capture of CO2 from combustion processes has been proposed as a potential solution. However, this approach is associated with high energy consumption, which can negatively impact the efficiency of power-producing facilities, the economy, and even the classification of some plants under current legislation. To allow the minimization of energy consumption, optimization tools supporting the design of capture systems are needed. This study focuses on a membrane-based post-combustion capture, specifically on the development of an appropriate supporting tool based on mathematical programming. The approach enables the finding of optimal membrane properties, membrane areas, and pressures for individual separation stages from the point of view of energy consumption. The mixed integer model utilizes external simulation module to enable finding globally optimal results. This external module approximate non-linear dependencies with any desired precision and allows the use of different mathematical descriptions of individual membrane stages without making changes to the model. The external module can be based on experimental data instead of theoretical equations and, therefore, the model can be conveniently adjusted for specific purposes, including decision-making, separation process design, and regulation of process parameters during dynamic operation. The second developed approach, based on a genetic algorithm, is suitable for a large number of calculations with different values of desired CO2 purity and recovery. The precision of this model is acceptable for the initial solution of the problem and can specify a closer range of desired parameters, which can be further evaluated by mixed integer approach to find optimal design. The model's ability to optimize the process is verified in a case study. By quantifying energy consumption, it becomes possible to compare different multi-stages schemes of membrane modules and also various carbon capture technologies based on their operating costs. The findings of this study confirm the significance of process optimization, demonstrate the impact of individual parameters on energy consumption.

Assessing Quality of Life across Europe

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Keywords: Assessing; QoL; VBDEA

The European Union (EU)'s core mission is to promote the well-being of its citizens, which goes beyond just economic output and living conditions. The quality of life (QoL) is a complex concept, incorporating aspects such as employment, health, social interactions, safety, and government policies (Eurostat, 2022). The assessment QoL can be carried out through a multitude of methods based on empirical evidence. This study proposes a novel approach by introducing the use of a window Value-Based Data Envelopment Analysis Approach (VBDEA) methodology for the first time in the assessment QoL at the country level in Europe. The time period analyzed was from 2008 to 2020, taking into account the financial crisis that began in 2008 and the COVID-19 pandemic that affected most countries in 2020. The Value-Based DEA (VBDEA) approach provides a more comprehensive assessment of the QoL dimensions being evaluated. The introduction of a novel window VBDEA method helped in the identification of best practices, sources of inefficiency and gaps regarding the benchmark countries in each period, investigating the impact of specific events, such as the 2008 financial crisis and the COVID-19 health crisis, on QoL.

Tools and Methodical Approach to Multimodal Waste Transport Modeling

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Keywords: Multimodal Transport; Techno-Economic Model; Waste Management; Methodology

The constantly growing trend of freight transport leads to the application of new and more efficient methods, both for individual types and multimodal transport. A combination of road and rail transport is most often encountered, but also ship transport can be used where available. While road transport is most common in waste management, rail transport is used to a lesser extent.

With the current effort to reduce transport emissions, the shift in the transport of goods from road to rail or combination is expected on a larger scale. For this shift to have the expected results, it needs to be supported by detailed project planning and calculation. However, the current state of computational support with a focus on waste management is insufficient. Current models are not detailed enough and do not always include all important parts of the logistics chain. One can often come across models that are not connected to real infrastructure or include only general types of transport systems. Many simplifications result in inaccuracies that affect the evaluation quality. Therefore, creating an advanced techno-economic model of multimodal transport, which can evaluate in detail the technical, economic, and environmental demands of a given logistic chain is required.

The paper presents the techno-economic model of multimodal transport, focusing on road and rail transport in waste management. The model includes a vast database of transport systems for both types of transport, where the user can modularly assemble the resulting transport system. The user can also add new parts to transport systems based on their parameters. The choice of transport system affects the following calculation and is thus an important part of the model.

The model comes with a detailed calculation of the speed profile based on physical principles, which leads to more accurate estimates of fuel consumption and related emissions production. The model includes an economic evaluation allowing the comparison of individual types of transport.

The model currently focuses on waste transport in the Czech Republic primarily due to road and rail data infrastructure availability. The model can be further expanded by adding other states' real networks. The paper also presents the methodology for assessing the logistics chains considering multimodal transport, which focuses on the correctness and consistency of evaluation, the integration of all individual sub-elements of the logistics chain, and the credible result interpretation.

The multi-Vehicle Set Orienteering Problem

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Keywords: Transportation and Energy Efficiency; Vehicle Routing; Fleet Management; Set orienteering; Matheuristic

In this work, we introduce the Multi-vehicle Set Orienteering Problem (MSOP), which is an extension of the Set Orienteering Problem (SOP). The MSOP generalizes the Orienteering Problem (OP) by considering customers to be divided into mutually exclusive clusters. The profit associated with each cluster is collected by visiting at least one of the customers belonging to this cluster. The problem aims to determine the routes that maximize the collected profit without violating a given maximum route duration.
The SOP has numerous applications in the distribution of mass products, such as delivering orders for all customers of a cluster by visiting a single customer and then serving the rest of the customers within the cluster independently. This approach, which involves two transportation levels, ensures that not all customers need to be individually served, resulting in significant cost and environmental savings. This model is applicable for delivery modes like lockers, pickup points, bikes, and other similar services. The model can also capture other problems, such as the travel guide problem, in which attractions are grouped in clusters and a guide seeks to maximize the profit from visiting attractions in a limited time, given that having visited at least one attraction of a single cluster, the total cluster profit is collected.
Initially, we model the MSOP, with a compact two-commodity flow formulation, along with valid inequalities and cuts. It can be solved in a branch-and-cut fashion for small instances. Furthermore, we propose a matheuristic algorithm for tackling large-scale instances. The matheuristic consists of a local search framework equipped with mathematical programming components. A shortest path algorithm is used for determining the best sequence of individual customers for the selected customer sets. Finally, an MIP-based move which can simultaneously remove and insert multiple customer clusters with approximated costs is applied. Diversification is enhanced with the promise mechanism.
To evaluate the formulation and the matheuristic algorithm efficiency, computational experiments are carried out. We assess the matheuristic optimality gap by comparing it against the branch-and-cut method for small instances. The matheuristic is able to provide high-quality solutions within reasonable computation times, making it a practical and efficient method for large scale problems. We also highlight the importance of using mathematical programming components in our local search framework.

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Data-driven Hub Network Design for Shared Mobility

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Keywords: Hub Arc Location, Ridesharing; Benders Decomposition; Clustering; Shared Economy

In the recent decade, electric vehicles (EVs) have become the abiding interest of the transportation sector as a future mode of transportation because of their various benefits: reducing oil dependency, carbon dioxide emission reduction, less noise, and utilization of renewable energy. For instance, the number of EVs on the world's roads increased from 17,000 in 2010 to more than 10 million in 2020, and its number is rapidly growing worldwide. Additionally, many leading companies, such as UPS, FedEx, and Walmart, have deployed EV fleets in their last-mile operations. However, despite several benefits of EVs and their growing penetration, EVs still have critical issues limiting their usage. One issue is their limited driving range compared to conventional vehicles fueled by gas or diesel. Other problems include the scarcity of the charging infrastructure and the long recharging time. Therefore, a more careful routing plan is needed to overcome EV's limited driving range, especially for commercial EVs. Thus, the integration of EVs with the energy grid has become an important area of research due to the increasing EV penetration in today's transportation systems. In this talk, we present the EV routing problem with time windows under time-variant electricity prices which optimizes the routing of a fleet of electric vehicles that are delivering products to customers, jointly with the scheduling of the charging and discharging of the vehicles from/to the grid. Given the energy costs that vary based on time-of-use, the charging and discharging schedules of the EVs are optimized to benefit from the capability of storing energy and shifting the demand from peak hours to off-peak hours when the price of energy is lower. The vehicles can potentially realize profits by injecting energy back to the grid during periods of high prices. The problem is formulated as a multi-period vehicle routing problem and a Lagrangian relaxation approach as well as a hybrid heuristic are proposed to obtain high quality solutions. The proposed model is evaluated on a case study of a grocery delivery service at the region of Kitchener-Waterloo in Ontario, Canada. Insights on the impacts of energy pricing, service time slots, as well as fleet size are presented.

The Impact of the Size of Electric Cars Size on its Economic and Environmental Performance

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Keywords: Mobility; Energy efficiency; Battery

The improvement of energy efficiency is one of the major strategies for the reduction of energy consumption and corresponding CO2 emissions in the transport sector. One of the contributors to this is increasing size of vehicles. It can be noticed clear shift towards heavier and less energy efficient vehicles. Over the last years, increases in use of larger cars like Sports Utility Vehicles (SUVs) has been observed. With the goal to reduce emissions, many countries have implemented a broad portfolio of measures and strategies such as implementation of CO2 emission standards for new vehicles and electrification of mobility.

Electric vehicles have a much higher energy efficiency in comparison to conventional internal combustion engine vehicles powered by fossil fuels and zero emissions at the point of use. Due to these reasons, they are supported and promoted worldwide by policy makers, especially in China, Europe and the US.

Few years ago, carmakers planned to offer a large number of electric vehicle models, about 350 by 2025, mostly in small-to-medium segments. However, in the meantime many carmakers are offering a majority of electric car models in the large capacity, mainly in SUV segment. In the US, more than 55% of all available electric vehicle models are in SUV segment, in Europe about 45%. In 2022, for the first time, it was sold more electric vehicles in SUV segment than in all other.

The core objective of this paper to analyze economic and environmental aspects of electro mobility considering increasing vehicle size, as well as to discuss corresponding increasing demand for the critical materials such as lithium, cobalt and nickel, which are essential for battery production.

In addition, the increasing size of cars increase also pressure on battery supply chains and our environment. In the most of countries, electricity is still largely produced from fossil energy, resulting in a high carbon content of electricity and consequently to a lower reduction of the total greenhouse gas emissions. For the successful contribution of electric vehicles to the achievement of emission reduction targets, it is essential to increase use of renewable energy sources in electricity generation mix as well as to reduce the average car size.

Heading Towards Competitive and Sustainable Electricity Markets

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Keywords: Renewables; Residual Load; Capacity Payments; Flexibility

Currently, the electricity system in many countries is undergoing significant changes. The following issues are important in this context: (i) More and more customers become interested in contributing to their own electricity supply and to switch to "prosumagers". (ii) This was supported especially by the emergence of decentrally applicable technologies such as PV, small CHP and accompanying use of battery storage; (iii) These developments lead on the systems side to a need for "back-up" capacity (incl. storage) and demand-side flexibility.

The major objective of this paper is to provide insights on how to bring about a competitive, sustainable and democtratic electricity system with even higher shares of variable renewables. Our method of approach is based on the principle of coverage of residual load (= difference between final electricity demand and generation provided by non-flexible electricity generation) on an hourly base over a calendar year based on assumed variable renewables generation and development of the load profil. The major results are: (i) Of core relevance is a pricing system in an energy-only market where the price signals provide information about scarcity or excess capacities at every point-of-time; (ii) to balance variations in residual load a portfolio of flexibility options is important, such as battery, pumped hydro and other storage; technical demand-side management; demand response due to time-of-use pricing. (iii) However, flexible power plants for capacity system adequacy will play a role in every system with and without regulated capacity payments.

Our major conclusions are:

Revised energy-only-markets have to be introduced which allow temporarily shortage prices higher than short-term marginal costs and in times of excess electricity negative prices

A very important element of such a market will be flexibility options. But these will only be harvested when sufficiently high price signals from the electricity markets trigger these options, when "the exploration principle in the markets work". Yet this will only be done if the market is not distorted by centralized capacity payments.

The major final conclusion is, that it will be necessary to accept a paradigm shift in our understanding of the whole electricity system where no longer the generators are the centre but coordinating entities such as balancing groups respectively the supply companies. Finally, we state that the evolution of such a creative system of integration of renewables in Western Europe may also serve as a role model for largely renewables based electricity supply systems in countries world-wide.

Investigating the Effect of Factorial Variables of a Product's Life Cycle, on its Environmental Performance, based on Simplified Life Cycle Assessment Scenarios

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Keywords: Product Design; Sustainability; Life Cycle Impact Assessment (LCA); Life Cycle Impact Assessment (LCIA)

The ever-increasing awareness of the population about the ecological degradation caused by the environmental pollution and the total exploitation of natural resources, was a springboard for changing the policy on environmental issues and sustainable development, of companies that produce products. The crowning achievement of this difficult task was the ecological approach to product development, which at the same time contributes greatly to competitiveness improvement, cost reduction, quality increase, and often, product availability time reduction in the market.

Until a few years ago, the process of product development was essentially focused on determining the characteristics that a product must have, in order to achieve specific functional specifications, which were determined by the constraints imposed by production processes. However, today the development process is considered in a wider range, incorporating external factors such as environmental impact, quality, cost, hygiene and ergonomics.

This new approach on product development constitutes this paper's subject of study, which was prepared in the context of investigating the effect of factor variables, which govern the stages of a product's life cycle, on its environmental performance, by conducting the LCIA study. The whole process is based on four different scenarios, where specific data and values of the variables are defined in each one of them.

The study is carried out through the Solidworks Sustainability software and according to the CML and TRACI methods, which are integrated in it. The result is the calculation of values in four indicators of the mid-range environmental impact category, such as air acidification (Kg SO2), carbon footprint (Kg CO2), water eutrophication (Kg PO4) and total energy consumption (MJ). To draw the necessary conclusions, the results are presented in the form of sectional and aggregate graphs. The aim of the former is to better understand the effect of each factor separately (material, production, transport) and are given in the form

of bar charts, while the latter is to present the total value of the environmental impact, depending on the calculated index and the factor under investigation.

Application of Regional Electricity Tariff and Estimation of Electricity Prices Throughout Turkey

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Keywords: Regional Tariff; National Tariff; Electricity

In countries with a large area, it is difficult to transport electricity from one end to the other. To eliminate this obstacle, a regional structure system is applied. However, this is not the case in Turkey. There is only one national price that applied to the whole country. However, even if the electricity produced in the east of Turkey can be transmitted to the west of the country without any restrictions dividing the grid system and distributing prices accordingly might be more beneficial and efficient for the sake of social welfare. For the case of Turkey; EPİAŞ, which deals with the market regulation is currently working on the impact on electricity prices when a multiregional structure mechanism is implemented in Turkey. The purpose of the study is the conduct a detailed literature survey on the possible implementation and technologies that can be used in Turkey. After the survey, if possible, create this new model by optimizing the prices with the real data provided by the EPİAŞ and create the simulations that recommend the possible policies that might be implemented. It is targeted to examine both the production and consumption sides of the market. When the literature was searched, it was noticed that there are many parameters affecting electricity prices, and by making some assumptions, the optimum electricity price to be created in the regions in Turkey was determined. To determine the best price, the priority is to balance the production and consumption profiles. In this study some parameters which are production, consumption, installed power, line length, number of transformers, etc., is examined. The main focus is maintaining the balance of electricity production and consumption. Half of the total consumption takes place in the Marmara region. At the end of the study, it is examined the use of a regional electricity tariff to Turkish economy and its effect on the total amount of energy consumed. A mathematical model is created to determine the regional optimum price by making some assumptions.

The Effect of Possible Carbon Pricing on Renewable Energy Investments and Emission Reduction Practices in Türkiye

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Keywords: Carbon Pricing; Renewable Energy; Bayesian Network

Each country has new policies to fight against the climate change based on local energy market conditions and local politics. Some countries have designed and implemented effective ETS, Green Certificate and Carbon Tax policies with positive results to reduce the greenhouse gas emissions. Furthermore, there are countries that have become carbon-negative by absorbing more emissions than they emit to the atmosphere. This study aims to analyse the possible ETS and Carbon Tax to be implemented in Türkiye in parallel with the existing Green Certificate trading. Türkiye has the Net Zero target for 2053, hence, the steps to be taken for carbon emissions are highly important. Considering that the main source of carbon emissions is energy production, the implementation of carbon pricing mechanism and increasing the investments in renewable resources are given priorities.

Within the scope of this study, the renewable energy incentive mechanisms being implemented over the world, the global situation of Green Certificate Markets, the historical processes related to climate the Net Zero targets of OECD countries are reviewed. Besides, carbon capture technologies are analysed, along with the strategies of different countries with Net Zero goals. A cognitive survey is run on expert opinions and a Bayesian Belief Network has been Constructed. The impact of a variety of policies are analysed on each other and the energy market as well as the Net Zero Policies by implementing the Scenario analysis using the NETICA program. Achievements will be shared with all the attendees during the Congress.

Drop-In Utilization of Hydrotreated Vegetable Oil (HVO) in a Locomotive Diesel Engine

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Keywords: Hydrotreated Fuels (HVO); Environmental Impact; Greenhouses Gas Emissions (GHGs)

The transition toward a fossil-free transport system requires the enabling of alternative and renewable energy carriers. The rail sector isn't exempt from such transition. The sustainability of the electrified railways lies mainly on the decarbonization of the electricity sources, while all non-electrified railways, mainly served by diesel railcars and locomotives, require the use of alternative technologies and energy carriers.

In parallel, regulations for a progressive reduction of the toxic emissions have been introduced (Stage III A, III B and V in EU). However, considering the substitution rate of the in-service rail vehicles, it will take many years before the phase-out of that oldest and polluting.

In this scenario, the use of renewable and paraffinic-based diesel fuels, characterized by low-carbon emission intensity, represents a very interesting opportunity for the progressive depollution of all the diesel rail vehicles. The Hydrotreated Vegetable Oil (HVO) is one of the most promising fuel, since it is already produced from large-scale plant and approved as alternative fuel to the regular diesel in Stage V engines. HVO has become more widely commercially available in 2020 and has been advertised as a "drop-in" substitute for fossil-diesel.

Before the approval of its use in older rail vehicles, both as blend with fossil diesel and as pure HVO, extensive validation tests are required, both at test bench and in-service. The present work is focused on the first point, and, at the best knowledge of the authors, this is the first comprehensive analysis of the impact of HVO in a pre-Stage V rail diesel engine.

In detail, the effect of fuel substitution on a Fiat 718 DI Diesel engine (6 cyclinders-13.8 liter-170kW@1850 rpm), Euro 0 as emission standard, generally installed on ALN type 663 railcar, has been investigated. Tests were performed at OMC-Trenitalia facilities in Rimini (Italy) with a commercial B7 gasoil (EN 590) and pure Eni HVO, that meets the fuel specification EN 15940. Most of the studies

available in literature show that paraffinic synthetic fuels or HVOs usually lead to exhaust emissions benefits and good engine performance.

The engine was tested in different steady steps rpm/load, corresponding to the more representative conditions of the railcar' use. A complete set-up for emissions (including particle number) and fuel consumption measurements, has been installed in the engine test cell.

The main results obtained with HVO are:

- no problems using pure HVO;
- full power performance achievable by pure HVO;
- fuel consumption (FC) can be decreased of about 3-4%, in mass, while volumetric FC increase of about 2-4%;
- CO2 and NOx exhaust emissions reduced of about 5% and 18% respectively;
- PM and PN emissions showed different trends: with gasoil higher PN emissions at low loads, instead with HVO at medium/high loads there are 10-30% higher PN emissions while PM shows a decrease by 25%.

The GHG emission based on a Well-To-Wheel analysis reduces between 70-85% depending on the feedstock. The results of the testing confirm the effectiveness of HVO as a drop-in fuel for old diesel loco engines.

Efficient Reuse of Wastewater from Industrial Laundries

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Keywords: Industrial Laundry; Wastewater Recycling; Vacuum Evaporation; Circular Economy

Industrial wastewater production is increasing every year, and global water supplies are diminishing as the discharges of polluted effluents are significantly degrading the quality of water bodies. Therefore, fresh water management in the industry must be efficient. One of the promising directions is the recycling of industrial wastewater, which is in order with the current circular economy concept.

Industries that produce high amounts of wastewater include industrial laundries. On average, the wastewater production is about 15 liters per 1 kilogram of processed linen, meaning a daily production of 150 m3 of wastewater for a conventional laundry with a capacity to process 10 tons of linen. Such effluent is loaded with various pollutants from using soap, soda, and detergent to remove grease, dirt, and starch from soiled linen. Laundry wastewater has toxic properties and negatively impacts the environment, such as water bodies pollution and eutrophication. Unfortunately, this wastewater is often not sufficiently treated.

Recently, research has been getting more focused on the efficient treatment of laundry effluents, mainly on a laboratory scale. The most commonly used techniques are physicochemical methods such as membranes, flocculation, and coagulation. However, their application can often present high operational costs. Due to the complexity of the chemical composition of the wastewater and the availability of waste heat in industrial laundries, this research has focused on the investigation of the efficiency of vacuum evaporation to treat and recycle this wastewater. The obtained outputs are distillate (pure water) and concentrate. In our Laboratory of Energy Intensive Processes at BUT, a vacuum evaporation unit has been used to process and recover clean water from various wastewater. The experimental results on laundry wastewater show that more than 90 % of the water can be recycled under optimal conditions. The chemical analysis showed that the properties of the obtained water are suitable for direct reuse in the laundry process, with a total COD value below 100 mg/L.

Among the most significant benefits of this technology is the production of significant volumes of high-purity water suitable for further reuse while using the present low-potential heat to operate the recycling unit. This allows the overall energy efficiency of the industrial process to be increased. This study will therefore describe the vacuum evaporation experiment and the results of the chemical analysis of the

obtained samples. Furthermore, energy intensity, economic feasibility, and the possibility of implementing this technology in an actual operation of an industrial laundry will be presented.

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Impacts of Climate Change on the Energy Performance of Prefabricated and Conventional Buildings

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Keywords: Climate Change; Buildings Energy Performance; Prefabricated Buildings; Dynamic Simulation

Climate change has a major impact on the urban built environment both with respect to the buildings energy demand, but also regarding the higher probability of confronting extreme events such as heatwaves. In this context and in order to propose adaption strategies, a growing scientific attention is paid on the accurate evaluation of the building's future energy performance. To date, most of the existing studies focus on the analysis of traditional construction solutions involving onsite construction processes and buildings made of reinforced concrete and brick masonry; yet prefabricated structures are far less evaluated in terms of their performance under the future climatic conditions. In fact, even if prefabrication presents multiple advantages compared to conventional buildings, such as significant reductions in cost and time, improved quality and accuracy in manufacture, easy dismantling and reuse of components, etc., they still only present a small part of the European building stock, mainly in the Mediterranean area. In this context, the aim of the study is (a) to evaluate via dynamic simulations the energy performance of a prefabricated building, considering both current and future climatic conditions and (b) to compare the obtained results with the respective outcome for a similar conventional building, made of reinforced concrete and brick masonry. To address the research goals, dynamic energy performance simulations with the EnergyPlus simulation tool are conducted for a one-story, family building, located in the city of Thessaloniki, Greece both for present and future period. Different wall configurations (i.e., conventional and prefabricated building elements) and various insulation levels ranging from 5 to 20cm are examined. To generate the future climate dataset as a necessary input for the energy performance simulations, the study employs dynamical downscaling approaches. The regional climate model RegCM4 is used under the RCP4.5 scenario. Emphasis is paid on the buildings' energy performance in the near future, therefore the generated future weather dataset refers to the period 2040-2060. Finally, EnergyPlus simulations are conducted for all the conventional and the prefabricated building scenarios for a reference period, corresponding to the current conditions and the

future period and the acquired simulation results are presented and discussed. The comparison of the present day and future mean monthly Tair indicate a rise of the latter values by 1.1^{o}C - 2.8^{o}C with the highest deviations being noticed during the summer period. Moreover, the obtained simulation results suggest that the future annual heating energy demand is always lower both for the conventional and the prefabricated buildings, given the higher future winter Tair values. On the other hand, the increased future summer Tair values always exacerbate the cooling energy needs of all the examined buildings. Finally, the simulation results indicate higher energy performance levels for the prefabricated scenarios, both for the current and future climatic conditions, since their total annual heating and cooling energy needs are always lower compared to the respective values for the conventional constructions regardless of the insulation levels.

Preliminary Design of an Innovative PV-PTES System to Enhance the Energy Efficiency in the Tertiary Sector: A Case Study

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Keywords: Energy efficiency; Pumped Thermal Energy Storage; Organic Rankine Cycle; Photovoltaic; Heat Pump

Climate change and the need for energy independence in European countries are driving decarbonization policies, which are increasingly promoting solutions toward Nearly Zero Energy Buildings (nZeb). Besides the high levels of energy efficiency achieved, the passive houses include significant implementation of renewables, storage and advanced management strategies for integrated electrical-thermal load control.

In this framework, this paper aims to investigate the performance of an innovative system based on the integration of renewables, energy storage and heat recovery in an existing building. The case study is characterized by electrical, heating and cooling demands that vary throughout the year. During winter, the energy demand of the building is given by electric load, space heating and data center's cooling requests. During other seasons, the energy demand is only given by electrical and cooling loads (AC and data center). With the aim of increasing the building energy efficiency and self-sufficiency, an innovative energy system configuration able to recover the waste heat from both the data center cooling system and the AC system (during cooling) and based on a PV system integrated with a Pumped Thermal Energy Storage (PTES) system is proposed. Such storage system is based on the coupling between a high-temperature heat pump (HP), a thermal storage section and an ORC power unit. During the charging phase, the electricity surplus from PV is used to charge the thermal storage and the recovered heat is used to reduce the temperature lift of the high-temperature HP. The stored heat is then reconverted into electricity through ORC power unit during electricity deficit periods.

To assess the energy performance of the proposed system configuration and to determine an optimal sizing of the components, a mathematical model has been developed in MATLAB. As main input, real data of electrical consumption, heat demand and occupancy of the building were used, as well as expected meteorological conditions for the location being considered, with resolutions variable in the range of 15-60 minutes. Since the rectorate is an historical building, with strict historical restrictions, the photovoltaic size has been determined under the realistic hypothesis of installing solar modules on a canopy covering the parking lot. A parametric analysis has been carried out on the main PTES design parameters, such as

temperature lift of the HP, power ratio between HP and ORC unit, thermal storage capacity etc. The influence of these design parameters on the system overall performance (PTES round-trip efficiency, self-sufficiency and self-consumption rates of the building) has been evaluated and the most suitable system configuration has been determined.

Implementation of Chemical Looping Combustion Technology with Waste-Derived Fuels: Process Analysis and Techno-Economic Evaluation

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Keywords: Chemical Looping Combustion; Waste-Derived Fuels; CO_2 Capture

Although waste management constituted mainly of landfilling at first, a turn to waste incineration has occurred in the past several years. More specifically, the implementation of Chemical Looping Combustion, an emerging and very promising method for incineration, with Waste-Derived Fuels is being examined. The combustion of waste, like other carbonaceous fuels, emits carbon dioxide, which must be captured in order to comply with the targets of the Paris Agreement and RED II, regarding the decrease in carbon dioxide emissions in the atmosphere. In conventional Waste-to-Energy plants, CO2 capture technologies are being implemented, such as amine scrubbing, in order to tackle this problem, which have however proved to be very energy intensive, reducing significantly the electric efficiency of the plant. Contrary to most existing CO2 capture technologies, Chemical Looping Combustion could be the solution to this issue, as it features an inherent CO2 capture with a low energy penalty and a high CO2 capture efficiency. The basic idea behind the Chemical Looping Technology lies in the constant recirculation of an oxygen-carrier material between two interconnected fluidized bed reactors. Air is inserted in the Air Reactor, which reacts with the oxygen-carrier material, oxidizing it and producing a stream of N2 and O2. The oxidized form of the oxygen carrier is then transferred to the Fuel Reactor, where it reacts with the incoming stream of fuel and the combustion reaction takes place. The flue gas exiting the Fuel Reactor consists mostly of CO2 and H2O, so after condensation of the stream, the CO2 is easily captured. In this study, the Chemical Looping Combustion technology with a Waste-Derived Fuel was implemented, producing electricity and heat through an adjoining steam Rankine cycle. The hot flue gases exiting both reactors are used to heat a stream of feedwater to supercritical conditions, which is then expanded on steam turbines to produce electricity. What is more, in order to examine the economic viability of such a plant, a techno-economic analysis was performed.

Ocean Thermal Energy Conversion (OTEC) Systems in the Mediterranean Sea: Availability and Cold Water Pipe Effect

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Keywords: OTEC System; RES; Ocean Energy

The recent promotion of the Renewable Energy Systems (RES) for the reduction of fossil fuels and CO2 emissions, is unavoidably connected to the ocean and marine environment as well. So-called Ocean Thermal Energy Conversion (OTEC) systems take advantage of the solar thermal energy stored in the ocean's surface, and exploit (either with the production of electricity or a byproduct – such as clean water) the natural temperature difference ΔT that is formed between the ocean's surface and its bottom at large depths of around 1 km. Because the efficiency of OTEC systems depends on ΔT, their availability and geographical location (i.e., distance from the equator) are their main drawbacks; note that their Carnot efficiency is at only 6.7% for a ΔT of 20°C.

OTEC systems can be utilized in the Mediterranean region, albeit they are more appropriate for usage in tropical countries where there is a significant ΔT between the seabed and the sea surface (for example, in the Caribbean and the Pacific). With relatively high mean values recorded, the Mediterranean region's sea surface temperature, which varies from winter to summer, is comparable to that of the Caribbean. The temperature profiles for various sub-basins of the Mediterranean Sea show a temperature of approximately 13°C at 1 km depths and no significant fluctuations for depths up to 4 km. In addition, various researchers forecast a rise in the Mediterranean Sea temperature owing to climate change and the impact of the sources in the deep seawater. It is hence clear that the primary physical requirement for installing OTEC systems for electricity generation – high enough ΔT between surface and deep seawater – exists in many regions of the world, but, by a preliminary assessment, not in the case of the Mediterranean Sea.

In order to determine how the OTEC systems, could contribute to the EU's climate emissions neutrality, this research seeks to investigate such a potential in the Mediterranean Sea, particularly in the south-eastern Mediterranean area on the island of Cyprus. In particular, a computational investigation on the effect of cold water pipe heat transfer loss is performed on OTEC systems.

Implementation of Energy Geo-Structures for Micro-Scale District Heating and Cooling in Mediterranean Environment

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Keywords: Energy Geo-Structures; Ground-Source Heat Pumps; District Heating and Cooling

Ground Source Heat Pumps (GSHPs) are used to heat and cool spaces using shallow geothermal energy (SGE) systems making use Ground Heat Exchangers (GHEs) (i.e., a network of pipes buried in the ground). GSHPs perform better than alternative traditional Air Source Heat Pump (ASHP) systems and can thus fit well in European Union's "Fit for 55" set target for reducing CO2 emissions. However, the primary preventing factor for using GSHPs is the high initial capital expenditure needed. An additional preventing factor is the lower heating and cooling demand resulting from EU's demand for nearly Zero Energy Buildings (nZEB) leading to a higher insulation.

With the current evolution of Geothermal Energy District Heating (DH), GSHP systems could become at last more viable. Having a central unit for distribution however, requires a large plant area, as well as the need for infrastructure and insulated pipes. Unfortunately, such infrastructure is primarily present in central and northern Europe, where a higher heating demand is required than in the southern EU. To overcome these fixes, using SGE systems on a "micro-scale" could serve as an alternative.

To this end, the overall goal of this research is to computationally examine the viability and potential of using SGE systems for a micro-scale urban setting using Energy Geo-Structures (EGS). A theoretical case study on residential blocks is thus performed for the production, distribution, and usage of EGS as a type of District Heating and Cooling (DHC) in the Mediterranean environment of Cyprus. The case study comprises several residential structures within a residential block, which is common for the island of Cyprus, with nZEB features. The COMSOL Multiphysics software is employed to investigate the effect of the ground temperature and the temperature gain or loss from the heat distribution. Subsequently, the potential of using GSHP systems as EGS at a micro-scale DHC residential level is concluded to be advantageous in relation to costs reduction and promotion of the geothermal energy use.

Do Financial Performances of Turkish Energy Companies reflect their Sustainability Performances?

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Keywords: Sustainability; Energy Companies

Macroeconomic developments in the world -especially Russia – Ukraine war- are triggering risks related to transitioning to a low-carbon economy. The energy sector, in particular, is one of the industries most exposed to these risks when considering its role in the transition to a low-carbon economy. Companies aim to reduce these risks by implementing sustainability practices. Within the scope of the study, the financial and sustainability performance of 22 companies listed in the BIST XELKT index was examined for the period between 2019-2022. Due to data availability, the study was carried out with 20 companies. The study used panel data of XELKT companies to investigate the effects of ESG performance, subsectors, sustainability index inclusion, and market risk exposure on financial performance. The results of the first scenario showed that profitability was significantly affected by the Russia-Ukraine War and the company's leverage ratio, but ESG performance had no significant effect on the financial performance. In the second scenario, the scope of the dataset was narrowed to only "responsible" companies and the evaluation focused on the effects of ESG performance on financial profitability. The results showed that ESG performance had a significant positive effect on financial profitability, with the overall ESG and S pillar having a positive impact, but the E pillar having a negative relation. Especially in the first scenario, it is very likely that the relationship between sustainability and financial performance, as interpreted in the model results, has been affected by the fact that only a small fraction of the 80 observations had an ESG score. The addition of the risk exposure as a dummy variable is also one of the factors that affect the result. In the second scenario, when the sample size is reduced, it has been observed that for the companies already implementing sustainability practices, their sustainability performance has significant effects on their financial performance.

Impact and Value Proposition Analysis of Renewable Integration

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Keywords: Energy storage; Offshore Wind; Hydrogen; Integration

This talk will focus on the optimization of renewable generation asset portfolio and integration to power grid in the Northeast USA. In particular, we will focus on the integration of energy storage and offshore wind farms, and the production and use case analysis of clean Hydrogen. Findings and results from a recent study completed in the Northeast will be presented, including project impact and value proposition in terms of economics, resiliency, and other social and environmental measures. The talk will focus on the network evaluation methodology and data forecasting tools developed in-house. Case studies will also be presented. The talk will conclude with a research question on how to analyze and synthesize demand and generation flexibility constructs in renewable-integrated power grids.

Improving the Power Distribution Grid Resilience through the Integration of Distributed Energy Resources: Case Studies in Greece

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Keywords: Climate Change; Distributed Energy Resources; Electricity Distribution Networks; Extreme Weather Events; Renewable Energy Sources; Resilience

With the energy transition of electricity generation from fossil fuels to renewable energy sources (RES) well underway, grid operators are increasingly facing the challenges of maintaining reliability but also ensuring the resilience of the energy system, i.e., its ability to adapt to changing conditions, as well as withstand and recover from disruptive events. Indeed, climate change is expected to exacerbate the impacts of extreme weather events on electricity network infrastructures, causing a rise in the number and duration of power outages and making the need for resilience even more imperative to ensure the uninterruptible and reliable operation of the power system. Resilience becomes, hence, an emerging concept of top priority for power utilities, encompassing the components of robustness, redundancy, resourcefulness, response, and recovery.

The electricity distribution network in Greece, being overhead at a percentage higher than 88%, is particularly vulnerable to climate change effects, especially as the electricity supply often requires the routing of the network in wooded areas or forests because of the existing urban structure. Network undergrounding constitutes a technical solution that can protect from climate-driven outages or precautionary shutdowns, being already reinforced by the recent legislation that obliges private Medium Voltage networks for the connection of RES producers to be underground for at least 80% of their length. In addition, the interconnections of the islands, imposed due to the withdrawal of diesel units according to the European Regulation, strengthen the stability and resilience of previously weak systems.

In the context of the net zero pathway, the RES contribution to the power system resilience can also not be disregarded, because they add flexibility capacity already from the planning stage. Distributed generation, by its wide geographic distribution, enhances system resilience since the loss of generation in extreme

weather events will be partial, thus leading to limited (local-level) voltage disturbances in comparison with those after the loss of a large production unit. Moreover, microgrids have reported resilience benefits of increased RES penetration in the face of climate extremes, and for intentional islanding during disruptions. Following a weather-induced outage, a microgrid could recover first with local energy resources and then reconnect with the larger grid after fault restoration. Besides, RES integration necessitates the replacement or modernization of the old network, incorporating remote management capabilities that can reduce restoration times and accelerate recovery in case of an emergency. The automation increase has also spurred the investigation into self-healing. In parallel, energy storage offers tremendous potential, by providing backup power in emergencies and creating a more flexible and responsive grid as power demand changes. This work aims to determine the relation of grid resilience with renewable-integrated power grids and storage schemes by capturing lessons learned from case studies in Greece, including residential (rooftop) applications and large-scale pilot projects (i.e. the transformation of the 115 Combat Wing at Souda Bay in Chania Crete into the first national net zero energy military airport). A holistic climate change adaptation approach aimed at grids to be resilient by design can mitigate climate change related disruptions.

Reducing CO_2 Production and Emissions through CO_2 Capture, Torefaction, Additivation and Catalysts

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Keywords: Emissions, Torrefaction; CO_2

There are a vast number in practices in the field of CO_2 reduction and the search for ways to implement and improve this activity. However, there are still some areas of mankind activities, industrial production, energy and other associated processes where there is still space to achieve reductions in emissions of pollutants.
In the framework of research activities and following the legislative requirements of national states and EU policy, our research team has looked at the possibilities of reducing pollutant emissions by alternative methods. The aim was to combine several interrelated areas and processes where unwanted CO_2 emissions are or can be released in individual steps. This involved research into the possibility of capturing gaseous CO_2 using algal cultures, which were then processed into alternative material for return to the ecosystem. Additivation and torefaction were used in combination with the possibility of better release of carbon back into the soil. This treated material was also subjected to combustion tests as a final step. The reason for this was to see if thermochemical conversion could be carried out using functional catalysts in such a way as to avoid the re-release of already captured COx back into the atmosphere.
Positive results and some surprising findings were found during the research activities, for example, a reduction of up to 18% of the total CO_2 content of the biogas studied was achieved by biological fixation. In subsequent pellet tests using catalysts and additives, it was possible to reduce the proportion of carbon pollutants produced by 20 percent or more. By returning the torrified alternative material back to the soil stock in the form of fertiliser, it can be concluded that CO_2 re-emissions to the atmosphere will be prevented. Moreover, it is a long-term soil additive. On the behalf of the data and experiments, specific functional devices have been developed, patent protection has been granted at international level and international cooperation in this field has been extended.

Environmental Disasters from the Occurrence of Dynamic Phenomena

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Keywords: Landslides; Seismic Energy; Dynamic phenomena; Disasters

Natural phenomena, which have the property of repeating themselves in the same way after a certain period of time, are called periodical. When they are accompanied by the release or transfer of energy, then they belong to the category of dynamic phenomena such as earthquakes, hurricanes, etc. Seismic energy creates intense stresses in structures, when it comes to an urban environment, but also intense landslides or permanent movements of road slopes in national roads as well as in a rural environment. In any slope, the difference in level and the gradients combined with the forces of gravity and the possible presence of water in the soil, create shear stresses inside the slope, which are opposed by the shear strength of the soil. When the developing stresses exceed the shear strength, they lead to slope failure and landslides.

Landslides can also be caused due to liquefaction of layers of fine sand silt, or due to general failure, with the combination of increased loads due to an earthquake, due to inertial forces, due to an increase in pore pressure and a decrease in the available soil shear strength. In particular, our country, which is characterized by a complex geological structure and intense tectonic stress, has suffered and continues to suffer the consequences of such catastrophic phenomena. Of the various destructive phenomena recorded on the Earth's surface, one of the most important problems is landslides.

Landslides with the energy they generate create phenomena, with enormous, in some cases, social and economic consequences, since apart from the financial burden due to the collapse of a technical project or the interruption of transport, they are accompanied by the loss of human lives and animal populations.

The aim of this work is to present the disasters created by landslides due to the release of seismic energy as well as the protection measures that must be taken to prevent the stability of slopes and any accidents that may occur on natural or artificial slopes.

Anode Modification with Polypyrrole-Derived Carbon Nanostructures for the Improvement of Microbial Fuel Cells Performance

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Keywords: Bioenergy; Microbial Fuel Cell; Anode Modification; Biofilm; Extracellular Electron Transfer

Microbial fuel cell (MFC) is a promising alternative technology for wastewater treatment and self-sustained bioenergy generation via microbial metabolism. The surface characteristic of anode materials is one of key factors affecting the bacterial attachment and extracellular electron transfer. The modification of anode with carbon nanostructures containing heteroatoms, such as nitrogen, could enhance the conductivity of carbon nanostructures and provide more active sites for interface electrochemical reaction and better biocompatibility. Among various strategies that have been developed to obtain these carbon nanostructures, carbonization of nitrogen-containing aromatic polymer nanomaterials, such as polypyrrole nanostructures, is a suitable alternative that can preserve morphology of the polymer precursors, simplify the preparation processes and reduce costs.

The present study investigates how the changes in the morphology of polypyrrole-derived carbon nanostructures influences the anodic microbial community of the resulting biofilms formed on the anode surface and MFC performance, in terms of bioenergy production. In this aim, two different synthesis methods were used to obtain polypyrrole with granular-like (called PPY-R) and tubules-like (called PPY-T) morphologies. The corresponding carbon nanostructures PPY-R-900 and PPY-T-900 were obtained after a thermal treatment under nitrogen atmosphere at 900 0C. Both polymer precursors and their corresponding carbon nanostructures were characterized using Scanning Electron Microscopy (SEM), Fourier Transform Infrared (FTIR) and X-ray diffraction. Dual chamber MFC systems with anodes of PPY-R-900 and PPY-T-900 modified carbon cloth and cathode consist of 40% Pt/C modified carbon cloth, separated by proton exchange membrane (PEM) (Nafion 117, Dupont, USA) were used for evaluation of MFC performance. Municipal wastewater supplemented with acetate and phosphate buffer were used as anolytes and catholytes, respectively.

The microbial communities of the initial wastewater and, following operation, of the anode biofilm were analyzed through 16S rRNA gene V3-V4 metabarcoding. At the genus and family levels, after MFC operation, results show multiple taxa with high relative abundance, which are frequently associated with the ability for extracellular electron transfer (EET). The Comamonas, Arcobacter, and Pseudomonas genera were most abundant on the both modified anodes, but the use of PPY-T-900 determined reduced alpha diversities with little variation between biological replicates. In term of bioenergy production, the polarization results show a better performance of MFC using anode modification with polypyrrole-derived carbon nanostructures with tubules-like (PPY-T-900) morphology, the maximum power density being almost double as compared with those using granular-like morphology.

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Optimal Design of Small Solid Dams' Systems in Mountainous River Basins, using GIS and Genetic Algorithms

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Keywords: Small dams; Optimization; Genetic algorithms; Flood protection; GIS

This paper deals with optimal management of surface water resources of a (semi)mountainous river basin, through appropriate design of a system of small solid barrier-type stone dams and corresponding borrow-pit. Practical goal is to determine the number (≤10), location (out of 40 pre-selected potential locations), and height (out of three fixed heights) of dams, and a borrow-pit's location (out of four pre-selected locations), for benefit maximization and cost minimization of objectives: a) max flood protection, b) max underlying aquifers' artificial recharge or/and irrigation by stored surface water upstream of dams, c) min dams' construction cost, and d) min stonework transportation cost. Although this is not a case study, for added realism, the theoretical study area is loosely based on a sub-basin of the Enipeas River in Thessaly, Greece. The main simplifying assumptions are: i) the simplified conceptual model involves no hydraulic simulation, thus flow characteristics are not considered, ii) no dam is assumed to affect another dam's benefit/cost values. Hence, all partial benefit/cost values can be separately pre-calculated, for each one of the available dam locations for all available heights and borrow-pit locations, deriving from data concerning topography (2m spatial resolution DEM by the Hellenic Cadastre), geology/soil (hydrolithological map derived from data by River Basin Management Plans and Greek Payment Authority of Common Agricultural Policy Aid Schemes), land uses (CORINE land cover), construction and transportation costs (Greek state-defined indicative pricing guide). This data pre-processing stage is the first (Stage 1) of the three stages of the proposed methodology, utilizing software like ArcGIS, QGIS and AutoCAD. Flood protection benefit is assumed to be proportional to the volume of stored water upstream of the dams, enhanced in locations upstream of settlements and road network, taking into account benefits/damages in the flooded areas. Benefit from aquifer recharge or/and exploitation of the stored water for direct irrigation of nearby crops is assumed to be proportional to the volume of water upstream of the dams. Dam construction cost is assumed to be proportional to the volume of stonework. The cost of stonework transportation from the four possible borrow-pit locations to the dams is analytically calculated based on the distances between dam locations and the borrow-pit, and the current transport pricing. Stage 2 includes the optimization procedure. The multi-objective optimization problem is formulated into a single-objective minimization problem; the difference of costs minus benefits is to be minimized by a simple elitist genetic algorithm. Stage 3 includes a sophisticated post-processing of results. A systematic investigation of proposed solutions leads to the identification of various alternative good (sub)optimal solutions, classifying them into different management strategies. Creating a pool of variations of good management strategies can act like a decision support tool for management authorities in the design phase, providing alternatives, even if some initial data are modified (a-posteriori modified or added constraints, budget restructure etc.).

Power Production by Using the Hydroelectric Power Plants and Cost Effect on Electricity Market in Turkey

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Keywords: Hydropower; Cost effect; Energy market; LEAP

In growing economies energy demand continues to increase in parallel with the economic growth. Hence, power generation increase is to be responded hand-in-hand with the sustainable economy. In this context, mitigation of the greenhouse gas emissions and reducing energy generation costs while protecting energy reliability are the main objectives in the energy market. Both goals can be satisfied when the renewable energy sources are used at the maximum level. Having all these concepts on the table, this study aims to perform the economic analysis of hydro-power based electricity generation with the impacts on the electricity market of Turkey.

The 2050 roadmap of hydroelectricity are considered to form the scenarios as realistic as possible by considering the hydroelectric capacity in Turkey. The long-range energy alternative planning (LEAP) model is used to analyze the cost-effectiveness by applying pessimistic and optimistic scenarios. The data accumulated for demand and generation costs for the different scenarios are used to have long-term predictions in Turkey.

The energy market model investigated shows that Turkey should use its full potential in renewable energy resources by encouraging the new liberal energy investments in transparency. The improvement in sustainable economic development and climate change, the power access is to be considered in the social dimension by reducing energy prices of residential consumers as well as the prices in transportation, and industry, etc., which are dependent on foreign energy imports.

The policies to be implemented in utilization of renewable energy resources have an important role on increasing the energy supply and reliability that will increase the development in the sectors besides reducing the emissions of harmful gases in the environment and improving the environmental indicators. As a conclusion, the net present value shows how much more cost reduction can be made in the base scenario.

Optimization Models for Water Pump Scheduling

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Keywords: Water Networks; Energy; Optimization; Benders Decomposition

The accelerated urbanization and the shrinking supply of fresh water are among the main reasons for the urgent need to optimize the cost effectiveness of water resources. From a sustainability perspective, water networks are largely inefficient due to the energy consumption and the large waste of fresh water. Furthermore, the majority of the operational costs of the water networks are due energy costs and the energy consumption contributes to the increasing demand for energy and consequently green house gas emissions. In this talk, we discuss our recent research on pump scheduling optimization for water networks. We present new approaches based on the combination on benders decomposition and simulation tools to optimize the energy consumption while meeting the demand restrictions.

Wastewater Recycling in Dairy Industry Using Membrane Processes

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Keywords: Sustainability; Reverse Osmosis; Water Reuse; Nanofiltration

Nowadays, water scarcity and water pollution are growing problems all over the world. The industrial sector consumes large amounts of freshwater, most of which is discharged as wastewater. One of the ways to reduce water consumption is wastewater recycling. This allows wastewater to be reused and valuable by-products to be recovered. As a result, it has a beneficial impact on the economic and environmental performance of industrial production. The food and beverage industry is one of the most water-intensive industries, with the dairy industry being one of the largest producers of wastewater. The main origins of wastewater in the dairy industry are cleaning and rinsing of plant and equipment or process operations such as pasteurization, chilling or cooling. The implementation of wastewater recycling in dairy production would lead to a more sustainable and environmentally friendly process. In the dairy plant, recycled water can be used for heating or cooling, as boiler make-up water, or for cleaning, washing and rinsing. By-products that can be recovered from dairy wastewater include whey proteins, milk proteins and caseins.
Membrane technologies (such as reverse osmosis, nanofiltration, ultrafiltration, membrane distillation, forward osmosis, etc.) are becoming increasingly popular for wastewater recycling due to their advantages over traditional methods. The application of these methods to dairy wastewater recycling is not yet widely used in practice. However, scientific publications are increasingly addressing this topic. This contribution reviews the membrane technologies used for dairy wastewater recycling.
The main benefits of membrane technologies include lower energy requirements, ease of scale-up, no use of chemicals, etc. On the other hand, the main disadvantage is membrane fouling, which depends on the initial wastewater characteristics. The successful implementation of a recycling unit in dairy production also depends on the level of separation of the wastewater streams. This is because the treatment of individual wastewater streams is more viable and efficient. Membrane technologies are often used in combination. According to the literature, a combination of reverse osmosis and ultrafiltration or nanofiltration is commonly used. In some publications, the use of less traditional methods such as membrane distillation can be found. Based on the literature review, membrane technologies appear to be a promising way to recycle dairy wastewater.

Identification of High Emitting Sources of Airborne Pollutants in Historical Centers

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Keywords: Air Quality; Sustainable Development; Historical Centers; High Emitting Sources

Historical centers, quite common in the Mediterranean area, are world heritage sites that must be protected from the impact of human activities. Air pollution represents one of the most harmful impacts which can jeopardize historical or archeological buildings and artifacts as well as human health. Traffic, domestic activities, heating and others release in the atmosphere many airborne pollutants like NOx, SOx, aerosol, hydrocarbons with noxious or corrosive properties. The emission rate of each pollutant from any source depends mainly on two elements: the emission factor and the activity rate. In many cases it has been demonstrated as a limited number of sources (e.g; high emitting vehicles HEVs) can emit in a disproportionally way with respect to average emission factors of the category they belong to, giving a large contribution to total emissions and therefore, to air pollution. In the case of vehicular traffic, it is reported that less than 10% of vehicles circulating in urban areas can contribute to more than 50% of total emissions of specific pollutants. The same scenario could apply also for other sources like ships in port or heating boilers even though in these cases less information is available. Identification of high emitting sources (HESs) requires contribution of several fields of research and technology including sensors and artificial intelligence. Remote sensing devices developed for on-road identification of high emitting vehicles (HEVs) include cross-road and top-down facilities. These solutions are not suitable for application in historical centers because of space footprint and aesthetic impact. In fact, historical centers are characterized by high density of buildings with narrow streets and high aspect ratio defined as the ratio between building height and street width (H/W).
A more appropriate solution for historical centers is represented by the point sampling (PS) technology that minimizes both spatial and aesthetic impact. However, its development presents some challenging issues for an accurate identification of HESs. The first is the need of simulation models like computational fluid dynamic (CFD) models tailored at the case study with the aim of modelling the dispersion of pollutants occurring in the atmosphere from the source to the receptor. CFD models could be necessary to optimize the analysis of data collected by sensors to get an accurate identification of HESs. However, a single receptor is not enough to identify HESs inside a large area like an historical center. It is necessary to design a network of sensors. Artificial intelligence (AI) algorithm, mainly machine learning (ML) ones, must be developed to analyze data collected by the network with the aim of the identification of suspected HESs. The ultimate classification of a source as HES can arise only after specific tests following the official procedure established for each category of sources: vehicles, boilers, ships, and others. Some results of monitoring campaigns for the identification of HEVs carried out in a historical center are reported and discussed.

Does the Area Seismic Zone Affect the Cost of Construction of a R/C 10-Storey Building with Spring Supports and the Resulting Emissions?

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Keywords: Construction Cost; Seismicity; Reinforced Concrete; Emissions

Building earthquake-resistant structures is an issue that troubles engineers and researchers worldwide. The key issue has to do with the fact that a structure which resists seismic action effectively has to be designed keeping in mind construction costs, too. Thus, a balance between the safety factor against earthquake action and the cost-effective construction has to be kept all the time. This issue has taken an even bigger value nowadays, after the recent earthquakes taken place at Turkey, which have been proven to be really catastrophic and devastating for the economy, the society and the numerous human losses. The present research work includes the modelling, analysis and dimensioning of a 10-storey building. This way helps to estimate the cost of a 10-storey reinforced concrete building whose cross-sections of the structural elements remain the same in all three seismic zones in which it is constructed. The modelling of the building takes place with the help of the software program SAP2000 using linear finite elements. The supports in this building were simulated using springs to take into account the influence of the soil. The analysis of the building was performed with methods of static and dynamic spectrum analysis, using the design spectrum of Eurocode 8. Reinforcement dimensioning of the load-bearing body is carried out in accordance with the provisions of Eurocode 8 for all three seismic zones. The purpose of this research work is to prove, through the comparative analytical estimation of the construction cost, to what extent the construction cost of the load-bearing structure of a reinforced concrete building is affected by the seismic hazard of the area, what percentage it reaches and if this influence is significant. Useful conclusions are drawn regarding the influence of seismicity on the construction cost of the load-bearing structure of reinforced concrete buildings with spring supports.

Investigating the Sources of Water-Soluble and Water-Insoluble Metals and Trace Elements of Ambient Coarse and Fine PM in Los Angeles

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Keywords: Particulate Matter; Source Apportionment; Water-Solubility; Metals and Trace Elements; Principal Component Analysis

A source apportionment study was conducted to identify the source of metal and trace elements in particulate matter (PM) in the air of central Los Angeles. The study took place during the winter season of 2021-2022, and samples were collected using a Personal Cascade Impactor (PCIS) on Teflon filters at the University of Southern California particle instrumentation unit (PIU). The collected samples were then analyzed chemically using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) to determine the water-soluble and insoluble portions of the metal content. The study employed a principal component analysis (PCA) to determine the sources of the metals and trace elements in the water-soluble and insoluble portions of both coarse and fine PM. The results of the chemical analysis showed that the most predominant elements found in fine total PM were S, Na, Ca, Fe, and Al, while in coarse PM, they were Al, Ca, Fe, Mg, and Na. The results indicated that a greater proportion of the metal content in fine PM was soluble in water compared to that in coarse PM. The water solubility of certain crustal elements, such as Ti, Fe, and Al, was found to be low (<5%) in both the fine and coarse size fractions of the selected metals. Additionally, La and Pb demonstrated low levels of water solubility, especially in the coarse fraction, with levels of 1.5% and 5%, respectively. Conversely, Ca, Na, and Zn had the highest levels of water solubility, with solubility levels of 72%, 69%, and 65%, respectively. The source apportionment analysis revealed that tire and brake wear were the primary sources of water-soluble metals in both PM sizes, while soil and road dust were the main sources of water-insoluble metals. In addition, a multiple linear regression (MLR) model was employed to assess the effect of each source on the emission of metals and trace elements. The results of the MLR analysis indicated that tire/brake wear was the major contributor to the water-soluble metal content in both PM sizes and that soil and road dust were the primary sources of water-insoluble metal.