ISSN 2653-8911

9th International Conference on "Energy, Sustainability and Climate Crisis" ESCC 2022

Book of Abstracts

Paphos, Cyprus, August 29 - September 2, 2022

9th International Conference on "Energy, Sustainability and Climate Crisis"
ESCC 2022

Edited by: Georgios K.D. Saharidis

Publication
Department of Mechanical Engineering, University of Thessaly

ISBN 978-618-84403-9-5

ISSN 2653-8911

Text editing
Georgios K.D. Saharidis

Layout & Book design
Eleousa Zygouri

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Enhancing Expansion of Rooftop PV Systems through Mixed Integer Linear Programming and Public Tender Procedures

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Keywords: Building integrated PV; Novel renewable energy growth mechanisms; Mixed integer linear programming; Public procurement;

Concerning the growth rate in Renewable Energy share, especially in the EU, it is fact that Rooftop Photovoltaic (PV) systems have a significant role to play. Nevertheless, it is also widely accepted that with current policies, schemes and scientific methods, today's Renewable Energy growth rate is still far from the desired one.

Based on that, the authors proposed a novel integration of a Mixed-Integer Linear Programming based model in a Public Tender Procedure, which enables the bulk installation and thus, the rapid expansion of Rooftop PV systems, in a least-cost manner. The main objective and contribution of this study is to provide an economic solution to interested Public Bodies for utilizing the rapid growth of rooftop PV systems through novel mechanisms and hence, to better achieve the desired Renewable Energy targets.

The proposed methodology was tested in a real-life project, and it was found that that the bulk installation of PV systems, in 404 public schools, in Cyprus, with a total PV capacity of 4.8 MWp, can be realized at an optimum cost. The main achievements found are: (i) high-level competition, due to the ability of the proposed model to select multiple PV Installers, (ii) a 35% lower project cost compared to the initial estimated budget and (iii) a significantly lower unit cost of about 0.7 million €/MWp, compared to about 0.91 and 1.54 million €/MWp obtained from other similar projects.

Furthermore, in order to prove the validity of the proposed methodology, the optimum solution found by the proposed MILP model – for the project under study – was compared with the one obtained from an exhaustive optimal solution search procedure. The comparison showed that both solutions are identical, allowing the Authors to conclude the validity of the model. Based on that, the Authors suggest and recommend to Public Entities, or even Private Bodies, to adopt such methodologies for the sake of the rapid Renewable Energy growth.

Genetic Algorithm Based Optimizations for Planning and Operation of Renewable Energy Communities

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Keywords: Renewable Energy Community; Optimization; Genetic Algorithm

Renewable Energy Communities (REC) have the potential to become a key agent in the energy transition process towards a democratic and sustainable energy system. The introduction of small generation facilities closer to consumers and the switch to renewable sources provides both environmental and economic benefits. The main environmental benefit comes from the reduction of carbon emissions due to the replacement of traditional sources by renewable sources. And the economic benefit comes from the reduction in the electricity bills due to the avoided purchase of energy from the grid as well as the sale of excess energy sold to the grid. This co-ownership of energy sources by citizens fosters consumer empowerment and creates energy independence, which helps to reduce energy poverty and contributes to the local economy by generating financial returns. In addition, from a social point of view, they enable the development of a more participatory energy system. These are some of the reasons why RECs should be promoted, in order to avoid the mere technological shift towards renewable energy sources. Moreover, since residential consumers have different consumption patterns depending on their schedules and appliances, their grouping in a sharing framework allows for a better use of the resource compared to individual self-consumption.

However, if this grouping of prosumers and their respective allocation of energy is not done in a smart way, the high potential of RECs will not be exploited. This may be reflected in energy generated by the REC but not being consumed, and having to be dispatched to the electricity grid, reducing the self-consumption and leading to lower economic profitability.

Therefore, given the importance of extracting the maximum potential of RECs, this study presents a tool to assist in the spreading of optimal RECs in both the planning and the operation phases. Specific Genetic Algorithms were developed to find the best combination of users and the optimal allocation of the generated solar energy. This novel development is validated with data from solar installations and residential electricity consumption from Barcelona. The results show that the novel algorithm successfully obtained optimal RECs with low solar excess, high self-consumption, high avoided CO2 emissions and low paybacks for all participants. This type of tool will be essential to help citizens conforming RECs to increase their economic revenues and their positive impact on the environment.

Supporting Tool for Strategic Decisions in Plastic Waste Processing Infrastructure Planning

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Keywords: Post-consumer plastic sorting; Decision making support; Sorting automatization; Multi-objective optimization

The waste management is currently undergoing a major transformation and enormous sums of investments and financial support flow in the system. The aim is to achieve the concept of a circular economy, which should be helped by progressive goals, which are included in the legislative series of mostly developed countries. An efficient and long-term sustainable system is key, and as the production forecast is more likely stagnant, it is crucial to design an efficient and long-term sustainable waste treatment system. The emphasis is mainly on its material use, however Individual types of waste differ in their properties and recyclability, where plastics in particular are among the most problematic. There are many plastic types that are variously combined, and additives make the recycling more complicated. It leads also to very challenging identification and the manual sorting is very difficult or almost impossible. Today, technologies are being developed that can automate sorting, streamline the entire process, and increase overall material utilization. However, a major obstacle is the high investment of such projects, so it is necessary to assess individual proposals of new facilities. From the point of view of global infrastructure planning and possible investments, it is desirable to take into account even the ecological criterion. Without efforts to reduce the burden on the environmental environment, the set goals cannot be achieved. However, changes in the system must be planned in a targeted manner since an oversized system can have a negative impact. The presented support tool based on mathematical programming makes it possible to take into account a number of key parameters and to find a suitable location for automatic sorting lines, which will complement the existing infrastructure and help increase the amount of plastic waste returned to the system. It enables to track individual waste streams with various properties and check the impact on plastic treatment system in various scenarios with economic and environmental assessment. The developed tool was applied to a case study in the Czech Republic using a wide database based on both data directly from real operations and technical and economic models describing various configurations of sub-equipment. The output of the trade-off between cost and ecology is the design of 5 new automatic lines, which should double the amount of sorting plastic waste thanks to new high-tech mechanisms.

Estimating Temperature Distributions and Thermal Stresses in a Shell and Tube Heat Exchanger with Fixed Tubesheets for Improved Material Selection

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Keywords: Heat exchanger; Shell and tube material; Material temperature; EN 13445; Expansion joint

A thermal stresses calculation for improved material selection method for shell and tube heat exchanger with fixed tubesheets (TEMA type NEN) according to the EN 13445 standard is presented in this conference paper. The main aim is to estimate the mean material temperature from material temperature field and propose material selection method for shell and tube heat exchanger with fixed tubesheets without the expansion joint according EN 13445 and estimate shell and tube axial stresses calculation. In many cases of shell and tube heat exchanger the compensation of different thermal expansion of shell and tubes is required, because of otherwise excessive thermal stresses. Thermal stresses in strength calculation according to EN 13445 standard are calculated based on mean material temperatures, and mean coefficients of thermal expansion. Unfortunately, the calculation of mean material temperatures is not specified in EN 13445 standard. Mean temperatures and mean thermal expansion coefficients along with fluid pressures have considerable influence on effective pressure, which directly impacts resulting axial stresses. The aim is to find out all material combinations for shell and tubes of tubular shell and tube heat exchanger with fixed tubeseet without expansion joint according to the mean temperatures, which are suitable for operating conditions and allowable pressure of components as well as reasonably priced. Various methods for estimates the material mean temperatures will be investigated. Expansion joints are often used in heat exchangers with fixed tubesheets in cases where the temperature difference between process media in shell and tubes is approximately between 20 °C and 100 °C. However, the expansion joint is very expensive component. Moreover, usage of expansion joint is often specified by good practise or based on estimate. Calculation approach to evaluating of necessity of shell expansion joint usage was not found in the literature. The focus of this calculation is to identify the applicable combination of shell and tube materials before the proper strength calculation according the EN 13445 standard. This simplified strength computation could be used in optimization calculations of shell and tube heat exchangers and it is well suited to preselect material combinations resulting in low axial stresses, thus the expansion joint need not be used.

Cost as the Barrier in Waste Collection Systems for Recyclable Fractions

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Keywords: waste collection; routing problem; web application; scheduling; route plan

Waste management is a public service provided to citizens by the local government. Currently, Czech municipalities usually use the services offered by specialized collection companies, often operating at the supranational level. The position of an individual municipality is disadvantageous for negotiations with large corporate companies resulting in high costs. Following the unions of municipalities from abroad, similar groups are nowadays formed in the Czech Republic. In some cases, alliances are formed in order to share information, represent the interests of member municipalities, and conduct negotiations with collection companies and processing facilities. However, there are also associations of municipalities that have taken over all responsibility for waste collection and transport. Such associations of municipalities are equipped with their own bins/containers and vehicle fleet, and sometimes they also operate processing facilities. Associations ensure the collection of waste from the municipalities to the place of its processing. The waste is collected from bins within the municipality, followed by inter-municipal transport and collection in other municipalities until the waste is transported to the processing facility. By optimizing collection routes among municipalities, reduction of costs and environmental impacts can be achieved. The contribution presents a web application for waste collection planning with emphasis on a friendly user interface and adjustability of boundary conditions – number of selected municipalities, heterogeneous vehicle fleet, multiple disposal points, selection of working days and hours, variable collection frequency, several types of municipal solid waste, different collection systems and additional features. The application builds on mathematical models and algorithms from operations research and statistics to describe links in waste management. The resulting tool works with real data regarding waste generation quantities, travelling distances, servicing times and vehicle properties. Therefore, it is a suitable tool for existing and emerging associations of municipalities, which can estimate personnel and vehicle requirements and at the same time obtain the plan of collection routes for the whole year.

A TOPSIS Solution Selection Strategy for the Vehicle Routing Problem with 3D Constraints in Urban Spaces

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Keywords: 3D Loading; Vehicle Routing Problem; TOPSIS;

Urban deliveries are a complex subject. While long distance hauling can be predictable and less constrained, the last mile of deliveries in urban spaces is the opposite. Parameters such as congestion, vehicle size and vehicle emissions create a volatile and unstable environment, hard to predict and even harder to maneuver around. The research in urban settings has been concerned with public transport applications. Furthermore, the existing Vehicle Routing Problem (VRP) variants on urban deliveries have focused on minimizing emissions and other sustainability goals.

In this research, the Capacity constrained VRP with Three-dimensional Loading constraints (3L-CVRP) is solved in an urban context. 3L-CVRP accounts not only for the weight of the items, but also for their dimensions, and that is its main difference from other VRP variants. It is not researched as extensively as other variants since its high complexity makes it hard and slow to solve realistic problems. In 3L-CVRP the loading sequence of the items must consider Last-In-First-Out constraints, item fragility, and sufficient support in cases of item stacking, in addition to the VRP constraints. It is worth noting that no complete mathematical formulation exists to date.

The use of small size vehicles within urban spaces mandates the development of efficient packing plans, in addition to efficient routing. However, routing plans are often affected by packing plans, therefore, a simple routing heuristic was used, based on the initial solution generation scheme of the Greedy Randomized Adaptive Search Procedure (GRASP). The item packing takes place in an exhaustive manner since only a few items can be placed inside each vehicle. The described solution generation method is simple enough to be completed fast and run many times but can extensively search the solution space and provide solutions of great diversity.

The issue that arises is how does the Decision Maker (DM) select which solution is the most desirable. To aid in that respect, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method was employed. Four criteria, vehicle load utilization, vehicle space utilization, total distance, and the number of served customers are used to help decipher the results. Using the TOPSIS method, no alternatives are excluded, as a not so good performance on one criterion can be outweighed by good performance on another one. An added benefit is the ability to shift the importance from one criterion to another since the needs of both the carrier and the customers are ever changing.

Formal Modeling of Industrial Wireless Applications

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Keywords: Formal methods; Industrial wireless applications; Industrial Control Systems; Model verification; Statistical Model Checking

The exponential increase in the number of wires needed for the deployment of industrial applications in production lines combined with the complexity of the application development using proprietary protocols, shifted manufacturers towards new directions. One such direction that is also reducing the system configuration and maintenance cost is the use of wireless connectivity. Nevertheless, industrial wireless applications face significant challenges, as communication channel interference, loss of bandwidth and the out-of-order delivery or loss of packets. Therefore, they cannot meet their critical operational and non-operational requirements. To this end, several tools have been proposed for modeling and simulation of these applications, in order to solve their challenges before their actual deployment and execution in the system architecture. However, these tools do not provide the ability to validate their functional and non-functional requirements nor provide guarantees for resolving their challenges. This article presents a new methodology that is using formal methods to model industrial wireless applications and architectures, but also to validate the deployment feasibility for industrial applications on wireless architectures. The method is based on formal methods and is using the BIP (Behavior, Interaction, Priority) framework and stochastic components which represent the application and the wireless architecture at different levels. The methodology is applied in an Industrial Control System (ICS), that is responsible for electricity production from hydro sources. The ICS application does not meet the existing requirements that are linked to message latency and packet loss and hence its deployment is deemed in-feasible. To tackle this challenge, we have built a formal model and conducted simulations to reason about the application deployment. Through our experiments we have validated that the application requirements are actually met and the issues that are faced in its deployment are due to the channel interference and occasional loss of signal in the access point. Hence, the considered wireless architecture is deemed as feasible as it satisfies the requirements of the ICS application.

Stochastic Multiobjective, Non-Convex CHPED, Incorporating Wind Power and V2G Under Environmental Constraints

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Keywords: Multiobjective, Stochastic, Particle Swarm Optimization, Economic Dispatch, Cogeneration, Wind Power Estimation, Environmental, V2G, Non-Convex, Harmony Search

The aim of a power and heat Economic Dispatch (ED) is to make optimal use of the power and heat generation capabilities of the online units to cover the demand. In the conventional ED problem, the operator must make the best power allocation between the thermal units and the Renewable Energy Resources. However, the presence of Combined Heat and Power (CHP) capabilities in the network adds extra decision variables to the problem as there is heat load that must be met simultaneously.
Furthermore, due to the stricter emission regulations stemming from the rising concern on environmental issues, all Greenhouse Effect gases have to be kept in check and in predetermined boundaries. For this purpose, CO2, SO2 and NOx emissions are introduced to the models and are either minimized simultaneously as the operating cost, with the necessary trade-offs, or used as constraints. Therefore, higher renewable energy penetration is imperative, for such environmental policies to be enforced.
The mentioned problem is usually approached deterministically. Such approaches are notorious for neglecting various aspects of the variability included in a real power system. Factors like power demand and generation, fuel prices, wind speed, solar radiation and temperature can introduce uncertainty that has to be included into any model trying to be as close to real world operation as possible. As a result, the stochastic formulation of the problems takes into account all the above, offering the operator solutions that can cover the uncertainty.
In this paper, an extended stochastic multiobjective ED model is introduced with the goal of utilizing optimally, the heat and power production capabilities of two (2) CHP units, assuming a non-convex Feasible Operation Region (FOR), along with the safe incorporation of wind power. Additionally, the effects of including a Vehicle to Grid (V2G) station in the system will be explored. The model takes into consideration the stochastic behavior of both wind power and V2G stations, incorporating penalties for both underestimation and overestimation of the expected power production. The environmental constraints concern the SO2, NOx and CO2 emissions, which are modeled stochastically and used as either an objective function or inequality constraints. The simulations are performed on the modified IEEE 30 bus network with two (2) CHP units and the wind parks of Crete Island aiming to determine the degree environmental policies affect the system and the role Eclectic Vehicles (EVs) play in such cases.
In addition, a Pareto based approach of Particle Swarm Optimization (PSO) or MOPSO (Multi Objective PSO) is used, that utilizes an external archive to store non dominated solutions found during the search, and uses diversification mechanisms to ensure the disparity of the approximated Pareto front. As a second

benchmark, the Harmony Search (HS) Algorithm is used to attempt to solve the CHPED problem. HS is in the class of meta-heuristics as well, drawing inspiration from the process of harmony improvisation of musicians. Similarly, with PSO, HS has found many applications in ED problems and in power systems in general.

Study of Vacuum Membrane Dehumidifiers on Heat and Mass Transfer Effects with Nafion 212 Membrane

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Keywords: Heat and mass transfer; Nafion 212; Vacuum membrane dehumidifier

Due to the global climate change, energy saving issue has been paying more attention in the world. In terms of electricity consumption, air conditioning is a major energy-consuming project. Therefore, reducing the energy consumption of dehumidification will have the opportunity to improve the energy consumption of the overall air conditioning system, achieve the purpose of saving energy, and also improve the efficiency of the air conditioning system. Thus, the membrane dehumidification method, which has the potential in reducing energy consuming in air conditioning system, is used to conduct experiment of heat and mass transfer in this study. Based on the previous research, we have chosen the triple serpentine (3-S) flow channel because it has more sufficient time for the water vapor movement through the membranes. In the present research, the dehumidification performance experiment of the vacuum-based membrane dehumidifier is conducted with indexes including dehumidification rate (DR), water flux (J), pressure loss (ΔP), pumping power (Ω) and coefficient of performance (COP). The effects of inlet air with temperature in 35℃, 40℃ and 45℃, with relative humidity in 60%, 75% and 90%, flow rate in 25LPM, 35LPM, 45LPM, 55LPM and pressure on the vacuum side in 5Torr, 10Torr and 20Torr were examined to observe the performance of Nafion 212 membrane. The results of experimental study reveal that the effect of temperature has the highest DR, J, ΔP, Ω and COP in 45℃. The effect of relative humidity in 90% also show the same tendency which means the more heat and mass energy in the inlet air brings the more water vapor through the membrane. For the effect of flow rate, the result in 55LPM shows the best dehumidification performance in all. In terms of pressure on the vacuum side, the vacuum pressure in 5Torr has the highest DR on account of pressure difference driving force that pushed more water vapor to flow through the membrane.

The Evaluation of Engineering Knowledge through an Interactive Escape Room Game

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Keywords: Engineering; Escape room; Research methodology; Engineering training

Education as a concept includes every effort to train and develop people and their skills by applying the appropriate tools. One of the categories of education is the formal education which includes a hierarchical organization system of the curriculum and is under the jurisdiction of state mechanisms. However, there is also the non-formal education, which, unlike the formal, refers to all organized educational programs that take place outside the institutional framework of formal education and are usually voluntary and short in duration. The non-formal education is mainly addressed to adults and usually does not provide a document certifying the education for this field. In this context, the present work, adopting the research methodology based on design, aims to develop and formulate a mobile game of augmented reality (AR) in the form of "escape room/s" aimed at training engineers.

'Escape rooms' is a name given to cover an interesting trend of modern times that has flourished in the last decade in many countries around the world. These rooms are puzzle and composition games, in which participants are asked to work together and solve problems using the information provided by the room/s in order to unlock the door and escape. These types of games belong to the broader category of escape games but differ from the rest due to the live interaction they provide with the environment. The benefits that are emerged from these games are mainly elements necessary for the professional activity of an engineer, i.e. they promote the collaboration, development of problem-solving strategies, critical thinking, imagination and creativity. Escape rooms require teamwork, communication, initiative, as well as critical thinking and attention to detail and simultaneously apply a wide range of knowledge and effective methods under the pressure of time.

The purpose of this paper is the evaluation of students who are in the last year of their studies, through a series of high level and content of polytechnic questions, in an AR environment of escape rooms. The procedure will incorporate one or more thematic escape rooms regarding the mobilization, satisfaction and involvement of students coming from Institutes of Technology, in puzzles and problems that require significant engineering knowledge.

The Sustainability Reporting in the Municipalities: A Study in Portugal

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Keywords: Sustainability; Municipalities; Disclosure; Reporting;

The sustainability practices are increasingly used and the target of concern by society in general. The citizens are increasingly more interested in environmental, economic and social issues.
The way in which this sustainability is promoted by public entities makes it possible to assess the extent to which society's concerns are addressed by these entities. The municipalities, which are the main objective of this study, are framed within the public sector, and they play a fundamental role in the daily life of the population, having as main mission to implement policies that defend the interests and needs of the population, through the availability efficient and transversal public services.
Knowing the importance of Municipalities for all aspects of society and the way they influence it, concerns about reporting information on sustainability have increased in recent years, giving special attention to environmental, economic and social factors. This work was developed with the objective of evaluating how much and what type of information on sustainability is reported in the various information disclosure documents presented by the municipalities in the north of Portugal. In addition to assessing the level of disclosure of public entities, we seek to identify the main factors that determine this disclosure.
Despite the importance of the topic under study, there are still very few works that analyze this subject. This research aims to contribute to overcome this lack of study and also to verify the weaknesses and strengths of disclosure regarding sustainability considering the information disclosed by municipalities of the northern region of Portugal on their websites.
The present investigation analyzes and quantifies the matter of disclosure of sustainability in 86 Municipalities belonging to the North region of Portugal, using the analysis of their web pages and investigating the possible explanatory factors for their level of disclosure. After identifying the explanatory factors, namely the sociodemographic, socioeconomic, fiscal and political factors, the disclosure index was prepared. The results obtained suggest that the disclosure of sustainability is average, as can be seen with the result that 56.77% of the Municipalities that disclose information. The category that presents the greatest disclosure is economic, followed by social, general, public procurement and, finally, environmental. The latter presents a visible lack of disclosure on the web pages, thus establishing an incentive for Municipalities to improve their performance systems regarding the information made available in this particular area, which is increasingly crucial.
The obtained results suggest that the greatest weaknesses are found in the dissemination of environmental information. Regarding the factors associated with disclosure, it was possible to identify that the disclosure of sustainability and the social responsibility information is related to the size of the population, with its dependent population, with the level of education, political competence and also with the percentage of participation in the elections. However, it was not possible to validate the existence of a relationship between the level of disclosure and the proportion of the unemployed population, with institutional capacity or with the level of indebtedness of the municipality.

Quantification of Smart Microgrid Benefits Using Sensitivity Analysis

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Keywords: Smart Microgrids, Dispersed Generation, Renewable Energy Sources, Sensitivity Analysis, Investment Deferral, Economic Benefits, Electricity Price, Power Losses, Voltage

The notion of Smart Grids (SG) refers to the evolution of electricity grids. A SG is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that assume both roles – to efficiently deliver sustainable, economic, and secure electricity supplies. Now, distribution grids are being transformed from passive to active networks, in the sense that decision-making and control are distributed, and power flows bidirectional. This type of network eases the integration of Distributed Generation (DG), Renewable Energy Sources (RES), Demand Side Integration (DSI) and energy storage technologies and creates opportunities for novel types of equipment and services, all of which would need to conform to common protocols and standards. The realization of active distribution networks requires the implementation of radically new system concepts. Smart Microgrids (SM), also characterized as the "building blocks of SGs", are perhaps the most promising, novel network structure. The organization of SMs is based on the control capabilities over the network operation offered by the increasing penetration of DGs at the distribution level. These control capabilities allow distribution networks, mostly interconnected to the upstream distribution network, to also operate when isolated from the main grid, in case of faults or other external disturbances or disasters, thus increasing the quality of supply.
There are several benefits related to SM such as reliability, power quality improvement, reduction in gaseous emissions, power losses reduction and the economic benefits the most important of which being the end-user electricity bill reduction capability. The "non-wire solutions" are now considered as an alternative to network upgrades. With significant penetration of SMs the power flows may become reversed, and the distribution network is no longer a passive circuit supplying loads but an active system with power flows and voltages determined by the dispersed generations of SMs as well as the loads. The change in real and reactive power flows caused by SM has important technical and economic implications for the power system.This paper targets to quantify the SMs capability to defer planned or required investments in distribution transformers using the method of sensitivity analysis. The methodology is based on the calculation of the sensitivity network coefficients (A/kVA) and the time that can be interpreted as a capacity deferral time in the sense that it will take some time more months or years for the current in substation transformers to reach the technical limits at which new investments are needed. The presence of a SM postpones the need for investment on certain portions of the network by a certain time and as a result, the economic benefits are related to the temporal value of money. Also, in this paper the power losses reduction, the voltage level improvement and the electricity price reduction due to Smart Microgrid concept are considered. The methodology is applied on a typical 17-bus test distribution network which acts as SM, representing a Hellenic Low Voltage network.

Moving from Air Source Heat Pumps to Ground Source Heat pumps: An Environmental Investigation of Different Types Ground Heat Exchangers

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Keywords: GHE Life Cycle Analysis, LCA, GSHP Environmental Impact, GHEs configurations

Shallow Geothermal Energy (SGE) systems falls well within the new European strategies for further adoption of Renewable Energy Systems (RES) and reduction of fossil fuels. A major application of SGE systems is space heating and cooling through the use of Ground Source Heat Pumps (GSHPs). GSHPs are coupled with Ground Heat Exchangers (GHEs) in order to absorb/reject heat from/to the ground. GHEs come in different forms and types, and orientation. The conventional systems for an urban environment use vertical GHEs, with either single U-tube, double U-tube, or coaxial configurations. In comparison to the Air Source Heat Pump (ASHP) systems, the GSHPs offer a superior performance, but have failed to prevail due to their longer payback periods and higher initial investment. However, new decision criteria within an overall multi point criteria framework, seen to be favored in the EU, with the environmental impact of a process/ product playing an important role. The aim of this study is therefore to investigate environmentally whether the switch from ASHPs to GSHPs, in terms of GHE types, provides an environmental advantage. To this end, the widely adopted Life Cycle Analysis (LCA) methodology is used. A case study is considered as a baseline from which the Functional Unit (FU) is set. The system boundaries are based per FU and the processes and Life Cycle Inventory (LCI) involved include the production of raw material, the installation, and the operation of the systems. The Life Cycle Impact Assessment (LCIA) is investigated in terms of a mid-point and an end-point perspective using two methods of the openLCA software, namely the CML2001 and Eco-Indicator99. The results indicate that the ASHP systems exhibit the highest impact in comparison to the GSHP systems, while the coaxial GHE configuration, although requiring the smallest GHE depth, has the highest impact among the GHE types. Finally, one should note that the GSHP systems are case sensitive and the heating and cooling loads of the investigated case plays an important role on these results.

Experimental Investigation of PV Cooling Methods with Focus on BIPV Applications

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Keywords: photovoltaics; overheating; natural ventilation; building integrated; PVPCM

High temperatures have negative impact on the efficiency and thus the electrical output of the PVs especially in the crystalline Si based cells. This phenomenon is made significantly worse if the components are integrated since the heat generated between the PV and the building wall is usually not effectively removed. Consequently, the BIPV panels get warmer compared to the ones mounted on free air, thus lowering more their electrical power output. The most common way to avoid PV overheating in BIPV systems is the creation of an air gap between the PV panel and the outer building's skin and ventilate this air gap either with natural or mechanical means. Another way to handle and drive the heated air gaining the attention of various researchers the last years, is the use of phase change materials (PCM) in BIPV systems. Various researchers state that with proper design and configuration, the BIPV-PCM systems can eliminate the PVs overheating and use the stored heat for different purposes or just reject it. In this study, three PV systems were experimentally tested under the same conditions using artificial solar radiation from a solar simulator in indoor controlled environmental conditions. The thermal behavior of an air based BIPV system, a BIPV-PCM system and a free standing PV panel were compared. Results show that the BIPV-PCM system has lower temperature distribution than the BIPVT system with an air gap and also a lower temperature distribution than the free standing PV panel in high solar radiation conditions for a specific period of exposure time.

A Methodology for Evaluating the Operation of Floating Solar Panels in the Aegean Sea

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Keywords: Floating solar panels; Renewable energy; Marine renewables

Given the ongoing energy crisis, developing renewable energy solutions is necessary to fill the population's energy needs and meet the goals framed by the European Green Deal. Although Solar Photovoltaics (PV) are technologically advanced and significantly contribute to the renewables' energy mix, their deployment in coastal and offshore locations in floating arrays has not yet been widely implemented. Compared to land-based implementations, one of the main advantages of Floating PVs (FPVs) is the achievement of lower panel temperature due to the cooling effect of water. Another benefit of floating PV versions is that they take advantage of marine space availability, allowing land to be used for other purposes (e.g. agriculture). Such systems can be used for large-scale power production but also for stand-alone applications supporting activities such as offshore aquaculture. Although the climate conditions in Greece can likely support FPV plants, not much research has focused on studying FPVs except for site selection methods focusing on marine spatial planning. Here, we present a rather practical procedure for evaluating the efficiency and operation of FPV installations in the Aegean Sea. For selected offshore sites, we present the available resource (solar radiation), temperature, and wind speed and assess those parameters' effect on the performance of FPVs. Data for the variables mentioned above are available from the Copernicus portal (ERA5) and are suitable for engineering purposes. Wind speed is essential at sea sites, affecting the system's temperature and efficiency; thus, for selected commercial panels, the PV efficiency is estimated under the studied environmental conditions using existing formulas. At the same time, monthly sea states are investigated employing ERA5 wave data, utilising significant wave height and peak period joint distributions since mild wave conditions will facilitate the long-term operation of moored FPVs. The methods and outcomes of the study reveal the suitability of the selected sites for the long-term operation of floating PVs and can be used as a foundation guide for future site suitability analysis and PV performance assessment.

Comparative Study for Selecting the Optimal Mixture as Well as the Most Suitable Origin of Biodiesel, for its Use in Internal Combustion Diesel Engines of Direct Injection

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Keywords: Biodiesel; Cooking Oils; Recycling; Greenhouse Effect

In recent decades, biodiesel has become one of the most promising alternative energy sources, as it can be a substitute for crude oil fuels. Modern scientific research has shown that used cooking oils are an excellent raw material for the production of biodiesel and bio-lubricants. Olive oil, kernel oil, corn oil, sunflower oil, cottonseed oil, pollutant "burnt" oils, end up in the sewer system or in landfills, causing significant impact on the environment, health and infrastructure, as their recycling in many countries is not mandatory by current legislation. The benefits of choosing to use biodiesel are numerous, with the mitigation of the Greenhouse effect being the most important, due to its non-toxic and biodegradable nature, since its combustion shows significantly reduced emissions of soot, sulfur dioxide and carbon dioxide. up to 85%. In addition, the recycling of cooking oils achieves both environmental and economic benefits, as it can offer energy autonomy, save natural resources, protect the food chain and reduce engine maintenance costs. The purpose of this paper is to find through experimental tests the most suitable composition of Biodiesel, produced from cooking oils, as a component of the fuel mixture used in diesel engines. In this context, two types of mixtures of diesel and biodiesel were used, with the second component participating in percentages of 5, 10, 30 and 50%. Regarding the raw material for the production of biodiesel, in the first mixture of fuel it was made from 100% frying oil, while in the second mixture it was made from a mixture of 50% frying oil and 50% soybean oil. For the tests was used a direct injection diesel engine of an agricultural tractor, on the (PTO) shaft of which, a FROMENT XT200 dynamometer was adapted accordingly. In the experiment, through the dynamometer controller, an electric braking load was imposed on the engine in order to calculate the change in speed. In the second stage, through the conversion ratios provided by the dynamometer's manufacturer, the change in power and hourly fuel consumption, depending on the speed, is determined. The tests were carried out in accordance with OECD Code No. 2 (Organization for Economic Cooperation and Development). Upon completion of the experimental stage, the comparative results between the use of pure diesel and biodiesel-diesel blends are provided in the form of characteristic curves of power, torque, total and specific fuel consumption and percentage of engine exhaust turbidity, depending on the engine's speed. The exported results determine the type of mixture and its percentage in biodiesel, which provides the engine with characteristics comparable to those of pure fuel.

Is the Cohesion Policy Efficient in supporting the Transition to a Low Carbon Economy?

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Keywords: Low Carbon Economy; Stochastic Frontier Analysis; EU countries; Value-Based DEA; robustness analysis

Cohesion Policy is one of the pillars of the European Union (EU)'s strategy in the transition to a low carbon economy. In this regard, European Regional Development Fund (ERDF) rules were created which obliged Member States, for the first time, to allocate a mandatory minimum proportion of available funding to the low carbon economy for the 2014-2020 funding period. Besides these rules, member states were mandatorily obliged to carry out assessments of the related Operational Programs. In this context, we evaluated the implementation of ERDF funds in the different beneficiary countries of the EU. Therefore, this study uses a three-stage Data Envelopment Analysis (DEA) model to evaluate the efficiency of the implementation of ERDF funds in 23 EU beneficiary countries. In the first stage, the efficiency scores of each country are obtained through the Value-Based DEA approach, which combines DEA with Multiple Criteria Decision Aiding. The second step consists of applying Stochastic Frontier Analysis to the countries classified as inefficient to obtain the input and output variables adjusted and in the third stage, considering the inputs and outputs adjusted from stage 2, the Value-Based DEA method is applied again. In the first stage, only 10 efficient countries were found, as well as the main factors that can influence the efficiency of the implementation of ERDF funds in different EU beneficiary countries. After running the SFA analysis only France remains efficient in the third stage. Additionally, a robustness analysis was carried out to the results obtained in stage 1, and it was found that when considering a tolerance of δ= 5% and δ=10% only 5 of the 23 countries remain surely efficient, with Spain being the most robust country. Finally, by considering value judgments through the introduction of restrictions on weights, Spain is chosen as a benchmark country both for the scenario more focused on the capacity of fund absorption and for a scenario more environmental prone.

vbDEA Web App Prototype

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Keywords: Sustainability; Decision Making; Optimization; vbDEA; Software; Web App

This work is aimed at presenting a web application, which is currently in a prototype phase. This application was developed in the framework of a research project devoted to the development of a tool that can help management authorities with the efficiency assessment of the implementation of operational programs (OPs) under different thematic objectives. The methodology implemented in this application is the value-based Data Envelopment Analysis (VBDEA) method, which is a non-parametric method based on linear programming that allows measuring the relative efficiency of Decision Units (DMUs), i.e., the OPs. The web application named vbDEA Web App was developed through the use different technologies, specifically it employs React to implement a responsive and user-friendly front-end that allows the execution of available operations as if it was a desktop application, and uses Python and the PostgreSQL database engine for the implementation of the back-end. The front-end allows the execution of operations common to other similar applications that implement the DEA method (e.g., DEA Solver Pro, Frontier Analyst Warwick DEA, DEA Excel solver) allowing, among others, to import text files (csv) and Excel data, particularly on the inputs and outputs of the DMUs under evaluation. Besides, it enables exporting the results to text (csv) and Excel files, manipulating the results using an Excel-like interface, the display of the DMUs' efficiency scores, and the possibility of saving the results of different executions. The next step consists of testing the developed prototype, particularly focusing on the implemented functionalities, also trying to unveil new ones that allow its enhancement until reaching the final application. Our solution is user-friendly and its purpose is to facilitate its use by management authorities/decision-makers/policy-makers for reaching well-grounded decisions with the implementation of the VBDEA methodology.

Funding: This work has been funded by the European Regional Development Fund within the framework of Portugal 2020—Programa Operacional Assistência Técnica (POAT 2020), under project POAT-01-6177-FEDER-000044 ADEPT: Avaliação de Políticas de Intervenção Cofinanciadas em Empresas.

Evaluating the Efficiency of Implementation of ERDF Funds Devoted to Research and Innovation in SMEs

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Keywords: ERDF; Research and Innovation; SMEs; EU regions; network slack-based measure; cluster analysis

Over the 2014–2020 programmatic period, the European Regional Development Fund (ERDF) provided nearly 66 billion Euros in European Union (EU) financial assistance to stimulate innovation in European firms. Small and medium-sized enterprises (SMEs), in particular, were at the heart of ERDF financial help to firms. Member states (MS) were obligated to examine the efficacy, efficiency, and impact of these financial aid programs beginning in 2014. Despite the existing plethora of studies devoted to their evaluation, there are a few concerns that receive insufficient research interest, particularly when evaluations occur throughout the implementation phase. In effect, policymakers face major challenges in designing and implementing research and innovation programs. This is especially true throughout the assessment and monitoring phases, due to the absence of relevant data, comparative evaluations, and lack of organizational skills. Furthermore, evaluation mechanisms throughout the 2014–2020 programmatic period focused heavily on analyzing process-oriented results, needing a comprehensive set of data to appraise the direct benefits of the interventions funded. Furthermore, in the case of research and innovation policies, the assessment techniques are very useful in assisting regions and countries in the enhancement of upcoming policy tools by identifying strengths and weaknesses in the previous policy cycle. In this framework, we evaluated the execution of the Operational Programs focused on supporting research and innovation, specifically in SMEs. To achieve this goal, we employed a network slack-based data envelopment analysis model in conjunction with cluster analysis, which includes multiple performance framework indicators, to evaluate 53 Operational Programs from 19 countries. Our results show that more developed regions have greater potential for improving their efficiency than transition and less developed regions. Furthermore, when compared to more developed countries, less developed regions outperform, implying that further investment should be directed at leveraging research and innovation in these regions. Overall, operational program managers should concentrate on addressing the issues that are intrinsic to these poor results, such as increasing the number of researchers working in enhanced research infrastructures and boosting technology transfer across research institutions and businesses. Funding: This work has been funded by the European Regional Development Fund within the framework of Portugal 2020—Programa Operacional Assistência Técnica (POAT 2020), under project POAT-01-6177-FEDER-000044 ADEPT: Avaliação de Políticas de Intervenção Cofinanciadas em Empresas.

Efficiency Analysis on the Implementation of European Structural Funds devoted to ICT Adoption in SMEs

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Keywords: ICT, EU regions, SMEs, DEA model, ERDF

Great expectations are placed around information and communication technologies (ICT) as enabler of structural changes that will expand European societies and enhance their economic competitiveness. During the 2014-2020 programming period, more than €20 billion from the European Regional Development Fund (ERDF) were allocated to ICT projects. It is largely consensual that ICT can provide a positive impact on firms' performance, while assisting them on the acquisition of innovative resources and on their preparing to international markets. Herein, small medium-sized enterprises (SMEs) represent a critical role since in Europe SMEs cover 99% of all firms, and are a major player regarding employment (i.e., around 100 million workers). Besides, SMEs are responsible for more than 50% of the European Union (EU)'s Gross Domestic Product (European Commission, 2022). In this context, we evaluated the execution of the operational programmes (OPs) committed to encouraging the adoption of ICT in SMEs. The literature review emphasis the scarce number of contributions regarding the implementation of ERDF initiatives to ICT scope devoted to SMEs. This study addresses precisely that literature gap and contributes with a novel methodological framework that allows policymakers (e.g. management authorities) to monitor the implementation of OPs devoted to ICT in SMEs. A non-parametric approach is used that allows to obtain insightful information to prevent and correct eventual deviations from best practices. When compared to other approaches – for example, macroeconomic evaluations, microeconomic studies that use control groups and case study evaluations – the DEA model used herein can be especially useful for management authorities (MA), because it allows to identify the benchmarks and modifications that must be done to enhance the execution of this type of funding, while also grasping the disparities between the different regions' categories. To achieve this goal, we employed a novel data envelopment analysis (DEA) model in conjunction with Stochastic Frontier Analysis (SFA), which considers performance framework indicators and environmental factors, to evaluate 51 OPs from 16 countries. The achieved results allow us to concluded that the number of operations supported by inefficient OPs was much lower than those supported by efficient OPs. Furthermore, since there was essentially no input excess, it can be established that the amount of funds devoted to enhancing the ICT adoption in SMEs was in the majority of cases suitable. However, only 5% of efficient OPs were considered robustly efficient while 59% remained robustly inefficient for data perturbations of 5% and 10%. Overall, it can be established that there is still a long way to go in order to enhance ICT adoption in SMEs through cohesion policy.

Assessing the Implementation of Structural Funds Dedicated to a Low Carbon-Economy in SMEs

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Keywords: Low-carbon economy; Structural funds; SMEs; Slack-based measure; Cluster analysis

The European Regional Development Fund (ERDF) contributes to reinforce economic, social and territorial cohesion in European Union (EU) regions. In the 2014-2020 period, member states (MS) became obligated to assess the efficacy, efficiency, and impacts of investments co-financed by ERDF funds. These assessment procedures assume a prominent role in helping regions in the improvement of effectiveness and inform decisions about current and future programming. Despite the abundance of papers for assessing EU structural funds, there are also gaps of knowledge, specifically when assessments occur throughout their implementation period. In this sense, and unlike other approaches that are specifically utilized in policy assessments (for example, microeconomic studies that involve control groups, case study assessment, and macro econometric evaluations), Data Envelopment Analysis (DEA) facilitates the efficiency assessment of operational programs (OPs) by considering the "performance framework" metrics made publicly available by the MS on the European Commission (EC)'s website. The achievements of the OPs' priorities are then reviewed through this mechanism, known as the "performance review", based on the data collected from the MS's yearly. If the programmes' aims are not met, the EC may impose financial penalties. In this context, DEA may give practical assistance in the development of future cohesion policy measures because it conveys information regarding the accomplishments and flaws of previous programmes, as well as insights on how to solve the highlighted inadequacies. Lastly, by combining DEA and cluster analysis, management authorities can explore disparities in the efficiency of OPs implemented in regions with different NUTS2 classifications. Since SMEs are the backbone of the EU economy, accounting for 99 percent of enterprises in the EU and roughly two-thirds of the total private sector employment, and their environmental footprint is therefore significant, their switchover to low-carbon processes is critical for meeting the EU's carbon-reduction target. As a result, we focused our study on ERDF-funded initiatives, which account for 70.5 percent of all EU structural and investment funding allocated to this area. This study evaluated 102 programmes from 22 countries using a non-radial slack-based DEA model paired with cluster analysis that encompasses distinct performance framework indicators. Overall, we found that 25 efficient OPs remained robustly efficient, while 51 remained robustly inefficient. Besides, we concluded that 25 efficient OPs remained robustly efficient, while 51 stayed robustly inefficient for data disturbances between 5% and 10%. There was practically no input excess at the present output level. As a result, efforts to foster a low-carbon economy should handle the issues that are causing poor outcomes, both in terms of greenhouse gas emissions reduction and the pace of programmes execution.

Improvement of Alternative Fuel Pellet Processing by Means of Torrefaction, Nanoparticles and Subsequent Thermal Degradation for Higher CO2 Capture

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Keywords: Environment; Torrefaction; CO_2 Capture;

In the context of research into the possibilities of reducing pollutant emissions, with a focus on reducing CO2 production and capture, production and research into alternative fuels related to this trend and associated technologies, it is possible to observe significant progress not only in the EU thanks to the enacted legislation, but also at international level. The so-called the "Green Deal" in its extreme form, as originally established the EU leadership, cannot be implemented as a result of Russia's military aggression against Ukraine, and it will therefore be necessary to adapt to a more realistic option. Now it will be possible to listen more to the proposals of technical experts in the field, which are based on facts and physical laws, and to pursue the real economic needs and energy realities of the European countries, rather than blindly following the gloom of ecological fanatics and politically correct decisions. On the basis of the obtained knowledge, our research team investigated the possibility of CO2 capture using algal cultures, with their subsequent application to an alternative biofuel in the form of pellets for further processing. By torrefaction of the pellets under the given process parameters, it was possible to further apply them as fertilizer and an anti-erosive component of the soil stock. In the next phase of the research, new algal cultures were applied and the research also focused on the possibility of additivation of the pellets with nanomaterials for their further use and energy recovery without additional CO2 emission production. We stated the aims of the research on the fact that if the resulting product in the form of pellets is not used for various reasons as fertiliser etc., their further direct processing - e.g. incineration - is inappropriate. The reason is the release of CO2 back into the atmosphere, which is then counterproductive. Therefore, a more appropriate method of energy recovery was proposed and new material mixture prepared. For testing, new device was developed and successfully registered in the field of national and international patent protection (PCT). Subsequent research is being carried out into the higher thermal processing of such a prepared mixture, where thanks to the set procedures it is possible to further separate gas from the pellets with increased calorific value and more suitable composition for subsequent energy use, e.g. in internal combustion engines. As a result, CO2 is captured in the new algal cultures, and due to the additivation and the new process control the CO2 component is converted into more favourable gas components (in terms of energy and emissions) and is not subsequently released into the atmosphere. This gives us the advantage of environmentally produced energy in the form of heat, electricity or cooling, while minimising the production of greenhouse gases.

* Acknowledgement: This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic under OP RDE grant number CZ.02.1.01/0.0/0.0/16_019/0000753 "Research centre for low-carbon energy technologies".

Carbon Pricing in Germany's Road Transport and Housing Sector: Options for Reimbursing Carbon Revenues

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Keywords: Electricity tax, housing benefits, distributional effects;

In 2021, Germany launched a national emissions trading system (ETS) in its road transport and housing sectors. This climate policy instrument aims at raising the cost burden of consumers of fossil fuels, the major source of carbon dioxide (CO2) emissions. A promising approach to secure public acceptance for such a carbon pricing would be to entirely reallocate the resulting "carbon" revenues to consumers. This article discusses three alternatives: a) a per-capita reallocation to private households, b) the reduction of electricity prices by, e.g., decreasing the electricity tax, as well as c) targeted financial aid for vulnerable consumers, such as increasing housing benefits. To estimate both the revenues originating from carbon pricing and the resulting emission savings, we employ a partial equilibrium approach that is based on price elasticity estimates on individual fossil fuel consumption from the empirical literature. Most effective with respect to alleviating the burden of poor households would be increasing housing benefits. While this measure would not require large monetary resources, we argue that the remaining revenues should be preferably employed to reduce Germany's electricity tax, which becomes more and more obsolete given the steadily increasing amount of electricity generated by renewable energy technologies. Alas, reimbursing "carbon" revenues to consumers in the form of an electricity tax cut or, alternatively, by per-capita transfers is not foreseen by the German government. Rather, carbon revenues are scheduled to support a large spectrum of policy measures, such as increasing the subsidies for the purchase of electric vehicles from 4 to 9 thousand euros and increasing the commuting allowance of a driving distance to work as of 20 kilometers to outweigh the higher costs of driving due to carbon pricing. Such measures hardly yield any environmental benefits and may even foster counterproductive behavior. Moreover, they tend to favor wealthy, rather than poor, households and are thus questionable from both an ecological and a social policy perspective. Instead, to sustain the currently wide acceptance of carbon pricing in Germany if carbon prices should rise substantially, which is indispensable for reaching the national emission reduction goals, it is critical that the government establishes measures to primarily favor poor households and alleviate their burden originating from carbon pricing.

Computer Simulation and Energy Optimization in Municipal Wastewater Treatment Plants: A Case Study of Larisa City WWTP

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Keywords: WWT plant; biological treatment; energy saving; energy optimization; aeration control;

Biological treatment requires high energy consumption in municipal wastewater treatment plants (WWTPs). The objective is to minimize energy consumption, while achieving the wastewater quality standards, on a real scale, in the existing WWTP of Larissa, Central Greece. An energy management system according to ISO 50001 standards will be implemented. Key indicators will be defined and energy optimisation will be continuously updated. We focus basically on the control of the secondary treatment process and then on sludge management. Energy savings of about 25% have been recorded in WWTPs due to interventions in aeration equipment, automation system and even in the P&I diagram. The secondary treatment plant in Larissa includes two lines with diffuse aeration and two with surface aeration systems. For process control, inverters and on-line measuring instruments (DO, N-NH4, NO3, MLSS) have been installed. The inverters regulate the operation of each blower or pump according to the response of the appropriate instrument. Thus, aeration control is applied to the diffused aeration system in order to maintain dissolved oxygen (DO) at specific levels according to NH4 values. Secondly, the NO3 meter in the anoxic tanks controls the internal recirculation ratio. Also, the MLSS meter in the secondary clarifiers controls the pumping rate of the excess sludge. At least 3 months of data are presented. These processes help to meet the respective requirements for the biochemical processes performed in the biological reactor and avoid overconsumption of energy. Energy consumption is recorded before and after the process control with energy loggers at each electrical panel. Energy consumption data from the PPC were also available. This quantified the energy savings in the WWTP due to changes in operation and verified the theoretical values. At the same time, the energy data of the WWTP operation are compared with the response of the Hydromantis GPS-X model. GPS-X simulates the operation of the entire plant to provide the energy consumption, carbon footprint and effluent quality from each unit. Several scenarios are presented in this study. Firstly, the operating processes were simulated without process control. The model responded correctly compared to the measured values. The DO-NH4 control scenario, simulated the control of aeration in diffused aeration systems. In this case the energy consumed in the aeration tanks could be reduced by 40-50%. The DO-NH4 and NO3 control scenario showed less energy savings when aeration control was performed in combination with the control of the recirculation pumps. Process control in the surface aerators is also simulated in the GPS-X model. A reduction in energy consumption (about 50% in the aeration unit) is obtained when a suitable control system with DO aeration control is installed in the surface aerators. The proposed interventions in the Larissa WWTP contribute to a substantial reduction (about 20%) in total energy consumption, with relative savings in operating costs. Further recommendations are made and the operational parameters in the other processing steps are examined in terms of energy consumption and optimization according to the requirements of ISO 50001.

Recent Advances in Biogas Plants and Treatment of Liquid Digestate

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Keywords: biogas plant; liquid digestate; vacuum evaporation; biomethane;

Biogas production by anaerobic digestion is one of the most promising ways of fully utilizing green energy in the circular economy. Biogas is considered the future of renewable and sustainable energy. Anaerobic digestion is the standard technology for biogas production mainly due to its lower energy consumption and its dependence on microbiology. Biogas can be upgraded by separating carbon dioxide and hydrogen and thus increasing the methane share. Biomethane production is currently sky-rocketing in Europe. Biogas and biomethane are both renewable and sustainable gases.

The biogas industry has been growing significantly in Europe since the 1990s. The expansion of biogas plants in recent years has been associated with increased production of digestate, as biogas plants are its significant producers. Liquid digestate is a rich source of nutrients, however, the concentration of the main nutrients (N, P, K) is low compared to commercial fertilizers. Therefore, there is a possibility to extract these essential elements from this waste stream, but the technologies for nutrient recovery are usually very costly, which hinders their more comprehensive application.

Although, problems with higher production of liquid digestate and its use in unprocessed form as a fertilizer for crops may occur in areas with increased intensity of the agricultural production, which are characterized by high concentrations of fertilizers in the soil or groundwater. Thus, even in such an environmentally friendly process, the liquid digestate produced from the residue of the decomposing bio-feedstock will require further processing.

Vacuum evaporation is well known from desalination processes. It is also a proven technology used to separate water from digestate. By using vacuum evaporation, the volume of liquid digestate can be reduced with the majority of the nutrients staying in this output stream. Thickened digestate can be processed, for example, in a crystallizer, where the aim is to produce struvite crystals and thus recycle essential elements. Struvite is an effective slow-release fertilizer with a relatively low content of contaminants, which can replace industrial fertilizers produced from phosphate rock.

Vacuum evaporation is a technology with wide possibilities of application. The advantage of evaporators is the ability to utilize waste heat, which is usually in excess in biogas plants. This paper will therefore describe the recent advances in biogas production, liquid digestate processing and then describe the possibility of treatment using evaporation technology. In our Laboratory of Energy Intensive Processes at BUT, evaporation technology has been used to process and recover water from wastewater not only from biogas plants, but also from industries such as laundries and wineries.

Acknowledgement:

This research has been supported by the project No. CZ.02.1.01/0.0/0.0/16_026/0008413 “Strategic partnership for environmental technologies and energy production”, which has been co-funded by the Czech Ministry of Education, Youth and Sports within the EU Operational Programme Research, Development and Education, and by the project from the TACR under the TREND Programme (Project FW03010481).

Novel Correlations of Saturated Flow Boiling Heat Transfer and Evaporating Flow Boiling Pressure Gradient

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Keywords: Two-phase flow; Flow boiling heat transfer; pressure gradient; correlation

Predictions of saturated flow boiling heat transfer and evaporating flow boiling pressure gradient have been important research topics for several decades. They are important design parameters for heat exchangers, evaporators, condensers and heat pipes. Accurate prediction of saturated flow boiling heat transfer and pressure gradient can reduce the cost and design of many energy-saving systems. In this work, the improved correlations of saturated flow boiling heat transfer and two phase pressure gradient for evaporating flow were presented. In First part, evaluating the exist correlations of saturated flow boiling heat transfer with 2500 experimental data points including 7 refrigerants (R22, R134a, R410A, R32, R513A, R1234yf and R1234ze), with hydraulic diameter from 1 to 7 mm, and propose the improved heat transfer correlation. According to different flow boiling regimes, the improved correlation of saturated flow boiling heat transfer divided into two regimes, convective boiling dominant and nucleate boiling dominant heat transfer, is demarcated by parameter K. The improved correlation has best prediction for the database, with a Mean Absolute Error (MAE) of 11.28%, and over 80% of the data within ±20% error bands, and improves the prediction of nucleate boiling dominant with a MAE of 14.6%. In the second part of this study, evaluating the 1954 experimental data points of evaporating flow boiling pressure gradient, including 7 refrigerants (R22, R134a, R410A, R744, R717, R1234yf and R1234ze) with hydraulic diameter from 0.509 to 14 mm, and propose a new pressure drop correlation, introducing the Bond number and Froude number. The new correlation of two-phase frictional pressure drop has much better prediction for the database, with a MAE of 19.07%, and 63.5% of the data within ±20% error bands, and new correlation improves remarkably the prediction for micro-channels with a MAE of 25.3%, because of the new correlation considers the influence of gravity and surface tension.

Reservoirs for Flood Control and Restraint. A Case Study for Larissa City, Greece

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Keywords: Climate Change; Flood Protection; Water Management; Soil Erosion; Natural Disaster Management

Floodings do not stand for a hazard that appeared in recent years, but the late decades has become a frequent phenomenon that produces huge economic consequences, as well as human losses occasionally. On a large scale, such phenomena could be referred to occur once every ten years, yet on smaller areas, may occur on annual basis, posing insurmountable obstacles to the development and prosperity of a region. Unfortunately, some settlements are affected by flooding even with low levels of rainfall. In general, the region of Thessaly, which is characterized as a rural area yet with large urban centers and crossed by many rivers with the Pinios being the largest of them (262 km length), stands out among the most flood-prone areas of Greece. Two of the most serious flooding incidents took place in October 1994, where the rainfall in one day as recorded by rain gauges in Argithea and Karditsa, has been measured to be over 300 mm, and in September 2020, where in Pertouli and Mouzaki the rainfall was over 250 and 300 mm, respectively. In both cases, the floods destroyed thousands acres of crops, as well as many settlements and caused several human losses. Phenomena of flooding that occur in Thessaly affect to a high degree the city of Larissa, since the rivers and large streams from areas of Karditsa and Trikala end up in the river Pinios. The main stream of the river runs through the northern side of Larissa and in a short distance from the districts of Nea Smyrni, Ampelokipi, Ippokratis and Agios Thomas. A tributary of Pinios river, flows through Larissa around the districts of Hippokratis and Ampelokipi, working as a relief zone in periods when Pinios has very high-water levels. Along the river and its tributary there are dikes that protect the city of Larissa, as well as pipe sluices, which prevent water from entering the city through the stormwater network. The above-mentioned areas included in the high-risk zone and have been affected from time to time from floodings, present damages in the cultivated fields on both sides and along the Pinios, mainly near the district of Agios Thomas and Nea Smyrni. During the last flooding event in mid-January 2022, the level of water in those areas reached up to 2 meters high. The present case study investigates the construction of a reservoir, primarily for the relief of flooding, in case the river level rises to the overflow point. The location of the proposed

reservoir is at the west of the prefecture of Larissa, nearby Gounitsa straits. During the survey, the construction of a reservoir with a capacity of approximately 5 million cubic meters of water, as well as the construction and operation of a pumping station are about to be studied. The potential of the pumping station is a flow rate over 30 m3/sec that is estimated to fill the reservoir with water, within 2 days. A shaping of the bed and banks of river, as well as a special sediment retention device, are meant to lead the water to the pumping station. Finally, the benefits of reducing flooding events, as well as the future uses for that specific construction are highlighted and the relevant construction cost is calculated, accordingly.

Decision Making on Integrated Hybrid Renewable Energy Systems Design

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Keywords: IHRES; Decision Making; Modelling; Simulation; Optimization

There is a significant number of research and several software on modelling, simulation, and optimization of hybrid renewable energy systems. But there are still many open questions and methodological challenges in the decision making on integrated hybrid renewable energy systems (IHRES) design. The main reasons for this are the difficulties in correctly considering uncertainties such as the stochastic nature of renewable energy sources and/or the fuzziness of the environmental impact of the practical implementation of these systems. The first question that arises when deciding on the IHRES design is under which conditions a renewable energy system becomes competitive with a conventional one. The criterion proposed in this study is intended to answer this question. This criterion integrates both technological and economic competition between conventional and renewable energy systems. The study also discusses different formulations of optimization problems for the IHRES design, such as deterministic, stochastic, and probabilistic ones and the models in classical mathematical programming and simulation optimization-based forms. The advantages and disadvantages of these formulations are discussed. Special attention is given to the models' so-called "bad" properties such as potential multimodality and/or flatness of the objective function and/or constraints. It is shown that avoiding these properties for real-life systems is often methodologically difficult and inexpedient without losing the essence of the model and its practical value. The study discusses approaches and methods for solving optimization problems of the IHRES design with such "bad" properties using modern metaheuristic algorithms. The peculiarities of optimization problems in the IHRES design with mathematical expectations and value-at-risk criteria are discussed as well. Also, it is demonstrated that it is not always reasonable to avoid the risks, even if there are such possibilities. The difference between the right decision and the formulated problem's optimal result is discussed. So, this study demonstrates approaches and methods for solving some open issues and challenges in decision making on IHRES design. The findings of this study are a) the proposed criterion for estimation of techno-economic competitiveness of renewable energy system compared with a conventional one, b) comparing the optimization problems in deterministic, stochastic, and probabilistic formulations, c) analysis of the optimization problems with mathematical expectation and value-at-risk as the objective functions, d) understanding the reasonability of not always trying to avoid the risks, and e) understanding the difference between a right decision and an optimal result.

Analysis of the Performance of an Industrial Dryer Developed for Dewatering Sewage Sludge

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Keywords: Sewage sludge; drying, waste management;

The rapid growth of the global population, mainly in urban areas, combined with the more restrictive standards of wastewater treatment before the release of water into the environment, has led to a significant increase in the production of sewage sludge (SS). While there is no consensus on the best method to manage SS, the best options are the application as a soil amendment to enhance the organic matter and nutrients or as biofuel in incineration plant. The application of SS into the soil can be a win-win solution because it is in line with the circular economy plan and reduces the costs and dependency of the European Union on imports of phosphorus. Although it can be a significant contribution to the pool of terrestrial organic carbon and nutrients, the agricultural application of SS is not consensual since potentially toxic metals, contaminants of emerging concern, and pathogen microorganisms are also present in its composition. Also, the emissions of bad odors during the management phase, namely hydrogen sulfide have a negative social impact. One the other side, if the option is the application of SS as biofuel the heat value and emissions of flue gas and fly ash are a critical point. Whatever the option, the high water content of SS at the begin of the process is a problem, so low energy consumption is expected for dehydration. Although several studies have been carried out at laboratory scale to characterize drying process, no one made an approach to real scale of a dryer for SS. The aim of this study was the construction and test of a pilot scale dryer for SS. The dryer is based in the transportation of a thin layer of SS by a belt of 2x8.3 m in a tunnel with a convective flow. The hot air for the dryer was obtained through a heat exchanger that use the energy of combustion products of syngas from a biomass pyrolysis furnace. The drying system built allowed to control the temperature and mass flow of hot air and the velocity of the belt, as also the layer thickness of SS. A blade paddle in the middle of the tunnel allowed to mix the SS breaking the superficial layer of SS, helping dryer performance. The test included the records of the humidity of SS at the begin and end of the tunnel as a function of the temperature and flow of hot air and the analysis of particles and gas emissions from the dryer.

Demand Pooling, Optimal Pricing and Infrastructure Decisions in a Novel Electric Vehicle Business Model

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Keywords: Electric Vehicles; Charging Infrastructure; Game Theory

Electric vehicles are considered as one of the main drivers to transition to a greener society. Their purchase price, the range that is travelled with a single charge, the number and location of charging stations as well as the price of electric energy are the key factors regarding electric vehicle adoption. This work explores a business model with three entities that leads to a competition between two of them: an electric energy retailer and an electric vehicle retailer. The third entity is an organization that desires to replace its conventional vehicles with electric ones and achieve lower energy and vehicle prices for itself and its members to increase member benefits and electric vehicle adoption. Both retailers are rational and decide on the unit profit of their respective products. The vehicle retailer also decides on the number of charging stations that will be installed at the organization's premises, shouldering part of their installation cost, in anticipation of an increase to demand. The main contribution of this work is the derivation of the optimal decisions of each retailer when they make decisions either simultaneously or sequentially. Moreover, the sensitivity of the results to parameter deviations around a case study's parameter set is examined. The results provide guidance both to academics and practitioners about pricing and charging infrastructure decisions.

Can Cyprus Embrace Carbon Neutral Electricity and Transport Sectors?

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Keywords: Carbon neutral, CO_2 footprint, renewables, electric vehicle fleet, emissions targets, power storage.

Besides being the only electrically isolated island of the EU, Cyprus is unique in that it predominantly relies on liquid fossil fuels for its power generation. Meanwhile, endowed with abundant solar irradiance the island can generate most of its electricity from photovoltaic parks. Concurrently, being a medium sized island Cyprus could serve as a testbed for a full electric vehicle fleet. Being an EU Member State, Cyprus will have to curb its carbon dioxide emissions by 55% by 2035 while the island state ought to become carbon neutral by 2050. Motivated by the preceding EU climate goals in this talk we will present the future electricity needs and the land vehicle fleet size of Cyprus, the latter of which accounts for 77% of the island's emissions. In parallel, stretching between 2018 and 2050 we implement a full electric fleet of passenger vehicles and buses. As far as power generation is concerned, four distinct scenarios, were formulated. As its name implies the Least Cost (LCSc) scenario endeavours to generate the most economically competitive electricity while the Business As Usual (BAU) case draws from the prevailing electricity trends. Utilising carbon capture technologies, the Carbon Capture and Storage (CCSc) scenario aims to remove from the atmosphere the power sector's carbon emissions. Lastly, the Renewables (RESc) case rests on a fully renewable electricity generation sector powered primarily by renewable energy sources. Weekly hourly profiles of electricity production and consumption were calculated in the context of winter and summer seasons. Moreover, the power grid's electrical load was calculated by considering passenger vehicle-to-grid units and desalination plants. At 0.115€ per kilowatt-hour, the RESc generates the most expensive electricity while accompanied by the highest electricity losses (40%), in year 2050. Strikingly, a domestic battery storage of 5,600MWh will be required to satisfy the island's electricity needs by the preceding year. To put things in perspective, Europe's current battery capacity is estimated at 3,400MWh. In relation to the of EC's goals, the BAU and the LCSc cases are unable to satisfy the 2°C emissions requirement while the CCSc conforms with the preceding target. Concluding, power generation drawing entirely on renewable energy sources (RESc) is poised to be entirely carbon free by 2050.

A Method of Increasing the Ductility of Shear Walls Integrating Structural Steel Hollow Beams and their Sustainable Design

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Keywords: Walls; ductility; slip; steel hollow beam

Several researchers propose placing diagonal reinforcing bars at the base of the wall to treat the shear slip, while others have suggested various ways to address this problem associated with halting the effects incurred by the through-crack in the base of the wall during cyclic loading. An indicative proposal of the bibliography is the use of large diameter reinforcement bars in the web of the wall as vertical reinforcements, so as to be able to better control the shear action through the dowel action of these bars. The two aforementioned proposals, while adequately addressing the phenomenon of shear slip, present significant disadvantages. The use of diagonal reinforcement is very difficult to construct, because of the density of the existing reinforcement in the base of the walls, which involves compromising good concrete condensation. Also, the use of large diameter vertical reinforcement along the length of the whole wall section, including its web, is a strongly uneconomical solution. This work examines a solution without the aforementioned side-effects. The innovation of the present work is the fact that it positions stoppers in combination with the use of conventional reinforcing bars at positions in the critical zones of the walls, in order to prevent the expected slip along the through-crack in the base of the rigidly supported wall. The work is experimental and includes two stages. The first stage was carried out with the construction of six test specimens, which can be considered as preliminary base specimens used for a first examination of the mechanical behavior of the walls with integrated steel hollow beams at their ends. These test results are a prelude to the second stage of the present study, including the experimental investigation of the seismic mechanical properties of a wall specimen, detailed either with conventional reinforcement according to EC8 or with the same conventional reinforcement but including also steel hollow beams at its confined edges. Moreover, some thoughts on a more sustainable design of R/C seismic walls are stated.

Electric Vehicle Routing for Sustainable Last-mile Delivery Services

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Keywords: electric vehicle routing, energy pricing, sustainable last-mile delivery, mixed integer optimization

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.

Experimental and Analytical Study on Out-Of-Plane Buckling of R/C Structural Walls Due to Intense Seismic Action and Their Sustainable Design

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Keywords: Lateral instability; seismic walls; flanges; wall thickness; tensile strain

One important aspect of the seismic design of buildings with a dual reinforced concrete structural system is the lateral stability of the shear walls, when they face this danger due to flexural overstrain. The deep excursion in the yield region, which is allowed because of the continuously growing maximum acceptable tensile strain (which reaches 25‰, from an initial value of 5‰) of the confined boundary parts of the shear walls, dramatically increases their flexibility. At the same time, earthquake vibrations make the walls liable to reverse axial loading (tension – compression) and their lateral stability is at stake. The possibility of failure because of lateral instability is significantly limited by the proper choice of an adequate wall thickness. Recently, there have been international concerns about the seismic behaviour of structural walls, mainly concerning their lateral instability under intense seismic loading. Seismic codes are well-known and approved of internationally and they have moved to more conservative choices, concerning the minimum thickness of shear walls. The current study deals with these aspects in an analytical and experimental manner and examines the influence of other parameters (apart from the height), such as the mechanical reinforcement ratio of the shear wall. An analytical procedure was carried out to estimate a new equation for calculating the minimum required wall thickness. The results of this equation are compared with the equations proposed by various researchers. The analytical procedure was followed by an experimental investigation comprising five test specimens. These specimens modelled the confined boundary edges of structural walls, which were strained to different degrees of elongation. The tensile loading was followed by a compression loading until the failure of the specimens. This type of two stage loading simulates the cyclic loading during an earthquake action. The analytical results are compared with the experimental results and useful conclusions arise. Moreover, some thoughts on a more sustainable design of R/C seismic walls are stated.

Solving the Non-Linear Waste Water Treatment Network Design Problem by Benders Decomposition

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Keywords: Waste Water; Non-Linear Programming; Benders Decomposition;

Water is vital not only for the humans but also for every form of life. Thus, the protection of the water environment is the key for sustainability. For this reason, waste water treatment is a very important process that removes contaminants from sewage and converts it into an effluent with acceptable impact when returned to the environment. This work studies the Waste Water Treatment Network (WWTN) design problem when it comes to the connections between the residential and industrial areas with the Waste Water Treatment Plants (WWTP). Moreover, the installation of distributed treatment elements in the network such as the Micro-Filtration (MF) and Reverse Osmosis (RO) systems is examined. The authors have taken into consideration the expansion and operational cost of an existing WWTP and the installation and maintenance cost both of gravitational or pumping pipeline connections between the residential and industrial areas and the WWTPs and of the MF and RO systems. The main characteristic of such a problem is that all the aforementioned cost functions are non-linear and especially they have a concave form. For example, the operational cost per waste water treatment capability of a WWTP is high if the capability is low and it becomes lower when the capability is higher. In other words, the bigger a WWTP is, the cheaper it is in terms of cost per capability. This is a typical characteristic of the economies of scale that rule such networks. Thus, the authors have developed a mathematical formulation as a Mixed-Integer Non-Linear Problem (MINLP) with the non-linearity being in the objective cost function. The model is linearized by using the piecewise-linearization function and especially its bounded variable variant. In order to examine the possibility of solving large-scale problems, the Benders decomposition method is applied. The authors implement three different approaches of Benders decomposition on the MINLP: 1) First Linearize, then Decompose, 2) First Decompose, then Linearize and 3) First Decompose, then Linearize and Accelerate. The developed techniques are applied on a case study in a region of the Luxemburg state where an existing WWTN is already established. Based on the estimated population growth of the residential and industrial areas under study in a 40-year time horizon, the solution proposes the optimal re-design of the WWTN with a minimum total cost. Regarding the computational results, the non-decomposed approach solved by CPLEX outperforms all the rest techniques. However, the developed Benders approach No 3 is the second fastest one with promising solution time.

Blockchain based Supply Chain Network Design

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Keywords: Supply Chain, Transportation, Fresh Produce

Modern supply chains involve multiple global players with different standards, quality, work ethics, and government regulations. It is common to source raw materials from one continent, manufacture in another, and store and serve markets all over the world. With more information available, customers are demanding more transparency before buying a product. Blockchain technology offers capabilities that can support this endeavor. Information can be shared in real-time among all players in the chain as well as with the consumers, increasing transparency and product traceability. Furthermore, with this newly available data, a new prospect on customer segmentation based on data visibility preferences is possible. While numerous papers discuss the benefits of blockchain adoption in supply chain operations management, the strategic design of supply chain networks with blockchain technology is key to ensure the profitability and the sustainable operation of these networks. In this research, we propose a supply chain network design optimization formulation that accounts for blockchain technology adoption. We particularly focus on the design of a supply chain network for fresh produce. Using a realistic use case of fresh cut flowers and the associated supply chain in Canada, we illustrate key challenges and opportunities for integrating blockchain technology for tracking the freshness of products as they are transported from producing farms to end consumers. While blockchain offers key capabilities in terms of data visibility, tracing, and accountability, the results show that the cost of this technology can have adverse effect on the average freshness of the products that are sold to end consumers, the profitability of the supply chain, and the overall cost to the customers. Strategically choosing the parts of the supply chain where blockchain technology is deployed, can limit this negative impact and more importantly can make the supply chain less sensitive to blockchain costs and changes in consumer demand.

CFD Modelling of Water Flow Field in Open Channel

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Keywords: hydrodynamic conditions; flow energy; CFD; numerical simulation.

Water resources distribution and the hydrological regime of many aquatic systems have been altered by climate change and human activities with implications for environment and ecosystem consistency. Climate change plays an important role in regulating the structure and function of aquatic ecosystems. In the last decades, the effect of climate change on precipitation and surface temperature distribution is constantly increasing. High intensity precipitation in a short time and rapid temperature changes significantly affect local ecosystems by increasing or decreasing the water surface elevation in natural rivers. Additionally, the hydrodynamic characteristics of a natural river, including the velocity magnitude and timing of maximum or minimum discharge are important parameters of its ecological functioning. Climate change influences these hydrodynamic characteristics and causes ecological changes in inland aquafers and river ecosystems. Therefore, an accurate estimation of river flow patterns with main hydrodynamic parameters, such as water surface elevation, velocity distribution and flow regime conditions along with the prediction of fluid behavior in natural or experimental channels is essential for an effective flood prevention and ecosystem management methodology. Computational Fluid Dynamics (CFD) is among the most important tool for the numerical simulation and analysis of such environmental problems. CFD models based on fluid mechanics principles are an accurate modeling tool for the computation of flow hydrodynamics and its energy characteristics utilizing numerical methods and algorithms. In the current research work the computational fluid dynamics Flow-3D finite-volume model is applied in order to numerically simulate free-surface flow variation through a non-fixed open channel geometry under different flow regime conditions. The three-dimensional Reynolds-averaged Navier-Stokes equations are numerically solved for laminar and turbulent flow conditions. A supercritical flow regime and a mixed flow regime simulation are applied in a converging open channel and variation of different hydraulics parameters is reported. For each test case, computed free-surface flow results of water depth variation were compared with available experimental measurements to evaluate the ability of the simulation procedure in estimating hydrodynamic parameters distribution that affect inland watersheds and natural river ecosystems.

A Technology-to-System Approach to Compare Electrification and Hydrogen Heat Decarbonisation Pathways

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Keywords: electrification; energy system; heat pump; hydrogen; net-zero.

Reducing the high carbon footprint associated with space heating, space cooling and hot water in the residential sector remains a challenge in many economies. Currently, natural gas is responsible for more than 70% of the provision of heat to buildings in the UK and the Netherlands, with countries like Italy, Canada, United States, Germany and France close behind. Furthermore, several countries including Belgium, Ireland, Portugal and Greece still experience a high penetration of oil products (more than 20%). Transition pathways for moving away from fossil fuels in domestic heating and cooling focus on electricity and hydrogen. Electrification would be implemented by using electric vapour-compression heat pumps. On the other hand, hydrogen-based heating systems would involve hydrogen substituting fossil fuels in boilers or being used in thermally driven absorption heat pumps. In this talk, we present our recent work on developing a thermodynamic and economic methodology to assess the competitiveness of three domestic heating technologies: (i) electric vapour-compression heat pumps; (ii) standalone hydrogen boilers; and (iii) ammonia-water absorption heat pumps driven by heat from hydrogen combustion. The three technologies are compared for different weather/ambient conditions and fuel-price scenarios under a unified framework, first from a homeowner perspective and then from a whole-energy system perspective. For the former, 2-D decision maps are generated to identify the most cost-effective technologies for different combinations of fuel prices. The UK, which is one of the countries with the lowest uptake of heat pumps and the highest electricity-to-gas price ratios in Europe, is used as a case study, but since the comparison is conducted for various fuel prices, insights can also be obtained for countries with different characteristics. For electricity prices close to 0.20 £/kWh, hydrogen boilers and absorption heat pumps can only compete with electric heat pumps if the price of hydrogen can be below 0.10 £/kWh. If hydrogen is produced by water electrolysis, given the current estimates for the costs of the required equipment, the associated predicted retail price of hydrogen is much higher (0.18-0.25 £/kWh), making electric heat pumps the most cost-effective option. From a whole-energy system perspective, the total system cost per household (which accounts for upstream generation and storage, as well as technology investment, installation and maintenance) associated with electric heat pumps varies between 790-880 £/year for different energy-system decarbonisation scenarios. If hydrogen is produced by electrolysis, the total system cost is almost double, varying between 1410-1880 £/year. On the other hand, if hydrogen can be produced cost-effectively by methane reforming and carbon capture and storage, the system cost can drop down to 1150 £/year.

A Hybrid Cycle Combining Fuel Cell, Internal Combustion Engine and Thermochemical Recuperation for Transportation Propulsion Systems

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Keywords: Electrochemical reaction, Combustion, Finite-time thermodynamics, Finite-speed thermodynamics, Fuel cell.

Numerical and analytical investigation of energy conversion into electrical and mechanical work in a hybrid cycle combining fuel cell (FC), internal combustion engine (ICE) and thermochemical recuperation (TCR) was performed. Hybrid cycles that composed of a fuel cell and a bottoming combustion or a heat engine have been studied since 1990s [1]. Efficiency gain with the bottoming cycle heat recovery was achieved. Chuahy and Kokjohn [2] performed detailed analysis of a hybrid powertrain with a solid-oxide fuel cell (SOFC) and ICE and reported a 70% thermal efficiency of the system. Both SOFC and ICE can use the same fuel, and fuel reforming using TCR can be integrated as the waste heat recovery method from both FC and ICE. The current study focus on power-efficiency relation of the mentioned above cycle. Irreversible thermodynamics principles was used for that purpose. This analysis is of high importance for transportation propulsion since specific power affects the travel range and the powertrain weight and size. The analysis of heat engines that undergo irreversible interactions with its reservoirs was performed for the first time by Novikov in 1957 [3] and later by Curzon-Ahlborn in 1975 [4]. They were able to express the efficiency at maximum power of a heat engine. In our study, finite-time thermodynamics was employed to account for the different efficiency dependency on energy conversion rate of each process involved in the cycle. Fuel cell zero-dimensional (0D) model was employed to simulate the electrochemical reaction in a solid-oxide FC (SOFC), and a finite-speed finite-time thermodynamics (FST-FTT) model of spark-ignition internal combustion engine (SI-ICE) was created for the combustion process simulation. The prediction results show that without TCR, in the range of cycle efficiencies between 50% and 60% there is a potential of power gain by the hybrid cycle compared to the FC. The achievable efficiency levels are much higher if waste heat recovery through TCR is employed. In such a case, the cycle efficiency can reach values above 70% with a significant power gain compared to FC operating alone. However, in almost any conditions, a maximal specific power is inferior compared to the ICE.

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Treatment of Hydroponic Drainage in a Electrochemical Reactor

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Keywords: energy efficiency; electrochemical purification; industrial wastewater

Electrocoagulation (EC) enables removing various types of pollutants and is claimed to be more effective that conventional chemical coagulation as it generates lesser amounts of sludge. In addition, it does not require additional chemical agents and is characterized by low electric energy consumption. Horticultural wastewater (drainage) is generated during soilless plant cultivation in an open system, wherein - after the flow through the cultivation system - the nutrient medium is usually discharged to surface waters or to greenhouse ground. Due to the high content of nitrogen and phosphorus, drainage should be treated before it may be discharged to the natural environment. Electrocoagulation has for years been extensively investigated to identify its viability in removing phosphorus compounds from wastewater and surface waters; hence, the aim of this study was to determine the effect of three intensities of direct electric current on the effectiveness of hydroponic drainage treatment in a fed-batch electrochemical reactor. Drainage used in the study derived from soilless tomato cultivation in an open system. The study examined 3 intensities of electric current, i.e. R1-0.045 A, R2-0.136 A, and R3-0.283, at drainage hydraulic retention time of 24 h. An anode made of iron sheet was mounted inside the reactor, while rotating reactor discs with a total surface area 0.113 m2 served as a cathode. The electric current was sourced from a laboratory power supply (HMP4040, Rohde & Schwarz, Germany). A similar effectiveness of phosphorus removal (88%) was achieved at current intensities of 0.045 A and 0.136 A. Increasing current intensity to 0.283 A enabled removing 99% of phosphorus from the drainage, which corresponded to its recovery rate of 86.82 mg P/L*d. Nitrogen removal efficiency in electrochemical treatment processes was significantly lower and reached 3.20%. The use of electric current resulted in increased concentrations of ammonia nitrogen and nitrite nitrogen in the treated drainage. The use of electrochemical processes in horticultural wastewater treatment enables almost complete recovery of total phosphorus and only a slight reduction of nitrogen compounds. Thus, electrochemical processes may prove viable in aiding other processes deployed for drainage treatment, especially in the case of phosphorus compounds.

Funding

The study was part of the project “Development a precise treatment of wastewater from soilless tomato cultivation technology using electro biological hybrid reactor” as part of the LIDER X programme, financed by The National Centre for Research and Development No. LIDER/4/0019/L-10/18/NCBR/2019. Co-financing amount: PLN 1,492,500.00.

Pulsed Electric Fields or Ultrasound - Comparison of Pretreatment Methods in Biogas Production from Rapeseed Straw

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Keywords: Pulsed electric field; ultrasound , pretreatment, methane fermentation; biogas;

Lignocellulosic biomass is an easily-available, and proliferative raw material than can be successfully converted in bioenergy, including methane-rich biogas. In order to increase the amount of gas produced from lignocellulosic materials, it is necessary to optimize the fermentation process by, e.g., substrate pre-treatment. The goal of this study was to compare effects of two methods of rapeseed straw pretreatment on its susceptibility to anaerobic degradation during methane fermentation. Rapeseed straw was pre-treated with the Pulsed Electric Fields (PEF) method at the following process parameters: electric impulse amplitude - 40 kV, rectangular pulse shape, pulse width - 50 µs, and pulse repetition frequency - 5 kHz. PEF is a non-thermal method exploiting electric impulses to destroy plant structures by forming pores in a cellular membrane. The simultaneously tested rapeseed straw pre-treatment method was the Ultrasound Pre-treatment (UP), which decreases biomass particles and reduces the extent of biomass polymerization. The UP was performed using an UP 400S ultrasound generator (Hielscher Ultrasonics) with a power of 400 W, generating ultrasound waves with a frequency of 24 kHz. Rapeseed straw was exposed to PEF and UP in 8 variants differing in energy dose supplied. The experiment was designed so as to ensure the same load of energy supplied in both conditioning methods. The effect plant biomass conditioning methods on the course of methane fermentation was then determined by measuring the biogas potential of the processed biomass under conditions of mesophilic methane fermentation. After pre-treatment, the substrates were evaluated in an AMPTS II analyzer. Apart from the amount of biogas produced, its quality was analyzed using the gas chromatograph with a TCD detector (Agilent 7890 A), which determined contents of methane, carbon dioxide, oxygen, hydrogen, and nitrogen in the samples. The experiments conducted allowed comparing the effects of rapeseed straw disintegration with PEF and UP methods. Better results were achieved upon the use of PEF, which in the most beneficial variant ensured 6% higher biogas production than UP, i.e., 476.4 NL/kg vs and 449.3 NL/kg VS, respectively. No significant differences were found in biogas quality. Methane content of the biogas approximated 60% in all variants tested.

The research was funded by the National Centre for Research and Development as part of the project entitled “Development a lignocellulose biomass disintegration technology using a pulsed electric field” LIDER/8/0026/L-9/17/NCBR/2018. Subsidy amount: PLN 1,166,250.00.

Use of a Pulsed Electric Field in Methane Fermentation of Sida Hermaphrodita Silage

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Keywords: Pulsed electric field; Methane fermentation; Biogas;

Consumption of fossil fuels covers over 88% of the global demand for primary energy. This results in the emission of large amounts of greenhouse gases to the atmosphere. Therefore, replacing fossil fuels with renewable energy sources may reduce global warming. Methane fermentation, in which clean energy is produced from organic waste, is a promising energy generation technology. Given the abundance of lignocellulosic biomass, which comprises agricultural biomass waste, agricultural and food waste, and paper and wood industry waste, the application of microbiological decomposition of lignocellulosic substrate for energy generation is economically viable and environmentally justified. Lignocellulose is successfully converted to biofuels, such as biogas, ethanol and hydrogen. However, due to the factors that restrict the lignocellulosic material biodegradation, it requires pretreatment. Lignocellulosic biomass disintegration destroys the compact structures and releases the organic matter to the dissolved phase, resulting in an increase in the concentration of dissolved, easily decomposed organic substances. The aim of this study was to determine the impact of the disintegration of Sida hermaphrodita silage with a pulsed electric field (PEF) on methane production. To this end, Sida hermaphrodita silage biochemical methane potential was assessed with an AMPTSII analyser (BioProcess Control). The qualitative composition of the produced biogas was determined with a gas chromatography unit with a TCD detector (Agilent). The analysis of the biogas potential of Sida hermaphrodita silage samples with no disintegration treatment showed the biogas productivity to be 541 cm3/g VS The best effect in biogas production was achieved for a sample following 8-minute disintegration (approx. 605 cm3/g VS). The methane productivity in a sample disintegrated for 8 minutes was approx. 368 cm3/g VS. A qualitative analysis of the biogas produced from Sida hermaphrodita silage showed that it contained 59.63 – 60.96% methane. The experiments as part of the research project showed that PEF disintegration of the lignocellulosic substrate increases methane productivity.

The research was funded by the National Centre for Research and Development as part of the project entitled “Development a lignocellulose biomass disintegration technology using a pulsed electric field” LIDER/8/0026/L-9/17/NCBR/2018. Subsidy amount: PLN 1,166,250.00.

Optimizing the Use of Electric Current to Support the Biological Treatment of Drainage Water from Soilless Tomato Cultivation in an Acidic Environment

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Keywords: energy efficiency; electrobiological purification; industrial wastewater

Soilless cultivation in greenhouses results in the generation of an overflow, called drainage. This type of wastewater is difficult to manage due to high concentrations of biogenes (nitrogen, phosphorus) and low contents of organic compounds. Drainage cannot be directly re-circulated or discharged to the natural environment; therefore solutions are sought to ensure its effective pre-treatment or treatment. At the same time, novel methods for the recovery of valuable elements, phosphorus in particular, are in a great need. Our earlier study has indicated the feasibility of drainage water treatment by deploying electrical current and an external carbon source. The conducted research was aimed at optimizing the use of electric current to support biological treatment of drainage waters. Effective bio-treatment requires appropriate loads of organic compounds. Simultaneously, pH in the reactor significantly affects the solubility and, consequently, the availability of phosphorus compounds. At alkaline pH, they appear in the form of insoluble sludge and are unavailable to microorganisms, significantly impairing their activity and development. On the other hand, electric current supports autotrophic denitrification and electrocoagulation of pollutants, including the precipitation of phosphorus with iron ions. The experiment was conducted in reactors included in the laboratory installation for drainage treatment operating based on biomass attached to the filling (biofilm). The direct current intensity was 0.2A and the hydraulic retention time was 24h. A steel plate (anode) was installed inside the reactor, while the stainless steel bed discs served as the cathode. Two methods of electrical current supply were tested: R1- HRT 24h, including 1-12h with electrical current flow followed by 13-24 h without the current flow; R2- HRT 24h, including 1-12h without electrical current flow followed by 13-24 h with the current flow. Acetic acid was used as an external carbon source at C/N=1.5. Initial pH was 3.2. The method of supply electric current to the reactors significantly influenced the efficiency of drainage water treatment. The final application of the electric current (R2) increased the efficiency of using the organic substrate by 18.0% and nitrogen removal by 5.4%. At the same time, the efficiency of phosphorus recovery decreased only by 1.0%. The conducted research has shown that by consuming the same amount of energy in R2 as in R1, we can significantly increase the efficiency of the treatment.

Funding
The study was part of the project “Development a precise treatment of wastewater from soilless tomato cultivation technology using electro biological hybrid reactor” as part of the LIDER X programme, financed by The National Centre for Research and Development No. LIDER/4/0019/L-10/18/NCBR/2019. Co-financing amount: PLN 1,492,500.00.

A Solar Simulator for Multidisciplinary Research on Solar Technologies

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Keywords: solar collector, solar simulator, photovoltaics, testing

The Archimedes Solar Energy Laboratory (ASEL) is a research lab at Cyprus University of Technology that deals with research in all areas related to solar energy. Some of the pioneer aims of the laboratory are to investigate ways to improve the performance of solar water heating systems and photovoltaic modules. The expected outcomes of the lab's research delivered from testing several types of photovoltaics and thermal collectors in order to improve their operation and energy performance. A large scale solar simulator has been designed and constructed to facilitate multidisciplinary research on solar technologies. The simulator is used to imitate in an indoor controlled environment the radiation of the sun. This study aims to present the laboratory protocol developed to evaluate the performance of water collectors and PVs. Developing a laboratory protocol for standardizing procedures on testing equipment is very important in order to ensure the reliability and comparability of results. A series of tests were conducted to calibrate the simulator including uniformity measurement of light intensity distribution and degree of light collimation. Afterwards, several tests have been carried out on photovoltaics and solar thermal collectors and all data were accordingly compared with outdoor measurements as well as with the manufacturer's data. The evaluation process of the solar thermal system is based on the ISO9806-1:1994, and the PV testing is based on standard IEC 61853. It is revealed that both protocols are functional with a low percentage of relative error.