ISSN 2653-8911

7th International Conference on "Energy, Sustainability and Climate Change"

ESCC 2020

Book of Abstracts

Skiathos, Greece, August 24-27, 2020

7th International Conference on "Energy, Sustainability and Climate Change"
ESCC 2020

Edited by: Georgios K.D. Saharidis

Publication
Department of Mechanical Engineering, University of Thessaly

ISBN 978-618-84403-4-0

ISSN 2653-8911

Text editing
Georgios K.D. Saharidis

Layout & Book design
Eleousa Zygouri

Table of Contents

Fast, Approximate Analyses of Heat Transfer and Fluid Flow using Finite Element Analysis

Vojtěch Turek, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: turek@fme.vutbr.cz
Tomáš Létal, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: letal@fme.vutbr.cz
Zdeněk Jegla, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: zdenek.jegla@vut.cz
Michal Hájek, UNIS, Brno, Czech Republic
Email: mhajek@unis.cz
Lubomír Mazánek, UNIS, Brno, Czech Republic
Email: lmazanek@unispower.cz
Radomír Nantl, UNIS, Brno, Czech Republic
Email: rnantl@unispower.cz
Martin Krňávek, EVECO Brno, Brno, Czech Republic
Email: krnavek@evecobrno.cz

Keywords: Finite Element Analysis; Fluid Flow; Heat Transfer; Process and Power Industry Equipment

Proper design of heat transfer equipment used in process and power industries can lead to improved energy efficiency. It can also prevent various operating problems, thus resulting in fewer service shutdowns and longer equipment service life. The most common operating problems encountered in the mentioned field are the increased local fouling rates due to uneven flow distribution and mechanical failures of the tubes in the bundle stemming from non-uniform thermal loading (which can, again, be a direct consequence of the flow distribution being largely non-uniform). Because of the significant computational demand and complexity of Computational Fluid Dynamics (CFD) models, however, the currently prevailing approach is to design equipment under the assumption of uniform fluid flow and temperature distributions in the bundle. Only in rare cases, the resulting apparatus is analyzed in more detail to verify that the previously made assumptions have been appropriate. In the presentation, therefore, a fast flow distribution and heat transfer model is discussed. The model is based on Finite Element Analysis (FEA) and utilizes a simplified mesh. This makes it suitable for approximate analyses of large, yet – construction-wise – relatively simple process and power equipment such as heat recovery hot water boilers. Computational times observed in case of typical industrial equipment tend to be of the order of minutes. Consequently, the model can be used to quickly get the estimates of velocity and temperature fields in the tube and the shell sides of the analyzed heat transfer apparatus or to rapidly and easily evaluate large sets of possible design options and discard the unsuitable ones. The capabilities of the model are demonstrated through the analysis of a heat recovery heat exchanger in an existing medium-size combined heat and power (CHP) plant. The outlook in terms of further development of the model is also discussed together with possible avenues leading to improvements in computational efficiency of the respective computer implementation.

Opportunities and Challenges in the Development of Modern Integrated Equipment for Waste-to-Energy Units

Zdeněk Jegla, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: zdenek.jegla@vut.cz
Vojtěch Turek, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: turek@fme.vutbr.cz
Tomáš Létal, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: letal@fme.vutbr.cz
Jiří Šikula, EVECO Brno, Brno, Czech Republic
Email: sikula@evecobrno.cz
Lubomír Korček, UNIS, Brno, Czech Republic
Email: korcek@unis.cz
Petr Gabriel, UNIS, Brno, Czech Republic
Email: pgabriel@unis.cz
Jan Horsák, UNIS, Brno, Czech Republic
Email: jhorsak@unis.cz

Keywords: Integrated Equipment; Waste-to-Energy Units; Fluid Flow; Heat Transfer

The current trend in waste-to energy (WtE) units for thermal treatment of solid, liquid and or gaseous wastes is to design and involve modern integrated equipment (MIE), the general principle of which is that they are characterized by maximum efficiency and multifunctionality (i.e. multiple unit operations are aggregated into a single apparatus). This reduces the whole WtE technology to the minimum number of present apparatuses, thus reducing both investment and operating costs. Moreover, such technology as a whole works more efficiently and is also more environmentally friendly. We are researching MIE for WtE processes within the research project “Strategic Partnership for Environmental Technologies and Energy Production”. The aim of this paper is to present the results of our research, especially the specific opportunities and challenges that the development of MIE for WtE units brings. Since the most common type of industrial WtE unit is a unit for thermal processing of some kind of waste gas (WG) containing combustible substances – shortly “waste gas-to-energy” (WGtE) unit - the paper is specifically focused on opportunities and challenges in the development of MIE for WGtE units. Typical WGtE unit consists of a quite small number of process equipment and the specific configuration of the WGtE unit will depend on the kind and amount of WG disposed. Depending on these two parameters, several progressive concepts of MIE can be identified, some of which have already been successfully implemented industrially. These MIE implementation opportunities will be specifically presented in the paper. However, designing MIE for WGtE units also entails several challenges that need to be addressed at present. These include, for example, the lack of reliable computational methods for designing some realizable multifunctional equipment, problems with nonuniform fluids flow distribution, heat transfer and mechanical stress within the integrated equipment, the risk of leakage of operating fluids (fugitive emissions) at various joints, etc. Attention in the paper will also be paid to these challenges and possible ways of addressing them.

Challenges in Bolted Flange Connection Performance Evaluation

Tomáš Létal, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: letal@fme.vutbr.cz
Pavel Lošák, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: Pavel.Losak@vut.cz
Vojtěch Turek, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: turek@fme.vutbr.cz
Zdeněk Jegla, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: zdenek.jegla@vut.cz
Marek Strakoš, UNIS, Brno, Czech Republic
Email: strakos@unis.cz
Ondřej Machola, UNIS, Brno, Czech Republic
Email: omachola@unis.cz
Vladimír Ucekaj, EVECO Brno, Brno, Czech Republic
Email: ucekaj@evecobrno.cz

Keywords: Bolted Flange Connection; Gasket; Tightness; Finite Element Analysis

Bolted flange connections are probably the most important separable connections in pressure equipment. Their design is mostly driven by two requirements: strength and tightness. The strength is quite accurately covered by ASME, EN and other standards. Although tightness is also considered in some calculations, these are usually very simplified and discrepancies between design and actual performance can be expected. Connection tightness can be quantified by leak rate in milligrams per year and gasket diameter. According to leak rates, connections can be divided into several tightness classes. When designing bolted flange connection, tightness requirements are usually specified in terms of specific tightness class. In ideal case with uniform contact pressures, the leak rate of the connection depends on gasket contact pressure at the moment and the highest gasket contact pressure in the history. Other significant factors influencing the leak rate include type of fluid, fluid pressure and temperature, and temperature distribution in the bolted flange connection. Two main challenges are estimation of gasket contact pressures and deriving overall connection tightness from these pressures. Estimating gasket contact pressures can be in theory done very accurately using finite element analysis, however, in practice, simplifications are often inevitable. Gasket behavior is usually highly nonlinear and parameters describing these nonlinearities may not be available. Temperature distribution may also severely affect contact pressures, however it is difficult to estimate it accurately. It is also important to note, that the whole history of the connection starting with assembly must be simulated, because important gasket contact pressures are not only at the end of the history, but also maximum values in time at every location. The presentation will be focused on discussing some of the issues, especially using gasket contact pressure histories to estimate connection tightness. Although it is not feasible to precisely estimate the exact leak rate, estimation of its lower and upper bounds may be possible. Consequently, conservative evaluation of bolted flange connection tightness class can be accomplished.

Thermal Thickening of Waste Water from Biogas Plants: Current State and Perspectives

Marek Vondra, Institute of Process Engineering & NETME Centre, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: m.vondra@vut.cz

Keywords: Biogas Plants; Liquid Digestate; Vacuum Evaporation; Ammonia Recovery; Anaerobic Digestion

Increased digestate production is associated with the boom of biogas plants in recent years. Digestate is a by-product of biogas production, consisting of water and residues of biological material that did not decompose during the anaerobic digestion process. The digestate from agricultural biogas stations is typically exported to the field and applied as an organic fertilizer.

Although the digestate is a good fertilizer, the concentration of the main nutrients (N, P, K) is low compared to mineral fertilizers. Field application of digestate requires a multiple passage of the spreading trucks, thus increasing fuel cost and machine maintenance, not to mention possible damage to the soil structure. Problems with the use of digestate occur especially in areas with increased intensity of agricultural production, which are typical of high concentrations of fertilizers in soil and groundwater respectively. In these areas there is a shortage of agricultural land that could be utilized for the digestate application. The solution is only an extremely costly transportation of digestate to remote areas.

Vacuum evaporation is a proven technology for digestate thickening with the advantage of simple construction, robust operation and waste heat utilization. Evaporators are capable of significant dewatering of the liquid digestate. However, high investment cost, chemicals consumption and utilization of subsidized and thus expensive electricity are the main obstacles for its expansion in the EU. To be acceptable for plant operators, beside price and reliability, a vacuum evaporator must meet all requirements for its product's (concentrate, separated water) quality.

To reach the desired product's quality, the evaporator must be supplemented by a system for ammonia treatment. Ammonia stripping, acid scrubber, reverse osmosis or prior nitrification of digestate are considered as suitable complementary options. As a result of ammonia recovery, ammonia sulphate solution could be produced and utilized or sold as a valuable fertilizer.

This study presents current state-of-the-art in digestate thickening by means of vacuum evaporation. Pros and cons of different treatment systems are discussed with main focus on the economic aspects.

The Role of Waste-to-Energy within the Circular Economy Concept - Recent Advances in Simulation and Optimization Approach

Martin Pavlas, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: Martin.Pavlas@vutbr.cz

Keywords: Waste-to-Energy; Reverse Logistics; Optimization; Mathematical Programming; Combined Heat and Power; Cogeneration

Waste-to-Energy (WtE) is an integral part of the developed waste management systems. Regarding data provided by Eurostat, 29% of municipal waste was incinerated in the EU in 2018, whereas 23% was landfilled. There are huge differences between the performance of individual countries, especially those located south, and east Europe, suffer from inadequate processing capacity for residual waste fractions by thermal treatment.

In this contribution, recent advances in the development of supportive tools for conceptual planning of WtE and related infrastructure is summarized. A complex reverse logistics model called NERUDA is introduced first. It is a mixed-integer linear model with a high practical impact for both authorities and/or investors. Some of its futures (waste transportation systems, future waste amounts forecasting, multi-objective approach, secondary amounts of non-recyclable wastes, etc.) and recent applications related to the regions of the Czech Republic, are mentioned. It will be demonstrated that economic and environmental efficiency of WtE plant is increased with high shares of delivered heat. Typically, this is achieved through deliveries to district heating systems. This also means that WtE plant is designed and operated in symbiosis with other energy-producing plants. Such cooperation requires detailed assessment. Heat delivery is optimised on a short-time basis, performance and technical limitation of individual pieces of equipment have to be known and described. As a result, an optimum capacity of WtE in an integrated system is proposed together with its operation plan.

Both afore-mentioned tasks can be efficiently linked in a two-step procedure. First, a regional model is applied to identify candidate locations for new WtE plants and costs for waste delivery are evaluated. Then the future operation is modelled to verify crucial parameters for a sustainable project.

Restoration of the Soil and Recirculation of Agricultural Waste in the Place of its Origin via Torrefaction

Ondřej Němček, ENET Centre, VSB – Technical University of Ostrava, Ostrava - Poruba, Czech Republic
Email: ondrej.nemcek@vsb.cz
Stanislav Honus, ENET Centre, VSB – Technical University of Ostrava, Ostrava - Poruba, Czech Republic
Email: stanislav.honus@vsb.cz

Keywords: Agriculture; Environment; Soil; Torrefaction; Waste

Local farmers, producers, and agricultural companies who exploit land for production of variety of cereals and growing crops, such as wheat, barley, corn, oilseed rape, flax, millet, etc. have to consider a number of different factors to be economically successful and also for their production to be environment friendly - to keep the land healthy and fertile. Lots of them apply artificial fertilizers, and later need to deal with erosion and nutrition degradation of the land due their application. In addition, erosive conditions also occur due to climate change. Another problem is the use of waste from agriculture, mainly organic waste. Besides, the agricultural sector has to cover its energy demands. We researched the possibilities and obtained results for the reuse and recirculation of agricultural waste, waste hay and straw as fertilizers applied into the soil to improve land fertility and to enhance its anti erosivity via torrefaction. Torrefaction is a well-known thermal process applied in drying, baking, or improving material energy properties. In our conditions, we constructed an experimental reactor for material preparation, and we used inert atmosphere with no oxygen to carry out the process. The material, which was applied in cooperation with partners from the industry and agricultural sector, was experimentally treated in Technological Centre Vítkovice – heavy laboratories of ENET Centre. The results show we prepared the concept and technology to transform this waste biomass into a long-term fertilizer and anti-erosive compound able to reduce many environmental impacts caused by artificial fertilizers. The research on the possibilities of recirculating produced waste directly on-site in the agricultural sector also showed other ways of using the products of torrefaction. The by-product gas and liquid fraction from the torrefaction process may be used in gas-piston engines, which come useful in off-grid operation systems, as many of the places of agricultural production are in remote regions and need to be energy self-sufficient.

CO_2 Capture through Chemical Looping Processes Using Perovskites as Oxygen Carriers

Charitini Matsouka, Chemical Process and Energy Resources Institute, Center for Research and Technology Hellas, Thessaloniki, Greece
Email: ch.matsouka@cperi.certh.gr
Antigoni Evdou, Chemical Process and Energy Resources Institute, Center for Research and Technology Hellas, Thessaloniki, Greece
Email: antigoni@cperi.certh.gr
Vassilis Zaspalis, Chemical Process and Energy Resources Institute, Center for Research and Technology Hellas, Thessaloniki, Greece and Chemical Engineering Department, Aristotle University of Thessaloniki, Thessaloniki, Greece
Email: zaspalis@cperi.certh.gr
Lori Nalbandian, Chemical Process and Energy Resources Institute, Center for Research and Technology Hellas, Thessaloniki, Greece
Email: nalbanti@cperi.certh.gr

Keywords: Chemical Looping; CO_2 Emissions; Oxygen Carrier; Perovskite; Oxygen Transfer Capacity

Increasing interest is recently received by the "Chemical Looping" (CL) concept as a means to reduce CO_2 emissions and global earth warming. Chemical Looping offers a solution for CO_2 separation without energy penalty via the use of a solid oxygen carrier which delivers oxygen to the fuel, instead of air.
Chemical-looping processes are alternative processes aimed either at generating heat and power (chemical-looping combustion, CLC) or to produce a CO + H_2 mixture (chemical-looping reforming, CLR) or high-purity H_2 (chemical-looping hydrogen/chemical-looping water splitting, CLH/CLWS).
In CLC the exit stream of the fuel oxidation reactor is a mixture containing only CO_2 and water, therefore after water condensation, a pure stream of CO_2 is produced as exhaust gas without any energy penalty for its separation. Furthermore, both CO_2 and NO_X emissions are highly reduced since the direct contact between air and fuel is avoided. The Chemical Looping Reforming (CLR) concept involves catalytic partial oxidation of a fuel using oxygen from a solid oxygen-carrier. A suitable oxygen carrier - catalyst is circulated between two reactors; in one reactor, a hydrocarbon is oxidized to synthesis gas by the lattice oxygen of the oxide, and in the other reactor, the reduced oxide is re-oxidized by air.
The oxygen carrier materials are a cornerstone in the CL processes. Crucial properties for oxygen carriers include high reactivity in both reduction by fuel and oxidation by oxygen in the air, as well as high resistance to attrition, fragmentation, and agglomeration. Perovskite materials have the ability to accommodate large concentrations of vacancies in their structure and to reversibly pick up and deliver oxygen at high temperatures. These properties make them ideal candidates for use as potential oxygen-carrier materials in CL processes.
The use of perovskites with the general formula $La_{1-x}Sr_xMO_3$ (M = Fe, Mn, Co, Ni) as oxygen carriers for syngas generation from methane by Chemical Looping Reforming is investigated in the present work. The perovskites are synthesized with a co-precipitation method and calcined at 1000°C. The calcined powders are evaluated for their reduction-oxidation behavior in a thermogravimetric analyzer IGA (Hiden–Isochema) with simultaneous chemical analysis of the evolved gases by mass spectrometry and their Oxygen Transfer Capacity (OTC) is determined. The selectivity towards gaseous products, CO_2, CO, H_2

and H_2O is examined during the oxidation of a fuel, using the oxygen from the solid oxygen-carrier, instead of oxygen from air. Subsequent oxidation of the reduced solid is performed with gaseous oxygen. Alternatively, solid oxidation can be performed, with CO_2 or water. In that case additional CO or hydrogen is produced, which is very pure and therefore appropriate to be used in fuel cell applications.

Air Quality Monitoring

George Kalantzis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: george.kalantzis4@gmail.com
Georgios Saharidis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: saharidis@gmail.com

Keywords: GreenYourAir; Particular Matter 2.5; PM2.5; Air Quality Monitoring; Low-Cost Sensors; Scattering Method

The ambient air pollution of particulate matter (PM) with maximum aerodynamic diameter 2.5 μm (PM2.5) is mostly related to anthropogenic emissions from industries, traffic transportation, power plants, and biomass burning. The GreenYourAir monitoring network consists of twelve measuring devices. The devices were designed and developed by the GreenYourAir research team. For the data collection is utilized the light-scattering method. The light-scattering method has been widely known in recent years and is used in research projects and in the creation of smart cities. The main parts of the device are a sensor that provides data for the concentration of PM2.5, temperature, and relative humidity, a I/O expansion shield and an Arduino YUN rev. 2. The programming language of the device is C++. The devices are collecting data per second and they are working 24-hours per day. Also, a 3D printed box designed for the installation of the devices and the creation of the network. For the creation of the network the GreenYourAir research team developed a mathematical formula and an optimization model to determine the locations of the twelve sensors. Volos City is divided in five zones. The traffic jam of the city is divided into three types. To determine the number of the sensors of each area according to the mathematical formula the research team analyzed the specific characteristics of each area. Those are the existence of parks, main roads, sports facilities, schools, universities, sources of heating, traffic jam, type of zones etc. The next step was to determine the locations of the sensors according to the areas and the number of sensors of each area. To do that research team developed an optimization model. The main parameters of the optimization models are the number of sensors of each area, the distance between the sensors in the same area, the distance between the sensors of different areas, the specific characteristics of each area and the coverage of different characteristics of the areas. Low-cost sensors like the GreenYourAir Device 1178/PM2.5, have advantages and disadvantages compared to the dust samplers. The main advantages of the low-cost sensors are the real-time measurements, the low cost and the large geospatial coverage of collected data. The main disadvantage of the low-cost sensor is in some cases the accuracy of the measurements. To solve that issue GreenYourAir research team developed a calibration methodology. At the development and testing period of the sensors, all the sensors tested under laboratory conditions with different characteristics in each phase of the testing period. Additionally, during the testing period a reference instrument was used to be compare the measurements of the low-cost sensors. According to the data of the testing period and the bibliography, the research team developed a calibration methodology for the GreenYourAir Device. Finally, GreenYourAir research team released a website with real time measurements of the network. The citizens of the city can be informed about the concentration of the PM2.5 in real time by using the http://greenyourair.org/ link.

Leguminous Crops Inputs Use Efficiency under Climate Change Index

Leonidas Sotirios Kyrgiakos, Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, Volos, Greece
Email: lkyrgiakos@uth.gr
Christina Kleisiari, Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, Volos, Greece
Email: chkleisiari@uth.gr
George Vlontzos, Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, Volos, Greece
Email: gvlontzos@uth.gr

Keywords: Leguminous Crops; Data Envelopment Analysis; Energy Use Efficiency; Inputs Minimization

Constantly increasing population has generated a series of challenges across different fields, including agriculture and livestock sector. Overpopulation has affected the consumed amount of food and there is an urgent need to ensure food security for current and future generations, preserving natural resources at the same time. In the era of minimum use resources, leguminous crops can be a great alternative in order to 1) fulfil human nutritional needs 2) substitute a part of productive animals ration 3) minimize ecological footprint and 4) raise resilience level for urban and rural areas. For this reason, a literature review has been made in order to assess leguminous crops advantages under climate change index. Recent findings reveal a great set of assets, including cultivars with high resistance in high or low temperatures, drought and salinity. Apart from the well-known capability of leguminous crops for nitrogen fixation and assimilation through symbiotic bacteria in their roots, their contribution is apparent for enhancing soil structure and biodiversity protection.

Farm data for leguminous crops, referring to amounts and values of all inputs involved (seeds, plant protection products, energy and water) in comparison with the final output which is the overall revenue obtained for farmer after the end of cultivation, have been calculated so as to evaluate performance of leguminous crops, focusing on inputs minimization. Data Envelopment Analysis (DEA) has been used in order to give an insight of production factors, with a view to minimize farmers' expenditures and environmental impact of this cultivation. Although there are some individuals that achieve high efficiency scores, integration of new techniques is necessary for the majority of farmers for reaching optimum scores, while others should implement radical changes on their cultivation protocols or switch to another crop. Carbon and water footprint indicators have been used in order to evaluate ecological impacts of leguminous crops. Concluding, cultivation of leguminous crops should be promoted due to their minimum inputs requirements and contribution to environmental protection, thus new practices should be implemented to achieve maximum efficiency of all factors involved.

Benchmarking Energy Efficiency Projects: A Multicriteria Approach

Aikaterini Papapostolou, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: kpapap@epu.ntua.gr
Charikleia Karakosta, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: chkara@epu.ntua.gr
Filippos Dimitrios Mexis, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: pmexis@epu.ntua.gr
John Psarras, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: john@epu.ntua.gr

Keywords: Sustainable Energy; Benchmarking; Stakeholders Consultation; Decision Support Systems; Multi-criteria Analysis; Electre Tri

Nowadays, European Union (EU) considers Energy Efficiency (EE) as one of its main pillars in order to reduce pollution and energy imports. The recently released Technical Expert Group (TEG) report on EU Taxonomy is a guide to green development, in continuance to EU's focus on reducing carbon emissions, scale down energy consumption and secure European energy autarky.
However, to the best of our knowledge hardly any standardized or integrated method supporting investors and financing institutes to identify highly efficient economic activities at an early stage that can unambiguously be considered environmentally green exist. In addition, investment benchmarking contributes in pointing out cost-effective and highly efficient EE project proposals, making them more attractive to investors by following a standardized procedure.
In the above context, this paper presents a multi-criteria approach based on the Electre Tri method, which aims to benchmark EE investment ideas incorporating financial, environmental and risk criteria. The EE investments are classified into three classes: Triple-A, Reserved or Rejected, reflecting their capacity to achieve environmental and financial goals, while stakeholders engagement will play a crucial role in this proposed approach. The profiles of the benchmarking classes and the criteria thresholds will be formed through a stakeholder consultation process, in order to be harmonized with the requirements and the specifications of investors, financing institutes and green financing instruments. The benchmarks obtained by the multicriteria method could facilitate decision makers in reducing uncertainty involved with EE investments, and support investors and financing institutes to target their capital towards green financing.

A Novel Approach for Handling Diverse Energy Consumption Issues in Large Passenger and Cruise Ships

Eirini Barri, Department of Computer Engineering and Informatics, University of Patras, Rio Patras, Greece
Email: ebarri@ceid.upatras.gr
Christos Bouras, Department of Computer Engineering and Informatics, University of Patras, Rio Patras, Greece
Email: bouras@cti.gr
Apostolos Gkamas, University Ecclesiastical Academy of Vella, Ioannina, Greece
Email: gkamas@aeavellas.gr
Nikos Karacapilidis, Department of Mechanical Engineering & Aeronautics, University of Patras, Rio Patras, Greece
Email: karacap@upatras.gr
Georgios Kournetas, Department of Mechanical Engineering & Aeronautics, University of Patras, Rio Patras, Greece
Email: kgiorgos837@gmail.com

Keywords: Energy Management; Agent-Based Simulation; Machine Learning; Decision Making; Visualization

This paper reports on the development of an innovative approach for handling diverse energy consumption and energy saving issues in large passenger and cruise ships. The proposed approach builds on an agent-based simulation model, which takes into account the size, characteristics (e.g. age, special needs etc.) and behavior of the different categories of passengers onboard, as well as the types of all energy consuming facilities and devices of a ship. In addition, the simulation model exploits spatial data corresponding to a detailed layout of the decks of a specific ship, thus offering customized visualizations. The model also caters for alternative ship operation modes, corresponding to cases where the ship cruises during the day or night, or is stopped at a port.

A novelty of our approach concerns the exploitation of the outputs obtained by carrying out multiple simulation runs by prominent Machine Learning algorithms to extract meaningful patterns between the composition of passengers and the corresponding energy demands in a ship. In this way, our approach is able to predict alternative energy consumption scenarios and trigger insights concerning the overall reduction of energy consumption in a ship. In addition, it handles the underlying uncertainty and offers highly informative visualizations of the energy consumption. The proposed agent-based simulation model has been implemented with the use of the AnyLogic simulation software (https://www.anylogic.com/).

The work described in this paper is carried out in the context of the ECLiPSe project, which aims at leveraging existing technological solutions to develop an integrated energy consumption and energy saving management system for the needs of large passenger and cruise ships. A major task of the project concerns the development of sophisticated algorithms for the analysis and synthesis of the associated multifaceted data, which may considerably enhance the quality of the related decision making issues during the operation of a vessel.

Wind Speed Forecasting Using Multi-Layer Perceptron and Support Vector Regressors

Berrin Cankilic, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: cankilicberrin@gmail.com
Gorkem Ozturk, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: gorkozturk@gmail.com
Berker Yurtseven, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: byurtseven@itu.edu.tr

Keywords: Energy Sustainability; Regression; Wind Speed; Forecasting

As energy demand increases with the recently developing countries in Africa, and the fuel owners and exportation change hands the Globe is trying to avoid the pollution caused by the primal energy sources. When the clean technologies are considered nuclear energy has become too expensive due to the security and waste removal processes. Both well based and pump based hydro energy productions have been installed to the limits of nature, while limited resources of geothermal energy forces the sustainability of the eco-system. Hence, as sustainable and renewable energy the Globe is focused on the solar and wind energies especially after the technological improvements that incredibly reduce the investment prices. Turkey has developed policies to support both wind and solar energies using the feed-in tariffs, hence, both the small sites and big energy farms have been developed in Turkey. However, the uncertainty caused by these two energy resources can be reduced only with more precision in prediction. Generally, meteorological studies use several statistical methods of prediction and choose the best. The study is organized in two parts. The first part gives the importance of wind velocity prediction and a review of the methods used, as well as the previous studies realized in Şile province, on the Black Sea shore of Thrace. The second part develops the artificial neural network algorithm that runs the multi-layer perceptron regressor (MLPR) or support vector regressor (SVR) and runs the algorithm on the wind speed data of Şile Province. Data was taken from the Air Quality Monitoring Stations Website of Ministry of Environment and Urbanization of Turkey. The prediction considers daily, monthly and seasonal climate changes by analysing the humidity, temperature, and air pressure. After achieving the results, the two regressors are compared using Mean Squared Error (MSE) and through the variances measured by R2. Both regressors certainly give smaller errors than the statistical methods used in general, but, it is observed that that MLPR gave more consistent results than SVR though SVR outperformed MLPR with smaller R2 and MSE values. This study will be enhanced to use other machine learning methods.

3D Printing Sustainability Issues, The case of Multi Mailboxes Production

Athena Baronou, Department of Industrial Design Engineering, School of Engineering, University of West Macedonia, Kozani, Greece
Email: abaronou@uowm.gr
Odysseas Manoliadis, Department of Civil Engineering, School of Engineering, University of Thrace, Xanthi, Greece
Email: omanolia@civil.duth.gr

Keywords: 3D Printing; AutoCAD; Multi Mailboxes

3D printing has been recognized as an efficient and sustainable technology in the fields of advanced manufacturing. In the past few years, a considerable research, including basic theoretical research, technology innovation and industries application, have been conducted to promote 3D printing for a better performance in manufacturing. However, the benefits of 3D printing from environmental perspective are still to be seen and its sustainability is also a mystery. This paper examines the application of 3D printing in manufacturing. In addition, based on the principle of multi-objective optimization, this paper proposes a novel framework for decision making in sustainability assessment and improvement by integrating the product Computer Aided Design (CAD) and Life Cycle Assessment (LCA). A multiple mailboxes design is used as a case study for this to provide a comprehensive understanding of 3D printing for the public and provide a better guide for the future research. The results have shown that material waste is significant reduced and also the supporting material, which is utilized to make the increasingly exotic geometries possible, is able to be recycled into raw material after 3D printing is finished. Although the waste materials can be recycled back, it will also generate second energy and resource consumption as well as environmental emissions. In contrast with traditional manufacturing process, 3D printing release less carbon dioxide because of less energy usage comparing with the traditional pattern of factory manufacturing and shipped to warehouse. At last, recommendations about major concerns when analyzing the sustainability of 3D printing are put forward, which might be considered for the design of mailboxes.

Optimization of Electricity Consumption Cost with Battery System in Turkey: Case of Ikitelli Industrial Zone

Kubra Yavuz, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kubrayavuz95@outlook.com
Gulgun Kayakutlu, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayakutlu@itu.edu.tr
M. Ozgur Kayalica, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayalica@itu.edu.tr
Irem Duzdar Argun, Department of Industrial Engineering, Duzce University, Duzce, Turkey
Email: iremduzdar@gmail.com

Keywords: Electricity Consumption; Industrial Zone; Optimization; Mixed-Integer Programming

Industrial power demand grows in parallel with technological improvements. The increase in the share of industrial power use is considerably high in Turkey. All the industrial organisations are either connected to the National Grid and follow a one-time tariff or three-time tariff, or choose the distributer as a free consumer above a certain amount. In the case of Industrial zones, three-time tariff is more economical for the industry owners. However, in industrial zones with the considerably high-energy consumption during peak hours, an alternative way should be found to reduce electricity costs. For taking the advantage of the three-time tariff and to reduce the electric charge in peak hours, a battery-powered model was developed earlier. In this paper, the expectation is to reduce the power utility costs of industrial consumption and mitigate the CO2 emission that can be a light tower for the business with high electricity costs. A mixed-integer optimization model is constructed as a mix of solar panels and the battery system to minimize the grid-connected energy consumption in the industrial zones during peak hours. The model is implemented for a case study in İkitelli Industrial Zone using the consumption data in 2018. Three different alternative energy mix is studied in scenarios: monofacial PV (photovoltaic) panel system with batteries, bifacial PV panel system with batteries and the electricity received from the Grid only in night tariff. Although monofacial and bifacial Photovoltaic systems and batteries are already analysed in several studies, they have never been compared for 24-hour scheduling altogether. In this study PV-battery system which reduces electricity consumption and enhances the electricity systems investigated. It is observed that a combined method can minimize the grid usage during the peak hours. This will be important for heavy power-using manufacturing companies with high carbon emissions like cement. Further studies will be performed to include the wind source in the energy mix.

Circular Economy in Waste Management: Network Flow Problem and Recycling Dilemma

Jaroslav Pluskal, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: Jaroslav.Pluskal@vutbr.cz

Keywords: Municipal Solid Waste; Network Flow Problem; Recycling Efficiency; Multi-Objective; Circular Economy

Recent research on waste management has primarily focused on the circular economy. This concept leads to increasing sustainability by putting emphasis mainly on the reduction of waste production, recycling, and restriction of landfilling. For the European Union, it is anchored in Circular Economy Package by separation and recycling goals. The obligation of member states is to put these goals into local legislation, while its effective implementation can be aided by mathematical programming. The article mainly focuses on the effectivity of sorting waste in sorting lines, which must be done before the following manufacturing of waste into secondary material. The general public awareness about the sorted waste is that all material can be recovered. However, real operations confirm that the return flow of non-recyclable or hardly-recyclable material increases as the maximum recycling rate is achieved. The goal is to determine dependency of the recycling process on the separation rate, which represents how much citizens sort their waste. The dependencies are studied for the main sorting fractions of municipal solid waste – plastic and paper. Afterwards, the influence of these dependencies is studied in the case study of waste management in the Czech Republic by sophisticated approach concerning economic and environmental impact. The task represents a network flow model, where several commodities of the produced waste are transported between producers and treatment facilities. The optimisation considers minimising trade-off between the mentioned criteria. Economic criterion is included through cost related to waste collection, its transport, sorting and final treatment. Environmental impact is measured by greenhouse gases produced, which is being expressed by the CO2eq unit. It is an equivalent for carbon dioxide that is based on the global warming potential of various greenhouse gases. The model formulated as mixed integer programming problem is implemented in the GAMS (General Algebraic Modeling System). Estimated real nonlinear dependencies describing separation and recycling efficiencies are used in the task. The results are discussed, and some solutions are suggested for future research.

Optimization in Electric Power Distribution Systems

Panos Pardalos, University of Florida, Gainesville, Florida, USA
Email: pardalos@ufl.edu

Keywords: Electric; Power; Distribution

Planning the operation and expansion of power distribution systems (PDS) is essential to assure that the growing demand can be satisfied with a reliable service at affordable costs. Given the size of these systems, the minimization of overall costs can be a considerable challenge. For instance, finding the topology or overall least-cost plan for a PDS can be a difficult task, since thousands of feasible design options can arise from a feeder design definition. The difficulty in solving PDS optimization problems relies on the combinatorial nature and the large solution space. In this context, the development of models and solution techniques is of great importance for power utilities, and Engineer's understanding of the system and its costs, performance, and trade offs can be facilitated with optimization concepts.

Significant changes are being imposed to PDS in the recent years, given the growing presence of distributed energy resources and the smart grid implementation. The abilities to dynamically optimize the operation, integrate diverse distributed generation types, and integrate demand response and energy resources are needed in this modern power system era. As a result, significant research efforts have been dedicated to the optimal expansion and operation planning of modern distribution networks.

Several models and techniques are proposed in the literature, covering the allocation of new substations, reinforcement of the existing ones, reconductoring or construction of new distribution lines, distributed generation placement, network reliability improvement, among other problems. In this lecture, we will discuss some optimization problems applied to PDS, ranging from theoretical contributions to practical applications. Finally, future research problems are presented and discussed.

Reference: Handbook of Optimization in Electric Power Distribution Systems, (Resener, M., Rebennack, S., Pardalos, P.M., Haffner, S., Eds), Springer (2020) https://www.springer.com/us/book/9783030361143

The Best Way to Improve the Energy Efficiency of a Small or Medium Industrial Enterprise

Vítězslav Máša, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: masa@fme.vutbr.cz
Michal Touš, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: Michal.Tous@vut.cz
Zdeněk Hajný, EVECO Brno, Brno, Czech Republic
Email: hajny@evecobrno.cz

Keywords: Energy Savings; Small and Medium Industrial Enterprises; Project Methodology; Data Acquisition; Modeling and Simulation

One of the most promising ways to make effective use of available natural resources is to increase their energy efficiency in the energy and industry sector. This contribution discusses the energy efficiency of buildings and processes in industrial and also municipal areas. Commonly used approaches in energy management (EM) have been found to be insufficient in many enterprises. There is a lack of procedures for identifying and implementing optimal saving measures in commercial and mid-size industrial facilities, with input from dozens of kW to units of MW. The benefits of energy saving solutions based on EM can be rather limited.

Systematic and critical observations of numerous energy saving projects performed by the authors revealed that it is possible to specify key elements which are crucial for successfully implementing these projects. They should be applied as much as possible and can be specified as follows:

1. Technical expertise: Knowledge of industrial facility and possible savings based on experience
2. Good operational data: The acquisition of data in a facility
3. Modeling and optimisation: Assessment of various options and the selection of the most beneficial one

This study introduces these elements in a systematic approach and explain them on various industrial projects. The projects differed greatly in their scope; some researched issues were from the commercial sphere (a modern heating system in a wood-processing facility, industrial and commercial laundries, calcium-based pharmaceuticals production), whereas other projects dealt with issues from the municipal sphere (the energy system in the Prague National Theatre, the energy system in the campus).

Research on Sustainable Use of Cultivated Land Based on Improved Three-Dimensional Ecological Footprint Model

Jingming Liu, School of Public Policy and Administration, Xi'an Jiaotong University, Xi'an, China
Email: jimmyliu1993@stu.xjtu.edu.cn
Xianhui Hou, College of Economics and Management, Northwest A&F University, Yangling, China
Email: houxh2017@nwafu.edu.cn

Keywords: Sustainable Use; Three-Dimensional Ecological Footprint; Energy Analysis; Cultivated Land; China

As an indispensable factor of natural production and economic development, cultivated land is important for the protection of food security. Based on the conception of energy analysis, footprint width and footprint depth, this paper improved the three-dimensional ecological footprint model (3DEF model) by combining the traditional ecological footprint model with energy analysis model. The width of footprint is used to indicate the degree of occupancy of natural capital flows, and the depth of footprint is used as an indicator to determine the sustainable use of cultivated land. We take 32 provinces in China from 2000 to 2018 as case studies and explore the sustainable spatial use of cultivated land in China since the 20th century, then use the gray correlation prediction model to predict the ecological footprint and ecological capacity of cultivated land from 2020 to 2030. The results show that the ecological width value of the central economic zone represented by the Yangtze River Delta, the Pearl River Delta and the Beijing-Tianjin - Hebei Metropolitan Circle is low, while the width value is higher in the major grain-producing regions such as Northeast, Hubei and Shandong regions. Areas with higher footprint depth values are concentrated mainly in Shaanxi, Sichuan and the Yangtze River Delta, indicating that the flow of resources in these regions has been fully occupied and that stock resource consumption has increased over the year. And since 2015, the footprint width value of most provinces in the country has remained constant, while the consumption of stock resources continues to increase. After 2020, both the depth and the width of the footprint of the cultivated land show an upward trend, but due to the characteristic of depth accumulation, which indicates that the consumption of China's cultivated land stock resources will gradually increase in the next ten years. Therefore, it is necessary to establish a long-term mechanism to promote sustainable agricultural growth as soon as possible, to strictly implement a protection policy of cultivated land, finally, we can effectively to achieve the dual objects of high efficiency in agriculture and sustainable use of resources and ecology.

Spatial-Temporal Analysis of Driving Factors of Cultivated Land Use in China from 2000 to 2018 Based on GWR Model L

Xianhui Hou, College of Economics and Management, Northwest A&F University, Yangling, China
Email: houxh2017@nwafu.edu.cn
Jingming Liu, School of Public Policy and Administration, Xi'an Jiaotong University, Xi'an, China
Email: jimmyliu1993@stu.xjtu.edu.cn

Keywords: Sustainable Use; Cultivated Land; Ecological Footprint; GWR Model; China

With the rapid economic development, the contradiction between the growing population and constant cultivated land resources has gradually deepened, and how to explore the sustainable development of cultivated land is crucial. Based on the three-dimension ecological footprint model(3DEF), this paper calculates sustainable use of cultivated land in 32 Chinese provinces from 2000 to 2018 from the perspective of stock resources and flow resources and takes the depth value of 3DEF as the dependent variable. The GWR model is used to examine the effect of various regional driving factors on the sustainable use of cultivated land from environmental, consumption and socio-economic perspectives. Through collinearity test and spatial autocorrelation test, six influencing factors were finally selected: Cultivation rate, multiple cropping index, mechanical input, chemical fertilizer input, agricultural product price and agricultural output value. The results are as follows. In most parts of the country, the width of the cultivated land's ecological footprint gradually increased from 2000 to 2015. At the national level, the consumption of cultivated land stock resources continued to deepen after 2015. Among them, the regression coefficient of cultivation rate, agricultural product price and mechanical input to cultivated land footprint depth are positive, which plays a significant role in promoting the sustainable use of cultivated land in the plain area. While the agricultural output value, multiple cropping index and fertilizer input have a negative impact on the sustainable use of cultivated land. In a mountainous area with a low cultivation rate, chemical fertilizer input will bring a significant increase in yield at the beginning of cultivation of cultivated land, and as the degree of cultivated land cultivation increases, chemical fertilizer input will have a negative impact on the utilization of cultivated land. The absolute value of the regression coefficient of agricultural output value shows a trend of decreasing from east to west. Due to the geographical location advantage of the coastal zone, the proportion of economic crops in the output value of agricultural products is high. The increase in output value has a negative effect on the sustainable use of cultivated land. Therefore, in the field of agricultural production, excessive use of chemical fertilizers should be avoided, land consolidation should be strengthened, agricultural machinery facilities should be improved to guarantee the structural safety of cultivated land use system.

Forecasting Electric Energy Demand for V2G and G2V Systems Under Different Charging Profiles

Sotirios Deligiannis, Department of Informatics and Telecommunications, University of Peloponnese, Tripolis, Greece
Email: dit16040@uop.gr
Elisavet Koutsi, Department of Informatics and Telecommunications, University of Peloponnese, Tripolis, Greece
Email: dit15069@uop.gr
Georgia Athanasiadou, Department of Informatics and Telecommunications, University of Peloponnese, Tripolis, Greece
Email: gathanas@uop.gr
Dimitra Zarbouti, Department of Informatics and Telecommunications, University of Peloponnese, Tripolis, Greece
Email: dzarb@uop.gr
George Tsoulos, Department of Informatics and Telecommunications, University of Peloponnese, Tripolis, Greece
Email: gtsoulos@uop.gr

Keywords: Electric Vehicles; Energy Flexibility Management; Energy Efficiency

The GHG emissions caused by transport sector and especially by road transport is a major problem for our society since it is associated to the climate change. Electric vehicles (EVs), may be a sustainable alternative to traditional internal combustion engine vehicles and possibly part of the solution.
The aim of this work is to investigate the impact of EVs on load profiles and load variations. Moreover, the different types of charging and their potential with respect to the flexibility offered in the system will be discussed. In this context, the main types of charging examined are uncontrolled charging (UCC), which is related to stochastic individual car travel behavior, individual charging strategies (ICS) and external charging strategies (ECS). Furthermore, different types of day will be considered, i.e. the load profile will be different in the peak hours of a typical weekday and different on weekends or public holidays.
Our work incorporates both G2V and V2G options; the energy that the grid offers to the EV (G2V) and the energy that the EV offers to the grid (V2G). For G2V the user can choose during the charging between slow, fast and very fast charging depending on time and cost constraints and preferences. During the V2G operation the EV returns electric energy back to the grid, which can be translated to profit for the EV user. It should be pointed out that energy from the EV cannot only be offered to the grid, but also to the user's home (V2H).

Influence of Spatial Variability of Soil Properties on the Behaviour of Underground Energy Pipelines under Permanent Displacement

Nikolaos Alamanis, General Department, University of Thessaly, Larisa, Greece
Email: alam@uth.gr
Panos Dakoulas, General Department, University of Thessaly, Larisa, Greece
Email: dakoulas@uth.gr

Keywords: Buried Pipelines; Seismic Performance; Spatial Variability; Random Fields; Permanent Displacements; Soil Liquefaction

The seismic performance of oil and natural gas steel pipelines embedded in earth slopes presents great uncertainty related both to the earthquake shaking characteristics and to the natural heterogeneity of geomaterials. Slope movements and landslides in general constitute a significant risk to pipelines because they can cause permanent deformations and rupture, resulting in spills, environmental problems and long periods of outage. Moreover, significant risks for underground pipeline integrity may be caused by permanent ground displacements from tectonic fault action, lateral spreading of liquefied soils, where soil can move for a distance of few meters and impose major deformation on the section of pipeline passing through the affected area. Similar risks appear also for the case of pipes embedded in a liquefiable soil layer passing below a river or ground aquifer. In all these cases, the pipe may be subjected to bending resulting to significant compression, with a high risk of local buckling, large plastic deformation and wall rupture.
The magnitude and the spatial distribution of the imposed ground movement may depend significantly on the spatial variability of the soil properties in a zone along the path of the pipeline system. The presented research aims at accounting in a rational way for the effects of the spatial variability of the soil properties on the seismic performance of buried steel pipelines passing below a river and embedded in a liquefiable soil layer. The study is based on numerical modelling of the soil – pipeline systems, by considering the soil – pipe interaction during seismic shaking. The results demonstrate that the influence of spatial variability of soil properties on the ground movement imposed on the embedded pipeline is very important and should be accounted for in the evaluation of its seismic safety.

Waste Heat Recovery Technologies: Recommendations on how to Overcome Barriers to their Adoption

Paul Christodoulides, Faculty of Engineering and Technology, Cyprus University of Technology, Limassol, Cyprus
Email: paul.christodoulides@cut.ac.cy
Lazaros Aresti, Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology, Limassol, Cyprus
Email: lg.aresti@edu.cut.ac.cy
Vassilios Messaritis, Department of Mechanical Engineering and Materials Science and Engineering, Cyprus University of Technology, Limassol, Cyprus
Email: vassilios.messaritis@cut.ac.cy
Gregoris Panayiotou, Faculty of Engineering and Technology, Cyprus University of Technology, Limassol, Cyprus
Email: gregoris.panayiotou@cut.ac.cy
Giuseppe Bianchi, Center for Sustainable Energy Use in Food Chains, Institute of Energy Futures, Brunel University London, Uxbridge, Middlesex, UK
Email: Giuseppe.Bianchi@brunel.ac.uk
Georgios Florides, Faculty of Engineering and Technology, Cyprus University of Technology, Limassol, Cyprus
Email: georgios.florides@cut.ac.cy

Keywords: Waste Heat Recovery; WHR Technologies; WHR Adoption Barriers

The fact that 30% of EU industry final energy is wasted through losses has led to the wide adoption of waste heat recovery (WHR) technologies. But their adoption is hindered by specific technical and non-technical “barriers”. An attempt is made here to determine such barriers and make recommendations on how to address them. This has been done through a literature review as well as on a review and discussions with people from related industry sectors. Moreover, a structured questionnaire on barriers to the adoption of WHR technologies has been issued to a number of industries across the EU. It turns out that the main barriers have been identified as: (i) lack of information, (ii) lack of technology knowledge, (iii) technology risks, (iv) high initial and running and maintenance costs, (v) lack of financial support and lack of governmental incentives, (vi) size and available space limitations, (vii) lack of available infrastructure, (viii) production constraints and risk of production disruptions, (x) risk of the system negative impact on the company operations, (xi) policy and regulations restrictions. Furthermore, an assessment of the importance and negative impact of each of the above-mentioned barriers is given based on the analysis of the questionnaire. Finally, based on the above, recommendations on how to overcome the barriers and a suggestion for related case study are presented, with the hope of their adoption, when possible, by stakeholders.

Acknowledgment: The research presented here has received funding from the European Union’s Horizon 2020 research and innovation program under Grant agreement No. 680599.

Fostering Energy Efficiency Investments at an Early Stage: A Standardized Toolbox

Filippos Dimitrios Mexis, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: pmexis@epu.ntua.gr
Aikaterini Papapostolou, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: kpapap@epu.ntua.gr
Charikleia Karakosta, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: chkara@epu.ntua.gr
Haris Doukas, National Technical University of Athens, School of Electrical and Computer Engineering, Decision Support Systems Laboratory, Energy Policy Unit, Athens, Greece
Email: h_doukas@epu.ntua.gr

Keywords: Energy; Energy Efficiency; Financing Schemes; Decision Making; Benchmarking Tool

Energy efficiency (EE) is considered one of the major pathways to reduce carbon emissions. In this context, the ambitious energy policy targets for 2030 and 2050 create the need for upscaling the energy efficiency finance. The challenge lies in identifying and mainstreaming EE investments, fostering sustainable growth, already from the first stages of investments generation and pre-selection/ pre-evaluation.
In order to make EE investments more transparent, predictable and attractive for financiers and project developers, this study introduces a three-step toolbox focused on the pre-screening process, where no standardization exists, supporting the identification of attractive project ideas. Within the first tool, which has a Go / No-Go character, the project ideas are evaluated according their perceived risk profile taking into account the country, sector and project category. The second tool incorporates various existing or new risk, financial and other key performance indicators (KPIs), in order to identify and benchmark the most financially efficient projects that passed the first tool, using a multicriteria classification method. Finally, at the third tool, beneficiaries of EE investments that seek financing instruments to support their project ideas are combined with financing bodies that search for a profitable portfolio of optimal projects to finance. This toolbox is expected to facilitate both project developers and financing institutions in selecting the most suitable, efficient and cost-effective project ideas according to their strategy and rules.

Industry 4.0 Impact of Sustainable Energy Management in Manufacturing Industry in Turkey

Eren Deliaslan, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: deliaslan19@itu.edu.tr
Gulgun Kayakutlu, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayakutlu@itu.edu.tr
M. Ozgur Kayalica, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayalica@itu.edu.tr
Irem Duzdar Argun, Department of Industrial Engineering, Duzce University, Duzce, Turkey
Email: iremduzdar@gmail.com

Keywords: Energy Efficiency; Energy Sustainability; Industry 4.0; Manufacturing

The emergence of the Fourth Industrial Revolution has encouraged organizations to take a technology path which consists of new hard and soft applications as well as resource concerns for sustainability. Intelligent networking of machines and processes with the contribution of the automation of work and digitalization is known as the Fourth Industrial Revolution. Rapid developments in the fields of IoT, augmented reality, big data, rapid prototyping technologies, block-chain applications are noticeable in the manufacturing industry. Energy efficiency and sustainability concerns are important elements of Industry 4.0. The increasing energy costs directly contribute to the total costs of manufactured goods and reduce the competition power of producers. Yet, the increasing ecological sensitivity of the consumers cause increasing demand directed towards the environment friendly products. This study is focused on the effects of Industry 4.0 implementations on the manufacturing industry in Turkey. Marginal changes in energy consumption due to the technological improvements will be analysed. In order to create awareness for the investors, the next ten years of energy consumption are studied based on two scenarios. In the first scenario, the manufacturing industry stays as is only taking regularly enforced energy efficiency cautions. Whereas, in the second scenario, it is assumed that more than 90% of the manufacturing companies apply the rules defined in the Turkish Industrialists Organisation (TUSIAD) report on Industry4.0. The analysis is made by using the Long-range Energy Alternatives Planning (LEAP) system. Achievements show that the energy consumption with TUSIAD Industry 4.0 Report will reduce the acceleration of the demand.

Data-Driven Energy Efficiency Improvement in Industry 4.0

Michal Touš, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: michal.tous@vutbr.cz
Vítězslav Máša, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: masa@fme.vutbr.cz
Sin Yong Teng, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: Sin.Yong.Teng@vut.cz
Lubomír Korček, UNIS, Brno, Czech Republic
Email: korcek@unis.cz

Keywords: Data-Driven; Energy Efficiency; Improvement

Improving energy efficiency is one of the most important efforts towards sustainable development. Energy consumption is continuously increasing and renewable energy sources still have small contribution in energy production compared to primary sources. Energy saving measures are therefore required. These typically consist of decreasing energy consumption of buildings by insulation and replacing inefficient devices with efficient ones. The other opportunity how to improve energy efficiency is based on process data. Data-driven models for industrial energy efficiency improvement heavily rely on sensor data, experimentation data and knowledge-based data. This work reveals that too much research attention was invested into making data-driven models compared to ensuring the quality of industrial data. Furthermore, the real challenge within the industry is with data communication and infrastructure problems and not with a quality of modelling techniques. Costs related to transition from traditional industry towards Industry 4.0 are very high and especially small and medium enterprises need introduction of cheap technologies. Typically, 2 years pay-back period is acceptable, rarely 5 years, which is currently difficult to achieve. It is but a matter of time that the industry will transition towards the “digital twin”-based approach. However, the sooner the effort will be adequately distributed between challenging issues the sooner the transition happens. Global government efforts and policies are already inclining towards better industrial energy efficiencies and energy savings. This indicates a promising future for the development of a "digital twin"-based energy efficiency improving system in the industry. This approach has been successfully tested in a petrochemical case study. This approach has been successfully tested in an Oil&Gas case study. Foreseeing some potential challenges, this contribution also discusses the importance of symbiosis between researchers and industrialist to transition from traditional industry towards Industry 4.0. The authors estimate that well-developed artificial intelligence based infrastructure available to wide range of enterprises will be ready not sooner than in 2040.

A BIM-Based Toolkit towards Enhancing Energy Efficiency in Building Renovation Activities

Spyridon Kousouris, Suite5 Data Intelligence Solutions limited, Energy Unit, Limassol, Cyprus
Email: spiros@suite5.eu
Konstantinos Tsatsakis, Suite5 Data Intelligence Solutions limited, Energy Unit, Limassol, Cyprus
Email: kostas@suite5.eu

Keywords: Building Information Model; Energy Efficiency; User Profiling; Sensors

Following the global target of governments to tackle climate change, the EU has set the goal to achieve an 80% reduction goal in primary energy consumption by 2050 (European Climate Foundation, 2010). A sustainable and powerful way to achieve these goals, including also the target to reduce the European greenhouse gas emissions by 80-95% below 1990 levels by 2050, is by improving the energy efficiency of the built environment. Towards this direction, EU has set at the top of its agenda the decarbonization of energy use in the European building stock, presently being the most significant consumer of energy (within the EU), collectively accounting for 40% of the total consumption and 36% of CO2 emissions.
Notably, renovation of the existing building stock (where a significant fraction in the European Union (EU) is over 50 years old) offers a huge potential towards successfully meeting the energy savings (80% reduction in primary energy consumption) and emissions reduction targets (80-95% below 1990 levels) set with view to 2050, being also the only truly sustainable solution (with regards to the building sector) for the realization of EU's policy objectives. The realization of such ambitious targets requires a significant acceleration and growth of the EU renovation market, at higher rates; through a radical shift of the Architecture, Engineering and Construction industry (AEC) away from traditional practices and through its digital transformation by adaptation of Information Technology (IT) solutions and implementation of Building Information Modelling (BIM). Utilising BIM (properly extended and enriched) can offer large benefits to the AEC renovation sector mainly by reducing critical mistakes, omissions and improving collaboration between stakeholders resulting in higher quality outcomes with less costs and greater speed.
Within this context, we introduce an innovative BIM-based framework for efficient renovation and energy management in buildings comprising of tools supporting the building's stakeholders (owners and occupants). Along with this innovative data management framework, a set of tools is considered integrating data in order to perform advanced analytics; incorporating energy consumption and occupants comfort data preferences in energy management tools on the way to provide added value energy services during the renovation and operational phase of the buildings. The overall framework is to be tested in three European pilot sites of different geographic and climatic conditions over a long period and the initial activities to be reported in this paper. The work detailed in this paper is carried out within the BIM4EEB project. The research has received funding under the European Union's Horizon 2020 research and innovation programme, under grant agreement No. 820660.

Quadratic and Linear ED Problems and their AMPL Implementations

Oksana Pichugina, Department of Mathematical Modeling and Artificial Intelligence, National Aerospace University "Kharkiv Aviation Institute", Kharkiv, Ukraine
Email: oksanapichugina1@gmail.com
Petro Stetsyuk, Department of Nonsmooth Optimization Methods, V. M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine, Kyiv, Ukraine
Email: stetsyukp@gmail.com
Oleksandr Butkevych, Department of Modeling of Power Facilities and Systems, Institute of Electrodynamics of National Academy of Sciences of Ukraine, Kyiv, Ukraine
Email: butkevych@ied.org.ua
Oleksiy Lykhovyd, Department of Nonsmooth Optimization Methods, V. M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine, Kyiv, Ukraine
Email: o.lykhovyd@gmail.com

Keywords: Economic Dispatch Problem (ED Problem); Quadratic Programming Problem; Unique Solution; Multiple Solutions; AMPL Modeling Language

An optimization problem in the form of a quadratic programming problem of the optimal scheduling of the output of power generating units in order to meet the required load demand is considered. The problem under consideration is known as Economic Dispatch Problem (ED problem). Here, a power system consists of the parallel running power units. For each power unit, the following parameters are given: lower and upper bounds of electrical power generated by the unit; maximum ramp-down and ramp-up rates of the unit. Duration of a planning period and the required electrical load demand for each time interval are also given. For each of the intervals of the planning period, it is necessary to find how much should each power unit generate in order to ensure that, for the entire planning period and prescribed electrical load demand, the minimum total cost of electricity generation is attained, and unit and system equality and inequality constraints are satisfied.

A specific form of an ED problem is determined by the type of objective functions of fuel consumption and constraints for the operational requirements of each power unit. Here, ED-problems in the form of quadratic and linear programming problems are studied. It is shown that, for a strictly convex objective function, the problem has a unique solution. This result is used to justify the existence of a unique solution for the corresponding linear program.

The problems are implemented in AMPL modeling language. The results of computational experiments using the Gurobi solver on a NEOS server for solving two test examples of ED problems for a daily hourly electrical load are presented. The first example has a power system with ten power units, while the second one has forty such units. For the first example with the linear objective function, the existence of the unique solution is justified, and for the second example, the existence of multiple solutions is confirmed.

Integration of Renewable Energy in Key Industrial Sectors for UAE: Case of Aluminum

Ali Bouabid, Department of Industrial and Systems Engineering, School of Engineering, Khalifa University, Abu Dhabi, United Arab Emirates
Email: ali.bouabid@ku.ac.ae
Andrei Sleptchenko, Department of Industrial and Systems Engineering, School of Engineering, Khalifa University, Abu Dhabi, United Arab Emirates
Email: andrei.sleptchenko@ku.ac.ae
Mohamed Ali, Department of Industrial and Systems Engineering, School of Engineering, Khalifa University, Abu Dhabi, United Arab Emirates
Gustavo Ospina-Aldana, Department of Industrial and Systems Engineering, School of Engineering, Khalifa University, Abu Dhabi, United Arab Emirates
Sgouris Sgouridis, DEWA, Dubai, United Arab Emirates

Keywords: Renewable Energy Integration; Aluminum Smelter; Heat Recovery

The UAE has a number of large industrial energy users; aluminum, steel, cement, petro-chemicals, refineries along with lower energy intensity facilities like food and dairy processors. These industries require significant amounts of energy in the form of electricity and heat at different grades. Given the increasing traction of renewable energy in the country after the record-breaking solar energy power purchase agreement bids, it is important to consider how these industries can integrate renewable energy in their operations and in what forms. Furthermore, to support the competitiveness of many of these industries, it is imperative for them to move from reliance on limited natural gas with subsidized prices to unsubsidized renewable resources and entry in the market for certified low-carbon materials.

In this paper, we present the findings of our study on the Aluminum industry. After briefly presenting the manufacturing processes of a specific smelter with a production capacity of one million tons of Aluminum annually, we present the main results of our investigation. Using a shell heat exchanger tested at industrial level, we found that the aluminum cell could shift from constant power operation to a power modulation between -14% and +8% from the nominal power. Using a conservative approach, we used a modulation cycle, where the power input to the cell can be increased by 8% from the nominal value (up to 477.2 kA, 4.2 V, at ACD 3.4cm), to a 8% power reduction (down to 432.1 kA, 3.9 V, at ACD 3.4cm). The new modulation cycle of the energy demand is used as input in an optimization model to determine the integration of a portfolio of renewable energies and storage capacities needed to satisfy the profile of the energy demand. The results of the optimization model lead to a portfolio of RE options that reduces the number of cells required to produce the same amount of Aluminum.

Finally, the modulation of the production and energy demand resulted in an excess heat that must be extracted to maintain the thermal conditions within the smelter cell. We present the analysis of the heat flow generated from the modulation of the production, and the potential of heat recovery. The potential of energy efficiency improvement for the manufacturing process was estimated at about 5%.

A Linearized Mathematical Formulation for the Waste Water Treatment Network Design

Pantelis Broukos, Imperial College London, Department of Chemical Engineering, Urban Energy Systems, London, UK
Email: pbroucos@gmail.com
Nilay Shah, Imperial College London, Department of Chemical Engineering, Urban Energy Systems, London, UK
Antonios Fragkogios, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: fragkogiosantonios@gmail.com
Georgios Saharidis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: saharidis@gmail.com

Keywords: Waste Water Treatment; Network Design; Non-Linear Programming; Piece-wise Linearization

Waste Water Treatment (WWT) is an issue of high importance affecting both the environment and public health. The on-going increasing urbanization dictates need for the optimal design and redesign of a WWT network towards purity of waste water runoffs from above mentioned distributed network to all kind of physical water bodies i.e. rivers, lakes and the sea at the lowest cost. In this paper, the problem towards an optimized Waste Water Treatment Network Design (WWTND) is addressed. To this end, different parameters affecting the problem have been taken into consideration. Among them, projections of future population of towns are made in order to estimate the expected waste water production. Also, distance and altitude difference between residential, commercial and industrial areas and existing or candidate treatment plants are calculated. Two types of treatment plants are considered, being mechanical and biological. Decisions on closing, keeping as they are or expanding existing treatment plants or building new ones based on future demands are made through the use of optimization methods. Furthermore, the impact of adopting applications such as installation of Micro-Filtration (MF) and Reverse Osmosis (RO) systems at the level of a typical 4-occupant household is also examined. These appliances reduce the waste water load eventually transferred to the treatment plants and are examined to be integrated in various percentage scenarios in residential areas. However, the most important parameter in these types of problems is the overall cost of such a network, which has various components namely being the construction and maintenance cost of pipelines and treatment plants infrastructure, the installation and operational costs of MF and RO systems etc. All these components are presented as non-linear functions being dependent on both the amount of waste water flow loads within the network as well as the design capacity of the treatment plants. The authors have developed a mathematical model for the solution of the WWTND problem and have applied the piecewise linearization method to handle all non-linear terms. The developed model has been implemented in the context of a fund raising research program for the Ministry of Energy and Infrastructure of Luxemburg, from which all necessary data were collected. The results prove the model's validity and usefulness for the efficient future design of WWTN in general. In the decision making context it is observed that the installation of MF and RO systems is not preferred because of their high cost per amount of waste water, while the creation of fewer and larger (central) biological treatment plants proves to be the most efficient strategy.

GreenYourRoute - Vehicle Routing Problem Modeling & Solution Approach

Zoi Moza, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: zoigr79@gmail.com
Georgios Saharidis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: saharidis@gmail.com

Keywords: Green Vehicle Routing Problem; LIFE GreenYourRoute; Logistics Platform.

Road freight transport and logistics operations in general, essential for the economic development, have several harmful effects on the environment. LIFE GreenYourRoute project is a project currently implemented with the contribution of the LIFE programme of the European Union and the co-financing of the Greek Green Fund, aiming to develop a European innovative logistics platform for last mile delivery of goods in urban environment, within a multidisciplinary approach of environmental engineering, computer science and operations research. The core objective of the project is to reduce produced emissions from transport by solving Green-Vehicle Routing Problems.

The vehicle routing problem (VRP) is a combinatorial optimization and integer programming problem, which calls for the determination of a set of routes, each performed by a single vehicle that starts and ends at its own depot, such that all the requirements of the customers are fulfilled, all the operational constraints are satisfied, and the global transportation cost is minimized.

The main idea of the vehicle routing problem developed under the frame of LIFE GreenYourRoute project was to develop a modeling and solution approach that could be easily applied and adopted by logistics companies, especially small and medium sized ones, and cover substantial daily routing operational requirements and therefore increase the transferability and replicability of the produced platform. The approach was based on the 5 demonstrators routing requirements communicated to the project team and cover several real-life aspects. The objective of the approach is to minimize transport cost taking into account environmental considerations.

The abovementioned problem is an NP-hard problem and therefore cannot be solved optimally, using mathematical programming. To solve the problem, we developed a hybrid approach, including both heuristics and steps based on mathematical programming models.

Initial results achieved by the developed approach indicate an average improvement of 13% for all project demonstrators; future work includes improving the solution time of the approach, solve additional datasets to test its effectiveness and make corrections and improvements where necessary.

A Multi-Objective Optimization Model for Reliability-Based Network Reconfiguration

Panagiotis Karafotis, School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece
Email: panoskarafo@gmail.com
Pavlos Georgilakis, School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece
Email: pgeorg@power.ece.ntua.gr

Keywords: Distribution Network Reconfiguration; Multi-Objective Optimization Model; Mathematical Programming; Reliability Improvement

Reliability is a vital aspect of modern power distribution systems. The reliability of a power system is defined as the system's ability to supply consumers continuously with high level of quality. Distribution network reconfiguration (DNR) is an important technique to improve system's reliability. DNR aims to find a radial topology that optimizes an objective function subject to specific operational constraints. Bus voltages and power losses must be within permissible limits, but also adequate reliability levels must be ensured. Therefore, a balance between power losses and system reliability should be provided by the objective function, as they are both of great importance for the distribution system operators. The majority of the most known optimization techniques are based on heuristic or meta-heuristic algorithms because of their simplicity and low computational effort. However, the heuristic and meta-heuristic models neither are flexible nor ensure optimality of the final solution. On the other hand, in convex mathematical programming models, convergence to optimality is guaranteed.

This research proposes a multi-objective optimization model for DNR, which minimizes the active power losses and improves system's reliability indices. A mixed integer second-order cone programming model is introduced, which transforms the original mixed integer nonlinear programming formulation into a convex optimization model that is easily solved by classic optimization techniques. The control variables of the suggested optimization model are the statuses of the network's switches, which are considered as binary variables. The presented method is applied to a 69-bus distribution system. By varying the weighting coefficients of the objective function's terms, different priorities for total active power loss and reliability indices are considered. The desired system topologies based on the requirement of the reliability indices or power losses or a trade-off between them can be offered by the proposed method. The results obtained indicate the usefulness of the proposed optimization model.

Load Forecasting Using Long Short Term Memory (LSTM) Method

Mert Unver Arslan, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: arslanm17@itu.edu.tr
Gulgun Kayakutlu, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayakutlu@itu.edu.tr
M. Ozgur Kayalica, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayalica@itu.edu.tr
Irem Duzdar Argun, Department of Industrial Engineering, Duzce University, Duzce, Turkey
Email: iremduzdar@gmail.com

Keywords: Electricity Consumption; Forecasting; Recurrent Neural Network; Long Short Term Memory

Short Term Load forecasting is critical for power markets due to the high impact on the electricity supply and marginal prices. There are generally accepted methods use for the short term energy load forecasting as in the technical problems, investment planning and distribution costs. Traditional methods such as the autoregressive moving average (ARMA), the seasonal autoregressive integrated moving average with external (SARIMAX) and the autoregressive moving average with exogenous impacts (ARMAX) have been used for decades. Using the Machine Learning and Artificial Intelligence techniques minimized the prediction errors. Artificial Neural Network (ANN) and Recurrent Neural Network (RNN) methods are the most preferred forecasting tools in the last few years. This paper aims to reduce the energy market imbalance caused by prediction errors by implementing a new deep learning method Long Short Term Memory (LSTM). Using capacity of LSTM to learn long term dependencies facilitated the achievement of better results. The algorithm is implemented for 20 months of electricity consumption in a region of Istanbul. The effect of data type is depicted from the time series analysis results. Performance is measured using mean absolute percentage error (MAPE). It is observed that MAPE is quite high on Sunday. Development of the algorithm is continued using a few timeseries of data.

Effect of Constant and Dynamically Adjusted Half-Cycle Times on the Performance of Solar Dual-Bed Adsorption Cooling Systems

Athanasios Basdanis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: abasdanis@mie.uth.gr
Alexandros Tsimpoukis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: atsimpoukis@mie.uth.gr
Dimitris Valougeorgis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: diva@mie.uth.gr

Keywords: Solar Cooling; Adsorption Chiller; Constant Cycle Time; Adjusted Cycle Time; Silica Gel–Water

Nowadays the demand for air conditioning and cooling is constantly increasing due to improvement in the comfort of human life. Electricity consumption for cooling accounts for about 15% of the total electricity produced worldwide and 45% of the electricity used by houses and commercial buildings. Therefore, energy consumption due to cooling demands is substantial and new systems are needed to replace electricity with renewable energy sources. Meanwhile, solar energy is one of the most promising renewable energy sources for cooling applications, having the great advantage that the solar radiation peak during the day coincides with the maximum cooling load demand. One of the most widely considered solar-powered cooling systems, with a lot of potential, is the solar adsorption cooling system, typically consisting of the solar thermal and adsorption cooling (or adsorption chiller) subsystems. The benefits of adsorption cooling and refrigeration are the utilization of low-grade heat and natural refrigerants, as well as relatively low operating costs. However, these systems present low performance and significant efforts are made to improve their efficiency. In this context, the present work is focused on the detailed parametric analysis of the effect of the cycle time on the performance of a typical solar thermal single-stage dual-bed silica gel-water adsorption system. The optimum half-cycle times maximizing the half-cycle chiller cooling capacity, in terms of the hot water inlet temperature are defined. Then, the adsorption chiller coupled with the solar system are simulated, in real time, during the day for a) constant and b) adjusted half-cycle times and the system performance (cooling capacity and COP) is monitored. The solar radiation and weather data are for the city of Athens, Greece, in July. In the former case, the half-cycle time is fixed, while in the latter one is dynamically adjusted according to the varying solar radiation intensity. Using a wide range of constant half-cycle times it is found that the maximum daily cooling capacity is obtained at some constant half-cycle time, which is larger than the optimum one. This is explained since the small reduction in the half-cycle cooling capacity, combined with the large increase in COP, improve the system performance, providing larger daily cooling capacity. Similarly, using a wide range of adjusted half-cycle times, the one, providing the maximum cooling capacity is defined. The analysis is performed in a systematic manner through a proposed algebraic expression. It is found that using a dynamically adjusted half-cycle time, provides more than 10% higher cooling capacity than the maximum constant one.

Computational Investigation of Dwellings' Foundations as a GHE in Mediterranean Climate

Lazaros Aresti, Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology, Limassol, Cyprus
Email: lg.aresti@edu.cut.ac.cy
Paul Christodoulides, Faculty of Engineering and Technology, Cyprus University of Technology, Limassol, Cyprus
Email: paul.christodoulides@cut.ac.cy
Christos Makarounas, Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology, Limassol, Cyprus
Email: christos.makarounas@cut.ac.cy
Lazaros Lazaris, Department of Mechanical Engineering and Materials Science and Engineering, Cyprus University of Technology, Limassol, Cyprus
Email: lazaros.lazaris@cut.ac.cy
Georgios Florides, Faculty of Engineering and Technology, Cyprus University of Technology, Limassol, Cyprus
Email: georgios.florides@cut.ac.cy

Keywords: Geothermal Energy; Ground Source Heat Pumps; Thermo-Active Geo-Structures

Geothermal energy finds application through Ground Source Heat Pumps (GSHPs) for space heating and cooling. GSHP systems extract or reject heat into the ground through a network of pipes, namely Ground Heat Exchangers (GHEs). GHEs can either be horizontal of vertical with various configurations such as U-tube, spiral/helical pipe and others. Although GSHPs provide higher performance than Air Source Heat Pumps, the longer payback periods and higher initial investment has made the systems unattractive as an investment. One solution to reduce the initial investment is the use of GHEs in the buildings' foundations. These systems are named Thermo-Active Structure systems or Energy Geo-Structures. The study here is concerned with Thermo-Active Geo-Structures systems for dwellings in Cyprus. Thermo-Active Geo-Structures coupled with GSHPs could provide an alternative solution to minimize the initial costs and make the GHSP system viable and economically encouraged. Such systems have yet to be applied in Cyprus, therefore, an initial computational investigation is considered using the COMSOL Multiphysics software and available weather and ground temperature data from the island of Cyprus. A typical dwelling in Cyprus is considered, namely a three-bedroom two-storey house of 190m2 total floor area, for which the heating and cooling loads are presented. Typical foundations are modeled at full scale in COMSOL Multiphysics to examine the rejected/absorbed energy to/from the ground. The convection-diffusion equation for heat transfer is used with the three-dimensional conservation of heat transfer for an incompressible fluid. The related parameters are adjusted to present actual parameters taken from experimental data. Preliminary results indicate that the use of a building's foundation as a GHE (Thermo-Active Geo-Structures) could be an alternative to borehole GHEs, where a detailed study on the buildings' loads is required.

A Simple Method for the Inhibition of the Corrosion of Inconel 625 by Molten Chloride Salt for Next Generation Concentrating Solar Power Applications

Argyrios Anagnostopoulos, Center for Thermal Energy Storage, School of Chemical Engineering, University of Birmingham, Birmingham, United Kingdom
Email: argyanag@gmail.com
Yaroslav Grosu, CIC Energigune, Albert Einstein 48, Miñano (Álava), Spain
Email: ygrosu@cicenergigune.com
Maria Helena Navarro, Center for Thermal Energy Storage, School of Chemical Engineering, University of Birmingham, Birmingham, United Kingdom
Email: h.navarro@bham.ac.uk
Yulong Ding, Center for Thermal Energy Storage, School of Chemical Engineering, University of Birmingham, Birmingham, United Kingdom
Email: y.ding@bham.ac.uk
Abdessamad Faik, CIC Energigune, Albert Einstein 48, Miñano (Álava), Spain
Email: afaik@cicenergigune.com

Keywords: Concentrating Solar Power; Thermal Energy Storage; Molten Chloride Salts; Corrosion; Inhibition

Corrosion is an important issue in high-temperature applications such as Concentrated Solar Power (CSP) technology, playing a crucial role in the long-term use of the structural materials in storage tanks, heat exchangers and pipes which account for a considerable percentage both the initial investment and maintenance costs in CSP plants. Several studies denote the high corrosion rates of molten salts on the structural materials of CSP plants, but few of them provide insight in degradation mitigation methods. Next generation CSP plants will be desirably operated using molten chloride eutectic salts (due to their high temperature stability) that have been shown to cause extensive degradation of alloys. Inconel 625 being the most corrosion-resistant alloy has been shown, through electrochemical corrosion, to lead to a corrosion rate of 2.80±0.38 mm/year. For CSP applications, this magnitude of corrosion is not acceptable due to huge costs associated with the required replacement of the storage tank materials. In this work a state-of-the-art method to improve the performance of Inconel 625 against corrosion by molten chloride salt at high temperature is demonstrated. This method has already been shown to mitigate corrosion of nitrate salts on stainless steel. It involves a spray-graphitization and polyethylene wrapping of the Inconel 625 sheets. With the use of this technique a competitive reaction to the oxidation (corrosion) takes place the on Inconel surface with the formation of a protective layer, which is found to be facilitated by the sprayed graphite coating and the polyethylene (carbon) film. The coated material was exposed to a molten chloride salt mixture (NaCl-KCl) for several hours at 700 °C and demonstrated an improved corrosion performance compared to the base case. The protection method proposed has potential due to its minimal costs, as could be demonstrated by tecno-economic analysis, to reduce maintenance costs for next generation CSP plants.

Short Term Balancing Power Market Trend Prediction Using Machine Learning Models

Burak Gokce, Department of Energy Science & Technology, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: bkgokce@gmail.com
Hasan Demirtas, Business School, Sabanci University, Istanbul, Turkey
Email: hdemirtas.academic@gmail.com
Gulgun Kayakutlu, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayakutlu@itu.edu.tr
M. Ozgur Kayalica, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayalica@itu.edu.tr

Keywords: Balancing Power Market; Artificial Intelligence; Machine Learning; Ensemble Model; Stochasticity; Prediction; Balancing Trend; System Direction; Turkish Market

Balancing Power Market is one of the short-term power markets which is managed by transmission system operators. It helps transmission system operators to balance supply and demand in real time in order to guarantee the power system security. On the other hand, it helps power generation companies to get additional profit by either increasing or decreasing their load. Balancing power market trend includes power system direction and price. The direction shows whether the system has energy deficit, surplus, or balanced. In the system deficit case, to cover missing energy, transmission system operators give power plants the order to increase their load. In the opposite case, a system surplus, orders are given to decrease the load. The balancing power price is formed with accepted generation orders by transmission system operator. Prediction of balancing power market trend has a critical importance for the market participants. Because the prediction results also give signals for intraday power market price. Market participants use the prediction results to cover their imbalances and bid their generations in a most profitable way. This paper makes a short-term prediction by predicting next 32 hours with latest information available. Because balancing power market has a different design in each country and prediction is difficult due to its stochastic nature, there is no significant study on this topic. To estimate the direction is challenging, because of uncertainty of intermittent renewables hourly generation amount and unplanned malfunctions or incidents of big generation companies. This paper tries to close the literature gap and provides the first study on the Turkish balancing power market trend prediction. Stochasticity-based regression machine learning models are built, then the results are compared. These models include traditional regression models and tree-based models. The models are run individually and with combinations using ensemble approach. The results show that ensemble models perform better over individual models.

Adaptive, Lean and Green Manufacturing: Implementations and Applications in Energy-Intensive Industries 4.0

Sin Yong Teng, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: Sin.Yong.Teng@vut.cz
Wei Dong Leong, Department of Chemical and Environmental Engineering, University of Nottingham Malaysia Campus, Selangor, Malaysia
Marek Vondra, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: m.vondra@vut.cz
Michal Touš, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: michal.tous@vutbr.cz
Hon Loong Lam, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Vítězslav Máša, Department of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology – VUT Brno, Brno, Czech Republic
Email: masa@fme.vutbr.cz

Keywords: Lean and Green; Adaptive Manufacturing; Adaptive Systems; Energy Industry Optimization; Industry 4.0

Since the birth of lean manufacturing in vehicle production companies such as Ford and Toyota, production efficiencies were being elevated by engineering heuristics and statistical approaches. This school of thought have been generally successful and relates to many different lean techniques like six sigma, Kaizen and other techniques for process improvement. In recent years, researchers have pointed out that lean manufacturing lacks the consideration of sustainability and various motive of production improvement does not align with environmental consideration. Various implementation of lean manufacturing has produced detrimental effects to the environment despite benefiting production economics. Nevertheless, it was shown that by carefully considering production objectives and implementation, it is possible to align both lean manufacturing and green manufacturing in the same direction. Later, lean and green manufacturing was popularized which considers a complete variety of objectives from materials, economics, machines, environment to social aspects. However, with more production objectives, better data collection systems and various uncertainties due to renewables, simple statistical tools from lean manufacturing are gradually growing less efficient. In the era of Big Data, machine learning and intelligent algorithms are performing multi-variate analysis much better and effective than traditional statistical lean manufacturing. Hereby, we propose a concept of adaptive, lean and green manufacturing to properly utilize the manufacturing-based Big Data within processing facilities. Our proposition covers a complete range of expert systems, machine learning algorithms, optimization and search algorithms for the purpose of industrial production improvement. This new concept of "adaptive" is designed to transform the energy-intensive industries to cope with varying and dynamic environment with minimal and effective efforts. We also demonstrate some successful case studies which have created tremendous value with partnering companies and facilities.

Complex Assessment of Waste Collection Planning: Pre-processing, Heuristics and Implementation of Routing Problem

Vlastimír Nevrlý, Institute of Process Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
Email: Vlastimir.Nevrly@vutbr.cz

Keywords: Waste Collection; Heuristics; Routing Problem; Bin Allocation; Waste Management Planning; Mathematical Programming

The trend in environmental protection resulted in the Circular Economy Package proposed by the EU. It gives the targets for the upcoming years related to the waste management policy. These include recycling rates for different waste types or the restriction of specific waste treatment. New fractions of waste have to be separately collected to fulfil issued goals. Also, increasing urbanization results in a higher concentration of waste at some collection points and generally in cities. Thus, extensive research in logistic systems is needed for optimal decision-making. A suitable method for the allocation of collection points is the requirement for effective waste management planning. The number of collection containers will grow due to implementation and expanding of bio, oil, E-waste, or textile collection. The analysis of allocation should be made based on the required fill-height and the given number of containers. The consequent waste collection belongs to the class of routing problems, which is also modelled. The identification of key parameters of waste collection at the municipal level is an important task. A presented comprehensive approach combines mentioned models, pre-processing phases and data analysis. It includes statistical evaluation of input data, mathematical model formulation, heuristics development and proper algorithm implementation. The whole procedure can be applied at the municipal or micro-regional level depending on the given task and boundary conditions. The presented case studies include allocation of waste containers and daily routing for all vehicles from the available fleet for the specified areas. Results are presented through the visualization in maps and also by quantitative evaluation of the designed solutions. Decision-making about the location of collection points and subsequent route schedules substantially influences the expenses of technical services. The designed solution can serve not only to improve the current operational situation but also to allocate containers and create route schedules for newly separated waste types.

Energy Project Portfolio Selection and Scheduling using Financial Criteria

Dimitrios Tselios, Department of Business Administration, School of Economy and Management, University of Thessaly, Larissa, Greece
Email: dtselios@uth.gr
Grigorios Papageorgiou, University of Thessaly, Larissa, Greece
Email: gpapageor@uth.gr
Nikolaos Alamanis, University of Thessaly, Larissa, Greece
Email: alam@uth.gr
Pandelis Ipsilandis, University of Thessaly, Larissa, Greece
Email: ipsil@uth.gr

Keywords: Project Portfolio; Project Selection; Energy Projects; Scheduling; IFM

In the present work, we formulated an integrated method in order to confront two semantic problems regarding a project portfolio that contains energy projects and/or proposals for projects to be implemented in the future. More specifically, the problems are: the selection of the most beneficial projects and their scheduling. Our approach is based on extending a tested and well-performed Dynamic Programming solution for project portfolio scheduling in order to serve the selection problem as well. The approach is utilizing the Incremental Funding Method (IFM).

Most of the existing bibliography is focused on project scheduling problems, although an adequate part is dedicated to the project portfolio scheduling problem. Moreover, the mainstream line of thought until recently, considered these two fields of study as relevant but the majority of the researchers tried to concentrate on only one of them treating them as two distinct domains.

However, contemporary organizations ought to handle simultaneously a bundle of project proposals, to select a group of them due to budget's constraints, and then to schedule them in order to maximize their potential profit.

Though the IFM was proposed to address software project deliverables, it can easily applied to other industries that have characteristics similar to software projects. Hence, according to IFM, the self-contained energy projects that offer business value can be considered as Minimum Marketable Features (MMFs). Usually, a MMF i.e. an energy project is depended on the development of other predecessor projects. Moreover, some energy projects require the completion of other projects, which do not provide direct business value. IFM terminology calls them Architectural Elements (AEs).

The proposed method extends the IFM concept in order to cover the energy projects and stands for a tool to select and schedule simultaneously the implementation of project proposals that give the maximum value to the performing organization. The outcome of this enhanced method produces quite promising results when tried on a tailor-made set of benchmark instances.

Assessment of Methodologies for Estimating Seismic Displacement of Slopes with Underground Energy Pipelines

Grigorios Papageorgiou, University of Thessaly, Larissa, Greece
Email: gpapageor@uth.gr
Nikolaos Alamanis, University of Thessaly, Larissa, Greece
Email: alam@uth.gr
Dimitrios Tselios, University of Thessaly, Larissa, Greece
Email: dtselios@uth.gr
Evangelos Paschalis, Department of Technical Services, Municipal Water and Sewerage Company of Larissa, Larissa, Greece
Dimos Zahos, Professional and Scientific Association of Technological Education Engineers (EETEM)
Nikolaos Xafoulis, University of Thessaly, Larissa, Greece

Keywords: Energy Pipelines; Seismic Displacements; Assessment; Pipeline Rupture; Highway Infrastructure; Estimation Methodologies

Numerous oil and natural gas pipeline systems passing through geohazard areas all over the world are vulnerable to seismically induced slope instability, large ground displacements and settlements. Underground pipeline deformations at active fault junctions develop due to territorial movements caused by slope seismic failure and are extremely significant, especially in the context of large-scale infrastructure projects, in the field of highway and geotechnical engineering.
Also, the landslides, represent a significant hazard for pipelines because they can generate permanent ground displacement and tend to result in complete failure or significant leaks, major environmental impacts and long periods of service disruption. Pipeline rupture is not uncommon in incidents caused by landslides. As such, landslide-related incidents often result in leaks that may have severe environmental impact as well as long periods of operational stoppage (e.g. Savigny et al., 2005; Marinos et al., 2016). Regarding pipelines running through mountainous areas, statistics show that landslides are the most common cause of pipeline rupture and as such the most significant operational risk (e.g. Sweeney et al., 2005; Marinos et al., 2016). Past design practices for pipelines, as well as almost all other construction projects, have focused on avoidance of areas that have a reasonable probability of experiencing geohazards (defined as large ground displacements that may arise from slope failure, slope creep, earthquake triggered slope movement and subsidence). This approach has been generally successful when there are limited restrictions on selecting a pipeline route. Avoiding potential geohazards is becoming increasingly difficult because of the inability to obtain landowner agreements, the lack of space in common utility corridors, environmental restrictions, incompatibility with existing land use, and/or public opposition. In route corridors where geohazards cannot be avoided, the potential risks associated with these hazards must be managed (Honegger et al., 2010).
As ascertained from the aforementioned, it is of utmost importance to estimate potential slope seismic displacements. The question arises is which is the optimal methodology for such estimates? In this work a multi-criteria assessment of three widely used methodologies, namely pseudo-static, “Newmark” and numerical analysis with finite elements or finite differences, is conducted. The criteria to evaluate these methods are accuracy, ease of application, range of application and completeness. The interesting findings of this research are presented herein, and the proposed assessment methodology stands for a useful tool for selecting the optimal alternative according to special characteristics of each case.

RES Investment Risks: Assessment Using System Dynamics Approach

Izzet Alp Gul, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: izzetalpgul@gmail.com
M. Ozgur Kayalıca, Energy Institute, Istanbul Technical University, Istanbul, Turkey
Email: kayalica@itu.edu.tr

Keywords: Renewable Energy System; Energy Investment; Risk Analysis; System Dynamics; Turkey

Renewable energy has a critical role in improving the energy mix and hence energy security. The benefit is threefold: domestic demand is responded by domestic resources, sustainability is improved through diversified resources and ecological sustainability is supported. Although the dependence on fossil fuels is still high, renewable energy usage rates are increasing in developing countries. However, impetuous development in the sector faces various risks due to rapid growth. The investment risks of renewable energy sources over the years have caused unexpected issues in financial, technical, legal and other dimensions. The efficiency and profitability performance of new investment depends on the evaluation of these risk factors. In this article, risk factors and interactions among them are identified for renewable energy system investments in order to mitigate, monitor, and control the probability and the potential impact of future events. The identified risk factors and interactions are analyzed using the Delphi and Entropy methods applied in to the case of Turkey. System Dynamics has been chosen as the main assessment methodology due to its unique aspect of allowing and representing the interactions and feedbacks even for non-linear links through a particular project lifecycle. This research is unique in combining technical, political, social and environmental risk factors with interactions for the evaluation of geothermal, solar, wind and hydroelectric power plant investments. Investigation of investments enlightens sector participants who are planning to make a long-term and strategic investments.

Comparative Study for Selecting Self-Supporting Pile Retaining Wall, in Energy Duct Passages, with Vertical Excavation Front

Dimos Zachos, Professional and Scientific Association of Technological Education Engineers (EETEM)
Georgios Bakalis, Professional and Scientific Association of Technological Education Engineers (EETEM)
Konstantinos Bakalis, Professional and Scientific Association of Technological Education Engineers (EETEM)
Nikolaos Alamanis, University of Thessaly, Larissa, Greece
Email: alam@uth.gr
Grigorios Papageorgiou, University of Thessaly, Larissa, Greece
Email: gpapageor@uth.gr
Spyridon Kotsopoulos, University of Thessaly, Larissa, Greece

Keywords: Excavation; Under Grounded Work; Pile Retaining Wall; Energy Pipelines

The purpose of this paper is to determine the minimum support requirements laid down for the safe execution of under grounded work for energy pipeline crossing. This term refers to open excavations carried out for the purpose of installing or constructing an underground energy pipeline which, depending on the conditions of their execution, are classified according to the site of execution and the categories of soil.
The present paper focuses on the study of the method of support in excavations carried out in urban environments and in particular those carried out in soil. According to European legislation on excavation of trenches within the urban fabric, it is imperative for the excavation fronts to be supported for safety reasons, even when the analyses show inherent stability.
Of particular interest are excavations at a depth of more than 3m, thereby qualifying as deep excavations. Such excavations may cause the surrounding soil to deteriorate, especially in the case of adjacent buildings, resulting in unwanted sedimentation and deformation of the structures.
In this context and for the purpose of averting the aforementioned consequences, before the excavation begins and at its boundary, it is advisable to form vertical support structures uniformly named “pile retaining walls”. The main criteria for selecting the type of retaining wall are soil characteristics, local conditions (proximity of adjacent buildings, and the aquifer level) and finally how long the trench will be held open.
On the basis of the above, the purpose of the paper is to investigate the temporary support of trench vertical fronts, 3m to 6m deep, excavated in soil. The study is based on the application of the Limit Balance Method and carried out in accordance with the provisions – guidelines set out in Eurocode 7 (EN 1997).
The study investigates the distribution of ground pressures on a cantilever pile retaining wall, extracting the main design parameters of such systems. The aim is to select the type of retaining wall depending on the soil properties (c, γ, φ and E) and local conditions, as a prerequisite for safe and rational design. In particular, the selection of the minimum support system is scrutinized by applying steel retaining systems as sheet pile wall and soldier pile wall.

The Free-Floating Bike Share Rebalancing Problem

Konstantinos Ampountolas, Imperial College London, Department of Chemical Engineering, Urban Energy Systems, London, UK
Email: k.ampountolas@uth.gr

Keywords: Free-floating; Bike; Share; Rebalancing

Free-floating bike share (FFBS) is a bike sharing scheme where bikes are tracked in real-time by built-in global positioning system devices. Bikes can be locked to an ordinary bicycle rack, thus eliminating the need for specific docking stations. However, the daily operation of the system leads to an uneven distribution of bikes in the network, and, thus to low quality of service. To cure this problem, operators relocate bikes across the network (i.e., rebalance the system) to achieve a desired distribution and to serve customer's demand. We formulate the FFBS rebalancing problem as a mixed capacitated general routing problem (MCGRP). The MCGRP is defined over a mixed graph (with directed arcs and undirected edges), for which some nodes must be serviced and some links must be serviced at least once. Requests with given demand size are located on the nodes, edges, and arcs of a graph, which excellently reflects the idea behind FFBS. The aim is to route a number of vehicles along the graph to satisfy all requests with minimum routing cost, obeying vehicle capacity. To solve this problem, an integer linear program is adopted involving a two-phase branch-and-cut algorithm. Some discussion on the availability of FFBS datasets and perspective computational experiments concludes the paper.

An Exact Cutting Plane Solution Algorithm for a Class of Bilevel Programming Models for Optimal Price-Bidding of Energy Producers in Electricity Markets

George Kozanidis, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: gkoz@mie.uth.gr
Eftychia Kostarelou, Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: ekostarelou@yahoo.gr

Keywords: Bilevel Programming; Optimal Bidding Offers; Energy Producers; Day-ahead Electricity Markets; Integer Parametric Programming; Cutting Planes

We develop an exact cutting plane solution algorithm for a special class of bilevel programming models utilized for optimal price-bidding of energy producers in multi-period day-ahead electricity markets. The proposed methodology utilizes a suitable problem relaxation that does not ensure a necessary condition for global optimality termed bilevel feasibility, which states that the lower-level decision variable values must comprise an optimal solution to the lower-level problem, in conjunction with the associated upper-level decision variable values. Special optimality conditions are embedded within this relaxation to ensure that the energy quantity distribution in each time period of the planning horizon is optimal for the corresponding set of producers that has been identified as active in that time period. Thus, solving the original problem to global optimality becomes equivalent to identifying the optimal set of active producers in each time period. In order to exclude from consideration those solutions for which these sets are not optimal, the algorithm employs a special type of cuts which is based on integer parametric programming theory. We illustrate the application of the proposed methodology on a small case study and we present computational results demonstrating its behavior and performance on randomly generated problems. These results reveal that the proposed methodology is capable of handling medium sized problems using reasonable computational resources.

Pay-as-you-go Road Pricing and Charging over VANETs

Chao Zhang, School of Engineering, University of Glasgow, Glasgow, United Kingdom
Konstantinos Ampountolas, School of Engineering, University of Glasgow, Glasgow, United Kingdom & Department of Mechanical Engineering, School of Engineering, University of Thessaly, Volos, Greece
Email: k.ampountolas@uth.gr

Keywords: Road Pricing; Pay-as-you-go; Willingness-to-pay; Utility Theory; Distributed Control

This paper addresses the problem of dynamic road pricing and charging that is based on a “pay-as-you-go” or “willingness-to-pay” principle. We consider automated vehicles equipped with communication capabilities to allow a satellite system to track their journey and to allow drivers to pay per kilometre in rural areas. The main idea in the proposed framework is that an application (network operator/agency) will be able to modify the ow rates (competing origin-destination flows of elastic traffic) by dynamic pricing according to the available capacity and across different routes within the network. This problem can be formulated as a combined network and user optimisation problem where payments declared by the drivers of the network and prices declared by the network operator. The drivers and the network need to exchange some information in real-time via a vehicular ad-hoc network (VANET). We show that an optimum is achieved when payments declared by the drivers and prices declared by the network are in equilibrium. Dual decomposition and synchronous projected gradient or sub-gradient methods can be used to solve the combined network and user optimisation problem in an iterative decentralised manner.