From the Guest editors

ENERGY SYSTEMS, MULTIPHASE FLOWS, AND SUSTAINABLE COMBUSTION TECHNOLOGIES

This Special issue of Thermal Science journal contains scientific articles presented at the 12th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2017) held in Dubrovnik, Croatia, in the period from October 4th to October 8th, 2017. The SDEWES conference is an international scientific conference that gathers scientists and professionals from the field of sustainable development. The conference has brought together 530 scientists, researchers, and experts from 60 countries in the field of sustainable development of energy and environment. This editorial is based upon 30 papers selected from among 550 contributions presented at the 12th SDEWES Conference. The topics covered in this Special Issue include experimental and numerical research in the field of heat and mass transfer, multiphase flows, sustainable combustion and pollutant emission, and advances in the energy systems and technologies within the framework of sustainable development.

Key words: *multiphase flows, heat and mass transfer, sustainable combustion, internal combustion engines, large-scale furnace, energy systems and technologies, sustainable development*

Introduction

The 12th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2017) was held in Dubrovnik, Croatia, during October 4th-October 8th, 2017. The main goal of the SDEWES conferences is to discuss the recent progress in sustainable development including the energy, water and environment.

The energy sector is in a state of transition to low carbon energy technology. The dependence of the world's energy production on the fossil fuels causes significant air pollution and global CO_2 emission, which are the largest drivers of global warming and climate change. Pollutant and CO_2 emissions from fuel combustion are having an unexpected consequence not only on the environment but also on a human health. Therefore, there is a big effort of scientists and researchers to develop new and optimized low carbon energy technologies to ensure that the atmosphere is warmed under the most stringent climate goals outlined in the Paris climate agreement. The need to burn fossil and alternative fuels more efficiently and cleanly remains a great challenge and huge responsibility for the international research community. Hence, the objective of this special issue was to bring together papers from experts and researchers that were presented at SDEWES 2017 conference covering topics of multiphase reactive flows, heat and mass transfer, pollution processes, low carbon energy systems and technologies, providing discussion and examination of different advanced energy technologies that can create more clean, sustainable and affordable energy systems.

They focus on the *Thermal Scienc*e journal for the sustainable developments are discussed in the following topics:

(1) mass and heat transfer for multiphase flows,
(2) sustainable combustion in internal combustion engines,

(3) power plants, large scale furnaces and boilers, and
(4) energy systems and technologies.

This special volume is a continuation of the successful collaboration between the SDEWES conference and *Thermal Science* journal [1].

Mass and heat transfer for multiphase flows

The efficiency and sustainability of the energy systems greatly depends on the optimisation of the processes of mass and heat exchange. Most of these processes are in multiphase regime due to the occurrence of phase change. In this special issue the focus is given on the waste heat and power recovery, film cooling in gas turbines, and optimization of heat exchanger operation. In the previous SDEWES conferences, a great number of research papers were dedicated to these topics. Wang *et al.* [2] showed the case study of recovering the waste heat from flue gases in a 600 MW power plant by using the low pressure economizer. Shown results indicate heat recovery benefits, such as decrease in the fuel consumption, water consumption and decrease in CO_2 emissions. An example for heat recovery in low temperature systems was shown in [3] where it was shown that the ORC power generation plant operating with ammonia (NH_3) can be employed for heat recovery. The dependence of heat recovery technologies on the economic aspect for different countries is described by Smolen and Budnik-Rodz [4] while the potential of waste heat in Croatian industrial sector is reported in Bišćan and Filipan [5]. A detailed 3-D computational model that simulates the heat recovery in glass industry was shown in Dolianitis *et al.* [6] where authors reported the reduce in a specific energy consumption of the observed furnace by 13.3% simultaneously reducing the flue gases temperature from 460 °C to 220 °C. In [7], authors showed the potential of applying the heat recovery system in a sewage sludge dryer focusing on the energy performance of the system and economic indices. In high temperature systems, the thermoelectric solid-state energy converters can be employed to recover the waste heat.

In this special issue a review in the recent progress on the thermoelectric power generator systems based on the heat transfer, including both theoretical analyses and numerical simulations was given by Ma *et al.* (p. 1885 in this issue). As reported in the review paper, there is a great potential to improve the thermoelectric conversion systems by optimizing the operation of thermoelectric generator system and thermoelectric module. This overview showed that in high temperature power and energy systems, the Thomson effect should be considered due to the nonlinear temperature-dependent characteristic of the thermoelectric material. In addition, it was concluded that the overall efficiency of thermoelectric power generator system can be enhanced increasing the thermohydraulic performance of heat exchangers.

The gas turbines are widely used for production of thermal and electric energy. In such equipment, the overall efficiency is enhanced by increasing gas temperature at the turbine entrance. However, this can have a negative effect of reducing the service life of hot components, such as turbine blades. One of the mechanisms for vanes and blades thermal load reduction is introducing the air or water cooling streams to their surfaces. In previous SDEWES conferences, several papers were based on such topic and on the gas turbine application topic. The research of [8] shows the use of gas turbines in desalination plant, while the work in [9] shows the impact of variable demand on the overall NO_x and CO_2 emissions emitted from the 800 MW combined cycle gas turbine. The thermo-economic analysis of an integrated biogas-fueled solid oxide fuel cell system, with a base layout consisting of a gasification plant, fuel cell, and retrofitted steam-injected gas system, was researched in [9]. The influence of specific fuel properties on stable, durable, efficient and low emission operation of the micro gas turbine while utilizing advanced/innovative fuels was presented in [10]. The authors emphasized the influence of fuel pH values on the fuel system materials, NO_x, CO, and total hydrocarbon (THC) emissions, and on the deposit formation. In research of [11], on a simplified channel it was shown that it is important to cool down the critical turbine parts due to the increased inlet gas temperature. The main focus of the research was given on the analyses of the bulge configuration and its influence on the cooling process.

In this special issue a review on the multiphase flow and deposition effects in film-cooled gas turbines is presented by Wang *et al.* (p. 1905 in this issue). The authors showed advances in experimental and numerical research where they concluded that many unknowns are still present to fully understand the roles of deposition and multiphase flows in gas turbines. However, authors pointed out those two methods, real and virtual, may be employed for experimental investigation. The real research method was used to analyze the deposition capture efficiency and its dependency on particle material, sizing, blowing ration, inlet turbulence level and deposition time. The virtual research method was used to analyze the film cooling effectiveness using the artificial particles made of materials such as epoxy, sand and wax.

To increase the efficiency of film cooling on the turbine blades, the research dealing with the film hole design was carried out by Tian *et al.* (p. 1923 in this issue). The authors used the CFD approach to calculate the cooling effectiveness of two film hole configurations where the main focus was put into the blowing ratio influence. The authors concluded that the cooling effectiveness for the cylindrical hole decreases with the increase of the blowing ratio, while in the case of combined holes the same effectiveness is increased. However, the cylindrical holes showed the better cooling further downstream from the coolant inlet. The authors performed the analysis of mist cooling and its effect on the temperature profiles where they noticed a significant enhancements of cooling effectiveness.

The research of Wang *et al.* (p. 1933 in this issue) shows the influence of flow distribution and film cooling effectiveness for various blockage and blowing ratios. The authors analyzed the influence of blockage ratios and mist injection on the overall heat exchange. They reported that the blockage ratio influences the lateral film cooling efficiency, in specific cases the cooling performance is increased by 10%. The research related to the film cooling processes is a continuation of research published in [12] where authors reported the influence of mist injection on cooling performance.

Another important physical process falling into the field of multiphase processes, researched within this special issue is the spray quenching process, as shown by Baleta *et al.* (p. 1943 in this issue). In this paper, authors emphasized the importance of spray process on the quenching efficiency where they reported the influence of spray impingement density, particle velocities and size distribution on the quenching process. In addition, authors developed the heat transfer model in Lagrangian spray approach that is able to cope with effects of pronounced wall wetting.

In the paper of Izumi and Mizuta (p. 1955 in this issue) a novel application of the Lagrangian moving particle based method to non-Darcy flow in porous media flow is presented. Non-Darcy flow occurs when groundwater flow moves through coarse gravel riverbeds under high Reynolds number. Such studies are very useful for sustainable groundwater use since it can be considered that groundwater is recharged through interaction between river water and groundwater. This is particularly important in small rainfall area where water supply depends on groundwater at a large rate. The authors used a moving particle simulation method as a chosen Lagrangian particle approach. The numerical model validity was checked against seepage experiments in different kinds of coarse porous media and found that the computational flow velocities at middle part of porous media are in good agreement with experimental ones while velocities at outflow end are overestimated.

Important topic dealt within this special issue is the problem of fire hazards in the underground parks. This process can be considered as the multiphase problem if the system of sprinklers is used to extinguish the local fires. For that reason, the research of Špiljar *et al.* (p. 1963 in this issue) deals with numerical modelling of fire hazards in underground car parks. It is known, that people and firefighter lives are greatly endangered in the occurrence of fire accidents. No matter how rare the fire in underground car parks occur, different tools are being developed in order to reduce its harmful effect. For example, in this research CFD approach was used to calculate the smoke gas stratification and smoke layer thickness during the evacuation time. Authors indicated that timely fire detection is of utmost importance and that people must obey the fire signals and follow the provided instructions. Such information could be further used to design safe and reliable fire extinguishing systems. The presented research, in combination with research presented in [13] shows an excellent example how CFD tools can be used for increasing the safety factor in the case of underground car park fire hazards.

In the past years, several papers dedicated to SDEWES special issues dealt with heat exchanger research. In [14], a detailed review of shell-and-tube heat exchangers with different type of helical baffles, primary surface heat exchangers with different types of primary surface plates and direct and indirect air-cooled heat exchanges was presented. In [15], authors showed how the image analysis can be used for evaluation of the flow structure in two-phase flows in the mini-channels for compact heat exchangers. Another research dealing with the mini-channel heat exchangers, but this time used in nuclear energy application reactor, is shown in [16] where the authors reported thermal-hydraulic performance of the zig-zag heat exchanger operating at high temperature conditions. To increase the heat recovery in the heat exchanger networks, authors in [17] showed the retrofitting method that takes into account the heat exchanger geometry. The mathematical model for prediction of plate corrugation parameters on plate heat exchanger performance is developed in [18].

In this special issue of *Thermal Science*, the heat exchangers research has continued. For that purpose, the research of Venkiteswaran *et al.* (p. 1973 in this issue) deals with CFD modelling of water-cooled micro-channel where a novel fin design was proposed. The authors considered that new design ensures effective work resulting in a lower energy consumption and better sustainability. For different designs, authors analyzed flow fields and temperature profiles where a velocity increase was noticed for the offset type fin design. On contrary, the lowest average temperature was noticed in parallel heat sinks. Based on the shown differences authors proposed the criterion for selection of an appropriate geometry of offset fins.

Wang *et al.* (p. 1987 in this issue) developed the determination method of hydraulic resistance implemented within the circuit network. The simplified network model, based on the Voronoi tessellation, was verified against the CFD simulation model and a good correlation was achieved for flow with maximum local Reynolds number less than 40.

Rauch and Galović (p. 1999 in this issue) developed the mathematical model in dimensionless form that describes the operation of one heat exchanger in a heat exchanger network, with a given overall area and based on the maximum heat flow rate criterion. For the validation of the model, authors used a case study of a condenser in a real Thermal Power Plant Plomin, unit 2. The developed models was used to determine a criterion for the existence of the maximum heat flow rate as a local extremum.

Sustainable combustion in internal combustion engines

Research presented on the previous SDEWES conferences was greatly focused on improvement of internal combustion engine efficiency. Researchers presented various methods and approaches, such as combustion of alternative fuels and fuel blends, multi-dimensional modelling, and different engine operating strategies. For example, influence of biofuels on pollutant formation in the conventional Diesel engine was elaborated in [19]. The research in [20] showed the reducing influence of bioethanol-diesel fuel mixing on the particulate matter emissions. The influence of diesel fuel mixing with *exotic* fuels, such as coconut and palm oil fuel, was experimentally investigated in [21]. Authors emphasized that the fuel blends reduce the pollutant emissions, except NO_x, but also influence the engine performance in terms of lower brake torque and higher brake-specific fuel consumption. The research dealing with redesigned Diesel engine operating in a dual fuel mode powered by bioethanol and gasoline fuel was published in [22]. The main contribution of their work was pointing out the influence of biocomponent addition on the maximum pressure and pollutant emissions. Another research analyzing the dual fuel approach for direct injection engine, but this time powered by transformer oil and acetylene blend, was shown in [23]. The authors showed that using such fuels, the nitric oxide emissions can be reduced. However, they noticed the increase in smoke emissions when comparing to the pure diesel fuel. For that reason, authors blended the transformer oil with acetylene in specific ratios. The operating range of the Diesel engine powered with and an alternative liquid fuel produced from waste tires was extended in the research of [24]. To extend the operating range, authors combined the exhaust gas recirculation approach with the tailored main injection strategy. To measure the emissions, authors employed different measuring methods stating their differences, advantages and disadvantages. The combustion of gasoline like fuels and effects of exhaust gas recirculation on particle size distribution was reported in [25]. Authors noticed that a nearly zero soot emissions could be achieved when combusting the gasoline fuel blended with different additives. In the past period, the great research time was invested in analyzing the biogas combustion in internal combustion engines. For example, the biogas combustion in homogeneous charge compression ignition (HCCI) and dual fuel Diesel engine was analyzed in [26, 27], respectively. The spark ignition engine-generator fueled with sewage biogas with different equivalence ratios and different spark timings was analyzed in [28]. The authors showed the correlation between the emission reduction and engine performance. The review paper that describes technologies that could be used in a large, gas fueled internal combustion engines is presented in [29]. In that research, authors focused their work on elaborating technological challenges and requirements that the next generation of gas fueled internal combustion engines will have to meet during the transition from conventional to carbon free fuel sustainable power generation systems. A great contribution to the CFD modelling of processes occurring within internal combustion engines was achieved through previous SDEWES conferences. For correct prediction of combustion of utmost importance is to correctly describe the spray process, as described in [30]. Furthermore, in [31] several conventional Diesel engine operating conditions were modelled with the Euler Lagrangian approach to calculate the pollutant emissions. The same engine was examined in more details in research of [32], where authors modelled the near nozzle region employing the Euler Eulerian approach and coupled it with the Euler Lagrangian approach in the rest of the combustion chamber. The influence of various combustion parameters on the engine cycle efficiency by coupling the 0-D and 3-D approaches was analysed in [33, 34]. Large eddy simulations were employed to model the internal combustion engines in [35, 36] where authors analysed the influence of fuel injection timing and positioning of the ignition process on the total kinetic energy, pressure traces and released heat.

In this special issue further analyses of internal combustion engines by using the experimental research and numerical tools were carried out. In research of Sremec *et al.* (p. 2013 in this issue), authors performed the experimental research on the spark ignition engine powered with the natural gas. They analyzed the influence of high compression ratio and excess air ratio on overall engine performance. The higher compression ratios of 12, 16, and 18 were analyzed due to the higher octane rating of natural gas, when comparing to the conventional gasoline fuel. To run the engine, instead of the natural gas authors used the characterized CH_4 from the pressurized cylinder. The main conclusions from the research are that the indicated efficiency of the observed engine depends on the air-fuel ratio and engine speed, but mostly on the compression ratio. Furthermore, authors have shown the reduction in ignition delay with increase of the compression ratio, which was addressed to different spark timings. Regarding to the total hydrocarbon emissions, the correlation between emissions and compression ratio was obvious, while its influence on CO emissions was shown negligible compared to the influence of excess air ratio. In the case of nitrogen oxide emissions, it was shown that the nitrogen oxide concentration is significantly influenced by excess air ratio and much less by the compression ratio.

To help the humanity in reducing the nitrogen oxides and particulate matter from the internal combustion engines, in work of Vučetić *et al.* (p. 2025 in this issue) authors showed the experimental research of a single cylinder Diesel engine. The engine was reconstructed to enable operation in spark ignition and in HCCI mode. To characterize two different combustion modes, engine tests were performed for three operating conditions, but at the same indicated mean effective pressures and engine speeds. In both cases, the engine was fueled with gasoline and CH_4 fuels. Authors characterized operating modes by comparing the mean in-cylinder pressure, temperature, and rate of heat release profiles, as well as pollutant emission concentrations. They noticed a much higher in-cylinder pressure of the HCCI mode due to the higher excess air ratio and the load control method. Furthermore, authors have shown the dependency of the fuel type on the combustion duration and on the indicated efficiency. From the conducted research, a clear influence of the engine operating mode on the hydrocarbons (HC), CO and NO_x emission was shown.

The research of Žvar Baškovič *et al.* (p. 2039 in this issue) shown deals with reduction of particulate matter and nitrogen oxide emissions through enhanced charge homogenization in Diesel engines. Authors established a low temperature combustion mode with a direct injection of conventional diesel fuel and tire pyrolysis oil. Comparing to the diesel fuel, the tyre pyrolysis oil showed a similar physical properties and lower cetane number. The main part of the research authors dedicated to investigate the influence of suitable injection strategies and exhaust gas recirculation rates on pollutant emission concentrations. Authors showed that the change in engine control strategy can be used to improve the emission trade-off with only slightly influencing the engine efficiency. In addition, authors established low temperature combustion with tire pyrolysis oil fuel and they showed the influence of such fuel on the emission formation.

An experimental research of biomorphic Silicon Carbide used in Diesel particulate filters was shown in research of Orihuela *et al.* (p. 2053 in this issue). Due to the optimal thermal and mechanical properties, Silicon Carbide is a popular substrate in commercial Diesel particulate filters. In their research, authors designed experimental rig and integrated it within the existing four cylinders, turbocharged, common rail engine test bench. In the first stage, authors tested two different filter samples. They measured the particle concentration with an optical particle sizer before and after passing through filter samples. The filtration efficiency, observing particles larger than 300 nm, of the clear filter was around 83% and increasing to almost 100% in period shorter than 2 hours. The increase in the filtration efficiency was addressed to the filter particle loading.

Another research dealing with particulate matter emission from internal combustion engine was shown in Wang *et al.* (p. 2065 in this issue). One of the promising combustion modes for reducing the nitrogen oxide and soot emission is a low temperature combustion using gasoline-like fuels. Therefore, authors separately blended n-heptane fuel with three fuels (iso-octane, toluene, and n-butanol) in different composition ratios. With mixed fuels, authors performed experimental research on the modified single-cylinder engine, as well as the numerical research using a homogeneous reactor method. After the initial analysis, authors used composition ratio of 70% and performed further experimental tests focusing on the particle size distributions.

In work of Zhang *et al.* (p. 2077 in this issue), authors experimentally and numerically researched laminar combustion characteristics of natural gas-syngas-air mixtures. Specifically, authors analyzed the effects of H_2 and CO species addition in CH_4/air mixtures on the flame stability, as well as the laminar flame speed. They noticed almost linear increase of laminar flame speed when increasing the hydrogen ratio. Furthermore, authors emphasized the influence of H_2 and CO addition on the increase of flame temperature, and an influence of H_2 addition on thermal diffusivity. In the same research it was shown that the pressure has opposite effect on the flame temperature (increasing) and thermal diffusivity (decreasing).

Power plants, large scale furnaces and boilers

Even though the usage of renewable energy sources is inevitably raising, the shear amount of energy needs for electricity generation still make the industry heavily reliant on the use of fossil fuels. In order to maximize the efficiency, and consequently, lower emissions of coal fired thermal power plants, constant improvements have to be made. In the previous SDEWES conferences, several research papers was dedicated to that issue. For instance, Marušić *et al.* [37] proposed thermal plant flexibilization by means of control system modifications, while Mikulandrić *et al.* [38] presented possibilities of implementation of advanced control concepts based on artificial intelligence. The article by Honus *et al.*, [39, 40] deals with comparison of different pyrolysis gases as alternative fuels in terms of their acceptability as replacements for natural gas and propane. The authors put focus on interchangeability – examining the possibilities of pyrolysis gas usage in conventional burners with as little adjustments to burner design as possible. Furthermore, exergy diagnosis, such as one done by Stanek and Budnik [41], lead to better identification of losses in the system, which, in turn, opens way for efficiency improvements. In addition, some papers were dedicated to using the advanced CFD models in large scale engineering systems. For example, Mikulčić *et al*. [42] developed the approach within the Euler Lagrangian framework capable to model the co-firing of pulverized coal and biomass in the cement production facilities.

In this special issue, the work by Krasniqi Alidema *et al.* (p. 2087 in this issue) aims towards identification of sources and magnitude of thermodynamic inefficiencies in utility steam generators. The work deals with a parallel analysis of the energy and exergy balances, based on methods presented in [43, 44] respectively, of a coal-fired steam generator that belongs to a 315 MWe power generation unit. Since the largest exergy dissipation in the thermal power plant cycle occurs in the steam generator, energy and exergy balances of the furnace and heat exchanging surfaces were established in order to identify the main sources of inefficiency. According to the exergy analysis, depending on the working regime, the steam generator is responsible for about 83% of the total exergy destruction in the power plant. The research concluded that the optimization of combustion through sufficient combustion air preheated by use of dryer exhaust gases, controlling the amount of excess air at optimal level, delivery of pre-dried lignite by use of combination of hot- and cold flue gas recirculation, creating conditions for suitable fuel and air mixing, can be effective in order to reduce the exergy dissipation. Authors pointed out that opportunities for limiting the exergy dissipation in the heat transfer process are mostly based on reduction of temperature difference between combustion products and working fluid in heat exchanging surfaces and, therefore, are less feasible.

Fuel-fired industrial furnaces emit large quantities of NO_x in atmosphere. NO_x can be reduced by employing gas after treatment technologies, such as selective catalytic reduction [45], or selective non-catalytic reduction [46]. Qi *et al.* (p. 2103 in this issue) carried out sensitivity study to investigate the influence of fuel flow rate, air-fuel ratio on the resultant concentration of NO_x in the flue gases. For the purpose of their research, a transient three-dimensional mathematical combustion model coupled with a heat transfer and pollution formation model of a walking-beam-type reheating furnace was developed. Using this model, the flow field, temperature distribution, the NO concentrations from the reheating were obtained. Based on the predicted results, the NO concentration in the furnace at different fuel flow rates and different air-fuel ratios were analyzed. The produced results revealed that the concentration of NO increases about 6% with the air-fuel ratio increasing from 1.05 to 1.2. Thus, authors pointed out that the air-fuel ratio should be strictly controlled in the actual production processes of a reheating furnace.

The research of Zhu *et al.* (p. 2113 in this issue) studies the effect of ash fusion characteristics on the biomass slagging behavior by carrying out the ash fusion experiments and CFD modelling. The experimental setup was carried out with simulated biomass ashes consisted of aluminum oxide (Al_2O_3), silicon dioxide (SiO_2), calcium oxide (CaO), and potassium oxide (K_2O), as they together take over 50 wt.% of biomass ashes. On the basis of the experimental results, an ash particle adhesion model has been developed using the corresponding characteristic temperatures of adhesion. The authors revealed that for a kind of cotton straw ash with low melting temperature, the modelling results indicate that adhesion of molten ash plays a major role during slagging. The accretion rate of molten ash adhesion was shown to account for 85% of the total accretion rate. For a kind of corn straw ash with high melting temperature, that proportion was 37%. Compared with the actual slagging during biomass combustion, the modelling results can reflect a similar slagging situation on the surface of tube, with a similar shape and larger amounts of deposits. The authors proposed the addition of target particle removal mechanism in future work to alleviate the deposit overestimation.

The research of Filkoski *et al.* (p. 2123 in this issue) deals with the possibilities of the exhaust gas waste heat utilization from a shaft kiln in order to improve the overall energy efficiency of the technology process. In order to perform a quantitative estimation, the kiln system was subjected to energy analysis using mass and energy balance equations. Several different options were analyzed: preheating of a raw material, preheating of heavy fuel oil, preheating of combustion air, preheating of combustion air and raw material with flue gas and preheating of air for combustion and for drying the raw material. The analysis has shown that the last option is relatively simple, feasible, and economically effective technical solution for energy consumption reduction, without affecting the calcination process. The ultimate conclusion of the research was that the simple payback period on investment for this option, without purchasing new compressor units, which would be the highest item in the specification list, is less than one and a half year.

Mustapić *et al.* (p. 2137 in this issue) investigated the thermodynamic and economic analysis of an ORC based geothermal power plant. The thermodynamic analysis was performed on the basis of the openoxrating conditions influence analysis, such as evaporation and condensation temperatures and pressures, and evaporator and condenser pinch point temperature difference, on the cycle characteristics such as net power output, and plant irreversibility. The economic analysis was performed on the basis of relationship between the net power output and the total cost of equipment used in the ORC in order to assess economically suitable working fluids and working parameters. It was concluded that working fluids which critical temperature was significantly lower than the input temperature of the geothermal fluid (about 25 °C), achieved high values of maximum net power output in the ORC, but had modest economic performances. On the other hand, working fluids which critical temperatures are significantly higher than the input temperature of geothermal fluid (about 65 °C to 75 °C) have achieved the highest values of the maximal net power output index with relatively low values of maximum net power output. However, authors pointed out that due to relatively similar value of maximal net power output index of all working fluids, it would be useful to further conduct economic analysis with another economic indicator.

Energy systems and technologies

Energy systems are complex systems where the production and utilisation of energy should be synchronised in a most efficient way. As various energy sources and conversion technologies are available nowadays, the planning of energy systems requires tools capable of handling such a complex task. As usually the energy system exist, in the first step a proper and validated description of existing system should be performed.

Many contributions along this line have stemmed from SDEWES research. An example being [47], where a combined heat and power retrofit for a large multiple effect distillation along with thermal vapor compression desalination plant has been proposed. In [48], an innovative solar-geothermal trigeneration system integrating water desalination was presented. The system includes the following technologies: parabolic trough collectors, ORC turbo-expander, absorption chiller, multi-effect distillation, and is able to simultaneously produce power, space heating and cooling and freshwater from seawater. Furthermore, [49] analyzes a solar and pellet combisystem for apartment buildings. Other examples include thermo-economic assessment of a novel cogeneration plant for sewage sludge treatment [50], systematic investigation of the performance of a passive direct methanol fuel cell with different structural configurations [51], analyses of different variants of combined heat and power plants (CHP) for electricity production from forest and agriculture biomass [52]. Also, the work presented in [53] shows how biomass hydrogen production has attractive features for the realization of the closed cycles of energy resources, even if technical, energetic, economic, environmental and social analyses of the specific production-use system have to be made.

In the work of Marcos *et al.* (p. 2151 in this issue), a case study of a solar cooling system with an optimized air-cooled double-effect water/lithium bromide (water/LiBr) absorption machine has been conducted. This system allows eliminating the cooling towers in those regions of the planet where water is scarce. For that reason, the authors conducted a case study on a hospital located in Almeria, in the south of Spain, where high solar radiation and little rainfall can be observed. The purpose of the study was to determine the advantages of air-cooled absorption solar cooling systems compared to the solar water-cooled single effect systems and conventional mechanical compression refrigeration systems in terms of efficiency, savings in CO_2 emissions and water consumption, comparing the annual performance of these three systems. The methodology applied in this work included collecting data from the Spanish weather for energy calculations (SWEC) database, calculation of annual cooling thermal loads, modelling, simulation and calculation of savings in water consumption of solar water-cooled single effect (WC-SE) and air-cooled double effect (AC-DE) water/LiBr systems over the conventional mechanical compression refrigeration systems. Furthermore, the comparison of these three systems was carried out using the solar fraction criterion of 75% for solar systems proposed by Tsoutsos *et al.* [54]. The study showed that the coefficient of performance of the AC-DE system is between 19% and 48% higher than WC-SE system and it consumes a 35% less energy to meet the cooling demand. On the other hand, comparing to the conventional mechanical compression system the saving in electricity consumption was 1,253 MWh. Regarding the environmental issues, AC-DE system saves annually around 35,377 m^3 of water and 11,007.6 tons of CO_2 compared to the water-cooled one, making its environmental footprint the lowest among the analyzed systems.

Research in the field of sustainable development and clean energy is taking a full swing due to the ever-increasing awareness of harmful consequences, which result from fossil fuel exploitation. Researches include proposals of new technologies, such as the work by Perković *et al.* [55] which demonstrated the concept of energy harvesting from high altitude winds. Some works focus on integration of renewable energy into existing energy production systems [56], or district heating systems [57]. The work by Ioakimidis *et al.* (p. 2163 in this issue) combines the topics of district heating and electricity generation with the usage of renewable energy by carrying out a case study on a Spanish village of Uruena. More specifically, this study considers the design of a district heating system consisting of a solar heating plant, a biomass using straw as a sustainable fuel for the base load and an oil boiler for the peak load, coupled with a hot water tank as a thermal energy storage option. Two alternative scenarios are analyzed for electricity generation purposes, namely a system consisting of three small wind turbines and a system with a single large wind turbine. Methodology included the analysis of the district heating system components, loads calculation, sizing the systems with the duration curve method for the solar heating collectors, sizing the thermal storage capacity, sizing the electric storage capacity, and electricity production with wind turbines. The special care was taken in order to incorporate backup boilers into the system to ensure the continuous energy supply to the village, even in the cases of system failures or non-favorable climatic conditions for considerable periods of time. Authors concluded that the proposed system configuration significantly contributes to the mitigation of greenhouse gas emissions. On the other hand, authors found out that the initial cost investment required for implementation of an energy system with electricity storage capabilities and a backup generator can be prohibitively high. Alternatively, the authors proposed a solution, albeit more energy dependent, by implementing a grid-connected system, where electricity can be bought directly from the grid when needed, while the surplus energy can be sold back to the grid.

The work by Turhan and Akkurt (p. 2177 in this issue) evaluated the perceived thermal sensation of occupants with respect to thermal comfort standards in Mediterranean climate. A small office building in Izmir Institute of Technology Campus Area in Izmir, Turkey was chosen as a case building and equipped with measurement devices to assess thermal comfort of occupants with respect to predicted mean vote (PMV) and actual mean vote (AMV). Both objective and subjective measurements were conducted. The former included indoor and outdoor air temperature, mean radiant temperature, relative humidity and air velocity that were used for evaluating the thermal comfort of occupants, as well as the oxygen concentration which can play an additional role in thermal comfort. Those measurements were used to calculate three PMV values. Furthermore, occupants were subjected to a survey via a mobile application to obtain subjective measurements to calculate AMV values which were then compared to PMV. Correlations showed that PMV values underestimated the perceived thermal sensation of the occupants. The results showed that neutral temperature in the university office building was 20.9 °C while the comfort temperature range was between 19.4 and 22.4 °C for the heating season. The conclusion drawn by authors was that if AMV values were taken into consideration, the energy consumption in the case building could be reduced.

Schellenberg *et al.* (p. 2189 in this issue) presented optimization of a heat pump system with sensible thermal energy storage using genetic algorithm. The system consists of a 15 kW_{TH} monovalent air-to-water heat pump and a thermal energy store. The minimization of running costs and emissions is achieved using the smart grid to charge a thermal store during favorable low-cost times and discharge as required later. Smart technology-integrated, adaptive control with artificial intelligence optimizes the heat pump schedule based on information from forecasting services and/or predictions of heat demand, heat pump source quality, stored heat and day-ahead electricity prices. Aim of the study was to test if the optimized control strategy performs better than the reference strategy in terms of operational cost and renewable energy fraction of the heat supplied. The developed model is a deterministic, quasi steady state model that facilitates the analysis of both, optimized and reference control architectures. The authors identified operational cost reductions of more than 17% compared to a load following reference system while delivering heat with a renewable energy fraction that exceeds 79%. However, the performance of an actual real-life controller is affected by the uncertainty of the weather forecast, heat demand prediction and electricity cost prediction, while the performance results of the different control strategies are based on actual finalized and measured data. Therefore, authors suggest it is crucial to develop methods to reduce uncertainty.

Wolf *et al.* (p. 2203 in this issue) compared the thermodynamic and economic efficiency of three different heat supply processes, based on exergy flows and costs of heat. A gas turbine process with a heat recovery boiler, a gas and steam turbine combined cycle process and a high temperature heat pump system recovering waste heat were analyzed. The aim of their research was to provide heat as 4 bar saturated steam. Calculations were carried out in the process simulation software IPSEpro and the results showed that the heat pump system has higher exergetic efficiency than the gas turbine or the gas turbine combined cycle process. For the consumption related costs, authors concluded that the operation of a heat pump, working with a coefficient of performance of four and for a natural gas price of 25 €/MWh, is the cheapest way of heat production as long as the electricity price is lower than 45 €/MWh.

The work of Barone *et al.* (p. 2215 in this issue) describes a detailed dynamic model for energy recovery from natural gas decompression. Natural gas is typically transported for long distances through high-pressure pipelines and such pressure must be reduced before the gas distribution to users. The available pressure drop can be recovered through a turbo-expansion system in order to provide mechanical energy to drive electricity generators. The authors developed a dynamic simulation model for the energy, economic and environmental performance analysis in MATLAB software, which takes into account the hourly fluctuation of gas pressure, flow rates as well as electricity selling-price to the grid and eventual incentives provided by the legislation. Such model can be useful tool for economic feasibility analyses of that kind of plants. The authors applied the model for two cases of gas preheating: gas-fired heater or solar thermal collectors. Among other findings they concluded that the economic profitability of the investigated novel technology depends on the available gas pressure drops and flow rates and on the produced electricity use.

Applying storages can be a convenient way for decoupling energy production and consumption and to increase the efficiency of an industrial process or energy supply system. The Ruths steam accumulator contains liquid water and steam and is an attractive storage component for processes in which steam plays a major role, because of the possibility to store steam directly, without heat exchangers. The paper of Dusek and Hofmann (p. 2235 in this issue) investigates an idealized hybrid storage concept-model. The system is based on typical Ruths type steam accumulator with phase change material (PCM) modules on outer side that can store part of the energy supplied to the accumulator. The authors did a numerical study where a dynamic model was created in Dymola 2015 FD01 with the TIL-Library 3.3. Also, an example which consist of a charging, storing and discharging phase is presented. The simulation results show a positive impact in terms of storage capacity. The authors concluded that the hybrid storage concept is a promising approach for integration in industrial processes.

The work of Torres *et al.* (p. 2243 in this issue) deals with the investigation of the effect of the collector geometry in the concentrating photovoltaic thermal solar cell performance. The authors focused on a redesign of the reflector geometry in hybrid concentrating collectors in order to improve its energy efficiency. The analysis is done using a numerical model that uses geometrical optics to study the interaction between the sunlight and a concentrating collector along the year. More complex physical models based on open-source and advanced object-oriented Monte Carlo ray tracing programs (SolTrace, Tonatiuh) have been used to study the relation between the collector annual performance and its geometry. On an annual performance basis, a comparative analysis between several solar collector geometries was conducted to search for higher efficiencies but with controlled costs. Results show that efficiency is deeply influenced by reflector geometry details, collector tilt and location (latitude, longitude) of the solar panel installation and, mostly, by costumer demands. The methodology presented in this paper for the design of the solar collector represents an important tool to optimize the binomial cost/effectiveness photovoltaic performance in the energy conversion process.

The paper of Virtič and Kovačič Lukman (p. 2257 in this issue) deals with a regional context of energy and environment in the EU. Within the Climate and Energy Directive, the European Commission has set three main targets: reduction of greenhouse gas emissions, increase a share of renewable resources and improvements in energy efficiency. The paper identifies needs and solutions for capacity building in cross-border regions of Slovenia-Croatia-Hungary in order to better implement energy efficiency and renewable resources potentials. Regarding the competencies gaps two studies were carried out, a review of energy related regional projects and a self-assessment competence questionnaire. These two studies revealed a set of missing competences, which were from the content perspective gaps in innovations (technology options), management (legal requirements, administrative procedures, financing), analytical and research skill (basic and general knowledge, data analyses) to personal, such as effective communication and interpersonal abilities. To address the competences gaps by the stakeholders, online training modules were designed and implemented. They are tested on the target audience, comprehending students, small medium enterprises, non-governmental organizations and decision-makers at the municipalities. The authors concluded that a lack of knowledge by the stakeholders represents a main obstacle for implementing more environmental and economic acceptable energy solutions on a local and regional levels.

Conclusion

In this paper some of the latest progress contributing to a sustainable development of energy and environment is discussed. As can be seen from the paper structure, getting close to sustainable development of energy and environment can be done from different perspectives, from enhancements on the micro scale to the analysis and optimization of entire energy systems. This special issue gives overview of research of several important topics within the framework of sustainable development of energy and environment such as multiphase flows, heat and mass transfer, sustainable combustion and pollutant emission, low carbon energy technologies, which can serve our community to create more efficient, clean, sustainable and affordable energy systems.

This special issue is dedicated to the 12th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2017). It is in the guest editors' opinion that the selected scientific papers from SDEWES 2017 conference will contribute to the knowledge published in *Thermal Science* journal and would be of interest for their readers.

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