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Editorial

Advances in Reduction Technologies of Gas Emissions (CO_2, NO_x, and SO_2) in Combustion-Related Applications

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Global energy production and consumption have increased continuously over the past few decades. Today, a significant part of our energy requirements is mainly met by the combustion of fossil fuels. Owing to their abundance and cost efficiency, fossil fuels have been used as major energy sources in power generation, transportation, and industry. However, the emergence of critical issues pertaining to the harmful effects of extensive fossil fuse use on human health and the environment has brought scrutiny to their use. This has seen, amongst other things, tremendous pressure be placed on the field of energy systems that use fossil fuels to reduce their carbon footprints (CO_2, NO_x, and SO_2) with increasing energy consumption. Therefore, it has become increasingly important that the research community ramp up its development efforts toward renewable energy technologies. However, it will take a long time for renewable and sustainable energy sources to completely replace fossil fuel energy sources. Ultimately, we must maximize the efficiency of using fossil fuels and reduce pollution emissions until the development of renewable and sustainable energy is complete. Over the past few decades, technologies for gas emission reduction and energy efficiency enhancement have been firmly established due to both basic and advanced research into energy systems in the sectors of power generation, transportation, and industrial process.

This Special Issue of *Energies* focuses on technologies for reducing gas emissions and improving energy efficiency in combustion-related applications. In particular, this Special Issue presents 10 excellent publications (nine research papers and one review paper). These deal with reducing gas emissions from combustion systems [1–4], reducing gas emissions from the transport sector [5–8], and improving the efficiency of energy systems [9,10]. In response to the call for the papers, 12 papers were submitted to this Special Issue, with 10 of these being accepted and published.

The first paper of this Special Issue, presented by Lee and Lee [1], provides an in-depth analysis of ammonia combustion technology in thermal power generation systems for carbon emission reduction. Ammonia is a carbon-free fuel that can be directly combusted as an effective hydrogen energy carrier and has a growing range of applications. In particular, as research results of the application of this technology to power generation systems, such as gas turbines and coal-fired power plants, have been reported, the technology required to utilize them is also gradually being advanced. By providing the application results for demonstration, the authors described the latest R & D trends related to gas turbines and coal-fired furnaces using fuel ammonia. They also reported the brief research results of the ammonia–air combustion flame and pulverized coal–ammonia–air co-firing experiments.

Sung et al. [2] presented experimental studies into NO emission reduction in a reheating furnace through burner and furnace air-staged combustion. The effects of the secondary combustion air ratio and air-to-fuel equivalence ratio on the NO emission level were evaluated using a single-burner combustion system and a real-scale reheating furnace. The authors concluded that the NO emission reduction in the real-scale reheating furnace was about 23% after the burner and furnace air-staged combustions were optimized but without additional investments in system modifications. The air-to-fuel equivalence ratio

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for the six individual combustion zones of the system yielded optimal values of 1.13 (top—preheat), 1.0 (bottom—preheat), 1.0 (top—heat), 0.97 (bottom—heat), 1.0 (top—soak), and 0.97 (bottom—soak).

Kim et al. [3] investigated the effects of a direct current electric field on the combustion behavior of a co-flow propane–air diffusion flame. They demonstrated that the electric field enhances the combustion process of the propane diffusion flame, resulting in a decrease in flame size. In the NO_x emission measurements, NO_x emission reductions ranging between 55 to 78% were observed increases in the applied direct current voltage and polarity. The authors concluded that the NO_x emission gradually decreased with an increase in the applied voltage (0 to 5 kV) for both polarities (positive and negative).

Lee et al. [4] investigated the effect of the ash removal treatment of biomass on ash deposition and gas emission characteristics during co-combustion with sub-bituminous coal. In drop tube furnace experiments, it was revealed that, the NO_x and unburned carbon levels decreased after mixing with 5% and 10% biomass, while the content of SO_x slightly increased. However, the SO_x levels were typically between 30 and 50 ppm, which is at lower point than that of the levels found in bituminous and sub-bituminous coal. In addition, while the unburned carbon showed no trends, the NO_x and SO_x readings for all samples decreased slightly. However, they converged around an error of about 10 ppm. The authors concluded that ash removal pretreatment can be adopted to minimize slagging and fouling in a boiler, to effectively eliminate internal corrosion and ultimately to reduce boiler operation cost.

Zhao et al. [5] proposed the use of a hierarchical model predictive control framework to reduce fuel consumption by coordinating the power split and the exhaust thermal management in a diesel hybrid electric vehicle. Simulation results showed that the proposed framework's total fuel consumption was reduced by 8.9% compared to the sequential method when conducing a worldwide harmonized light-vehicle test cycle. Moreover, the total fuel consumption and thermal on slope forecast optimized controller were reduced by 5.2% compared to the fuel and thermal on sensor information optimized controller working with real-time road grade information.

The effect of the breaking pattern on a vehicle's exhaust emissions can be analyzed using the novel method for estimating driving dynamics during breaking that was put forth by Song and Cha [6]. The real driving emission (RDE) test results showed that the proportion of the total energy lost by braking in relation to the total energy consumed by driving in urban, rural, and motorway areas of each driving section was about 54%, 18%, and 7%, respectively. The authors concluded that, although the current real driving standard solely considers positive acceleration when evaluating driving validity, it is necessary to establish regulation on braking patterns because braking patterns can also affect exhaust emissions.

Yu et al. [7] simultaneously measured NO_x emissions via the measured by the portable emissions measurement system (PEMS) and the smart emissions measurement system (SEMS) equipment in a test vehicle, under various test modes both in the laboratory and on road, to confirm the accuracy of NO_x emissions as measured by the SEMS equipment. The slope was significantly equal to 1, and the coefficient of determination was 0.93 or more when comparing the vehicle speed and exhaust flow rate measured by the PEMS and SEMS equipment. NO_x emissions, measured by the SEMS equipment, were higher than those measured by the PEMS equipment under RDE tests. When NOx emissions increased due to lean NO_x trap regeneration and the selective catalytic reduction (SCR) efficiency reduction, the SEMS equipment increased NO_x emissions by exceeding the limit of the O_2 measurement range.

In urea-based marine diesel SCR systems, the injection, mixing, and NH_3 conversion reaction behavior of the urea–water solution all decisively impact the de-NO_x performance of SCR systems. Jang et al. [8] investigated exhaust gas flow and mixing characteristics in a urea-based SCR system with a static mixer by employing numerical analysis in a 2 MW marine diesel engine. The computational fluid dynamics simulation was validated by comparing the uniformity of the NH_3 distribution with an experiment performed at a specific location. The results showed that the performance of the uniform distribution of NH_3 is raised by 25% higher by installing the mixer at the inlet of the catalyst in comparison to when the mixer is not present. The authors concluded that doing so results in better de-NO_x efficiency, a conclusion which has been demonstrated in the industrial field at a practical level.

Na et al. [9] performed the evaporator optimization of a refrigerator through both experimental and simulation methods. They investigated the effects of the lubricating oil and compressor operating time on evaporator performance. The effects of oil were evaluated by eliminating oil and comparing oil systems based on cooling capacity and power consumption. The cooling capacity of the system from which the oil had been system was 2.6% higher, and the power consumption was 3.6% lower, than that of the oil system. After determining the optimal operating conditions of the refrigerator system, visualization experiments and simulations were conducted to decide the optimal evaporator and it was found that the conventional evaporator size can be reduced by approximately 2.9%.

Lee et al. [10] presented experimental studies on the thermal absorption performance evaluation of various nanofluids in a halogen lamp-based solar simulator. The results showed that the thermal absorption performance was high in the order of carbon-based nanofluids (CNTs), metal-based nanofluids (Cu), and oxide-based nanofluids (Al_2O_3). In CNTs nanofluids, the thermal absorption performance expressed the time reduction rate, which was 12.8%, 16.3%, and 16.4% at 0.01 wt.%, 0.1 wt.%, and 1 wt.% test cases, respectively. Therefore, the 0.1 wt.% CNTs nanofluid was more economical and appropriate. However, in Al_2O_3 nanofluids, the time reduction rate of the 1 wt.% nanofluid was significantly higher than that of the 0.01 wt.% and 0.1 wt.% nanofluids. In Cu nanofluids, unlike CNTs and Al_2O_3 nanofluids, the time reduction rate constantly increased as the nanoparticle concentration increased.

Finally, we hope that the published papers contained in this Special Issue will be of broad interest to a broader readership of *Energies*.

Conflicts of Interest: The authors declare no conflict of interest.

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