Refuelling the future: between global sustainability and local emissions

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Since the advent of the Industrial Revolution, scientific and technological progress has been closely intertwined with the utilization of fossil fuels such as petroleum, coal, and natural gas as energy sources. Although these fuels are highly efficient and have high energy yields, they are limited and are being depleted at an accelerating rate. In addition, the use of these fuels release greenhouse gas emissions into the atmosphere, causing global warming and climate change. For these reasons, researchers are seeking alternative energy sources to mitigate the problems associated with the use of fossil fuels. Among the viable options, biofuels and alternative synthetic fuels are considered as renewable energy sources worthy of exploration.

Biofuels are considered a renewable energy source because they can be produced from plant biomass: algae and aquatic biomass, oil crops, oil-based residues, sugar and starch crops, manures, and organic waste, enabling up to 65% reduction in carbon and greenhouse gas emissions compared to their fossil counterparts. However, the production costs of biofuels are generally higher than those associated with fossil fuels. Additionally, the cultivation of biofuel feedstock in monocultures and the significant water requirements pose additional challenges, leading to soil depletion, nutrient loss, and diminished water reserves in certain regions. Nonetheless, the utilization of waste products for biofuel production holds promises for future advancements, as it is expected to be a more feasible and cost-effective approach.

E-fuels are synthetic alternatives to fossil fuels made from hydrogen and CO_2. They can be used in conventional internal combustion engines and distributed through existing networks. Hydrogen must be produced with renewable or CO_2-free energy, and the CO_2 must come from emissions capture to be considered carbon neutral. E-fuels can ultimately serve as smart energy carriers that can be integrated into the overall electricity production cycle from renewable sources. They provide a means to efficiently store and transport surplus energy. By converting renewable energy sources into e-fuels, excess energy can be captured, stored, and readily distributed as needed, helping to address the intermittency and variability of renewable energy generation.

Overall, the use of new fuels enables the exploration of a diverse range of molecules with combustion and emission characteristics that still require comprehensive investigation. Hence, if on one hand biofuels and e-fuels reduce CO_2 emissions, on the other hand they may cause epidemiological damage at the local level and generate new types of particulate matter with unknown characteristics and pollutant types.

Thus, the goal of our work is to experimentally investigate the emissions of biofuels and alternative synthetic fuels using in situ and ex situ techniques, focusing on their particulate and gas phase emissions, exploring their chemical kinetics to be ultimately related with their formulation.

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