A simulation-based analysis for the performance of thermal solar energy for pyrolysis applications

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Solid plastic waste presents a perplexing waste disposal challenge, which has increased in importance due to increasing demand for plastic products over the last century. Chemical recycling approaches such as pyrolysis, allow the conversion of the polymer waste into value-added fuels and chemicals. Pyrolysis provides potential pathways for the circular economy of plastics, especially because of the potential to produce feedstock chemicals for remanufacturing of new plastic products. The high temperatures required to operate the pyrolysis process, however, affect its environmental performance due to the indirect emissions generated when supplying the process with energy. This drawback can be overcome by using renewable energy sources. This work investigates the integration of concentrated solar power (CSP) with the pyrolysis of high-density polyethylene (HDPE), to evaluate the process environmental performance. A mechanistic model is used to describe the pyrolysis reaction kinetics, and is integrated into an Aspen Plus flowsheet model to describe the entire pyrolysis process. System Advisor Model was used to model the solar-thermal process system, which supplies the process with the required heat throughout the year. Process simulations show that operating the pyrolysis reactor at 520°C would convert 78%wt of HDPE to light gases and liquid fuels. The process requires 752 kWhth/ton-HDPE, out of which 82% is used to heat the feed and operate the distillation column. Model simulations showed drastic reductions in fossil fuel usage, with solar energy capacity providing 52.5% of the pyrolysis process annual heat demand. Model-based optimization analysis showed that 72.6% of the pyrolysis plant thermal requirements could be generated via solar energy during the summer, with a CO2 avoidance potential of about 67 kg/ton-HDPE.