Modular Catalytic Reactors for Single-Use Polyolefin Conversion to Lubricating Oils from Upcycled Plastics (LOUPs)

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Industrial Partners: Chevron Philips Chemical Company, Chemstations Inc., American Packaging Corp., City of Ames Resource Recovery Facility, and Hy-Vee

Objectives: In the U.S. just 3.0 million tons of the 35 million tons of plastic wastes that consumers threw away was recycled in 2017. Polyolefins (POs), consisting primarily of polyethylene (HDPE and LDPE) and polypropylene (PP), represent the largest amount of discarded waste plastics with 6.15 million tons of HDPE, 8.08 million tons of LDPE, and 8.00 million tons of PP being discarded in 2017. Of the non-recycled plastic waste, 5.6 million tons was combusted to produce energy while 26.8 million tons was landfilled representing 19.2% of all the municipal solid waste (MSW). Thus, non-recycled HDPE, LDPE, and PP represent a significant resource opportunity for producing chemicals.

Iowa State University (ISU) in partnership with Argonne National Laboratory (Argonne), Texas A&M University (TAMU), Chevron Philips Chemical Company, Chemstations Inc., American Packaging Corp., City of Ames Resource Recovery Facility, and Hy-Vee propose to improve carbon and energy efficiency through a circular plastic economy, by creating innovative deconstruction pathways for existing polymers that generate high value products. With this novel polyolefin upcycling processes, our ultimate goal is to repurpose the constructed carbon-carbon bonds in waste mixtures of POs to produce high performance lubricants with a cost of production of $4.19/gal (current average sale price $9.00/gal)

Approach: Argonne and ISU have recently developed a series of hydrogenolysis catalysts which convert single-use POs quantitatively (>99% yield by mass) into shorter, lubricant-like, hydrocarbon chains. In this project, we will *i*) advance an cost-effective synthetic methodology to scale-up the hydrogenolysis catalyst, while maintaining the required structural features for the selective upcycling of single-use POs; *ii*) deconstruct post-consumer waste POs via selective catalytic hydrogenolysis in a modular continuous process that, through process intensification, combines this catalytic cleavage of long polymeric hydrocarbons into branched C_{40} to C_{60} species with their separation from the catalyst by vapor-phase transport, to produce LOUPs; *iii*) create reliable bench-scale test protocols, and use them to establish friction and wear data bases on existing base oils and LOUPs produced from plastic wastes; *iv*) develop a TEA framework for conceptual understanding of high performance oil production by using an integrated systems-engineering approach; and *v*) evaluate the environmental impacts of chemical conversion of pure and mixed-stream waste plastic POs into a set of LOUPs using GREET.

Impact: This DOE EERE-BETO/AMO project will contribute to the circular economy by reducing consumption of fossil crude oils and accumulation of plastics, increasing the recovery and repurposing of plastic waste, and reducing the cost of high-performance hydrocarbon oil through production of high value products from upcycled waste plastics streams. We will develop a modular scalable process at TRL 4 that produces LOUPs from waste at >40% energy savings, >35% chemical recyclability, and >80% mass yield. A critical outcome is the production of LOUPs which provide >20% improvement in friction and wear scarring in blends with Group III mineral oils and synthetic PAO oils.