Project Title: Biocatalysis Enabled Conversion of Lignin to Adipic Acid: Establishing a Commercial Route to Bio-Nylon

Applicant: University of Wisconsin-Madison

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This project will convert industrial lignin streams to adipic acid, which will be used to produce the engineering polymer nylon-6,6 at pilot scale. We will pursue a tandem chemocatalytic and biocatalytic strategy, initiated by continuous aerobic oxidative depolymerization of lignin and continuous liquid-liquid extraction to produce aromatic monomers. The mixture of aromatic monomers will then undergo biological funneling into cis,cis-muconic acid, which is a direct precursor to adipic acid. The bioconversion process will use an engineered strain of a robust soil bacterium, Pseudomonas putida KT2440, to achieve industrially relevant titer, rate, and yield of muconic acid from lignin-derived aromatic compounds. Muconic acid will be separated from the fermentation broth and hydrogenated into adipic acid in a continuous process. Finally, the lignin-derived adipic acid will be used to synthesize nylon-6,6 on a scale suitable for full material performance testing.

The project focuses on the integration of key unit operations and the transition from bench-scale to pilot-scale to produce sufficient polymer-grade adipic acid to prepare and validate nylon-6,6 performance. Technoeconomic analysis and life-cycle assessment of this process estimates that we can approach cost parity with fossil-derived adipic acid, while achieving >70% reduction in greenhouse gas (GHG) emissions.

Lignin from pulp-and-paper mills and emerging biorefineries continues to be burned for low-value heat and power, adding an expensive unit operation and contributing substantially to local air pollution in biomass processing communities. The process targeted here will displace both lignin combustion and a GHG-intensive process that uses a petroleum-derived feedstock by establishing a first-in-class bridge between an industrial lignin source and a valuable industrial (bio)product. Establishment of a scalable platform for lignin conversion to bio-available feedstocks has broad implications for future chemical production via biological funneling. Adipic acid is the first of many potential targets for industrial replacement of GHG-intensive petroleum-derived chemicals with lignin-derived bioproducts.

This project includes an ambitious Community Benefits Plan focused on 1) activities in Diversity, Equity, Inclusion, and Accessibility to foster the participation of under-represented groups in research, 2) the development of new energy equity tools that will be broadly impactful for the identification of locations for biomass processing facilities that grow the economy and consider the broader impact on local communities, 3) ensuring a equitable and diverse skilled biomass-processing workforce, and 4) a collaborative engagement between science and art that broaden the dialogue about sustainable industrial practices and fosters national awareness of marginalized communities that have been affected by pulp-and-paper mill closures and could benefit from growth within the biomass-processing industry.