

## Executive Summary

The purpose of this study was to optimize the design of a biorefinery in the United States. This biorefinery incorporates the production of biofuels with chemical commodity processes. A mathematical model was used to optimize the biorefinery design around net present value. The optimal biorefinery design determined combined biofuels 3-hydroxypropionic acid, levulinic acid, and tetrahydrofuran production from a switchgrass feedstock. The biorefinery will be built in Lexington, KY with a total capital investment of \$176 million. The yearly production of biofuels 3-hydroxypropionic acid, levulinic acid, and tetrahydrofuran from the refinery are 1.44 billion, 6.5 million, 57.6 million, and 40 million kg/yr respectively. This design has a net present value of \$687 million with a return on investment of 24.5%.

After setting the here-and-now decisions, a second optimal design was determined based on stochastic, or uncertainty, analysis of product and raw material prices and demand. The same processes from the base-case, biofuels, 3-hydroxypropionic acid, levulinic acid, and tetrahydrofuran, are built with initial capacities of 800 million, 5.87 million, 61 million, and 37.8 million kg/yr respectively. Two different processes, glucaric acid and 5-hydroxymethylfurfural at initial capacities of one million and 59.8 million kg/yr respectively, were built in addition to the processes from the base-case. The model was also used to optimize the incorporation of biofuels production from algae into the biorefinery. The major advantage of this addition is the significant reduction of CO<sub>2</sub> emissions from the biorefinery. While the return on investment decreased to 14.8% with a net present value of \$542 million, CO<sub>2</sub> emissions were reduced by 25% in the model including algae.

With the combination of multiple processes in a single biorefinery, it is possible to minimize capital investment and operating costs, especially those related to utilities. A major aspect of this report is the incorporation of centralized utilities which allows for a single utilities infrastructure as opposed to a utilities infrastructure for each process; in addition, excess utilities can be shared and recycled between processes. The mathematical model used in this study found the optimal solution by maximizing net present value.