Development of a scalable, robust electrocatalytic technology for conversion of CO_2 to formate salt via graded microstructures and development of a bioengineered C1 pathway for subsequent upconversion to ethylene glycol

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Summary for Public Release

The goal of this project is to develop and demonstrate key steps in an economically feasible pathway to convert CO_2 into mono ethylene glycol (MEG) via two key steps:

1. Electrochemically converting CO_2 to a formate salt intermediate
2. Biologically upgrading the single carbon formate to ethylene glycol, a two-carbon compound

Ethylene glycol is used as: an industrial dehydrating agent; a heat transfer fluid in HVAC systems; a de-icing fluid; and as a precursor in the plastics industry to create polyester. It is currently made from fossil fuels. MEG has a market of 26.8 million ton (2016). Generating green, renewable MEG should increase annual demand over present estimates of 10%.

The following proposed advancements of electro-bio-technology will lead to a 2-order reduction in CO_2 to MEG production costs, making it competitive with present commercial production:

Demonstrate optimal electrochemical reactor performance at near commercial scales. With significant improvements (high reaction rate & selectivity, stable operation, low chemical consumption) already achieved with smaller cells, emulating this performance with 30x larger reactors will be the focus. Optimal operation of large reactors necessitates efficient CO_2 distribution throughout the electrolyte to eliminate mass transfer limitations and maximize product selectivity across entire electrode. The team will employ innovative processes to create gas diffusion layers that are mechanically strong and have a varying porosity for uniform CO_2 distribution against a varying hydrostatic head. The proposed 30x scaled up reactor demo at TRL=6 will reduce the CapEx ($400/M.t./day) below current industrial process ($490/M.t./day).

Process modifications to make electrochemical formate bio-compatible for eliminating formate pretreatment costs. Presence of high concentrations of salts, such as chlorides, and trace by-products in electrochemically generated formate may inhibit bacteria, making direct bio-feed impossible. The project will tune the electrochemical process chemistry and will simultaneously identify host bacteria that are chloride tolerant so the reactor output formate solution can be directly used for biological upgrading.

Devise a simple, direct bioconversion pathway. Project team members recently discovered a new enzyme catalyzed, carbon-carbon bond forming reaction that uses single carbon inputs. Team members will employ state-of-the-art molecular biology strategies and genetic construction techniques to identify enzymes and host bacteria that can directly convert formate to ethylene glycol in reactor process output fluids.