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Pilot Scale Carbon Negative Hub Recycling Wastes and Producing Carbon Negative Chemicals and Polymers

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Abstract

This project aims to establish the world's first Carbon Negative Hub (CNHub) in the Latrobe Valley of Australia with partners from the research, academia, government and industrial sectors. The CNHub pilot plant's goals are to demonstrate a number of world's first by: (1) producing carbon negative hydrogen at less than Australian dollar ($) 2 per kilogram; (2) using renewable CO_2 to value-add hydrogen to chemicals and fuels; and (3) utilising a fermentative process that consumes non-food biomass and CO_2 for the production of chemicals. This CO_2 consuming fermentative process is superior to competing fermentation processes like that of biogas or bioethanol production where CO_2 is emitted as a waste product.

Following a stage-gate approach, the project began in 2020. The stage 1 of the project is now completed. This paper provides the details of the stage 1 wherein the CNHub process was developed. Figure 1 shows the top-level process flow of the CNHub with four areas, namely: pre-treatment (to allow for the infiltration of chemical reagents); succinic acid (hydrolysis and fermentation using *Actinobacillus succinogenes*); power (generation with CO_2 capture); and methanol (production). The CNHub consumes biowastes and CO_2 to produce methanol and succinic acid. Both chemicals are used as precursors for the production of valuable polymers such as poly(methyl methacrylate) and poly(butylene succinate) respectively. Additionally, methanol has potential application as a renewable fuel.

This study presents the developed mass and energy balancing model and simulated via process-flow sheeting in COCO-ChemSep. Simulation results show that the pilot plant consumes 415 kilogram per hour (kg/h) of waste biomass and 240 kg/h of CO_2. This CO_2 is used to fulfil the gaseous CO_2 feed demands for succinic acid and methanol production. An additional 240 kg/h of renewable CO_2 is locked-in via the biomass' conversion to succinic acid. Thus, in total 480 kg/h of CO_2 is removed from the atmosphere making the overall process carbon negative. The facility produces 160 kg/h of succinic acid and 80 kg/h of methanol. The process also incorporates an electrolyser that produces 25 kg/h hydrogen for consumption in the methanol production. The pilot plant produces its own energy, and all the parasitic heat and electricity duties are fulfilled within the pilot plant. The wastewater is also recycled in the process. Another advantage of the process is minimum waste.

The process is also capable to use as feed and produce recyclable plastic so can be a viable option to solve the current plastic recycle problems. Simulation results also show the potential of replacing 7% of the CNHub's biowaste feed with fossil fuel based plastic waste while keeping the products carbon negative. In the simulation polyethylene is used as the model plastic waste. Such a strategy opens the door for reducing plastic waste whilst generating platform chemicals for the plastics.

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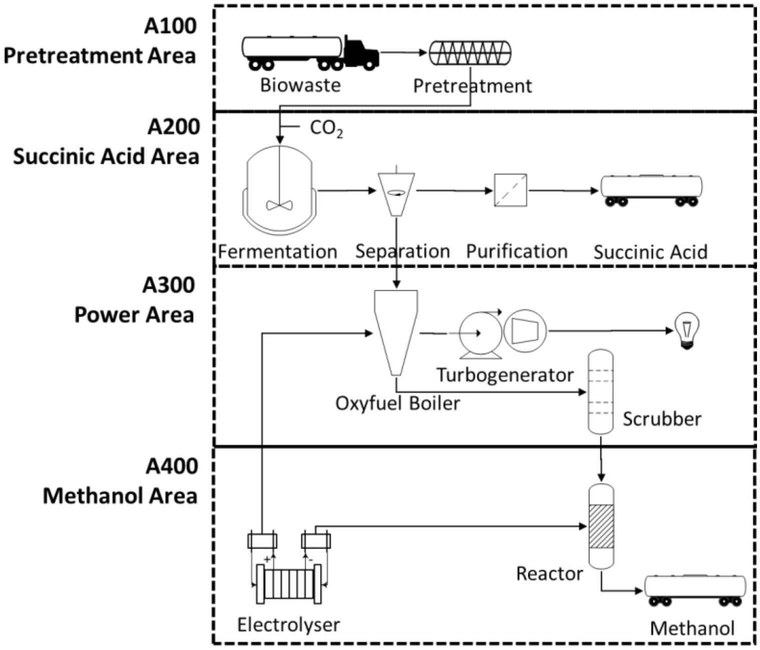

Figure 1: CNHub Simplified Process Flow Diagram

The economic viability of a commercial carbon negative biorefinery resulting from demonstrations at the CNHub has been established and shows hydrogen's production cost at less than $ 2/kg. Carbon negative biorefinery is a negative emission technology (NET) that sequesters CO_2 into products.
The Intergovernmental Panel on Climate Change has identified NETs as essential for the climate target of limiting the temperature increase to 1.5 °C. The biorefineries that produce chemicals via CO_2 consumption are the only type of commercially viable NETs. Biorefineries with carbon negative products present enormous potential for helping in the mitigation of climate change. The current CNHub project is an attempt in this direction, building on learnings from existing commercial biorefineries and aiming to develop and commercialise carbon negative hydrogen value-addition into platform chemicals and polymers; creating a circular bioeconomy with net negative CO_2 solution.

Keywords: Carbon Negatve; Negative Emission Technology; Biorefinery; Waste; Recycling; Hydrogen