Biorefineries for Business Sustainability in the Era of Climate Change: New Chemistries, Commodities, New Materials

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The old petrochemical model is cracking under the forces of climate change [1]. The rise of the electric cars predicted more than a decade ago [2] is a symptom of the powerful force at play on the macroeconomy to remodel businesses where electricity has become the primary energy currency as demonstrated by the welcome worldwide decrease in coal-fired power stations and the increased deployment of renewable sources of electricity generation and renewed interest in nuclear energy in a post-Chernobyl and post-Fukushima world. Remarkably, creative destruction can nowadays be observed where conventional petrochemical refineries are being displaced by biorefineries for producing commodity chemicals, perhaps best exemplified by the industrial-scale production of bioethanol that is nothing but a steppingstone to develop cost-efficient processes for an array of commodity chemicals [3]. To meet the growing global demand for biofuels and other sustainable commodity chemicals while avoiding straining the global food supply, the bioprocessing industry must produce increasing amounts of renewable, petroleum-displacing chemical building blocks, chemicals, and liquid transportation fuels from sustainably produced non-food plant biomass, including agricultural residues, municipal waste, and dedicated bioenergy crops. Novel fermentation technologies and energy-efficient in situ product recovery must be developed and optimised to meet this industrial goal, factoring in several critical parameters including biomass availability, pretreatment, fermentation, and water recycling. Notably, these novel fermentation technologies need to be coupled to superior downstream processing comprising high-productivity membrane cell-recycling reactors and other high-cell-density reactor systems. The successful commercialisation of technologies for manufacturing fuels from lignocellulosic biomass depends on overcoming such challenges by integrating individual unit operations and sufficiently diversifying products. What is more, to sufficiently displace petroleum as a feedstock, novel chemistries and novel industrial materials need to be developed to reflect the less reduced redox potential of agricultural biomass as compared to fossil feedstock. Similarly, engineered pathways need to be developed to enable microbial workhorses to optimally utilise available sugars and thus improve the ultimate process economics. Here, an attractive concept is to decouple vegetative growth and product production phases. This design has been deployed successfully in the facultative anaerobe *Corynebacterium glutamicum* [4]. Autotrophs are microorganisms that can produce valuable complex compounds from primary raw materials such as CO_2 or H_2. *Hydrogenophilus thermoluteolus* TH-1 is being developed at UCDI to produce not only chemicals and biofuels, but also biofeeds and single cell protein. These advances provide an example of integration of biofuel production within the production of renewable chemical building blocks in biorefineries to make commodity chemical production systems technologically, logistically, and economically ready for their implementation on a global commercial scale.

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