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Editorial

ACS Sustainable Chemistry & Engineering Welcomes Manuscripts on the Circular Economy of Biomass

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This editorial highlights key research challenges associated with closing the loop on the biomass-based biorefinery, with a particular focus on areas in which *ACS Sustainable Chemistry & Engineering* welcomes manuscripts. While there are established biomass processing industries that are fully entrenched in world economies, most only participate in specific parts along the arc. For example, the pulp and paper industry makes use of lignocellulosic biomass—mainly wood—to manufacture paper and specialty chemicals, while residual lignin and hemicelluloses (in the form of concentrated spent process liquor) are combusted, resulting in a low-value-added process with a small product portfolio. Food processors, who work on thin profit margins, are focused on a specific edible portfolio and generally do not manage generated food byproducts and waste streams, nor do they participate in soil regeneration activities. Biorefineries centered around fuel and specialty chemical production are nascent, struggling to become economically viable, and are at this point focused primarily on high-value, low-volume products. The profitable long-term implementation of biorefineries relies on the development of cascade processes able to valorize the rich diversity of biomolecules and building blocks in biomass, targeting a diverse product portfolio (from high-value specialty bioactive compounds and multifunctional materials to platform chemicals and energy). Despite the research and industrial investments into biomass-based processes, there remains a dearth of operations that make use of biomass contributing to a circular economy.

Thus far, much of the research efforts have been concentrated on developing processes from food processing byproducts or from novel feedstock sources but have not examined the processes developed in the context of a circular economy. Heterogeneous sources of food waste have been identified and quantified but are not integrated within downstream operations or processes, and financial success hinges upon a diverse product portfolio. This is exacerbated by the absence of uniform metrics to connect extraction processes with other processes or markets. Moreover, because of the nascent nature of the circular biorefinery, applications for chemicals and products are not yet defined, making the required levels of purity uncertain.

The term "biomass processing industry" relates to any industry that relies upon biological plant material originating from either marine or terrestrial environments. Scalable processes—such as extraction, fractionation, and separation—that link upstream with downstream operations ostensibly connecting all aspects of biomass production, transformation, distribution, consumption, and disposal are needed to push biomass processing industries into a more sustainable circuit. The connection between upstream and downstream operations must evolve and be realized while being mindful of both economic viability and environmental ramifications.

We should look to the adoption of a "no carbon left behind" type of mindset and start more fully integrating both the feedstocks entering into the bioprocessing facility (i.e., increased co-mingling of carbon-rich material, such as mixing existing plastics with biobased monomers) and the waste-to-feedstock distribution (i.e., an industrial ecology approach). Figure 1 shows an idealized biomass processing concept. The

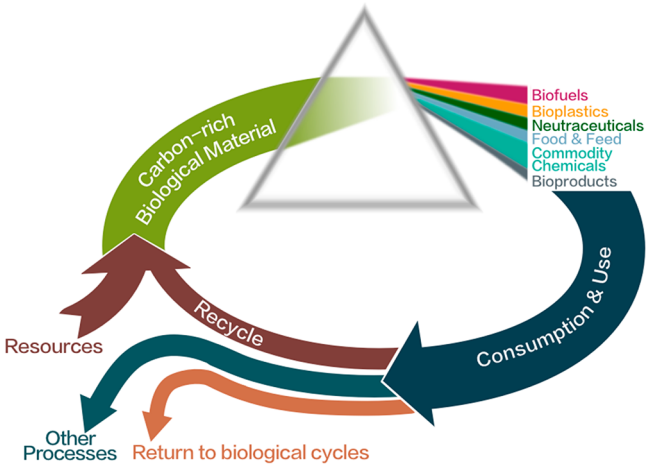

Figure 1. Idealized and simplified circular biomass-based biorefinery concept. Carbon-rich material enters the cycle and is fully fractionated or transformed into the most suitable product. At the end of life, the product is either sent back for recycling, reprocessed at an appropriate facility, or the material and energy is returned to the biological cycles, such as soil nutrient recycling. The stylized prism is intended to illustrate that the carbon-rich material contains the necessary components to be refracted into a variety of products through application of the appropriate processing steps.

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carbon-rich material enters the processing facility, where it is fully fractionated, and the resulting products are suitably transformed considering their properties and principal activities, finally progressing to the end user. Ideally, under the circular economy approach, at the end of life the material is reprocessed or retransformed (whenever possible) and employed in the adequate commercial sector(s).

The strategies under development included in the circular economy paradigms should be aligned with sustainable development goals crucial to guarantee a prosperous, healthy, and educated global society. Consumers must be included in the transition to a circular economy because their habits can both influence and be influenced by the processes and products in question and because they can demand public policy centered on recycling stratergies. Ideally, consumers would forego ultrafinished commodity products for less transformed substitutes that require less severe chemicals and processing steps (i.e., bleached versus unbleached table napkins). Consumers could also participate by actively separating their postconsumer streams prior to collection, alleviating costly postconsumer separation steps and ultimately allowing for easier, more efficient, and more usable materials for recycling.

Broadly, three topical areas represent a sampling of the types of contributions that *ACS SCE* would welcome on the topic of biorefineries and the circular economy: (i) upstream and downstream integration of biorefinery operations, taking into account cascade processes and a multiproduct valorization of biomass, (ii) development and exploration of extraction, fractionation, and separation technologies that are mindful of upstream and downstream operations, and (iii) integrating consumer preferences and habits on processing sustainability. Manuscripts narrowly focused on a single aspect (i.e., extraction of a single niche product from a waste stream without regard for further integration or overall use of the waste stream in question) are of less interest. Careful attention should be paid to the fuller spectrum of use for the biological material of interest. We welcome your feedback and look forward to your manuscript submissions in these areas.

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