World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:13, No:03, 2019

Bio-Hub Ecosystems: Expansion of Traditional Life Cycle Analysis Metrics to Include Zero-Waste Circularity Measures

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Abstract : In order to attract new types of investors into the emerging Bio-Economy, a new set of metrics and measurement system is needed to better quantify the environmental, social and economic impacts of circular zero-waste design. The Bio-Hub Ecosystem model was developed to address a critical area of concern within the global energy market regarding the use of biomass as a feedstock for power plants. Lack of an economically-viable business model for bioenergy facilities has resulted in the continuation of idled and decommissioned plants. In particular, the forestry-based plants which have been an invaluable outlet for woody biomass surplus, forest health improvement, timber production enhancement, and especially reduction of wildfire risk. This study looked at repurposing existing biomass-energy plants into Circular Zero-Waste Bio-Hub Ecosystems. A Bio-Hub model that first targets a 'whole-tree' approach and then looks at the circular economics of co-hosting diverse industries (wood processing, aquaculture, agriculture) in the vicinity of the Biomass Power Plants facilities. It proposes not only models for integration of forestry, aquaculture, and agriculture in cradle-to-cradle linkages of what have typically been linear systems, but the proposal also allows for the early measurement of the circularity and impact of resource use and investment risk mitigation, for these systems. Typically, life cycle analyses measure environmental impacts of different industrial production stages and are not integrated with indicators of material use circularity. This concept paper proposes the further development of a new set of metrics that would illustrate not only the typical life-cycle analysis (LCA), which shows the reduction in greenhouse gas (GHG) emissions, but also the zero-waste circularity measures of mass balance of the full value chain of the raw material and energy content/caloric value. These new measures quantify key impacts in making hyper-efficient use of natural resources and eliminating waste to landfills. The project utilized traditional LCA using the GREET model where the standalone biomass energy plant case was contrasted with the integration of a jet-fuel biorefinery. The methodology was then expanded to include combinations of co-hosts that optimize the life cycle of woody biomass from tree to energy, CO_2, heat and wood ash both from an energy/caloric value and for mass balance to include reuse of waste streams which are typically landfilled. The major findings of both a formal LCA study resulted in the masterplan for the first Bio-Hub to be built in West Enfield, Maine. Bioenergy facilities are currently at a critical juncture where they have an opportunity to be repurposed into efficient, profitable and socially responsible investments, or be idled and scrapped. If proven as a model, the expedited roll-out of these innovative scenarios can set a new standard for circular zero-waste projects that advance the critical transition from the current 'take-make-dispose' paradigm inherent in the energy, forestry and food industries to a more sustainable bio-economy paradigm where waste streams become valuable inputs, supporting local and rural communities in simple, sustainable ways.

Keywords : bio-economy, biomass energy, financing, metrics
Conference Title : ICCEB 2019 : International Conference on Circular Economy and Bioeconomy
Conference Location : Paris, France
Conference Dates : March 28-29, 2019