Towards a Circular Economy Systems Engineering Framework

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Circular Economy represents an economy that is restorative and regenerative by design, which aims to be a solution to the resource challenge society is facing, by keeping products, components, and materials at their highest utility and value at all times. Circular Economy operates at three levels, the micro-level (products, companies and consumers), meso-level (processes, eco-industrial parks) and macro-level (cities, regions, nations and beyond) – based on four actions: reuse, repair, remanufacturing, and recycling. These actions close loops and connect different stages of the supply chain of a product that in a linear economy are typically discrete. These interconnections along with the various players and stakeholders involved in them make decision making for Circular Economy supply chains very challenging. A holistic systems engineering approach may thus be required to navigate the multi-scale, multi-faceted and interconnected circular economy supply chain, identify opportunities for synergistic benefits and systematically explore interactions and trade-offs.

In this presentation, we first address the questions of (i) *what is the relevance and links of Circular Economy to Chemical and Process Systems Engineering*?, and (ii) *what Process Systems modeling, analysis and optimization can offer to Circular Economy?* We then present the foundations of a ***Circular Economy Systems Engineering*** framework towards the analysis and trade-off optimization of interconnected resource networks to potentially achieve a circular economy. The framework combines data analytics, mixed-integer modelling and multi-objective superstructure-based optimization methods to establish & explore (i) the interconnections between different stages of the circular supply chain, involving alternative processes, materials, resources and technological options, (ii) the potentially competing interests amongst various stakeholders, and (iii) policy, regulation and societal issues. Links to multi-scale energy systems engineering & circular carbon economy, life-cycle & sustainability analysis and the Food-Energy-Water Nexus are also discussed. Finally, we highlight possible advantages, limitations, and open questions of circular economy systems engineering through a number of representative case studies.

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