System Analysis and Optimization of U.S. PET and Polyolefin Packaging Supply Chains in a Circular Economy

Utkarsh S. Chaudhari [a], Abhishek Patil [b], Tasmin Hossain [c], David W. Watkins [d], Damon S. Hartley [c], Anne T. Johnson [e], Barbara K. Reck [f], Robert M. Handler [a], Vicki S. Thompson [g], Alejandra Peralta [h], David R. Shonnard [a]

[a] Department of Chemical Engineering, Michigan Technological University, Houghton, Michigan 49931, USA.

[b] Department of Mechanical and Aerospace Engineering, Michigan Technological University, Houghton, Michigan 49931, USA.

[c] Economic and Operational Analysis, Idaho National Laboratory, Idaho Falls, Idaho 83415, USA

[d] Department of Civil, Environmental, and Geospatial Engineering, Michigan Technological University, Houghton, Michigan 49931, USA.

[e] Resource Recycling Systems, Ann Arbor, Michigan 48105, USA.

[f] Center for Industrial Ecology, Yale School of the Environment, New Haven, Connecticut 06511, USA.

[g] Bioenergy Feedstock Technologies, Idaho National Laboratory, Idaho Falls, Idaho 83415, USA.

[h] Chemstations, Inc. Houston, TX

Corresponding Author: David Shonnard, Michigan Technological University, drshonna@mtu.edu, Cell: 906-370-4024.

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Abstract

A transition from a linear to a closed-loop circular economy for plastics is envisioned by many to involve integrating emerging advanced recycling technologies into plastics supply chains in ways that complement current mechanical recycling and existing domestic and commercial waste materials collection and processing. However, the environmental sustainability of such a transition is not well understood from the perspective of greenhouse gas emissions and energy consumption. In this work, a system analysis framework developed in a prior REMADE exploratory project was applied to this question and an optimization model was developed and implemented to determine the best end-of-life (EOL) management decisions and locations of existing and emerging recycling infrastructure in the U.S. This was accomplished by minimizing the environmental impacts of closed-loop material flows with PET and polyolefin plastics packaging as an important case study.

Our systems analysis model includes U.S. material flows from virgin resin production through semi-manufacturing processes to EOL disposal and recycling processes, including emerging advanced recycling technologies for which data is available such as pyrolysis of polyolefin wastes and hydrolysis/solvolysis of waste PET. The basis for the system optimization is the annual plastics

packaging material streams that enter EOL management based on national US EPA waste generation statistics and county population density data. From a set of existing and proposed future facility locations for material recovery facilities (MRFs) and plastics recycling facilities (PRFs; mechanical and chemical recycling), optimum transportation logistics distances, facility locations and capacities were determined.

The optimization model predicts that 78% of U.S. PET and polyolefin packaging will be collected for sorting and recycling and 22% should be sent to landfills across the U.S, with zero percent incineration to achieve minimum GHG emissions of the system assuming a 100 km maximum collection distance. However, the percents collected versus landfilled varies greatly by state and by maximum collection distance. Furthermore, the results show that compared to a linear economy for U.S. plastics packaging, an optimized circular plastics packaging system is expected to achieve greenhouse gas emissions savings of up to 28% and cumulative energy demand savings of up to 46%. The optimal systems-level circularity ranged from 57% to 75%. Overall, transitioning to an environmentally optimum closed-loop recycling supply chain for packaging plastics requires both mechanical and emerging advanced recycling technologies to achieve the best results.

Graphic

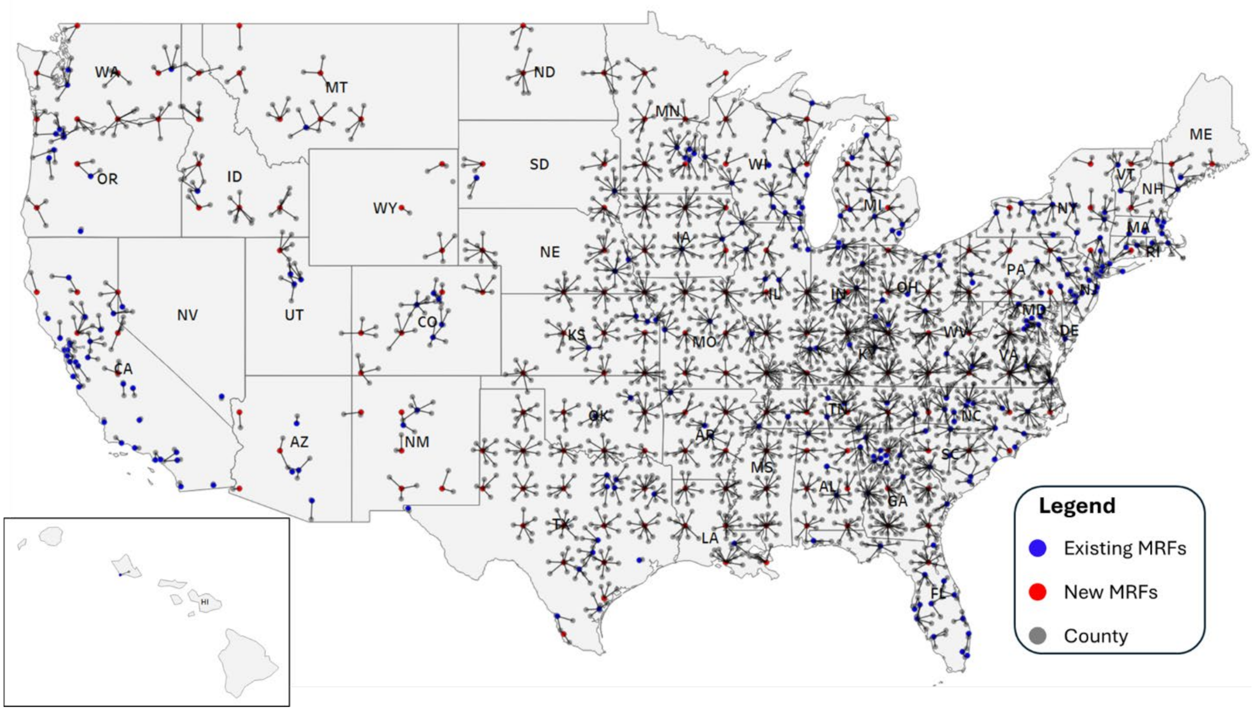

Figure Caption. County-to-MRFs (C-2-M) optimal U.S. EOL PET and PO packaging recycling material flow network for system optimized on GHG emissions with 100-km MRF collection proximity. Notes: 1) Only the counties participating in recycling within the 100-km collection distance are shown in this figure; 2) Alaska has a 0% recycling rate, therefore, is not shown in this figure. 3) This figure shows material flows from counties (origin) to MRFs (destination)