DYNAMIC TECHNO-ECONOMIC MODELING FOR PAPER RECYCLING

The user-friendly, open-source PRISM can analyze the feasibility of different paper processing approaches.

To support the robust growth of the domestic paper recycling system, a technology-rich system dynamics model of the U.S. paper recycling system was developed to assess its economic performance, energy use, CO2 emissions, and resource saving benefits under different economic, technology, policy, and recyclable material market assumptions.

Rebuilding a strong paper industry requires increasing the paper recycling rate, which was 68% in 2021.[1] However, the U.S. domestic paper recycling system has no scientific model that can guide the technology transition and help track milestones.

A team of researchers led by Northwestern University has developed the Paper Recycling Integrated System Model (PRISM) to fill this gap. PRISM simulates the performance of the U.S. domestic recycling system under different technology, policy, and recovered paper trade assumptions. The partnering research institutions were Yale University; University of California, Santa Barbara; and the Institute of Scrap Recycling Industries.

One of the model's research innovations is that it integrates operations at Material Recovery Facilities (MRFs) and recycled paper processing mills with a variety of process technologies for sorting and reprocessing recovered paper. This feature provides a way to explore how technical innovations can enable the U.S. paper recycling industry to increase recycling rates with the maximum environmental and economic benefits.

PRISM is an open source tool with a user-friendly interface. The model enables industrial stakeholders and the research community to analyze the environmental and economic performance of different paper-recycling technologies at a facility or national level.

PROJECT DESCRIPTION

PRISM is based on system dynamics modeling and unit process modeling to simulate the U.S. paper recycling system, including its material flows, technology resolution, economic conditions, and trade relationships.

The research team began by characterizing the current U.S. paper and paperboard recycling system, identifying key unit processes and parameters related to operations at MRFs and recycled paper processing mills. The team collected information through industrial surveys, literature reviews, and virtual interviews with industry experts.

Based on the characterization work, the team built datasets comprising techno-economic sub-models that quantify the mass and energy flows and economic characteristics of all major unit processes in the operations at MRFs and recycled paper processing mills. PRISM was then developed as a technology-rich system dynamics model to evaluate step-by-step domestic paper recycling scenarios for MRFs and recycled paper mills, compared to virgin paper products on a life-cycle basis. Economic data in PRISM include capital equipment investment, location-specific electricity, fuel, and labor costs, operations and maintenance costs, and other fixed costs for collection, transport, sorting processes, and reprocessing processes in the paper recycling system.

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[1] American Forest & Paper Association. "Unpacking Continuously High Paper Recycling Rates." May 23, 2022. https://www.afandpa.org/news/2022/unpacking-continuously-high-paper-recycling-rates. Accessed July 8, 2023.

The research team ran a baseline scenario on PRISM using 2018 U.S. paper production data to evaluate the environmental and economic performance of the domestic paper recycling system. They then analyzed three different scenarios for achieving a 15% increase in both the U.S. domestic paper recycling rate and recovered paper utilization rate, considering changes in collection, operational practices, and technology deployments.

PROJECT IMPACT

In the analysis of three scenarios for increasing the U.S. paper recycling rate by 15%, the results indicated that one feasible action would be to increase the residential and commercial single stream collection rate to 80%% and promote good sorting behavior (80% correct separation efficiency) among residents to boost the collection rate of recyclable paper in recycling bins.

A trade shift of sorted bales from export to domestic recovery can increase recovered paper utilization rate by 15%. This action would require expansion in the domestic recycled paper processing mills to process 23.8 million tons of sorted bales, with additional investments and production costs.

Advanced technology implementation enables MRFs and mills to produce recycled paper products that are more energy efficient with fewer GHG emissions, except for newsprint products. However, this requires capital investments, especially for advanced drying technology deployment.

NEXT STEPS

The team's scenario analysis results have been submitted to a peer-reviewed journal for broad dissemination of pathways. Built with a user-friendly interface on the Analytica Cloud Platform, PRISM is publicly available online. Training recordings demonstrate how to use PRISM to solve different problems at individual facilities or at the scale of the national paper recycling system.

The team will continue to update the datasets with the best available data, especially for emerging advanced technologies. Furthermore, they are collaborating with industrial operators and integrating unique advanced technologies to test how those technology implementations affect the system performance indicators. Finally, the team is promoting its findings and model through academic conference presentations and seminars.

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