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UNIVERSITY OF WISCONSIN–MADISON

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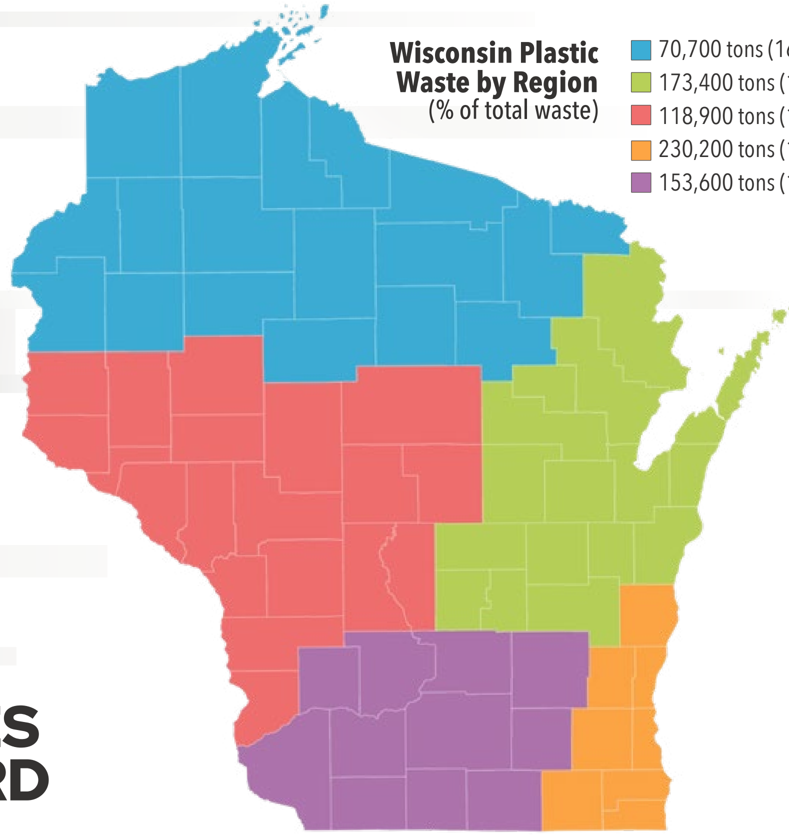

Map adapted from the Wisconsin Department of Natural Resources' 2020–21 Wisconsin Statewide Waste Characterization Study.

PLASTICS: CHALLENGES AND PATHWAYS TOWARD SUSTAINABILITY

Introduction

Wisconsin communities are facing a wide range of challenges associated with plastic pollution. From budget-related limitations on local recycling to microplastic impacts on environmental and human health, we are just beginning to scratch the surface on the problems associated with an industry that also employs tens of thousands of Wisconsinites and generates billions for our economy. How can we tackle plastic pollution across Wisconsin while continuing to support Wisconsin businesses that employ our families and make our lives more convenient? What solutions are best equipped to protect environmental health while supporting our local governments, capitalizing on Wisconsin industries, and fueling our agricultural economy? How are Badgers leading this work?

In this *Nelson Issue Brief*, we aim to contribute to critical conversations around plastics by highlighting recent UW–Madison research that highlight pathways for addressing plastic sustainability. Research presented here covers *tackling microplastics pollution in the Great Lakes* with innovative filtration and sensor technologies; *maximizing profitability and minimizing emissions* with a new framework for assessing waste management technologies; *supporting Wisconsin manufacturers and making Wisconsin a national leader in advanced recycling* through a breakthrough recycling technology; *supporting Wisconsin farmers* through a promising plastic alternative; and *improving institutional purchasing and accelerating sustainable innovation* through findings from waste audits. This research cuts across UW–Madison's Nelson Institute of Environmental Studies, the College of Engineering, and the College of Agricultural and Life Sciences — pointing to the importance of interdisciplinary research in moving us forward on one of Wisconsin's biggest environmental challenges.

The masthead map (above) shows Wisconsin plastic waste by region, based on findings from the Wisconsin Department of Natural Resources (DNR)'s 2020–21 Wisconsin Statewide Waste Characterization Study.

KEY POINTS

- Innovative filtration and sensor technologies could be key to detecting and understanding microplastic pollution in the Great Lakes.
- A new framework for assessing plastic waste management technologies can identify pathways that maximize profitability and minimize environmental impact.
- A breakthrough technology in plastics recycling could support Wisconsin manufacturing and make us a national leader in advanced recycling.
- Flax is a promising plastic alternative that could support Wisconsin farmers, protect our pollinators, and make Wisconsin a leader in the circular bioeconomy.
- Waste audits can help improve plastic recycling rates, inform institutional purchasing, and accelerate sustainable innovation.

Detecting Microplastics at the Smallest Scales in the Great Lakes

Innovative filtration and sensor technologies could be key to detecting and understanding microplastic pollution in the Great Lakes.

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The smallest plastic particles in the Great Lakes, those under 10 micrometers, are entering human bodies, yet we lack the tools to detect them reliably. Nano- and low-micrometer microplastics (NLMMPs) are the least understood form of plastic pollution in the Great Lakes. They are far too small to see and very difficult to measure, yet they may pose the greatest risk. These particles have been detected in human blood and in newborn babies' first diapers. We urgently need to understand what that means for human and ecosystem health. These tiny particles can move through water, wildlife, and the human body, but current monitoring tools are not effective in detecting them. This is the core challenge our research aims to solve.

Plastic pollution has become a growing concern worldwide. In 2016 alone, an estimated 19 to 23 million metric tons of plastic waste entered rivers, lakes, and oceans — about 11 percent of all global plastic waste generated that year. While larger microplastics are now measured routinely, the smallest particles often slip through traditional monitoring. Recent studies show that microplastics are widespread in the Great Lakes, yet almost nothing is known about the smallest fraction: where they travel, how they degrade, and how they accumulate in the food web.

With support from the National Oceanic and Atmospheric Administration (NOAA) Wisconsin Sea Grant and the NOAA Marine Debris Program, our team is developing a new approach to detect, quantify, and characterize these tiny particles in the Great Lakes. We have created a fractionated membrane filtration system that separates and recovers particles in the 1–10 micrometer range with more than 90 percent efficiency.

To improve detection further, we designed a new plasmonic membrane sensor, a filter coated with a thin layer of gold that enhances the optical signals of microplastics during analysis. These sensors function both as filters and as analytical platforms, allowing researchers to visualize and identify individual particles even in murky or algae-rich lake water. Compared to conventional membranes, they increase Raman signal intensity by nearly 50 percent, enabling rapid and accurate detection at the single-particle level.

We are now applying this platform to study how plastic debris breaks down in the Great Lakes under sunlight, waves, and microbial activity, generating the first systematic dataset on microplastics degradation in freshwater. In partnership with the U.S. Geological Survey and Wisconsin Sea Grant, we are also beginning to examine potential toxicity concerns for species in the Great Lakes food web. To support future large-scale monitoring, we are also developing an AI-based framework to automate particle detection and understand how environmental conditions influence microplastic release and transformation.

Assistant professors Mohan Qin and Haoran Wei are leading a project to study the presence of microplastics in the Great Lakes. Photo by Ziyan Wu; Below: Qin and Wei work with Ziyan Wu (foreground) as she pours water for testing. Photo by Alex Holloway

Evaluating Tradeoffs in Plastic Waste Management

A new framework for assessing plastic waste management technologies can identify pathways that maximize profitability and minimize environmental impact.

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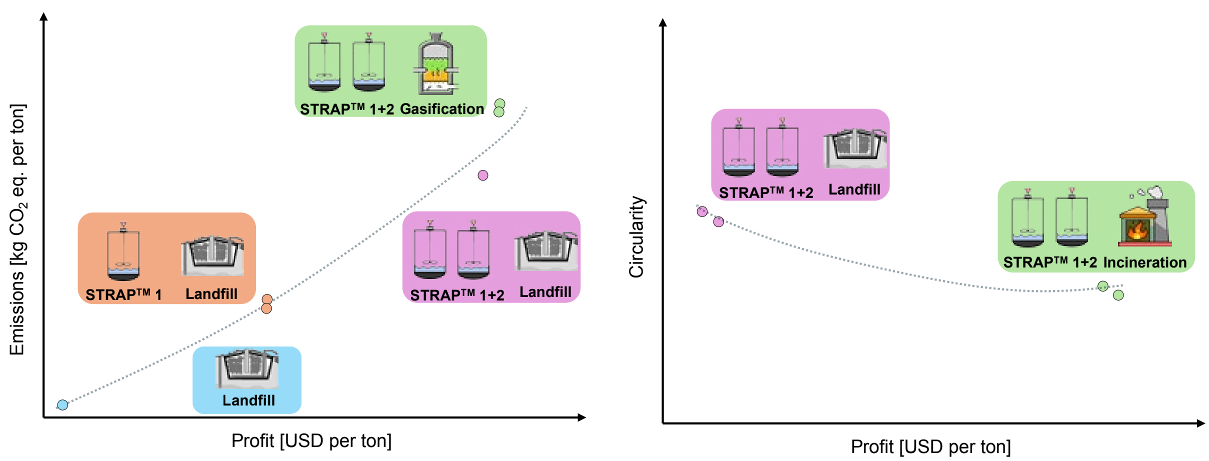
A decision-support framework can help legislators understand which plastic waste management pathways best balance economic, environmental, and circularity goals. Increasing levels of plastic waste, combined with unsustainable waste management infrastructure, pose profound challenges to environmental sustainability and human welfare. Contemporary waste management systems remain dominated by landfilling and incineration, both of which impose environmental burdens and prevent the recovery of reuseable materials. Post-industrial waste (PIW) is an underutilized, high-value recycling stream due to its low contamination and well-defined composition, providing opportunities to reduce resource use, environmental impacts, and costs. Yet, determining optimal management strategies is difficult given the range of emerging technologies and the need to weigh multiple, often competing, objectives.

To address this challenge, we propose an optimization-based framework that identifies the most suitable technologies for PIW plastic streams by clarifying the trade-offs between economic performance and environmental outcomes. The framework involves identifying feasible technologies, representing their combinations as a full network of possible pathways, defining economic and environmental objectives, and formulating an optimization model to determine optimal solutions.

Our case study examines a mixed plastic feedstock that reflects the types of materials commonly found in PIW, including polyethylene (PE), polyethylene terephthalate (PET), nylon (N6), and ethylene-vinyl alcohol (EVOH). We evaluate both emerging and established technologies that can process these materials, such as pyrolysis, gasification, and a solvent-based separation method known as the Solvent-Targeted Recovery and Precipitation (STRAP™) process (see article page 4), along with conventional options like incineration, and landfilling. Because STRAP relies on solvents to separate the components, we also apply a solvent screening step to determine which polymers can be targeted and which solvents can be used.

The aim of the analysis is to understand how each possible pathway performs with respect to financial cost, environmental impact, and circularity. To do this, we estimate costs and potential revenues, evaluate greenhouse gas emissions, and assess circularity considering aspects like material recovery, resource consumption and waste generation. Together, these measures capture the economic, environmental, and circularity implications of different pathways to provide a clearer picture of the tradeoffs involved in managing complex plastic waste streams.

The results indicate that different waste management choices have different strengths and impacts. For the location and PIW stream composition studied, STRAP combined with incineration or gasification produces the highest financial return. Landfilling results in the lowest greenhouse gas emissions, while pairing STRAP with landfilling is the most circular alternative. The results demonstrate the real trade-offs between the economic and environmental goals. Options that generate more profit often come with higher emissions and lower circularity. By making these trade-offs visible, the framework helps decision makers compare pathways on equal footing and choose approaches that best align with economic goals, environmental commitments, and long-term resource management needs.



Trade-offs between emissions, circularity, and profit with sample solutions.

Advancing Plastic Recycling in Wisconsin: The STRAP™ Technology

A breakthrough technology in plastics recycling could support Wisconsin manufacturing and make us a national leader in advanced recycling.

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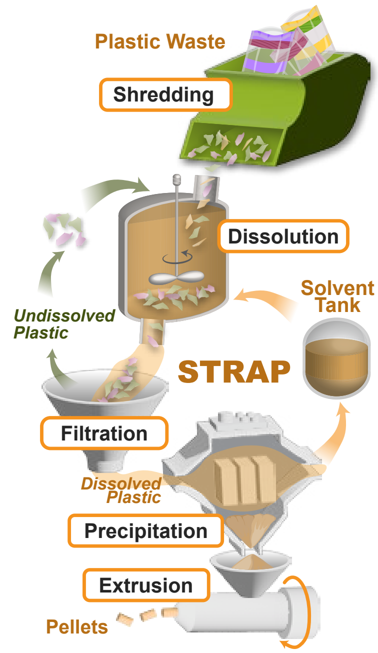
Wisconsin has an opportunity to lead the nation in next-generation plastics recycling through a breakthrough UW–Madison technology that can recycle plastics previously thought unrecyclable. The plastic packaging industry is a cornerstone of Wisconsin's economy, ranking eighth nationally in plastics employment and third in flexible plastic packaging with major companies like Amcor, Berry Global, and Glenroy supporting thousands of jobs. However, this thriving sector also produces hundreds of millions of pounds of plastic waste annually, much of which cannot be recycled with current technologies.

To address this challenge, researchers at UW–Madison's Center for Chemical Upcycling of Waste Plastics (CUWP) have developed a breakthrough recycling technology called Solvent-Targeted Recovery and Precipitation (STRAP™). STRAP makes it possible to recycle plastics that were previously unrecyclable, including multilayer packaging, flexible films, and rigid packaging material. It works by selectively dissolving and purifying individual polymers from mixed plastic waste, producing high-quality recycled plastics without degrading their properties.

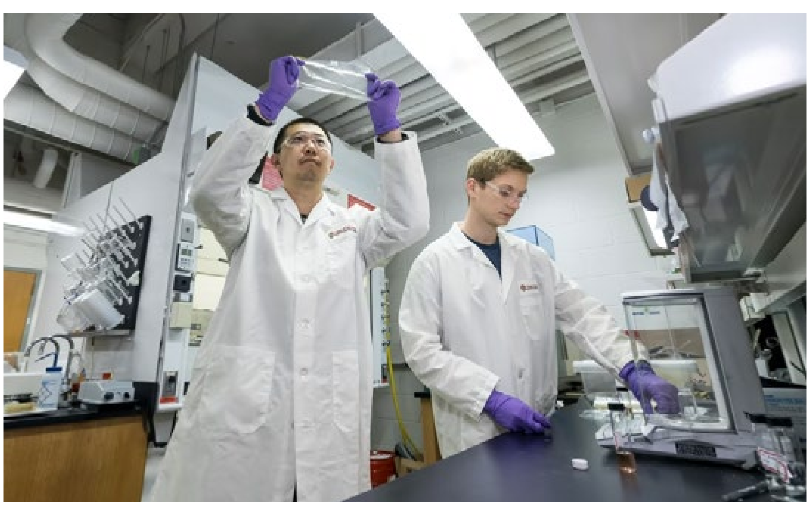
Traditional recycling systems are limited to clean, rigid containers, even though flexible packaging accounts for 40 percent of all plastic packaging waste as it is especially difficult to recycle. STRAP overcomes this challenge by removing contaminants such as food residue, paper, inks, adhesives, and metal, allowing recovery of valuable materials that would otherwise be landfilled or incinerated.

Investing in advanced plastic recycling technologies like STRAP will strengthen Wisconsin's economy by creating new manufacturing and engineering jobs, supporting local supply chains, and attracting private investment in recycling infrastructure. Economic analysis shows plastics recycled by STRAP can be cost-competitive with virgin plastics, particularly at scale. With improvements to waste collection and sorting systems, Wisconsin could become a national leader in advanced recycling, driving economic growth and job creation while reducing reliance on fossil fuels.



The STRAP process includes five key steps. 1) Mixed plastic waste is shredded, 2) The desired plastic is dissolved, 3) Contaminants are filtered out of the dissolved plastic, 4) The plastic is precipitated back to a solid state, and 5) Recycled plastic pellets are formed. The solvent is reused within the process, and the remaining waste can be processed to remove another polymer if desired.

STRAP also offers major environmental benefits, reducing greenhouse gas emissions by 60 to 80 percent compared to producing new plastics from petroleum and reduces waste disposal requirements. This directly supports Wisconsin's goals for sustainability and climate action.



Graduate researchers in the lab at UW-Madison test the quality of their recycled plastic. Photo by Jason Daley

To transition from laboratory development to large-scale industry use, STRAP must be demonstrated at commercial scale. The UW team is partnering with Amcor to test recycled plastics on industrial equipment and is building a 25 kg/hr pilot plant with Michigan Technological University, expected to be operational in early 2026 .

Wisconsin is uniquely positioned to lead the nation in next-generation plastics recycling, and we are eager to work with industry, government, and community partners whose collaboration will be essential to scaling this promising technology and building a more sustainable and economically vibrant future for our state.

Flax: A Wisconsin Grown Alternative to Plastics

Flax is a promising plastic alternative that could support Wisconsin farmers, protect our pollinators, and make Wisconsin a leader in the circular bioeconomy.

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Moving away from plastics requires material alternatives, and the flax plant offers one that can be grown on Wisconsin farms.

Humans have cultivated flax for thousands of years for high-quality linen, papermaking, and its nutritious seed. New technologies now use flax fibers to produce bioplastic composites for consumer products currently made from plastic. Today's global textile industry relies heavily on petroleum-based plastics like polyester and nylon, contributing significantly to microplastic pollution where 30 percent of microplastics in waterways are shed directly from clothing fibers.

Top: Flax variety trial harvest, 2024; Above: Steffen Mirsky with UWEX Emerging Crops Team and Leslie Schroder inspect flax variety trial plot. Photos courtesy of Leslie Schroeder (2)

With funding from the Forward Agriculture, Use Inspired Research and Development grant program, this work is building a detailed assessment of the infrastructure, processing, and logistical investments needed to connect Wisconsin farmers with existing manufacturers and realize the significant economic potential of flax across the entire supply chain. Building on the momentum of the Fibershed movement, the project also explores the feasibility of expanding Wisconsin's small but growing artisanal textile sector to incorporate regionally grown and sewn linen.

Flax grows well in the upper Midwest and requires minimal inputs, offering Wisconsin farmers a pollinator friendly crop that differs from the state's major commodity crops that can support more diverse crop rotations, disrupt pest and weed cycles, and reduce financial risk through forward contracting.

As concern over plastics increases and consumers seek alternatives to synthetic materials, existing manufacturers can integrate Wisconsin-grown flax fiber into a wide variety of products such as paper, erosion control mats, gauze bandaging, carpet backing, and in bioplastic composites for car parts, boats, sporting goods, and more. Long line flax fibers can be spun into natural, durable linen garments. Additional coproducts are derived from shive, the plant's woody core, which can be used for soil amendments, mulch, animal bedding, packaging, and acoustic tiles. Flax seed is also valued for human and animal consumption and pressed for oil to make wood finishes, personal care products, and naturally derived linoleum.

With more than 70 percent of the world's fiber flax currently grown in northern Europe, strategic investment in raw fiber processing equipment would allow Wisconsin to take a leadership role in producing durable biodegradable materials that reduce plastic pollution in the environment and strengthening a circular bioeconomy benefitting farms and rural communities.

Types of Single-Use Plastic Cups Influence Recycling Accuracy

Waste audits can help improve plastic recycling rates, inform institutional purchasing, and accelerate sustainable innovation.

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The sorting of single-use plastic cups for recycling varies widely by plastic type, revealing that some plastics are far more likely to be sorted accurately than others. Plastic recycling rates remain low, with only 5 to 10 percent of plastics recycled each year. Single-use plastics account for approximately 40 to 50 percent of all plastics produced annually. Improving recycling rates depends on accurate sorting, yet human disposal behaviors for single-use plastics are complex.

Left: A student researches how to dispose of a plastic cup on the Zero Waste Compass. Photo by UW–Madison Office of Sustainability; Right: Bucky Badger and a student stand in a recycling bin. Photo by Jeff Miller / UW–Madison

Waste audits conducted at the University of Wisconsin–Madison examined how students, staff, faculty, and visitors sorted plastic cups into available campus landfill and recycling streams. Across eight waste audits, disposal outcomes for nearly 700 kilograms of plastic cups were recorded. The examined cup materials included polyethylene terephthalate (PETE), polypropylene (PP), polystyrene (PS), and polylactic acid (PLA). All these plastic cups can technically be recycled, though PP and PS have known challenges, and PLA is not recyclable in standard systems and may contaminate recycling streams.

Sorting accuracy of single-use plastic cups varied markedly by material. PETE cups were placed in recycling 67 percent of the time, 40 percent for PS, and 36 percent for PP. PLA was correctly placed in the landfill stream 52 percent of the time. The higher accuracy of PETE sorting suggests that individuals may take more deliberate action or have better alignment between available information and disposal decisions when handling this material. Disposal behaviors are influenced by a range of factors, including recycling knowledge, product familiarity, and feedback in the recycling process. Given these findings, selecting PETE cups when single-use plastics are needed may support more accurate disposal and increase recycling rates. As UW–Madison works toward its "Zero Waste by 2040" goal, understanding real-world plastic disposal outcomes are essential.

These results can inform institutional purchasing, policies designed to promote plastics recycling, and environmental assessments. Using the campus as a living laboratory fosters experiential learning, supports evidence-based decision-making, and accelerates sustainable innovation. UW–Madison can serve as a replicable framework for broader local and regional sustainability efforts. Incorporating empirical disposal behaviors into environmental impact and life cycle assessments will also yield more accurate and relevant outcomes than stylized scenarios and assumptions. Moving plastics use towards circularity reduces the need for newly extracted materials. Enhancing transparency in plastic flows can reduce environmental burdens and strengthen institutional resilience.